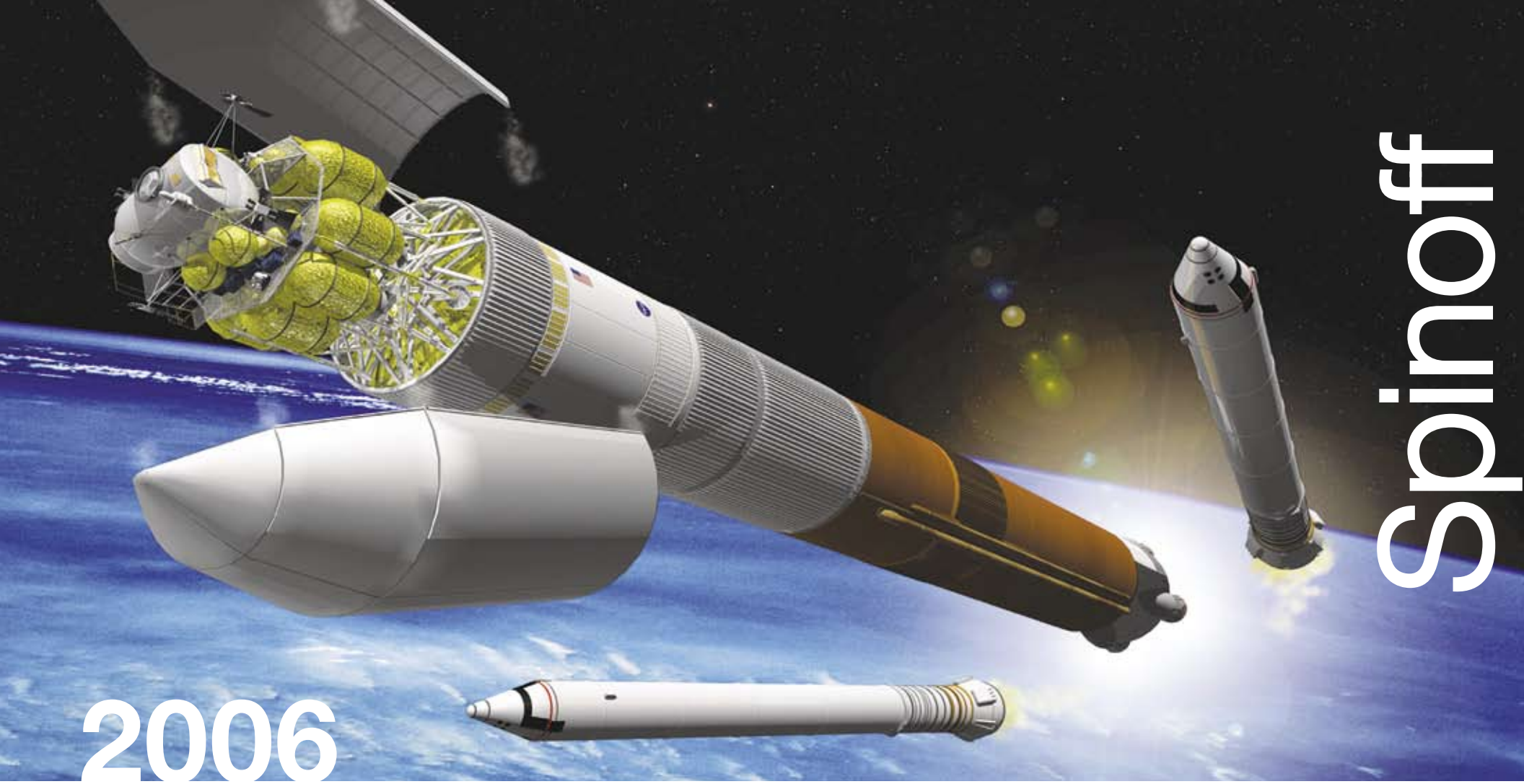
National Aeronautics and Space Administration

2006 spinoff



Innovative Partnerships Program

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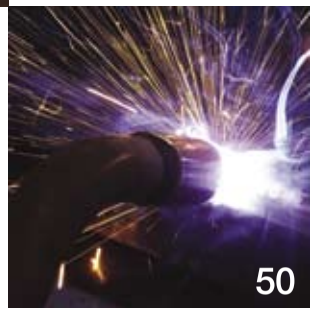
On the Cover: Early in the next decade, the new Crew Exploration Vehicle will begin to ferry crew and supplies to the International Space Station. Cutting-edge technology like this leads the way for development of new spinoff products that benefit life on Earth.

Table of Contents



5 Foreword

7 Introduction

8 Partnership Benefits

Health and Medicine

Ingestible Thermometer Pill Aids Athletes in Beating the Heat 10
Space-Proven Medical Monitor: The Total Patient-Care Package 14
From Planetary Imaging to Enzyme Screening.....16

Transportation

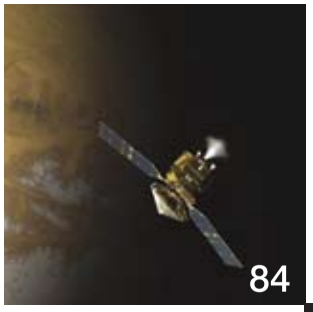
Damage-Tolerant Fan Casings for Jet Engines 18
Steering Aircraft Clear of Choppy Air 20
Advanced Air Data Systems for Commercial Aircraft 22
NASA Helps Design the 'Cockpit of the Future'.....24

Public Safety

Water Vapor Sensors Go Sky-High to Assure Aircraft Safety.....26
Clean Water for Remote Locations 30
Fire-Resistant Reinforcement Makes Steel Structures Sturdier.....32
Feeling Well Rested and Wide Awake When it Counts.....34

Consumer, Home, and Recreation

X-ray Device Makes Scrubbing Rugs Clean a Spotless Effort.....38
A Match Made in Space.....42
Affordable Space Tourism: SpaceStationSim.....44
Preventing Ice Before it Forms.....46
Microspheres in Plasma Display Panels.....48
Look Sharp While Seeing Sharp.....50
Raised Relief Mars Globe Brings the Red Planet Closer 52
Modern Exploration of the Lewis and Clark Expedition 56
Reflecting on Space Benefits: A Shining Example.....60



Environmental and Agricultural Resources

PRP: The Proven Solution for Cleaning Up Oil Spills 66
Progressive Plant Growing Has Business Blooming.....68
FLIPPER: Validation for Remote Ocean Imaging.....72
Paper-Thin Plastic Film Soaks Up Sun to Create Solar Energy 74
Saving Space and Time: The Tractor That Einstein Built.....78

Computer Technology

A Predictive Approach to Eliminating Errors in Software Code.....80
Scheduling Software for Complex Scenarios.....82
Difficult Decisions Made Easier.....84
The Echoes of Earth Science.....86
GPS Eye-in-the-Sky Software Takes Closer Look Below 88
A History of High-Performance Computing.....90

Industrial Productivity and Manufacturing Technology

Cryogenic Cooling for Myriad Applications—A STAR Is Born!.....92
Temperature Sensing for Oil, Gas, and Structural Analysis 94
Robust, Thin Optical Films for Extreme Environments.....98
The Cutting Edge of High-Temperature Composites 99
Nano Goes Magnetic to Attract Big Business 100
Laser Mapping for Visual Inspection and Measurement.....102
Electrical Conductivity in Textiles.....104
Spatial Phase Imaging.....106
Miniature Wireless Sensors Size Up to Big Applications.....108

110 Research and Development at NASA

126 Education News at NASA

134 Partnership Successes

146 Innovative Partnerships Program Network

While NASA does not manufacture, market or sell commercial products, many commercial products are derived from NASA technology. Many NASA originated technologies are adapted by private industry for use by consumers like you. Spinoff developments highlighted in this publication are based on information provide by individual and private industry users of NASA originated aerospace technology who acknowledge that such technology contributed wholly or in part to development of the product or process described. NASA cannot accept responsibility or liability for the misinterpretation or misrepresentation of the enclosed information provided by these third party users. Publication herein does not constitute NASA endorsement of the product or process, nor confirmation of manufacturers' performance claims related to any particular spinoff development.

Foreword

NASA is making significant progress in implementing our Nation's space exploration strategy, which calls for American leadership in exploring other worlds and in the inevitable expansion of human civilization into the cosmos.

This past year, NASA engineers developed the Exploration Systems Architecture for the spacecraft and launch vehicles that will enable the renewed human exploration of the Moon, as early as 2018. On August 31, 2006, we announced the selection of Lockheed Martin Corp. as the prime contractor that will build a key element of the architecture, our new Crew Exploration Vehicle Orion. Throughout the year, NASA engaged with potential international, academic, and commercial partners to develop a strategy for scientific, commercial, and exploration activities on the lunar surface, as this next great era of space exploration unfolds.

The past year was also marked by the resumption of space shuttle missions, continued productive activity onboard the International Space Station, the launching of the New Horizons mission to Pluto and the CloudSat and CALIPSO Earth-monitoring satellites, the Spitzer Infrared Space Telescope's imaging of a remarkable nest of red supergiant stars—14 supernovas in the making—and the exciting findings of the Cassini spacecraft and Huygens probe in the vicinity of Saturn and its fascinating moons, Titan and Enceladus.

When NASA engages in activities such as these, we make discoveries of fundamental scientific importance and we develop new technologies that help improve people's lives. Our investment in exploration is an investment in the highest of high-tech sectors and will help maintain America's position as the preeminent technical nation on Earth. Space exploration is a lens that brings a focus to the development of key technologies in a way that simply would not occur without the "demand pull" that arises when trying to accomplish the near-impossible.

To this point, *Spinoff* 2006 highlights NASA's work, consistent with our Agency's charter, to "research, develop, verify, and transfer advanced aeronautics, space, and related technologies." Below are a few of the beneficial, NASA-derived technologies that are featured in *Spinoff* 2006 and utilized in the commercial and public sectors:

- A Global Positioning System-controlled steering device that automatically steers farm equipment to maximize productivity. The device, which prevents the skipping and overlapping of rows when planting or watering fields, was inspired by a NASA experiment that tested two extraordinary predictions of Albert Einstein's theory of general relativity.
- Microencapsulating technology with roots in NASA research that is helping to clean up contaminants in bodies of water and other ecologically fragile areas in an environmentally safe manner.
- Wireless patient-monitoring systems used in hospitals across the country today that were derived from concepts behind the medical telemetry devices used to monitor astronauts' health.

As impressive as these technologies are, I am confident that NASA's ongoing efforts to expand our exploration horizons will significantly increase our Nation's return on investment in the future. I thank a supportive American public, and all those who are dedicated to the noble work of exploring the space frontier, for helping to achieve this progress.

Michael D. Griffin
Administrator
National Aeronautics and Space Administration

Introduction

Spinoff is one of the products of NASA's Innovative Partnerships Program. We are proud to highlight the advances that come out of the Agency's pioneering work in space exploration, scientific discovery, and aeronautics research. It is a primary function of this publication to share such knowledge and capabilities with private and public sectors.

More broadly speaking, the charter of the Innovative Partnerships Program is to produce leveraged technology through investments and partnerships with industry, academia, and others. We accomplish this through longstanding avenues such as technology transfer and licensing, and through new forms of partnerships with the external technology community. As an example, this year we are adding a new partnership—Red Planet Capital—which will invest in promising new technologies through financial equity instruments.

NASA requires this technology innovation by the very nature of its charter. For the Human Exploration Mission, the Agency has the challenge to protect humans in hostile environments and from adverse effects of long-duration habitation in zero gravity, and to limit their exposure to extreme temperatures and radiation.

This applies to hardware as well. Throughout its history, whether on the outer edge of the solar system, communicating with space assets on Mars, orbiting Earth, or sending commands from the ground, NASA has enabled sensors, energy systems, and electronic systems to function in extreme environments. For example, temperature conditions can be as high as 400 °C or as low as -180 °C. Radiation poses challenges too—space systems must operate through the mission with total radiation exposures up to 5 megarads. Likewise, navigation demands extraordinary accuracy, such as nanoradian precision for an encounter with Neptune. This is like a golfer who tees off in California and hits the green in Washington, DC.

NASA has a significant technology portfolio from its years of meeting these needs. Not surprisingly, as we developed technology to meet these requirements, we found synergy with high-performance commercial markets and with companies serving other Federal agencies. Benefit to both sides is achieved through joint development of technology, and through licensing.

The Partnership Benefits section in *Spinoff* highlights some results of NASA's technology licensing and partnering, and the added value derived for the public at large. A preview of this year's technology-to-product benefits include:

- NASA satellite imagery which helps a new generation of researchers explore the trail blazed across the country by Lewis and Clark through a unique online geospatial network.
- A special, laser-based sensor technology NASA developed to measure atmospheric planetary gases that now improves real-time weather forecasting and helps aircraft avoid dangerous weather conditions here on Earth.
- An environmentally friendly deicer developed for airplane wings that is now available to consumers to prevent ice from sticking to car windshields.

In publishing NASA's most current technological achievements, I am confident that this *Spinoff* 2006 publication offers enlightening information that heightens your awareness about NASA's focused research and development activities, the creation of extraordinary technologies and capabilities, and the public benefit inherent in its utilization.

Merle McKenzie
Acting Director
Innovative Partnerships Program

Partnership Benefits

NASA seeks to create industry partnerships to develop technology that both applies to NASA mission needs and contributes to competitiveness in global markets. As part of NASA's mission, the Agency facilitates the transfer and commercialization of NASA-sponsored research and technology. These efforts not only support NASA, they enhance the quality of life here on Earth.

Ingestible Thermometer Pill Aids Athletes in Beating the Heat

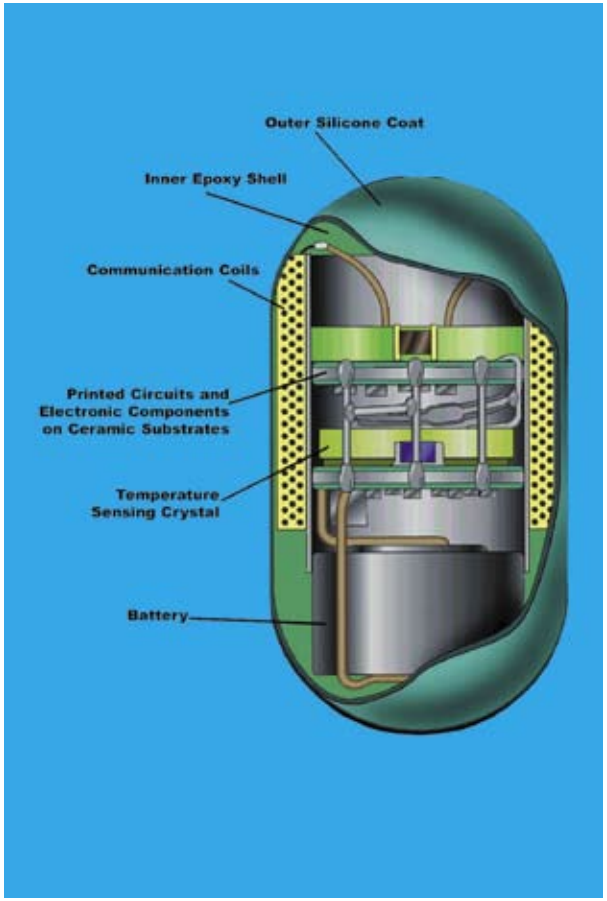
Originating Technology/NASA Contribution

From the football turf to high above the Earth, heat exhaustion is a life-threatening concern. Heat exhaustion, or hyperthermia, is an acute condition caused by excessive exposure to heat and dehydration. It occurs when the body can no longer dissipate heat adequately because of extreme environmental conditions or increased heat production from within. Heat exhaustion may progress to heatstroke when the body's thermoregulatory mechanisms become overwhelmed and fail, ultimately leading to brain and organ damage or even death.

In football, heat exhaustion is a dangerous reality. Football players take the field for preseason training during the dog days of summer, frequently in full pads, when the heat index can easily exceed 100 °F. On top of all the pads and the sweltering heat—or underneath, to be more precise—are players who weigh over 300 pounds. In fact, there are more than 300 players in the National Football League (NFL) topping 300 pounds. Due to their body mass, these players, who generally serve as offensive and defensive linemen, face a high risk of suffering from heatstroke. Even players in top shape can be at high risk for a variety of reasons, including if they quickly shed pounds to meet stringent weight requirements (a practice known as "cutting weight"), or if they reach critical dehydration because they sweat out fluids without properly replenishing.

In space, astronauts on extravehicular activity assignments are constantly exerting themselves, which can cause rapid increases in body temperature. Although the space suit is insulated to keep astronauts comfortable from the extreme temperatures of space—the side of the suit facing the Sun may reach temperatures as high as 250 °F, while the opposite side, exposed to the darkness of deep space, may reach temperatures as low as -250 °F—astronauts still release body heat and humidity inside the suits, which could lead to heat exhaustion and eventually heatstroke.

In order to monitor the body temperature of astronauts during space flight, NASA teamed up with Johns Hopkins University in the late 1980s to develop an ingestible "thermometer pill" called the Ingestible Thermal Monitoring System. Incorporating a number of space technologies, including wireless telemetry (wireless signal transmission), microminiaturized circuitry, sensors, and batteries, the thermometer pill became commercially available in research, university, and military markets in 1988 (*Spinoff* 1994). Due to a heightened awareness of heatstroke risk among athletes, brought on by the deaths of a professional football player and a college football player just a week apart in 2001, the product is now well received as a means to detect elevated core body temperature during sporting activities.



Developed by Goddard Space Flight Center and the Johns Hopkins University Applied Physics Laboratory to monitor the core body temperature of astronauts during space flight, the ingestible "thermometer pill" has a silicone-coated exterior, with a microbattery, a quartz crystal temperature sensor, a space-aged telemetry system, and microminiaturized circuitry on the interior.

Partnership

Under a $75,000 grant from NASA, the Johns Hopkins University Applied Physics Laboratory worked closely with Goddard Space Flight Center to develop the Ingestible Thermal Monitoring System. The resulting ¾-inch capsule consisted of a silicone coating on the exterior and a telemetry system, a microbattery, and a quartz crystal temperature sensor on the interior.

Once ingested and inside the gastrointestinal tract, the quartz crystal sensor vibrates at a frequency relative to the body's temperature, producing magnetic flux and transmitting a harmless, low-frequency signal through the body. This signal can then be retrieved by a recorder, outside of the body, that displays the core body temperature reading with an accuracy to within one-tenth of a degree, Celsius.

The temperature-reading pill was first put to use by a Johns Hopkins University veterinarian named Dr. Phillip Brown, who monitored an animal's temperature during and immediately following surgery. Brown noted that large animals can be erratic and dangerous while coming out of anesthesia; with the capsule, "doctors can monitor animals from a safe distance."

HQ, Inc., of Palmetto, Florida, licensed the temperature pill in 1988 for widespread commercial use. (The company was then known as Human Technologies, Inc.) The company previously had a licensing agreement in place

with the Applied Physics Laboratory for another medical device, so this preexisting relationship opened the door for it to purchase the exclusive patent rights on the temperature pill and market a commercial version globally.

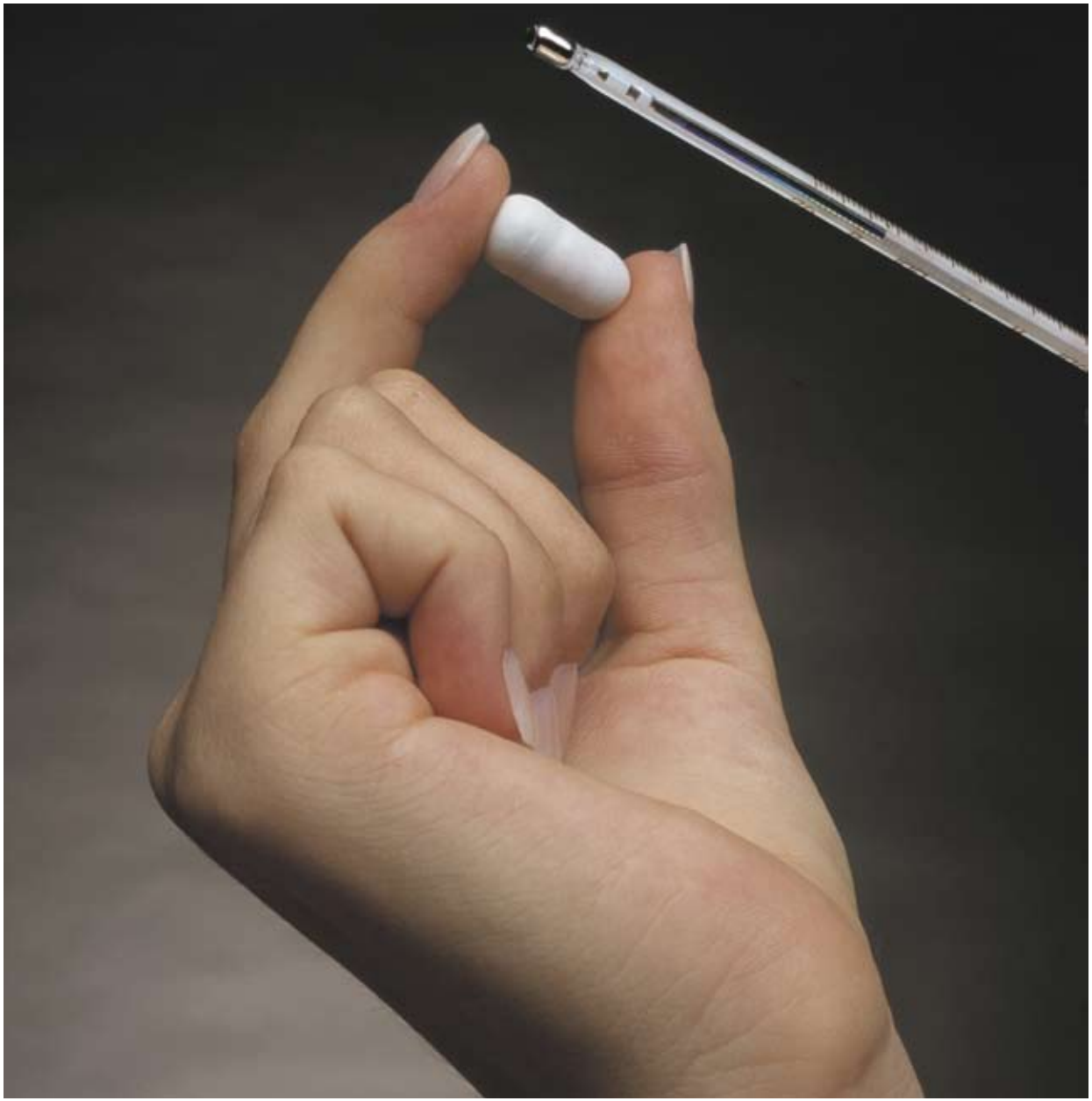
Three years later, in 1991, the pill technology made its debut in space, where astronauts ingested the capsules so that their core body temperatures could be monitored via radiofrequency signals that were transmitted to NASA laptop computers back on Earth.

In 1998, astronaut and U.S. Senator John Glenn swallowed the pill as part of his Space Shuttle Discovery medical experiments. NASA scientists tracked the data produced by the pill to study then 77-year-old Glenn's condition during his stay in space. Specifically, the scientists wanted to better understand the physical deconditioning experienced by astronauts in the weightlessness of space and the similarities of this space deconditioning to the human aging process.

Product Outcome

Heatstroke is the third leading cause of death among athletes in the United States. University of Florida freshman fullback and pre-med student, Eraste Autin, collapsed from heat exhaustion on July 19, 2001, after completing a voluntary workout. The 18-year-old was in a coma for 6 days before he died. Korey Stringer, a Pro Bowl offensive tackle for the NFL's Minnesota Vikings, died on August 1, 2001, from heatstroke complications suffered during a hot and humid practice session the previous morning. He was 27 years old.

News of the back-to-back tragedies rocked the country, prompting athletic programs to consider better precautions



At three-fourths of an inch, the commercially available CorTemp Ingestible Core Body Thermometer Pill wirelessly transmits core body temperature as it travels through the human digestive tract. A sensor within the pill sends a signal that passes harmlessly through the body to the CorTemp Data Recorder outside of the body.

HQ, Inc.'s Core Body Temperature Monitoring System—consisting of the CorTemp Ingestible Core Body Thermometer Pill and the CorTemp Data Recorder—reveals vital information necessary for the prevention and treatment of heat-related illnesses.

for protecting their athletes from heat-related illnesses. Enter the CorTemp Ingestible Core Body Thermometer Pill, made for NASA and manufactured commercially by HQ, Inc.

Within 1 to 2 hours of ingesting, the CorTemp thermometer pill will reveal vital information necessary for the prevention and treatment of heat-related illnesses. (It will remain in an individual's system for 18 to 30 hours, before passing safely.) The absence of catheters, probes, and wire connections allow team physicians and certified athletic trainers (ATCs) to noninvasively and wirelessly monitor the core body temperature of multiple athletes in real time during field play or practice. These medical professionals have several options and configurations for tracking athletes. The simplest is direct manual monitoring, whereby they hold the CorTemp Data Recorder (a physiological monitoring system) near the small of an athlete's back.

The patented, U.S. Food and Drug Administration-regulated pills are numerically coded, and an individual Data Recorder can monitor up to 99 athletes. When a two-digit athlete identification number (or jersey number) is entered on the recorder keypad, that athlete's core temperature will instantly appear on the recorder's liquid crystal display. Temperatures of multiple athletes can quickly be taken by an ATC on the sidelines, allowing the athletes to get back on the playing field within seconds. Trainers and physicians can also program the hand-held monitoring unit to set off an alarm if a player's core temperature reaches a designated level.

Other system components can be added to gather additional data, such as a strap-on heart monitor that allows continuous heart rate monitoring during physical activity. Real-time information can be transmitted wirelessly to a PDA or a PC, or downloaded straight from the Data Recorder, for analysis away from the playing field; CorTemp data-graphing software is included with the purchase of the hand-held recorder. Another component, the CorTemp Barcode Scanner System, provides an accurate input feature that eliminates the possibility of human errors during data entry.

In August 2005, the University of South Florida Sports Medicine Department received a $20,000 grant from the NFL Charities to conduct tests on the school's football players during their first practice of the season in full pads. With these tests, the sports medicine staff aimed to determine how closely core body temperature correlated with symptoms such as chills, nausea, cramps, and confusion. Of the linemen who participated, one player's core body temperature reached 103.5 °F. He was pulled immediately from activity. As an indication of how serious a situation this presented, a person usually suffers a heatstroke when core body temperature exceeds 105 °F.

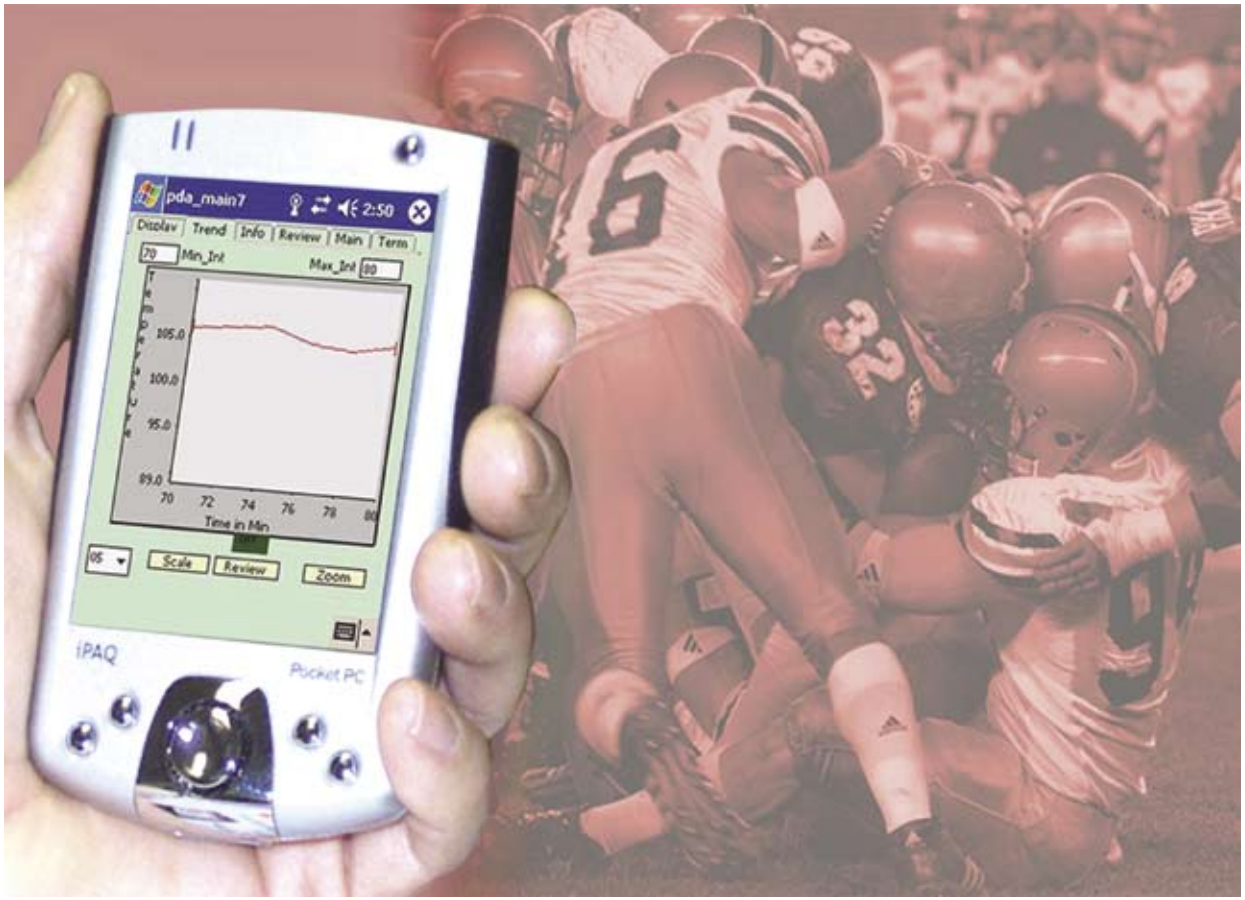
The Tampa-based university has also applied for a Federal grant to use the temperature pill on other athletes in a laboratory setting, where heat and humidity can be carefully controlled, to look for the earliest signs of heat-related illness.

Just a few hours north in Gainesville, the University of Florida—where Autin played—is also trying out the technology, as are the University of Connecticut, the University of Oklahoma, and West Chester University

(Pennsylvania), all under a National Collegiate Athletic Association (NCAA)-sponsored study that has led to the development of new guidelines regarding the amount of time players can practice and the amount of padding they can wear during hot summer days.

In the NFL, the Jacksonville Jaguars, Philadelphia Eagles, and Minnesota Vikings are using the CorTemp technology to monitor their players. According to HQ, Inc., and widely published reports, all three teams are pleased with how the sensor pill is keeping their players safe from the heat. HQ, Inc., is currently talking with several other professional football teams about investing in its products.

CorTemp is also keeping athletes from overheating in other sports. In track and field, Olympic triathlon champion Simon Whitfield, of Ontario, Canada, used the technology in preparation for the 2004 Olympic Games in Athens. In auto racing, Ford Australia is testing it as part of a program that it hopes will someday lead to a better way of monitoring drivers for dehydration and heat exhaustion. Other sports making use of the pill include soccer, hockey, and cycling.



While certified athletic trainers can retrieve athletes' core temperatures right from the sidelines, they can also get the same information away from the playing field, since it can be transmitted wirelessly to a PDA (pictured) or a PC in real time.

Beyond the sporting world, the ingestible capsules have been used to monitor the core body temperatures of firefighters as they battle blazes and divers as they work in deep, cold waters. The technology has also been used to monitor critical temperatures in paper manufacturing, in food processing, and in jumbo television sets found at sport stadiums.

Furthermore, doctors studying sleep disorders have used it to determine when people are sleeping most deeply, because that is when their temperature is the lowest. It has additionally been utilized in heart surgery, when patients' bodies needed to be cooled down.

Applications are expanding for HQ, Inc., leading to a spike in the company's sales, more celebratory spikes on the football field, and, most importantly, fewer spikes in temperature. ❖

CorTemp™ is a trademark of HQ, Inc.

Space-Proven Medical Monitor: The Total Patient-Care Package

Originating Technology/NASA Contribution

By mid-1963, American astronauts had visited space on six different occasions, all as part of NASA's first human space flight program, the Mercury Program. During the final Mercury mission, launched on May 15, 1963, astronaut Leroy Gordon Cooper logged 34 hours in orbit, the longest an American had spent in space to that point. Still, very little was known about the impact that space would have on humans and spacecraft that were subjected to long-duration missions. With this in mind, NASA decided to follow the Mercury Program with a new initiative called the Gemini Program.

On June 3, 1965, Gemini IV astronaut Edward H. White II became the first American to step outside a spacecraft and let go for a space walk, effectively setting himself adrift in the zero gravity of space. For 23 minutes, White floated and maneuvered himself around the Gemini spacecraft; he logged 6,500 miles during this historic orbital stroll.

The primary objective of the Gemini Program was to develop techniques that would allow for advanced, long-duration space travel—a prerequisite of the ensuing Apollo Program that would put man safely on the Moon before the end of the decade. In order to carry out this objective, NASA worked with a variety of innovative companies to develop propulsion systems, onboard computers, and docking capabilities that were critical to the health of Gemini spacecraft, as well as life-support systems and physiological-monitoring devices that were critical to the health of Gemini astronauts.

One of these companies was Spacelabs Medical, Inc., the pioneer of what is commonly known today as medical telemetry. Spacelabs Medical helped NASA better understand man's reaction to space through a series of bioinstrumentation devices that, for the first time ever, were capable of monitoring orbiting astronauts' physical conditions in real time, from Earth.

The company went on to further expand its knowledge of monitoring and maintaining health in space, and then brought it down to Earth, to dramatically change the course of patient monitoring in the field of health care.

Partnership

Spacelabs Medical was co-founded by Ben Ettelson and James A. Reeves in 1958 for the express purpose of working with NASA and the U.S. Air Force on systems to monitor the vital signs of astronauts in space. As a prime contractor to NASA for the Gemini Program, the company manufactured and delivered prototypes of miniaturized signal conditioners to measure astronauts' temperature, respiration, and cardiac activity. This technology was first worn by astronauts James A. McDivitt and Edward H. White II during their historic Gemini IV flight—the first American spacewalk—to assure proper evaluation of their health and performance.

In July 1969, just days after Neil Armstrong become the first man to walk on the Moon during the Apollo 11 mission, NASA's Manned Spacecraft Center (now Johnson Space Center) honored Spacelabs Medical with a certificate of appreciation for its "outstanding" contributions to the Apollo Program—contributions which proved vital to successfully achieving the Nation's goal of landing men on the Moon and returning them safely to Earth.

Product Outcome

After pioneering medical telemetry in the mid-1960s, Spacelabs Medical began making the transition from monitoring in space to monitoring in hospitals. In 1968, it unveiled its first systems for intensive care unit (ICU) and critical care unit (CCU) monitoring. In 1974, it launched Alpha, the first-ever patient-monitoring system to incorporate digital microprocessor technology. This helped to make patient monitoring faster, not to mention more affordable, since complex systems could now be produced by using smaller, less expensive parts, with less assembly work. In 1979, the company introduced the first bedside arrhythmia-monitoring system, allowing physicians to view real-time arrhythmia data, by the patient's side, for the first time.

Entering the 1980s, the company was enjoying accomplishment after accomplishment, as a result of its decision to adapt the technology it originally developed for NASA to commercial use in health care. By heavily investing in research and development, the company was able to dream up new, innovative enhancements that were necessary for it to stay ahead of the technology curve. It was during this time that Spacelabs Medical delivered the Patient Care Management System (PCMS) product, complete with a system architecture—incorporating Ethernet communication connections and "smart" touchscreen controls—that was well ahead of its time. In the latter part of the decade, the PCMS product line expanded to include portable, color monitors and remote-access laptops, as well as Flexport system interfaces, which the company reports are the first interfaces to integrate standalone monitoring devices with a larger monitoring network.

WinDNA gives clinicians easy and immediate access to more information and more functions from the patient's bedside.

This technology continued to evolve throughout the 1990s, with Spacelabs Medical making it easier for clinicians to access more information from either the patient's bedside or from a remote location and, thus, provide better care. Spacelabs Medical's introduction of Windows Dynamic Network Access (WinDNA) marked yet another milestone in the company's illustrious career of pioneering patient-monitoring technology. WinDNA is software that provides staff access to and interaction with medicine administration records, laboratory test results, any type of electronic report or chart located in other areas of a hospital, and any Windows program on a hospital's network. It also possesses Internet and Intranet capabilities, which allow hospital staff to maintain schedules and check e-mail.

By allowing seamless data acquisition and exchange across an entire health care organization, this technology improves overall efficiency and prevents caregivers from having to leave a patient's side to obtain information that is physically located somewhere else.

"I can go to the lab, library, and records—and never leave the NICU (neonatal intensive care unit)," asserted a nurse from North Carolina Children's Hospital, adding that WinDNA is keeping this facility on the cutting edge of patient care.

Children's Hospitals and Clinics in St. Paul, Minnesota, has the largest all-private-room NICU in the United States, due in part to the WinDNA technology, which allows for around-the-clock, remote patient monitoring. This system is linked to pocket-sized, wireless handsets carried by primary nurses, as well as designated back-up nurses, in the event that the primaries cannot respond immediately. Instead of having an immediate-response alarm sound in a patient's room, the alarm is transmitted, instantly and silently, to the wireless devices. This concept has translated into constant, effective care, all while reducing noise levels and room traffic, so that the infants can progress in a quiet, stress-free, and more natural environment.

Spacelabs Medical's technology has not only created a calm over Children's Hospitals and Clinics' NICU, it has affected the staff, too. NICU workers report that they are not as uptight at the end of their shifts and are better able to relax and sleep at home.

This patient-monitoring technology has also been embraced by many other health care organizations, including the University of Illinois Medical Center, St. Louis Children's Hospital, the Nemours/Alfred I. duPont Hospital for Children (Wilmington, Delaware), Lakeland Regional Medical Center (Lakeland, Florida), the University of North Carolina Health Care System, and the University of Missouri Health Care System.

In 1999, Spacelabs Medical's products became the first to operate in the Wireless Medical Telemetry Service. This service consists of frequencies that were established by the Federal Communications Commission and have been set aside for medical uses only. Because neither land-mobile radios nor television are allowed to operate on these frequencies, they are safe from radio frequency interference that previously posed serious risk to medical telemetry equipment.

Based in Issaquah, Washington, with regional offices spanning the globe, the company is leading the way into the 21st century with the introduction of the Intesys Clinical Suite (ICS), a set of solutions that enables ubiquitous access to patient information. One component of this suite is the Vital Signs Viewer, which allows physicians to see a patient's live waveforms remotely from any networked personal computer located outside of a hospital, such as a laptop set up in a physician's offsite office or home. Another component is the Clinical Event Interface (CEI), which advises caregivers of patient status or patient alarms, via advanced communication devices. Spacelabs Medical has also introduced a new, wireless networking option for its Ultraview SL compact, bedside patient monitors.

Forty-eight years after opening its doors to develop technology for NASA, Spacelabs Medical's health care expertise has once again been called upon by the Space Agency. Under contract to Johnson Space Center, it recently performed field tests of space-related telemetry equipment for use in disaster-response situations on Earth.

"We are pleased to have had the opportunity to participate in this exercise," noted a Spacelabs Medical representative. "Our company got its start making telemetry systems for monitoring vital signs of the early astronauts in the late 1950s, and now we are once again involved with NASA." ❖

Flexport®, WinDNA®, and Ultraview® are registered trademarks of Spacelabs Medical, Inc.

Windows® is a registered trademark of Microsoft Corporation.

From Planetary Imaging to Enzyme Screening

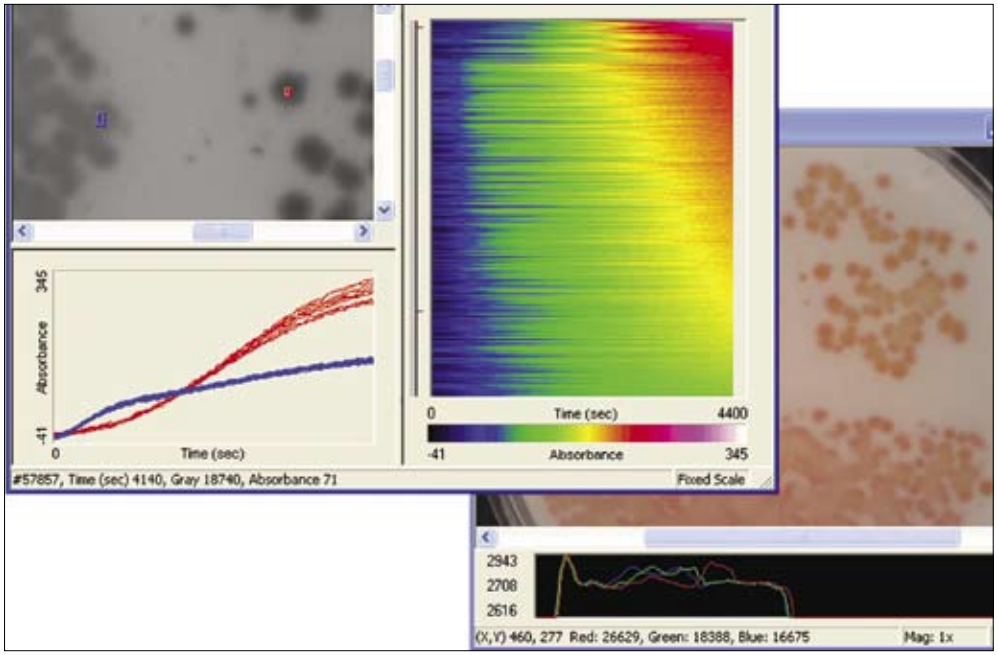
Originating Technology/NASA Contribution

To work in NASA's Mission Control Center and share in the excitement of seeing the very first close-up images of Saturn being piped back to Earth (from the Pioneer 11 spacecraft in 1979) is not a sensation that most high school students get to experience. However, as part of an internship in NASA's Space Biology Program, Mary M. Yang had the opportunity to do just that.

This rewarding experience of working with NASA turned out to be the first of several for Yang, who, as a young student, was fascinated with planetary imaging and remote sensing observations. Following high school, she worked at the Jet Propulsion Laboratory, developing sensors for NASA, and attended the University of California, Berkeley. Yang then went on to pursue a doctorate in geology at Princeton University, where her thesis covered spectroscopy and data analysis of minerals and solutions—themes she also encountered in her work for NASA. After completing her doctorate, Yang joined the research laboratory of Douglas Youvan, then a chemistry professor at the Massachusetts Institute of Technology.

At the time, Youvan's lab was studying photosynthesis, the process by which light is converted to chemical energy in living organisms. Studies were performed by measuring the spectral properties of genetically engineered photosynthetic bacteria. "In the early days, a series of arduous tasks were necessary to prepare the bacterial samples for spectral analysis," said Yang. "Bacterial colonies had to be hand-picked from Petri plates, cultured, and then the cells were concentrated and subjected to high pressure in order to obtain enough samples to perform conventional spectroscopy, one sample at a time."

In order to bypass weeks of sample preparation time, Youvan and Yang developed prototype imaging spectrophotometers that enabled them to acquire spectra directly from bacterial colonies growing on the surface of a Petri plate. This type of imaging instrument analyzes a combination of spatial and spectral information so that spectra can be obtained for each feature in an image. Analyses of this kind were initially applied by NASA to rather large scenes, such as planetary and remote sensing studies. In remote sensing, for example, NASA utilizes aircraft- and satellite-based imaging spectrophotometers to collect airborne data.



KAIROS Scientific, Inc.'s graphical user interface for digital imaging spectroscopy. Close to 60,000 individual kinetics data have been sorted, with single pixel reaction kinetics being shown here.

In 1991, Yang and Youvan founded KAIROS (now KAIROS Scientific, Inc.) to extend Yang's NASA "know-how," plus the imaging spectrophotometers initially developed for laboratory-based photosynthesis studies, to the fields of materials science, health, and biotechnology.

Partnership

Based in San Diego, KAIROS Scientific develops molecular biology methods, instrumentation, and computer algorithms to create solutions to challenging problems in the medical and chemical industries. The company's pioneering efforts in digital imaging spectroscopy (DIS) enable researchers to obtain spectral and/or time-dependent information for each pixel or group of pixels in a two-dimensional scene.

In addition to having Yang's NASA experience at its foundation, KAIROS Scientific was established with the support of many government grants and contracts. Its first was a NASA **Small Business Innovation Research (SBIR)** grant, from Ames Research Center, to develop HIRIM, a high-resolution imaging microscope embodying both novel hardware and software that can be used to simultaneously acquire hundreds of individual absorbance spectra from microscopic features. Using HIRIM's graphical user interface, MicroDIS, scientists and engineers are presented with a revolutionary new tool which enables them to point to a feature in an image and recall its associated spectrum in real time.

The HIRIM instrument was delivered to the Earth Science Division at Ames in May of 1998. This delivery marked the end of the 3-year SBIR research and development program, which included acquisition of spatial and spectral information of hundreds of algae and cyanobacteria immobilized on slides. NASA wanted to collect this information as a ground-truthing means (the use of a ground survey to confirm the findings of an aerial survey or to calibrate quantitative aerial observations) for satellite and remote sensing studies of oceanic phytoplankton, and to provide insight into the contributions of these organisms to primary production and global carbon cycles. Since this original application, HIRIM has also been used by NASA scientists to study meteorite specimens called meteorite thin sections. By mounting a very thin slice of a meteorite specimen (about 30 microns thick) on a glass slide, the scientists can determine its make-up and learn what environmental conditions the specimen has been exposed to.

Product Outcome

KAIROS Scientific has licensed and applied its DIS technology platform to several application areas. In the area of disease management, DIS is demonstrating that it may be possible, in certain situations, to differentiate healthy and diseased tissue, based on their spectral properties. By using DIS to combine spectral and image analyses, it may also be possible to detect subtle spatial features in human tissue for applications in pathology and oncology.

KAIROS Scientific is most known, though, for commercializing a DIS-based solid-phase enzyme screening technology, called Kcat Technology. With the combination of Kcat Technology and years of experience in protein engineering, the company is significantly accelerating the pace of custom enzyme development and commercialization.

KAIROS Scientific, Inc.'s Kcat Technology consists of methods, instrumentation, and algorithms for solid-phase enzyme screening. The Kcat instrument seen here is connected to a desktop workstation and displaying a panel of results from the sorting of approximately 12,000 individual absorbance spectra. Kcat Technology has been commercialized in the form of products and services for chemical companies, pharmaceutical firms, and academic laboratories.

In order to develop new enzymes at a faster pace, the population of enzyme variants must be carefully designed and an efficient high-throughput screening method must be used. Kcat Technology consists of methods, instrumentation, and algorithms that enable rapid and efficient screening of enzyme variants expressed in microcolonies. It utilizes a solid-phase format and incorporates a small assay disk on which thousands of individual variants can be simultaneously screened. This is a thousandfold reduction in volume as compared to traditional liquid-phase screening. Only tens of nanoliters per reaction are needed, making the Kcat Technology particularly useful for performing assays that require expensive or difficult-to-synthesize reagents. The multispectral capability of Kcat Technology is especially useful for multiplexed reactions (for evolving new substrate specificity or enantioselectivity). The solid-phase format allows assay design flexibility so that multiple properties can be evolved and screened for in the same variant. It is also particularly effective on insoluble or high-molecular weight substrates (proteins or polymers), since it requires almost no pipetting. A throughput of up to a million variants per instrument per day can be achieved on a bench-top instrument without the need for complex robotics.

Kcat Technology has been commercialized in the form of products and services which KAIROS Scientific provides. Clients include multinational specialty chemical companies, large pharmaceutical firms, and academic laboratories.

KAIROS Scientific was recently awarded its sixth Federal Phase II SBIR grant, to develop cellulase enzymes for biomass conversion. Engineered cellulases may be applied to papermaking, paper recycling, and the efficient conversion of agricultural waste into ethanol for fuel. ❖

HIRIMTM, MicroDIS™, and Kcat TechnologyTM are trademarks of KAIROS Scientific, Inc.

Damage-Tolerant Fan Casings for Jet Engines

The braided composite creates a lighter, more fuel-efficient engine casing that is stronger and safer than those made with aluminum or other traditional materials.

Originating Technology/NASA Contribution

All turbofan engines work on the same principle. A large fan at the front of the engine draws air in. A portion of the air enters the compressor, but a greater portion passes on the outside of the engine—this is called bypass air. The air that enters the compressor then passes through several stages of rotating fan blades that compress the air more, and then it passes into the combustor. In the combustor, fuel is injected into the airstream, and the fuel-air mixture is ignited. The hot gasses produced expand rapidly to the rear, and the engine reacts by moving forward.

If there is a flaw in the system, such as an unexpected obstruction, the fan blade can break, spin off, and harm other engine components. Fan casings, therefore, need to be strong enough to contain errant blades and damage-tolerant to withstand the punishment of a loose blade-turned-projectile.

NASA has spearheaded research into improving jet engine fan casings, ultimately discovering a cost-effective approach to manufacturing damage-tolerant fan cases that also boast significant weight reduction. In an aircraft, weight reduction translates directly into fuel burn savings, increased payload, and greater aircraft range.

This technology increases safety and structural integrity; is an attractive, viable option for engine manufacturers, because of the low-cost manufacturing; and it is a practical alternative for customers, as it has the added cost saving benefits of the weight reduction.

Partnership

A&P Technology, Inc., of Cincinnati, a leading manufacturer of braided fabrics for composite reinforcement and advanced technology applications, received a **Small Business Innovation Research (SBIR)** grant through Glenn Research Center to develop damage-tolerant fan casings for jet engines. Additional collaborators on this project included the Federal Aviation Administration, Ohio State University, and the University of Akron, Ohio. This group effort enabled the rapid development and fabrication of the prototype composite fan cases for direct comparison to the metal fan cases currently used in aircraft engines.

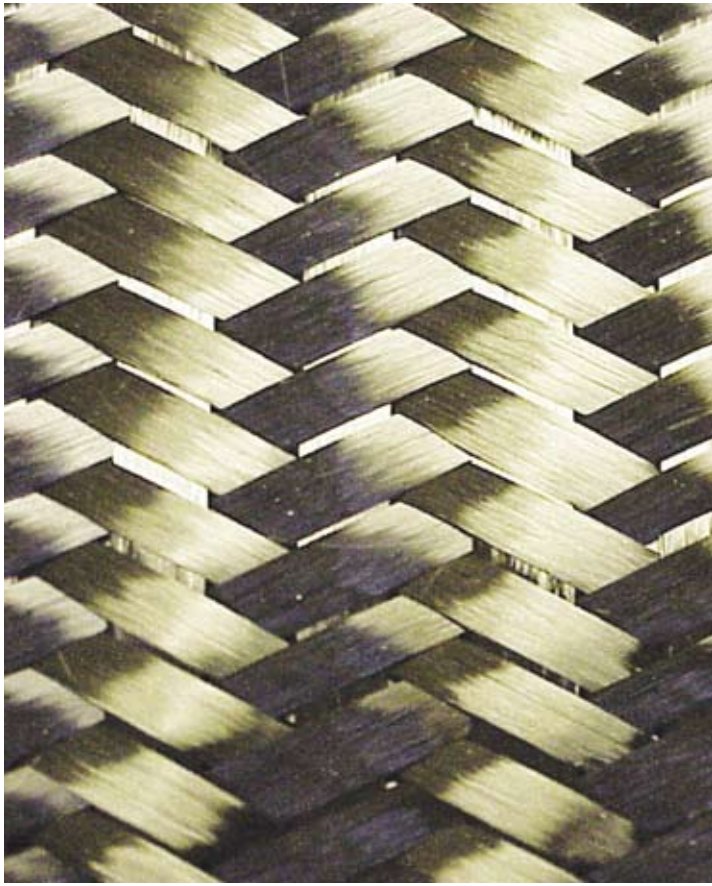
The prototypes proved feasible. A&P, a seventh-generation, family-owned company is partnered with two major manufacturers of jet aircraft engines—Williams International and Honeywell International Inc.—and is sponsored by General Electric Corporation's Aviation division, GE Aviation, in the development and production of these braided composite fan cases.

For the successful work on this SBIR, A&P received the "Emerging Technology Award" from the Ohio Department of Development. The work also contributed to Glenn's Jet Engine Containment Concepts and Blade-Out Simulation Team receiving the NASA "Turning Goals into Reality" award.

Product Outcome

A&P uses triaxial carbon braid as an alternative to aluminum or other solid metal in the manufacture of braided fan containment cases for jet engines. The braided fan case has a toughness superior to aluminum and enables significant reductions in weight and fuel consumption.

The use of braided reinforcements also allows for a low-cost, repeatable manufacturing process. A&P produces a braided sleeve with a custom shape that exactly fits the geometry of the fan case. Instead of having to cut



complicated shapes to match the geometry of the fan case, the manufacturer can simply wrap A&P's tailored braid circumferentially in a continuous lay-up to create the needed structural reinforcement. This cuts down significantly on manufacturing time and costs.

Not only can the efficiency of the manufacturing process increase noticeably with the braid, but the performance of the braided case exceeds the performance of conventional fan cases. Impact testing has shown that braided laminates perform better, because the failure mode is much more controlled. In impact tests, the braided laminate experiences fracturing only near the point of impact while the rest of the laminate remains intact. In contrast, a conventional laminate that fractures from an impact spreads rapidly to regions remote to the initial impact location, like the "spider web" cracking of a windshield. This extensive failure results in a fan case structure that is less able to withstand secondary loads as the fan decelerates.

The efficient distribution of loads makes braided structures highly impact resistant. Since all of the fibers in the structure are involved in a loading event, a braid absorbs a great deal of energy as it fails, making it very effective for use in fan blade containment for commercial jet aircraft.

A braid's resistance to crack propagation is a result of two key features: the interwoven fibers within each layer of braid, which distribute load evenly, and the isotropic architecture offered within each individual ply. Since each ply is isotropic within itself and identical to each neighboring ply, the interlaminar stresses are minimized during response to an impact event. Upon impact, crack propagation is contained to an area substantially smaller than those found upon impact of aluminum or laminate cases.

Although braiding has been a mechanized process for over 300 years, creating everyday products like clotheslines and candlewicks, A&P has advanced the manufacturing technology to incorporate cutting-edge materials such as carbon fiber into structures of previously unthinkable scale. For instance, one fan case design it built is approximately 10 feet in diameter and 5 feet long. The braided reinforcements for this composite fan case were produced on one of A&P's Megabraiders—an 800 carrier braiding machine—the largest braiding machine in the world.

The braided fan case has a toughness superior to aluminum and enables significant reductions in weight and fuel consumption.

In the case of the GEnx engine, the composite fan case A&P is making for GE Aviation, braid will reduce engine weight by 350 pounds, or 700 pounds in a two-engine aircraft. The overall weight reduction is more than 800 pounds for the aircraft, because composite materials also allow for weight avoidance in the engine installation. The weight reduction translates directly into fuel savings, increased payload and/or greater aircraft range, and those are really just secondary benefits of this technology, with the primary benefit being the added safety of a stronger fan casing. ❖

Steering Aircraft Clear of Choppy Air

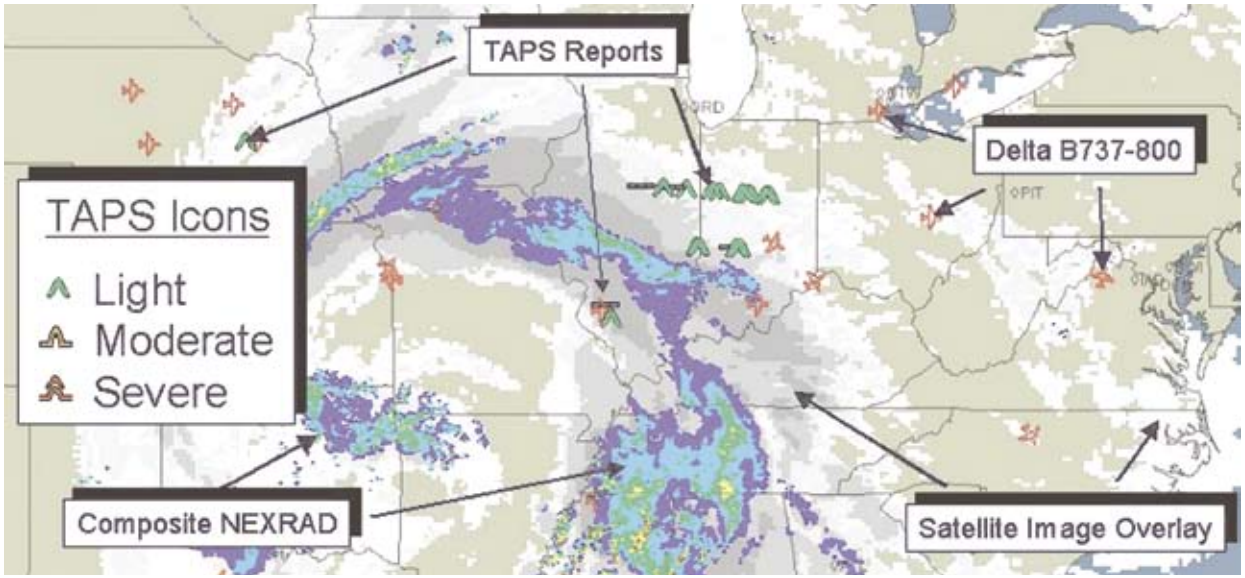
Originating Technology/NASA Contribution

On December 28, 1997, a United Airlines plane flying from Japan to Hawaii experienced severe turbulence while over the West Pacific Ocean. Over 100 individuals on this flight of 374 passengers and 19 flight crew members were injured during the encounter, one fatally. Investigative reports issued following the incident indicated that the plane was subjected to a "sudden upward push of almost twice the force of gravity," followed by a "sharp, downward push" about 6 seconds later.

In other incidents, turbulent air has ripped off airplane engines, broken wings in half, flung food carts to the ceiling, and caused broken bones in passengers and flight attendants. Whether it is an injury to a human, damage to onboard equipment, or damage to a plane itself, airlines are facing greater than $100 million in turbulence-related costs annually, according to the U.S. Department of Transportation and the Federal Aviation Administration (FAA). Moreover, NASA has found that turbulence encounters by commercial transports are the leading cause of injuries to passengers and flight crews in non-fatal airline accidents.

But what exactly is this turbulence phenomenon, and how does it occur? Turbulence is an irregular or disturbed flow in the atmosphere that produces gusts and eddies. What makes turbulence so dangerous is that it normally cannot be seen, and onboard radar systems that track weather cannot detect it—even though weather is accountable for turbulence in many instances. In fact, nearly 80 percent of all turbulence-related accidents are associated with thunderstorm activity.

It is not always the weather, though. If you are accustomed to flying the "friendly" skies, you have likely noticed that the rough and bumpy parts of a trip can often occur when the skies actually appear to be friendliest; that is, clear and blue as far as the eye can see. This type of clear-air turbulence can be attributed to jet streams, or fast, high-altitude air currents that disturb nearby air, as well as air that passes over mountains or other high obstructions. The wakes created by other nearby planes or helicopters can also stir up turbulence. Wake turbulence is more prevalent in areas where planes are taking off and landing.



Screen shot of a ground station display showing a storm system over the central United States. The colored areas represent radar reflectivity. Also shown are various aircraft in the area and the TAPS reports made by TAPS-equipped transiting aircraft.

A team of researchers at Langley Research Center, under the Turbulence Prediction and Warning Systems (TPAWS) project, developed two special technologies that can automatically alert pilots of potentially hazardous turbulence conditions, in real time.

The first technology, called the Enhanced Turbulence (E-Turb) Mode Radar, is software in an aircraft's radar that can provide flight crews advance warning of turbulence, so that they can avoid it altogether and keep themselves and their passengers out of harm's way, or, at a minimum, prepare the aircraft for it by stowing loose equipment and having passengers and crew seated with seatbelts fastened.

"The radar technology is an enhanced turbulence-detection radar system that detects atmospheric turbulence by measuring the motions of the moisture in the air," said NASA's TPAWS project manager, Jim Watson. "It is a software signal-processing upgrade to existing predictive Doppler wind shear systems that are already on airplanes."

The second technology, known as the Turbulence Auto-PIREP System ("PIREP" is a term used in the aviation industry for pilot reports), or TAPS, is software that improves situational awareness of the location and severity of actual turbulence encounters for pilots, dispatchers, and controllers. If a TAPS-equipped aircraft encounters turbulence that exceeds the designated turbulence threshold, the onboard TAPS software will generate a turbulence report that is then broadcast over a data link. The report is received by ground stations, where it is automatically shown on a display, accessible via the

Internet by dispatchers, controllers, airline operations personnel, and maintenance crews. Various functions allow the ground station display users to process and tailor the information for specific users. If there are any other aircraft on course to approach the region where the turbulence was reported, then the ground station can directly uplink the TAPS report packet to them.

The E-Turb Mode Radar and TAPS developmental efforts were carried out as part of NASA's Aviation Safety and Security Program, which has tapped into decades of aeronautics research to make commercial air travel more secure. The goal is to reduce the number of turbulence-related accidents 50 percent by 2007.

Partnership

AeroTech Research (U.S.A.), Inc., a leader in turbulence-detection and warning systems, has been involved with NASA Aviation Safety research since 1998. AeroTech served as a contractor for the TPAWS government/industry development project, and was funded by NASA to develop the E-Turb Mode Radar algorithms and the TAPS software. (Other contributors to this project include the National Center for Atmospheric Research, the FAA, North Carolina State University, and the Research Triangle Institute.)

The radar algorithms combine an aircraft's turbulence-response characteristics with radar measurements to determine the predicted turbulence loads the aircraft will experience, and present this information to the pilot. The TAPS software monitors and processes onboard aircraft sensor data; generates automatic reports when an aircraft encounters turbulence and a set turbulence threshold is exceeded; and then displays the reports and underlying information to ground personnel to improve situational awareness of the location and the severity of the turbulence encounter.

Once the E-Turb Mode Radar and TAPS were developed, AeroTech helped NASA perform the initial flight testing of the technologies. For this, the systems were implemented on NASA's B-757 research aircraft. Upon installation, the B-757 was flown through regions of significant turbulence, caused by thunderstorms. The actual flight data gathered allowed NASA and AeroTech to fully evaluate the systems' performances and then optimize the technologies to ensure they were ready for commercial application.

NASA and AeroTech began an in-service evaluation of the TPAWS in concert with Delta Air Lines to evaluate the effectiveness of TPAWS to a wider variety of turbulence experienced in operational conditions.

The E-Turb radar software was integrated into a Rockwell Collins WXR-2100 radar, which was installed on a Delta Boeing 737-800 aircraft and has been flying in revenue operations for over 2 years. The TAPS software was implemented on a total of 123 Delta Boeing 737-800, 767-300ER, and 767-400ER aircraft, and has also been flying in revenue operations for over 2 years. TAPS was additionally integrated into a ground station graphical display system, where turbulence reports generated by TAPS-equipped Delta aircraft have been viewed and used by Delta dispatch, operations, flight safety, management, and maintenance personnel since August 2005.

Installation of the E-Turb radar, a modified radar unit that can detect turbulence associated with thunderstorms by measuring the motions of the moisture in the air.

Product Outcome

AeroTech's versions of these airborne turbulence technologies are being implemented into commercial systems. The E-Turb radar algorithms are being developed for different aircraft types and for incorporation in new radars. A retrofit option for existing radars is also under consideration. This would allow the maximum number of aircraft to take advantage of the new, enhanced turbulence radar-detection capabilities. The FAA is currently developing minimum performance standards for airborne weather radar with turbulence-detection algorithms.

TAPS, meanwhile, continues to fly on the Delta aircraft. Additional airlines have shown interest in participating in the effort and, hence, sharing TAPS reports.

Besides improved in-flight safety measures, TAPS also enables more judicious use of airspace and can lead to potential savings in fuel and reductions in flight delays. The technology can also assist meteorologists in validating and enhancing weather forecasts.

"With these [TAPS] tools, we'll have better knowledge of where turbulence is, and we won't cry wolf as much," said Bill Watts, Delta Air Lines' Turbulence Program manager. "We can get people to sit down when they need to sit down."

In its current format, however, TAPS information can only be sent to the cockpit and received by airborne crews via text and voice messages from dispatchers. AeroTech was awarded a NASA **Small Business Innovation Research (SBIR)** contract to carry out this work, and will continue to collaborate with various industry groups to ensure that the turbulence technology reaches its potential. ❖

Advanced Air Data Systems for Commercial Aircraft

Originating Technology/NASA Contribution

It is possible to get a crude estimate of wind speed and direction while driving a car at night in the rain, with the motion of the raindrop reflections in the headlights providing clues about the wind. The clues are difficult to interpret, though, because of the relative motions of ground, car, air, and raindrops. More subtle interpretation is possible if the rain is replaced by fog, because the tiny droplets would follow the swirling currents of air around an illuminated object, like, for example, a walking pedestrian. Microscopic particles in the air (aerosols) are better for helping make assessments of the wind, and reflective air molecules are best of all, providing the most refined measurements. It takes a bright light to penetrate fog, so it is easy to understand how other factors, like replacing the headlights with the intensity of a searchlight, can be advantageous.

This is the basic principle behind a lidar system. While a radar system transmits a pulse of radiofrequency energy and interprets the received reflections, a lidar system works in a similar fashion, substituting a near-optical laser pulse. The technique allows the measurement of relative positions and velocities between the transmitter and the air, which allows measurements of relative wind and of air temperature (because temperature is associated with high-frequency random motions on a molecular level).

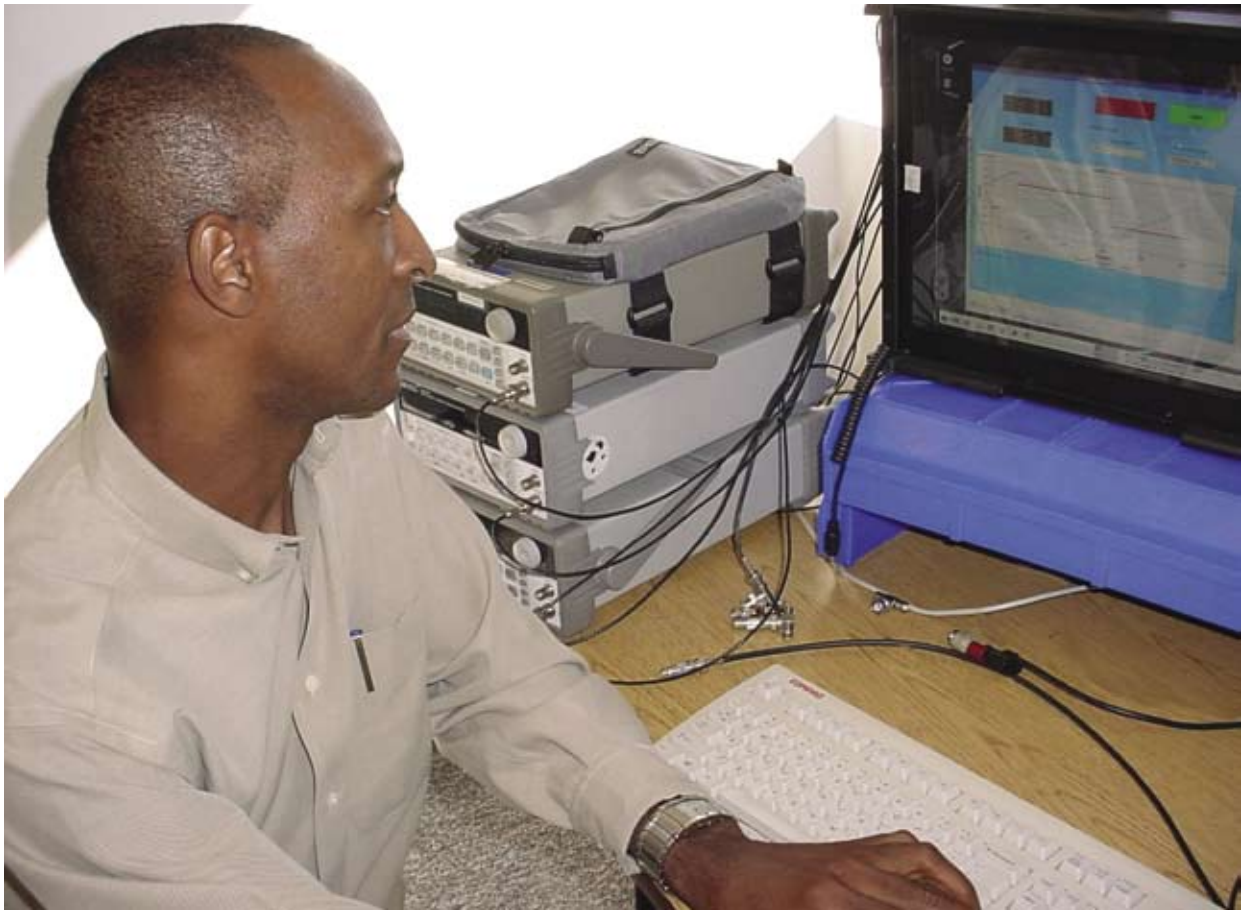
NASA, as well as the National Oceanic and Atmospheric Administration (NOAA), have interests in this advanced lidar technology, as much of their explorative research requires the ability to measure winds and turbulent regions within the atmosphere. Lidar also shows promise for providing warning of turbulent regions within the National Airspace System to allow commercial aircraft to avoid encounters with turbulence and thereby increase the safety of the traveling public. Both agencies currently employ lidar and optical sensing for a variety of weather-related research projects, such as analyzing the water content of snow and forecasting lightning.

Partnership

NASA has been working with Ophir Corporation, of Littleton, Colorado, since 1985, on a variety of remote optical sensing projects. Most of this work has been in the form of **Small Business Innovation Research (SBIR)** grants.

An infrared air temperature radiometer—the by-product of one of the early Phase I and Phase II SBIR projects carried out through Dryden Flight Research Center—is now resident at the National Center for Atmospheric Research. The device delivers highly accurate, remote air temperature measurements, and it provides remote detection of atmosphere thermal anomalies, precursors for the formation of clear-air turbulence and other flight hazards.

In the 1990s, Ophir's work with NASA shifted from the weather-related sensors it had been developing to



An Ophir Corporation engineer works with a ground-based unit that provides air data for air vehicles, as well as information for turbulence detection and wind profiling.

remote sensing instrumentation to measure temperature, humidity, and airspeed. The resulting measurements could be used to improve flight safety.

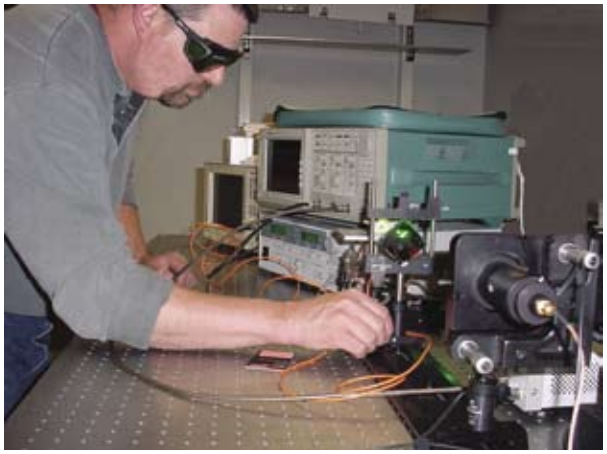
From 2002 to 2004, Ophir worked under new SBIR Phase I and II contracts with Dryden to provide proof-of-concept laboratory testing of a new approach to Optical Air Data Systems (OADS). Traditionally, air data is measured with several probes that are mounted on an aircraft, including immersion temperature probes and Pitot airspeed probes, as well as with flush-mounted static pressure ports.

In this project and in a follow-on effort, Ophir addressed the problem of determining the characteristics of the air outside of the boundary layer of an aircraft. This development included the use of a single sensor to replace the conventional air data sensors that are prone to such failures as icing and the plugging of Pitot tubes. An optical air data sensor now provides the potential for important benefits to high-performance aircraft. These include measurements in difficult aircraft attitudes, potentially higher update rates, and reduced calibration and maintenance costs.

Product Outcome

The company has made great strides in this research, and although the studies continue, it has already commercialized a portion of the work. Through its efforts to develop a lidar OADS for modern aircraft, Ophir has developed a technology it calls senseAir that overcomes the problems inherent to the early laser-based OADS.

Early laser-based OADS made use of the backscattered signal from natural atmospheric aerosols to measure airspeed. This approach suffered due to the fact that insufficient atmospheric aerosol loading at critical flight altitudes sometimes made system operation unreliable. Also, early systems, operating as they did on aerosol backscattered energy, did not have access to mean molecular velocity and, therefore, could not measure atmospheric temperature. Molecular density is another parameter that



Ophir Corporation has developed a significant innovation in the field of Optical Air Data Systems, since its device can measure all air data parameters in both aerosol and non-aerosol conditions from a single sensor.

can be obtained using molecular backscatter, and this parameter, when combined with the temperature measurement, can provide the full set of air data information from a single system, which was not possible from systems using only aerosol scattering.

The senseAir technology can provide air data (velocity, temperature, and pressure) even when no aerosols are present—in clean-air atmospheric conditions. It does not rely on coherent, optical wavefront mixing. This is an important advantage in a high-vibration aircraft environment, since it dramatically reduces the need for precise optical alignment and thermal stability of the optical components. Moreover, atmospheric turbulence and refractive index fluctuations in the aircraft boundary layer will not degrade the performance of incoherent laser radar, such as used in this system.

The new system uses Rayleigh/Mie lidar, an optical laser-based, remote sensing technique intended to offer an option to traditional sensors used for measuring air data outside a vehicle's boundary layer. Laser light is scattered by the atmospheric aerosols and gas molecules, and an optical receiver collects a fraction of that light. The air molecules or aerosols have a net velocity along the direction of the laser light propagation, and the center wavelength of the scattered light is Doppler shifted. (This Doppler shift is analogous to the change in auditory pitch one hears from an oncoming train or automobile.) Measuring this frequency shift allows the relative airspeed to be measured along the laser's line of propagation.

The laser light is transmitted and collected along three different axes, and then the three-dimensional air velocity is measured. This provides total airspeed, angle of attack, and angle of sideslip. The aircraft's airspeed is found from the Doppler shift of the Rayleigh molecular scattering augmented by the aerosol Mie scattering, and will, therefore, not fail if the air becomes free of aerosols. Measuring the airspeed on three perpendicular axes allows the aircraft velocity relative to the air to be determined.

The innovative system uses optical scattering from atmospheric gas molecules (Rayleigh scattering) to obtain the mean random molecular velocity from which atmospheric temperature is derived. Again, using the molecular backscattered signal strength, the atmospheric gas density is obtained. Then, using the ideal gas law formula, pressure is obtained to provide the remaining parameter in the set of air data parameters, with the three vector components of airspeed and atmospheric temperature.

The Ophir system shows promise for improved reliability and reducing the need for periodic calibration, thereby contributing to a reduced life-cycle cost. When the air data measurement is made sufficiently ahead of the flight vehicle, the disturbance to the measurement by the presence of the aircraft is acceptably small so that one system calibration can be used for all aircraft. ❖

senseAir™ is a trademark of Ophir Corporation.

NASA Helps Design the 'Cockpit of the Future'

Originating Technology/NASA Contribution

Langley Research Center conducts research in support of all of the aeronautics project at NASA. It continues to forge new frontiers in aviation research, as it has since 1917, when it was established as the Nation's first civilian aeronautics laboratory. Langley's mission and contributions to aerospace, atmospheric sciences, and technology commercialization are improving the way the world lives and flies.

One of the initiatives at Langley involved the research and development of a Small Aircraft Transportation System Network (SATS-Net), which was the communications infrastructure for NASA's SATS program.

SATS research focused on four operating capabilities that may help permit people and goods to travel faster and farther, anywhere and any time; higher volume operations at airports that do not have control towers or terminal radars; pilots to land safely in low-visibility conditions at minimally equipped airports; increased single pilot performance; and SATS aircraft to integrate seamlessly into the complex national airspace.

The primary goal of SATS-Net was to develop secure virtual travel portals for the Nation's general aviation airports and to offer an alternative to commercial air and ground transportation through general aviation. The secondary goals were to increase mobility, reduce door-to-door travel times, and provide air transportation to underserved markets at an affordable cost. One of the specific plans was to create a network of information about the 2,000-plus non-tower, non-radar airports in the Nation.

This information would be accessible from a person's home, office, PDA, or local airport. This network provides real-time information and would be a "one-stop shop" portal with dynamic access to real-time Web cameras for weather conditions, flight planning information, local lodging, restaurants, and attraction information. SATS-Net would provide membership services much like that of AAA.

NASA, Dynamic Systems Integration, and Microsoft Corporation collaborated to create the Connected Cockpit of the Future, a Windows-based collection of NASA's Small Aircraft Transportation System Network (SATS-Net) information available online. Members of the team pose here with Bill Gates, Microsoft chairman.

Partnership

Dynamic Systems Integration (DSI) of Virginia Beach, Virginia, a voice, video, security, and data communications firm, partnered with Langley through a **Small Business Innovation Research (SBIR)** contract to develop a new system to assist in the data management for SATS-Net.

The project aimed at developing a system that would give pilots and passengers of small aircraft centralized access to information about local airports and travel information for the areas in which they are based, via the Internet.

Edwin Tirona, president of DSI, said of the experience, "We're very excited about the SBIR program. It takes some of the risk out of the process and still allows you to create a revenue-producing product."

Product Outcome

DSI has pushed its NASA SATS research in several directions, mostly as part of its Assured Aviation Web Services (AAWS) product, one of the key components in creating the airborne Internet.

The company partnered with Microsoft Corporation to create the Connected Cockpit of the Future, which has the potential to make flying an aircraft as safe, easy, affordable, and connected as driving a car, but without all of the headaches and traffic problems found on today's highways.

The Connected Cockpit of the Future is built on a Microsoft platform, allowing it to extend and embrace third-party applications through a new, aviation-grade communication standard that allows multiple applications to collaborate and share information.

A pilot enters flight information into a portable device. This can be done anywhere. The portable device is docked into the Connected Cockpit of the Future, where the information is downloaded, and the cockpit responds to the input by realigning itself and reorganizing its displays to match that pilot's user preferences, so that information is available to the pilot in familiar formats.

After the interface makes accommodations for user preferences and destination, it then runs through a series of checklists and monitors plane status. The system alerts the pilot both visually and by voice of any current or potential problems, then automatically connects to and receives clearance from the SATS Airport Management Module (AMM) to taxi. The AMM is a centralized, automated airport arbiter and sequencer. It receives requests from aircraft via data link and grants or denies access. The AMM also provides estimated times of arrival when access is granted and an "expect further clearance" time when access is denied.

Once the AMM has granted clearance, the cockpit display anticipates the information the pilot will need and makes it available at the most opportune time according to what stage of the flight the pilot is in and according to the predefined user preferences.

Another area where DSI used its NASA research is the subscription-based Web site, Airtraveler. The service provides pilots with up-to-date, detailed information about weather and airports, including the scope and amenities each airport provides, whether it is a full-service facility, or has landing facilities for seaplanes or helicopters. Pilots can access necessary assessments of the ground conditions from up in the air. Before landing, aircrews can even make arrangements for rental cars, read restaurant reviews, and learn about local attractions. It is a realization of the airborne Internet. ❖

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

Screen shot from the Airtraveler Web site, a first step in the realization of an airborne Internet.

Water Vapor Sensors Go Sky-High to Assure Aircraft Safety

Originating Technology/NASA Contribution

A laser diode is a semiconductor-based laser used to generate analog signals or digital pulses for transmission through optical fibers or through open air. In simpler terms, it is the type of laser that scans the barcode of a product to determine its price or reads the information stored on a compact disc to play music.

While laser diodes make for great sensors in detecting product prices and playing music, they are also very good at detecting gasses. NASA's Jet Propulsion Laboratory (JPL) developed a special type of laser diode-based gas analyzer that the Space Agency could use to measure atmospheric gasses on Earth and Mars.

In doing so, JPL used a special tunable diode laser, which NASA scientists could tune to different wavelengths—like a radio being tuned to different frequencies—to accurately target specific molecules and detect small traces of gas. This tunable diode laser was designed to emit near-infrared light at wavelengths absorbed by the gas or gasses being detected. The light energy being absorbed by the target gas is related to the molecules present. This is usually measured in parts per million or parts per billion. Multiple measurements are made every second, making the system quick to respond to variations in the target gas.

Miniaturized tunable diode laser packaging for sensing and measuring atmospheric water vapor.

NASA scientists developed this technology as part of the 1999 Mars Polar Lander mission to explore the possibility of life-giving elements on Mars. NASA has since used the tunable diode laser-based gas sensor on aircraft and on balloons to successfully study weather and climate, global warming, emissions from aircraft, and numerous other areas where chemical gas analysis is needed.

SpectraSensors, Inc., was formed in 1999 as a spinoff company of JPL, to commercialize tunable diode laser-based analyzers for industrial gas-sensing applications (*Spinoff* 2000). Now, the San Dimas, California-based firm has come back to the market with a new product featuring the NASA-developed instrument for atmospheric monitoring. This instrument is now helping aircraft avoid hazardous weather conditions and enabling the National Weather Service to provide more accurate weather forecasts.

Partnership

Prior to co-founding SpectraSensors, Dr. Randy May spent 15 years at JPL, where he led several major research tasks related to the development and utilization of tunable diode lasers in gas sensors for atmospheric studies. Additionally, May oversaw a laboratory program that developed spectroscopic analysis techniques and algorithms for the manipulation and interpretation of molecular gas spectra.

After many years of successful instrumentation development for atmospheric studies on Earth, May and his JPL research team received NASA funding in the mid-1990s to further develop and miniaturize the technology for planetary and space station studies, where overall size, mass, and power consumption are critical. They first responded by designing and building two onboard diode laser gas-measurement systems for the Mars Polar Lander. The intention of these two systems was to give the spacecraft

SpectraSensor, Inc.'s WVSS-II (Water Vapor Sensing System-II) helps pilots reroute around bad weather, increasing public safety and saving money for airlines. The technology consists of an electronics box, an air sampler on a filler plate, and connection hoses.

the ability to determine water vapor and carbon dioxide levels in the Martian atmosphere and in gasses evolved from heated soil samples.

The refinements made by May and his team prevailed in other realms of planetary research. They also provided NASA with an improved means of atmospheric measurement pertaining to ozone layers and a better understanding of weather/climate and aircraft emissions. All of these strides led to more applications for the sensors and made it feasible for NASA to consider their use in industrial monitoring and commercial aviation applications.

Soon after this realization, May—along with Dr. Carl Kukkonen—co-founded SpectraSensors to commercialize the tunable diode laser instrument for the industrial-process and environmental-monitoring markets.

Armed with proprietary technology and 15 years of NASA-related research experience, SpectraSensors moved into the marketplace with a laser device poised to revolutionize the way gasses are detected and monitored.

Product Outcome

SpectraSensors' latest product, the WVSS-II (Water Vapor Sensing System-II), combines the NASA-developed tunable diode laser analyzer with an air-sampling device the company licensed from the University Corporation for Atmospheric Research (UCAR) to deliver real-time weather forecasting and help aircraft avoid dangerous weather conditions. Water vapor measurement is key to accurate weather modeling and forecasting, because of water vapor's role in spawning unexpected turbulence, wind shear, fog, and thunderstorms. (When water vapor condenses, heat escapes through rising columns of air that create sudden instability in the atmosphere.)

Water vapor measurement, however, has long been the meteorologist's missing forecast element. Wind and temperature measurements are routinely made for weather forecasting, but water vapor measurement does not occur as regularly. The conventional method for collecting water vapor data is to use an older type of sensor that employs a thin film capacitor. According to SpectraSensors, National Oceanic and Atmospheric Administration weather balloons equipped with these sensors are launched only twice daily to measure water vapor, at less than 100 sites in the United States. The problem with this method is that, in only a couple of hours, sudden atmospheric instability induced by water vapor can make the data collected by these balloons unusable.

Painting a picture of just how prominent water vapor is in the skies is UCAR scientist Rex Fleming: "In a typical year, more water in the form of vapor and clouds flows over the dry state of Arizona than flows down the Mississippi River; yet we have not had a sensing system to collect accurate water vapor data frequently enough to be really useful for forecasts." He added: "Commercial aircraft can fill a critical gap in atmospheric

observations by gathering accurate data throughout the global atmosphere."

The WVSS-II can fill this gap by providing water vapor information every 2 seconds when applied to a commercial aircraft. This continuous stream of data can fill that hole in the meteorologist's forecast, plus help pilots to reroute around severe weather in real time. SpectraSensors noted that just 25 WVSS-II-equipped aircraft can supply more than 100 times the number of measurements made by weather balloons and satellites, all at a fraction of the cost.

The instrument's air-sampling device was built to be mounted onto the side of a plane. This air-sampler channels air into a measurement cell that is housed in a casing the size of a cigar box and located on the inside of the aircraft. The sampler gives a true air reading by weeding out rain, ice crystals, particles, air contaminants, and any other distractions that might otherwise compromise an accurate measurement.

When a true water vapor sample is collected, it is analyzed onboard the plane by the tunable diode laser system, which contains the advanced control electronics and data-processing software specifically designed for this application. The results of the analysis can then be transmitted to entities on the ground, which can then disseminate it to passenger and freight carriers, and to government agencies for short- and long-range weather planning.

Since the laser sensor is housed inside the plane, it does not come into direct contact with the outside elements. This noncontact feature prevents the laser from becoming contaminated and, thus, gives it a longer operating life. Moreover, the WVSS-II coexists with traditional aircraft data streams, such as engine performance and fuel level, so fewer customized modifications are necessary.

The WVSS-II was certified by the Federal Aviation Administration for commercial aircraft flights in December 2004. Installation of the first 25 units took place on Boeing 757 aircraft flown by the United Parcel Service (UPS), which has been responsible for providing wind and temperature data to meteorologists since 1994. Now, with the WVSS-II, UPS is adding another dimension to its weather forecasts.

"In a typical year, more water in the form of vapor and clouds flows over the dry state of Arizona than flows down the Mississippi River," said Rex Fleming, a scientist with the University Corporation for Atmospheric Research.

In addition, Southwest Airlines is planning to incorporate it in the near future. On an international scale, Lufthansa Airlines is installing the unit on its commercial aircraft, and the German Weather Service is in the process of certifying it for use, in collaboration with Australia, South Africa, and New Zealand.

A secondary function of the WVSS-II will be to calculate water vapor levels at extremely high altitudes to better understand global warming and the highly debated role that cirrus clouds play in this phenomenon. High, thin cirrus clouds tend to act as insulators, trapping heat before

it can radiate into space. In many scientific circles, it is believed that this heat contributes to global warming.

Water vapor is a major factor in the rising global temperatures. It is the greenhouse gas that contributes more to the greenhouse effect than any other natural gasses in the greenhouse family. Water vapor levels in the upper troposphere and stratosphere are as low as a few parts per million, and traditional measurement techniques are not adequate to provide accurate, timely data, according to SpectraSensors. In the long term, the company sees its WVSS-II technology helping to address many unanswered questions related to the causes and effects of global warming.

In fulfilling the Vision for Space Exploration, NASA plans to use the sensors aboard space vehicles to measure water vapor and carbon dioxide in the soil and atmosphere of other planets. These measurements could provide information on the geological history of these planets and their potential to support life. ❖

The air-sampling device was built to be mounted onto the side of a plane. Its aerodynamic design removes ice crystals, particles, rain, and other distractions to improve the sensitivity of the air measurement.

The United Parcel Service, which provides wind and temperature data to meteorologists, is now flying the technology on its aircraft, for increased reliability of forecasts.

Clean Water for Remote Locations

Originating Technology/NASA Contribution

Water is indispensable for human health and well-being. A person cannot live for more than a few days without clean, drinkable water. It is, therefore, one of the most crucial provisions astronauts need to live and work in space, whether orbiting Earth, working at a lunar base, or traveling to Mars.

Currently, astronauts aboard the International Space Station (ISS) receive their water from Russian delivery missions and from a device that catches some moisture from respiration and recycles it into limited amounts of drinking water. This water replenishment is a costly endeavor, and engineers are working on ways to make the process more efficient.

Toward that effort, Marshall Space Flight Center engineers are working on creating the Regenerative Environmental Control and Life Support System, a complex system of devices intended to sustain the astronauts living on the ISS and, in the future, sustain those who are blasting off to the Moon or Mars.

The devices make use of the available resources, by turning wastewater from respiration, sweat, and urine into drinkable water.

One of the devices that Marshall has been working on is the Water Recovery System (WRS). Marshall has teamed with long-time NASA contractor, Hamilton Sundstrand Space Systems International, Inc., of Windsor Locks, Connecticut. Hamilton Sundstrand, the original designer of the life support devices for the space suits, developed the Water Processor Assembly (WPA). It, along with the Urine Processor Assembly (UPA) developed by Marshall, combines to make up the total system, which is about the size of two refrigerators, and will support up to a six-member crew. The system is currently undergoing final testing and verification.

"The Water Processor Assembly can produce up to about 28 gallons of potable recycled water each day," said Bob Bagdigian, Marshall Regenerative Environmental Control and Life Support System project manager. After the new systems are installed, annual delivered water to the ISS should decrease by approximately 15,960 pounds, or about 1,600 gallons.

The WPA is tentatively scheduled for launch in 2008, but the technology is finding applications on Earth well before that date.

This is a close-up view of the Water Recovery System (WRS) racks, the hardware that will allow a constant supply of clean water for four to six crewmembers aboard the ISS. The WRS provides clean water through the reclamation of wastewaters, including water obtained from the space shuttle's fuel cells; crewmember urine; used shower, handwash, and oral hygiene water; cabin humidity condensate; and extravehicular activity waste.

Partnership

Water Security Corporation, Inc., of Sparks, Nevada, owns the patents for the commercial use of this technology and has begun to offer it around the world—anywhere people need affordable, clean water.

The company's terrestrial water treatment device has been recognized by the Space Foundation as a Certified Space Technology, not only for its use of space know-how, but also for its humanitarian mission. "Water Security Corporation's technology was awarded the Certified Space Technology seal, because it effectively applies space-based knowledge to a needed application on Earth," said Kevin C. Cook, director of brand management for the Space Foundation. "Their water filtration systems are providing safe, affordable drinking water throughout the world."

Product Outcome

By combining the benefits of chemical adsorption, ion exchange, and ultra-filtration processes, Water Security Corporation's products yield safe, healthy, good-tasting water from the most challenging water sources, such as in underdeveloped regions where well water may be heavily contaminated with bacteria.

The patented Microbial Check Valve (MCV), created by UMPQUA Research Company, of Myrtle Creek, Oregon, releases iodine into the water, which then kills bacteria and viruses. The next step is to add a proprietary resin called Iodosorb that functions as an iodine scrubber. Testing of the system demonstrates 6-log bacteria kill (99.9999 percent) and 4-log virus kill (99.99 percent), which meets U.S. Environmental Protection Agency standards and is equivalent to, if not better than, water in many industrialized countries.

The United Nations estimates that 1 billion people lack access to safe drinking water, 10 million people die each year of waterborne diseases, and 2 million of those deaths are children. The major sources of this contaminated water are bacteria, viruses, and cysts. These pathogenic organisms breed in unprotected water and unsanitary conditions. Even cleanup efforts are often thwarted by recontamination of treated water during transportation and storage prior to use. The spaceborne technology is uniquely suited to address these concerns.

The Discovery – Model WSC4 unit pictured here has been deployed to rural areas around the world to assist in providing people with clean, drinkable water.

One of the innovative products using this patented space technology is Water Security Corporation's Discovery – Model WSC4. Discovery has a 4-gallon-per-minute output and a 30,000-gallon capacity. It is ideal for rural water disinfection applications and was specifically designed to filter and disinfect fresh water that may be microbiologically contaminated. Its modular construction and simple maintenance procedures make it an ideal solution for remote installations and situations where the quality of supplied water is unsatisfactory. It can be carried by trailer to locations in need of fresh water and requires little training to operate.

Another model that Water Security Corporation has created is the Apollo – Model WSC 0.5. Smaller than the Discovery, it is mobile and ideal for remote locations, as well as mobile disaster relief. While still providing the same level of water filtration and purification as its larger kin, the Apollo has a reduced flow capacity of 2 liters per minute. This reduced flow is offset by the fact that the Apollo model can be lifted easily into the bed of a pickup truck and driven to wherever clean water is needed. This unit can be operated with a generator or even with a hand pump.

Water Security Corporation is currently in the process of making a countertop model using the same MCV technology. This would be useful in urban areas, where piped-in water is still subject to contamination. In some developed nations, it is not uncommon for municipalities to issue "boil water alerts" when the water systems become overloaded, or perhaps during an *E. coli* scare. The countertop unit would be ideal for these locations. ❖

Microbial Check Valve® and MCV® are registered trademarks of Water Security Corporation, Inc.

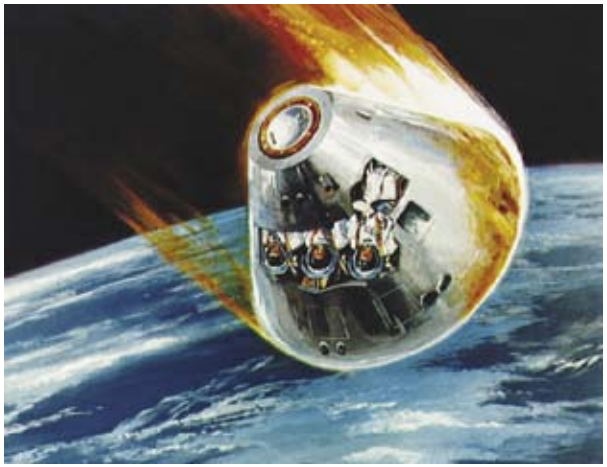
Fire-Resistant Reinforcement Makes Steel Structures Sturdier

Originating Technology/NASA Contribution

In preparing to send man to the Moon in the 1960s, no detail was too small for NASA to consider when it came to ensuring that humans and their transporting spacecraft could withstand the powerful thrust of a launch, the harsh and unforgiving conditions of space, and the extremely high temperatures of reentry into the Earth's atmosphere. When a tragic launch pad flash fire occurred during a routine preflight test of the Apollo 1 spacecraft at Cape Kennedy (renamed Cape Canaveral in 1974), NASA put into action major design and engineering modifications for the Moon-shooting spacecraft, plus revisions to test planning, test discipline, manufacturing processes and procedures, and quality control.

Detailed accounts of the Apollo Program's birth and evolution from the NASA-published book "Apollo Expeditions to the Moon" confirm NASA's commitment to getting the job done right, depicting the Space Agency as ever so meticulous in pledging to safely land man on Earth's lone natural satellite and then return him home. According to one historical account documented in this book by George Low, NASA's deputy administrator from 1969 to 1976, NASA built mock-ups of the entire Apollo spacecraft, and then tried to set them on fire. If they burned, Low continued, NASA redesigned them, rebuilt them, and tried again. For vibration testing, the Agency tried to shake things apart.

Additional tests within simulated environments also occurred to emulate the vacuum-like effects of space, the heat of the Sun, and the cold of the lunar night. Furthermore, Low wrote, all spacecraft systems were subjected to humidity and corrosive salt spray, to the thunderous noise of the rocket booster, and to the shock of a hard landing. To simulate a normal "splashdown" landing simulation, NASA dropped the command module—the portion of the spacecraft that astronauts inhabit—into water, and to simulate an emergency landing, it dropped the lunar module—the portion of the spacecraft that carries astronauts from the command module to the Moon and back—on simulated lunar terrain.



Artist's drawing of Apollo Command Module—with cutaway showing three astronauts—oriented in a blunt-end-forward attitude, reentering the Earth's atmosphere after returning from a mission.

Low's account acknowledged that NASA overstressed and overloaded spacecraft components until they broke, and if they broke too soon, the Agency redesigned, rebuilt, and tested them again.

The final safety exam came in the form of flight, according to Low. NASA designed three unmanned test flight missions to ensure the Apollo orbiter met all of the Agency's requirements. The first two flights utilized a 1,300,000-pound (with propellant) Saturn IB rocket booster that gave off 1,600,000 pounds of thrust. The third unmanned mission was the most critical test. This mission was deemed the Apollo 4 mission. (No missions were ever officially designated Apollo 2 or 3.) It utilized a Saturn V booster, which weighed 6,200,000 pounds (with propellant) and gave off 7,500,000 pounds of thrust.

After the spacecraft achieved an altitude of 10,000 miles, its engines drove it back down into the Earth's atmosphere at an unprecedented speed of approximately 25,000 miles per hour. During reentry, temperatures on the orbiter's heat shield reached 5,000 °F, more than half the surface temperature of the Sun. The heat shield charred as expected, but the spacecraft's inside cabin remained a comfortable 70 °F. A milestone had been passed, Low wrote, making way for man to go to the Moon.

Partnership

Built and designed by Avco Corporation, the Apollo heat shield was coated with an ablative material whose purpose was to burn and, thus, dissipate energy. The material charred to form a protective coating which blocked heat penetration beyond the outer surface.

Avco Corporation subsequently entered into a contract with Ames Research Center to develop spinoff applications of the heat shield in the arena of fire protection, specifically for the development of fire-retardant paints and foams for aircraft. This experience led to the production of Chartek 59, manufactured by Avco Specialty Materials (a subsidiary of Avco Corporation eventually acquired by Textron, Inc.) and marketed as the world's first intumescent epoxy material. As an intumescent coating, Chartek 59 expanded in volume when exposed to heat or flames and acted as an insulating barrier. It also retained its space-age ablative properties and dissipated heat through burn-off.

Further applications were discovered, and the fireproofing formulation found its way into oil refineries, chemical plants, and other industrial facilities working with highly flammable products.

Product Outcome

Four decades and 12 moonwalks later, the technology still exists in new, advanced products. In 1999, Houston-based International Paint, LLC, acquired the Chartek fireproofing brand. The company's latest product derived from Chartek technology is coined Interchar and geared toward making America's high-rise buildings and public structures safer.

According to Craig Scott, International Paint's director of fire and infrastructures, the new-construction industry has been forced to reevaluate traditional methods of fire protection in commercial infrastructures. This includes everything from building codes to structural design issues and the less-durable fireproofing materials currently specified for commercial steel structures.

Although steel does not burn, it loses strength in a fire, which can lead to a structural failure. Above 500 °F, steel starts to lose its structural integrity, and at 600 °F, steel loses 75 percent of its strength, according to International Paint. Interchar and other Chartek fireproofing materials swell to provide a tough and stable insulating layer over the steel to protect it.

An Interchar coating is typically applied at a thickness between 1 and 8 millimeters, so it does not impact the overall shape of the steel. Because this is a thin layering process, architects and building planners can still explore intricate and innovate architectural designs, especially when the steel is exposed. According to the company, Interchar's aesthetic versatility is a unique characteristic for commercial construction that previous Chartek products could not match.

Interchar offers fast cure times, superior adhesion to steel surfaces, and a strong, durable barrier to the steel beam underneath. Altogether, Interchar provides up to 4 hours of fire protection and helps prevent steel infrastructures from collapsing prematurely, in turn, giving building occupants more time to evacuate safely.

The technology is also made to be applied offsite, so that all of the materials that require fireproofing are ready before they are delivered to the construction site. Many benefits stem from the offsite application process: a controlled environment is used to ensure the appropriate thickness, as under- or over-coating could negatively affect Interchar's function; it saves time and money, since scaffolding and the sealing off of areas during spraying are not involved; and it does not disrupt the work of other contractors or cause project delays.

Fabrication shop application of Interchar fireproofing material to structural steel beams. Since Interchar is typically applied at a thickness between 1 and 8 millimeters, it does not impact the overall shape of the steel. This means architects and building planners can still explore intricate and innovate architectural designs.

In addition to fire protection, Interchar is ideally suited for corrosion protection, in structural steel facilities as varied as office buildings, hospitals, stadiums, shopping malls, hotels, airports, schools, power stations, and industrial complexes.

"This is a technology that has come of age," noted Scott. "The human and economic costs of fire damage can be significantly reduced by the use of a fireproofing system that can address any emergency fire event." ❖

Chartek® and Interchar® are registered trademarks of International Paint, LLC.

Feeling Well Rested and Wide Awake When it Counts

Originating Technology/NASA Contribution

Responding to a congressional concern about aviation safety, NASA's Ames Research Center created the Ames Fatigue/Jet Lag Program in 1980 to examine the extent to which fatigue, sleep loss, and circadian disruption affect pilot performance. The program's primary research was conducted in field settings, as well as in a variety of aviation, controlled laboratory, and full-mission flight-simulation environments, to study fatigue factors and circadian disruption in short-haul, long-haul, military, cargo, and helicopter operations.

In 1990, NASA changed the program's name to the Fatigue Countermeasures Group, to provide a greater emphasis on the development and evaluation of countermeasures that would mitigate the adverse effects of fatigue and maximize flight crew performance and alertness. The research conducted by this group at Ames included field studies of cockpit rest, quantity and quality of onboard sleep, and performance changes associated with long-haul flights.

Partnership

Dr. Mark Rosekind initiated the transition to the Fatigue Countermeasures Group, along with several other NASA colleagues. Rosekind led the program from 1990 until 1997. During his tenure, he made many important contributions to applied research, accident investigation, aviation policy, and operational environments. In addition, he served as the chief of the Aviation Operations Branch in the Flight Management and Human Factors Division at Ames, where he helped enhance aviation safety and performance through the analysis, experimentation, and modeling of human performance and human-automation interaction. Prior to working for NASA, Rosekind had directed the Center for Human Sleep Research at Stanford University's Sleep Disorders Center.

For over 20 years, Rosekind's research, publications, presentations, and practical applications in the fields of fatigue and alertness paved the way for significant improvements in real-world settings. These accomplishments did not go unnoticed, as Rosekind racked up award after award for his work. Honors included the NASA Exceptional Service Medal, NASA "Group Achievement" awards, a NASA "Turning Goals into Reality" award, a Flight Safety Foundation "Presidential Citation for Outstanding Achievement in Safety Leadership," a Flight Safety Foundation "Business Aviation Meritorious Service" award, and being named a Fellow of the World Economic Forum, in Davos, Switzerland.

The majority of NASA's fatigue countermeasures studies are performed in the field during normal flight operations or in simulators. Pictured here are two pilots undergoing tests in the Crew-Vehicle Systems Research Facility's Boeing 747-400 Simulator at Ames Research Center.

In 1997, Rosekind brought his expertise to the private sector by founding Alertness Solutions, Inc., a scientific consulting firm that translates knowledge of sleep, circadian rhythms, alertness, and performance into practical products, services, and strategies that improve safety and productivity. These offerings are geared towards individuals and organizations involved with around-the-clock operations, altered shift schedules, sustained or continuous requirements, and frequent travel across time zones.

In 2005, Cupertino, California-based Alertness Solutions added another NASA fatigue countermeasures

veteran to the mix, when Dr. Melissa Mallis, who led the Fatigue Countermeasures Group from 2000 to 2005, joined the company as its director of scientific affairs. While with NASA, Mallis had made significant contributions to safety, research, and education in aviation, space, and other diverse operational settings. She had also helped other Federal agencies set standards for evaluating technology designed to enhance human awareness of neurobehavioral decrements, by performing the first-ever controlled, double-blind scientific studies of the validity and reliability of various drowsiness-detection technologies and alerting countermeasures.

Together, Rosekind and Mallis are applying the scientific prowess they honed at Ames and incorporating the latest research available to help individuals and organizations manage and overcome the operational challenges of their environments. Such challenges include drowsy driving that occurs from long durations behind the wheel, jet lag from crossing multiple time zones in a short period of time, and sleep deprivation resulting from irregular schedules and challenging sleep environments.

Product Outcome

Sleep-related crashes cost the American Government and businesses $46 billion each year, estimates the National Commission on Sleep Disorders Research. Thirty-seven percent of drivers have nodded off for at least a moment or fallen asleep while driving at least once in their driving career, according to a 2002 National Highway Traffic Safety Administration report compiled from a national survey. Nine out of every 10 police officers responding to an Internet survey from the AAA Foundation for Traffic Safety reported having stopped a driver who they believed was drunk, but turned out to be drowsy.

These statistics should be alarming enough to open even the drowsiest of eyes, but they are just a small sampling of available data illustrating how drowsy driving and fall-asleep crashes are major road-safety issues, accounting for thousands of fatalities and injuries every year.

"People don't realize how common fall-asleep crashes are; that they often have tragic consequences, and that a variety of people are affected," said Rosekind, who resides as president and chief scientist of Alertness Solutions.

"Drowsy driving is a significant and largely unappreciated cause of motor vehicle crashes," added Susan Coughlin, former vice chair of the National Transportation Safety Board. "Alertness Solutions has an innovative remedy that combines state-of-the-art science with a practical tool, offering the potential to reduce crashes and make highway driving safer."

This solution, called Awake at the Wheel, serves as a unique driver-alertness tool for various at-risk groups, including sleep-deprived shift workers—particularly those who work at night; young adults, age 16 to 29; and commercial drivers who spend long hours on the road, especially at night. It combines information, self-evaluation tools, alertness strategies, travel planning, and safe driving activities in an "engaging, real-time format."

Awake at the Wheel includes a 32-page alertness guide and a 36-minute audio CD to give drivers: information about what makes them sleepy and how this affects their ability to drive safely; ways to accurately evaluate their alertness (when it is time to "get out of the fast lane and get into bed," as the company says); "sure-fire" strategies to help them stay alert; and planning tools that allow them to implement alertness strategies on the next big trip. The alertness guide is full of scientific-but-easy-to-understand information and exercises, and the CD contains vignettes

Awake at the Wheel is a unique alert-driving tool consisting of an audio CD and a printed alertness guide.

and characters that aid the listener/driver in staying awake and alert.

Johnson & Johnson's "Safe Fleet" corporate driving safety program was the first to implement Awake at the Wheel. The alertness tool was distributed to 15,000 corporate drivers and has received resounding accolades. Besides all of the direct benefits promoting driver alertness, one individual even reported that the information in the tool directly led to the diagnosis and treatment of their sleep disorder, sleep apnea.

Moving from road safety to air safety, there is a plethora of research showing that the aviation industry has been profoundly affected by fatigue. For example, in 1997, NASA conducted a survey on fatigue factor in corporate/executive aviation operations, wherein 1,488 corporate flight crewmembers—the majority of whom flew jet aircraft—responded. Nearly three-quarters (71 percent) of the responding pilots reported that they had "nodded off" during a flight—yet another alarming statistic to open some eyes.

Alertness Solutions is indeed opening eyes, with a product called AvAlert that has come to the aid of numerous pilots and crewmembers, and other key flight operations personnel plagued by fatigue. As the predecessor for the principles and objectives that make up Awake at the Wheel, AvAlert consists of multimedia presentations and adaptable tools on CD-ROM that provide scientifically based information on, and practical management strategies for, fatigue, alertness, and performance.

"The AvAlert program has been very useful in the battle against aviation fatigue. We've applied what we learned on our trips, and it works," according to representatives of ACM Aviation, LLC, a worldwide charter service based at the Mineta San Jose International Airport.

Alertness Solutions markets AvAlert as comprehensive, convenient, and customizable. The technology is comprehensive in that it includes: guidelines and resources for creating an active and effective in-house alertness management program; guidelines for duty- and rest-scheduling;

The Alert Traveler passport is a handy reference guide containing techniques for managing jet lag. AvAlert is a comprehensive package of multimedia resources that provides corporate flight operators with the education, tools, and training they need to successfully implement alertness management programs.

educational materials for a better understanding of sleep, circadian rhythms, and performance; fatigue-related findings and insights from NASA aviation studies; and a management communication package to convey the importance, benefits, and requirements of alertness management to corporate/executive management.

The technology is convenient in that it incorporates interactive lessons, practical tools, and paper and electronic forms in one easy-to-use package. (Two full sets of materials are included: one to remain with flight departments, the other to travel with flight crews.) Because human physiology and flight operations are complex, other methods of creating and promoting a comprehensive and effective alertness management program would take months of research, preparation, planning, and, often, outside expertise, according to Alertness Solutions. Conversely, AvAlert provides corporate flight departments with the knowledge and materials they need to create a comprehensive alertness management program, "literally, overnight," added Alertness Solutions.

Finally, it is customizable. Since every corporate aircraft operation is unique, AvAlert allows flight departments to tailor an alertness management program to their specific operational requirements, for maximum efficiency and impact. For example, tools are provided that allow a flight department to audit its specific schedules and create tailored strategies to address any identified fatigue issues. Also, electronic versions of resource material can be edited and personalized for use within the flight department.

Based on its NASA experience, Alertness Solutions also created Alertness Metrics Technology, an empirical approach to collecting objective data related to fatigue, alertness, and safety. The Alertness Metrics Technology makes use of an actigraph, a wristwatch-like device that objectively measures 24-hour sleep/wake patterns and provides a valid and accurate determination of sleep quantity and quality. It also makes use of a specially programmed PDA that collects daily log information on activities such as meals, sleep timing, exercise, and caffeine use. The PDA includes a simple, 5-minute reaction time test that is taken on a regular basis to assess performance.

The tips offered in the Alert Traveler passport have helped airline pilots through long-duration, multiple-time-zone flights.

In 2004, Alertness Solutions was engaged by JetBlue Airways to develop and implement a comprehensive alertness management program (by expanding and tailoring a core set of AvAlert tools), and then collect data during actual JetBlue flights, using Alertness Metrics Technology.

To help pilots and passengers fight off the effects of jet lag, Alertness Solutions created a handy reference guide entitled "Alert Traveler: Your Passport to Managing Jet Lag." Whether it be for a pilot responsible for landing a jet in a new time zone where day quickly changed to night, or for a passenger who just crossed multiple time zones and needs to be clearheaded for a business meeting, this reference guide contains all of the hints and tips needed to successfully manage jet lag.

In another example of applying science to a practical situation, Alertness Solutions worked with Hilton Hotels Corporation to combine "renowned hospitality expertise with the power of science" to give U.S. Olympians an optimal sleep environment and, hence, a competitive edge at the 2006 Olympic Winter Games, in Torino, Italy. As a result of this partnership, Hilton—an official sponsor of the U.S. Olympic Team—modified 160 resident athlete dorm rooms at the Colorado Springs U.S. Olympic Training Center, based on recommendations from Alertness Solutions, to help increase the athletes' alertness and reaction times for peak performance.

"Sleep is so important and so basic that it could make the difference between winning the gold or the silver at the Olympic Games," said Rosekind. "The proper amount of sleep could boost an athlete's performance as much as 30 percent."

Modifications included enhanced bed size and bedding, a usable work area, enhanced lighting controls, "blackout" drapes, and an effective MP3/CD player-compatible wakeup mechanism that Hilton Hotels proclaims is the "world's easiest-to-set" alarm clock.

"It sounds so simple, but getting the proper rest really does increase my confidence and abilities on and off the track," said U.S. Olympic speedskater, Apolo Anton Ohno. "Rest and relaxation is a critical component to competing at your best. With the improvements that are being made to our living space, I'm excited to come home to a place designed to help my performance."

The redesign paid off, as Ohno turned in a brilliant overall performance at the 2006 games, winning a gold medal (men's 500-meter race) and two bronze medals (men's 1,000-meter race and men's 5,000-meter relay). ❖

Awake at the Wheel®, AvAlert®, Alertness Metrics Technology®, and Alert Traveler: Your Passport to Managing Jet Lag® are registered trademarks of Alertness Solutions, Inc.

X-ray Device Makes Scrubbing Rugs Clean a Spotless Effort

Originating Technology/NASA Contribution

If "pulling the rug out from under" means suddenly withdrawing support and assistance, then NASA is pretty good at "putting the rug under" when it comes to offering technical support and assistance to private industry. In the case of a new X-ray fluorescence (XRF) sensor featuring enhancements compliments of NASA, the Space Agency not only provided the rug, but helped give private industry a means to ensure it keeps clean.

This sensor, utilized by NASA to read chemical bar codes concealed by paint and other coatings, perform on-the-spot chemical analyses in field conditions, and detect difficult-to-identify contaminants, has found another use as a tool that can measure how much soil is removed from household and commercial carpets.

The original technology was developed in 2002 to conduct quality control for critical aluminum alloy parts destined for the space shuttle. Evaluation of these parts is critical for the Space Agency, as any signs of contamination, corrosion, or material deviation could compromise a shuttle mission.

KeyMaster Technologies, Inc.'s TRACeR III-V portable, hand-held scanner, for detecting and tagging unique elemental codes. This instrument was designed to help NASA evaluate parts destined for the space shuttle.

Partnership

In the summer of 2001, NASA began seeking a company that could design and manufacture a lightweight, hand-held scanner capable of detecting data matrix symbols on parts covered by layers of paint and coatings containing various chemicals. The Federal Aviation Administration (FAA) was also looking for this type of technology, to eliminate the use of unapproved parts. (Counterfeit parts, like expended pieces that had been sold for scrap and pieces made by unqualified suppliers, do not fit the criteria for FAA acceptability. Without safeguards, the potential exists for such unapproved items to find their way back into the supply chain. One of the safeguards is to provide a positive identification system for all parts in the FAA system—one that goes beyond the simple marking of a data matrix bar code or human-readable identity on a part.)

In its search, the FAA came across a company named KeyMaster Technologies, Inc., that was willing to let its XRF hand-held scanning technology serve as the basis for new developments. Since the FAA had recently participated with NASA in developing a technical standard for part marking, it recommended NASA and KeyMaster work together to create an anti-counterfeit technology that would benefit both agencies.

KeyMaster agreed to meet with NASA, sharing its opinion that its XRF scanner could be adapted to fit the required needs. Up to this point, the XRF instrument was primarily being used as an alloy analyzer in the metals industry.

In January 2002, KeyMaster visited Marshall Space Flight Center's Technology Transfer Office to demonstrate the XRF technology. Technical personnel from Marshall's Engineering and Science Directorates were on hand to witness the demonstration. The XRF demo was

convincing, as all of the NASA participants were impressed with the portability of the XRF scanner, its proven ability to quickly analyze the composition of most materials in the Earth's environment, and its potential to help NASA avoid hardware nonconformance issues. NASA and KeyMaster signed a Space Act Agreement in March 2002, instituting the formal research and development partnership.

Dr. Bruce Kaiser, KeyMaster's chief technology officer, worked with NASA personnel, guided by Fred Schramm of Marshall's Technology Transfer Office, to enhance the preexisting XRF scanning technology for NASA's purposes. During the early stages of development, NASA found that advances were required to extend the XRF instrument's detection range to include aluminum alloys, since aluminum is used to build the space shuttle, its external tank, parts of the reusable solid rocket motor, and many other shuttle-related components. To extend the detection range, NASA and KeyMaster determined that the air between the X-ray source, the object being evaluated, and the detector would have to be removed, because X-rays emitted by the instrument were strong enough to penetrate the air on the way to the object and stimulate atoms in the substrate, but X-rays returning to the detector were not strong enough to penetrate the air and, therefore, could not be detected. According to Schramm, this was an industry-wide limitation.

First, NASA and KeyMaster needed to conduct a test to gauge whether the air-removal concept was even possible. To do so, the partners placed the XRF instrument inside a vacuum chamber, where it was then used to detect aluminum alloy samples. This proof-of-concept was successful, as the instrument quickly analyzed the samples with ease and precision.

The next step was to devise a way to actually remove the air from the instrument chamber, outside of a vacuum chamber and in a real-life environment, so the return X-rays could travel easily to the detector. By incorporating a vacuum system into the instrument, NASA and KeyMaster arrived at a design that successfully accomplished this. In addition, this new design provided a new capability for detecting low-energy elements.

KeyMaster forged ahead with manufacturing three of the advanced instruments for NASA's Return to Flight mission. Upon completion, the scanning devices were delivered to NASA's External Tank Project, Space Shuttle Main Engine, and Reusable Solid Rocket Motor offices.

Researchers at the Carpet and Rug Institute use the TRACeR III-V to test the carpet-cleaning efficiency of a commercial vacuum cleaner. The TRACeR III-V is capable of detecting the amount of soil a vacuum cleaner removes, determining how well an extracting vacuum cleaner recovers water, and determining whether a vacuum cleaner is causing excessive carpet wear.

NASA and KeyMaster filed two patent applications for the finished product, called TRACeR III-V. The first patent pertained to the vacuum-assist element that removes air from the instrument chamber and enables the detection of low-energy elements, like aluminum and magnesium, as well as contaminants within NASA hardware, like silicon. The second patent was for intrinsic product authentication through chemical tag identifiers that are converted to bar code language. This patent was primarily intended for commercial applications, as NASA and KeyMaster had realized the technology's value in other industries.

Product Outcome

Shaped like a portable drill and weighing less than 5 pounds, TRACeR III-V has found commercial success in bar code identification and chemical analysis. Recently, the technology set the stage for a major breakthrough in carpet cleaning, helping to create stricter standards for today's vacuum cleaners, to ensure that they are removing soil and stains impervious to conventional cleaning techniques. This breakthrough came courtesy of NASA and KeyMaster, in collaboration with the Carpet and Rug Institute (CRI)—the national trade organization for the carpet and rug industry that represents over 90 percent of all carpeting produced in the United States and offers scientific insight into how carpet and rugs can "create a better environment for living, working, learning, and healing."

The three organizations worked together to establish a multifaceted testing program that utilizes an XRF-detectable soil media that can be quantified after a carpet cleaning, to measure the effectiveness of a given cleaning system. This designer "soil" contains properties similar to actual soil found in carpeting throughout the country, according to CRI.

Using the TRACeR III-V scanner, laboratories can measure the starting compound applied to a carpet sample and then quantify the precise amount of soil removed following a cleaning. The scanner can additionally be used

Image courtesy of Nilfisk-Advance, Inc.

The Advance AquaClean 16XP carpet extractor, from Nilfisk-Advance, Inc., was honored at the Carpet and Rug Institute's Seal of Approval program launch at Kennedy Space Center in September 2005.

to determine the amount of water being removed from a carpet during a cleaning, in the event of a spill, or if a wet-vac had been used. To measure how well an extractor (vacuum cleaner) recovers water, a carpet sample is weighed before and after the testing process to determine how much water remained.

Extractors that do not sufficiently remove soil or water from a carpet can increase the potential for growth of mold spores, plus damage the carpet fibers. Add to this the buildup of everyday contaminants that are prevalent in the home, such as dust mites, pet dander, pollen, and other allergens, and the potential for health problems exists.

Compounding these concerns for mold and contaminants is air quality. According to the U.S. Environmental Protection Agency, air within homes and other buildings can be up to 5 times more polluted than outdoor air. "Removing dirt and particles from a carpet and containing them within the canisters of the best performing vacuum helps improve overall air quality," maintained CRI.

Michael Berry, Ph.D., former deputy director of the National Center for Environmental Assessment of the Environmental Protection Agency and a leading authority on indoor air quality, stated, "In my 30 years' experience, the XRF taggant technology is the first scientific approach to quantifying carpet cleanliness that I will stand behind 100 percent."

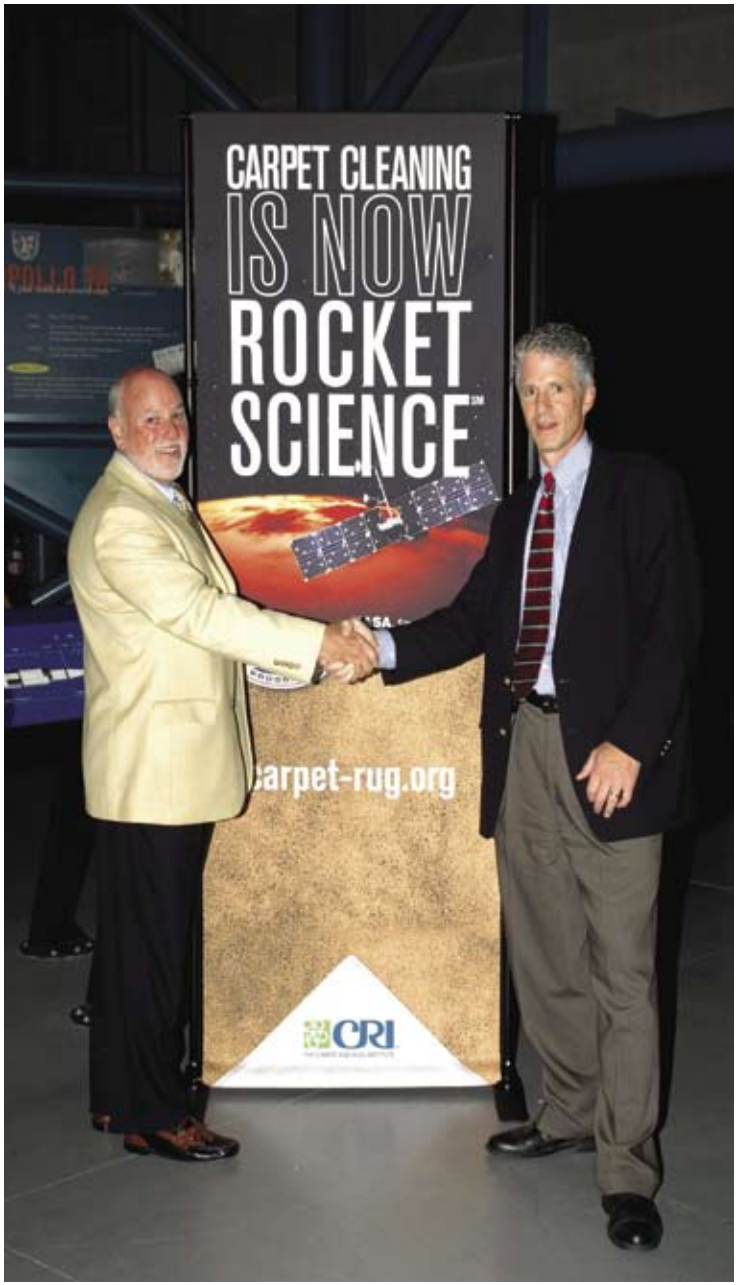
The XRF testing also evaluates surface-appearance changes in carpeting, as a result of vacuuming. This test is included, because experience has shown that some extraction machines can cause excessive wear on carpet, according to CRI.

Any carpet-cleaning companies that subject their extraction products to CRI's XRF testing and meet the institute's strict standards for soil removal, water removal, and surface appearance are awarded a CRI Seal of Approval. Since soil removal is the primary test, efficiency is rated on three levels: extractors that exceed average soil removal receive a Bronze Seal rating; extractors achieving higher soil removal receive a Silver Seal rating; and extractors removing the highest amount of soil measurable receive a Gold Seal rating. So far, more than 30 products have received Seal of Approval certification.

On September 12, 2005, Kennedy Space Center hosted the official launch of CRI's Seal of Approval program. Several national carpet manufacturers in attendance were honored with the Gold Seal of Approval, including: Sears Carpet & Upholstery Care, of Lewis Center, Ohio; Mohawk FloorCare Essentials, of Fayetteville, Georgia; Prochem, of Englewood, Colorado; ZeroRez, of Lindon, Utah; and CleanMaster Corporation, of Mukilteo, Washington. Two weeks later, on September 23, 2005, the product-testing program was recognized as a Certified Space Technology by the Space Foundation.

In March 2006, CRI announced that it is accepting products for testing under the latest phase of the Seal of Approval program. This new "Deep Cleaning Systems" phase evaluates the combined effectiveness of cleaning equipment and cleaning chemistries. ❖

AquaClean® is a registered trademark of Nilfisk-Advance, Inc.



KeyMaster Technologies, Inc.'s Lloyd Starks (left), special projects consultant, and John Landefeld, chief executive officer, share a handshake at the Seal of Approval program launch.

A Match Made in Space

Originating Technology/NASA Contribution

Just before the space shuttle reaches orbit, its three main engines shut down so that it can achieve separation from the massive external tank that provided the fuel required for liftoff and ascent. In jettisoning the external tank—which is completely devoid of fuel at this point in the flight—the space shuttle fires a series of thrusters, separate from its main engines, that gives the orbiter the maneuvering ability necessary to safely steer clear of the descending tank and maintain its intended flight path. These thrusters make up the space shuttle's Reaction Control System.

While the space shuttle's main engines only provide thrust in one direction (albeit a very powerful thrust), the Reaction Control System engines allow the vehicle to maneuver in any desired direction (via small amounts of thrust). The resulting rotational maneuvers are known as pitch, roll, and yaw, and are very important in ensuring that the shuttle docks properly when it arrives at the International Space Station and safely reenters the Earth's atmosphere upon leaving.

To prevent the highly complex Reaction Control System from malfunctioning during space shuttle flights, and to provide a diagnosis if such a mishap were to occur, NASA turned to a method of artificial intelligence that truly defied the traditional laws of computer science.

Partnership

Dr. Michael Georgeff, the inventor of the radical methodology, is among the world's leading experts in the research and application of artificial intelligence. He is a former director of both the Artificial Intelligence Center at Stanford Research Institute (SRI) International, Menlo Park, California, and the Australian Artificial Intelligence Institute Ltd., at the University of Melbourne.

It was during Georgeff's tenure with SRI in the early 1990s when NASA tapped his expertise to improve upon the computers that monitor the shuttle fleet's Reaction Control System engines. NASA desired advanced computer technology that could provide a variety of solutions for the many things that could potentially go wrong during a shuttle mission.

In response to NASA's call for assistance, Georgeff and his SRI team developed the first "intelligent agent" software system to ever go into space. This system had its own goals and beliefs, and could pursue these goals and beliefs and then determine how it wanted to achieve them, in much the same way that humans do. Essentially, a computer equipped with this intelligent agent software could make decisions and deal with problems through a human-like power of reasoning. Should a first attempt at a solution fail, it takes into account alternative solutions, rather than it having to depend on a constrained, preprogrammed set of parameters that only leads to one attempted solution—as most conventional computers do. By furnishing a computer with a human-like power of reasoning, it ultimately assumes human-like logic and behavioral traits.

Georgeff playfully acknowledges that this intelligent agent is somewhat like a first version of HAL 9000—the neurotic supercomputer from the science fiction movie "2001, A Space Odyssey" that ends up endangering the space crew's lives for the sake of the mission—only this time, he says, the true-to-life technology is fully under the control of NASA astronauts in space and Mission Control personnel on Earth.

Center: Workers in the Orbiter Processing Facility watch closely as Discovery's Reaction Control System is lowered into position in the orbiter's forward fuselage nose area. This system contains the engines that provide the thrust for rotational maneuvers and small velocity changes along the orbiter axis. Top Left: Dr. Michael Georgeff, the inventor of the real-time reasoning and control software that monitors the space shuttle Reaction Control System. Bottom Right: Staff members of weAttract.com, Inc., conduct research on a series of individual profiles.

Georgeff and NASA's Johnson Space Center worked together to integrate the intelligent agent software system with the space shuttle computers. This real-time reasoning and control software was first used to monitor Discovery's Reaction Control System in 1997.

Product Outcome

The intelligent agent software system utilized to monitor Discovery's Reaction Control System engines has come down to Earth to improve the operation of a different kind of engine: an online matchmaking search engine.

Founded in 1998 and incorporated in 2000, weAttract.com, Inc., combines scientific and mathematical innovations to enhance human relationships. The concepts that Georgeff developed for NASA are at the core of the company's computerized matchmaking technology.

"Although on the surface this was unlike anything I had been involved with before, the underlying issues were similar to ones I have faced on many commercial projects," explains Georgeff, who currently resides as weAttract's executive scientific advisor. "Even with something as complex as the space shuttle malfunction handling system I worked with at NASA, the underlying system involves helping create flexible avenues to meet goals. This was at the heart of what the weAttract technology aimed to do with relationships online.

"The work we are doing at weAttract has much in common with the approach we used at NASA," he continues. "The key idea is to have some way of modeling human cognitive and emotional attitudes so that we can predict [human] behavior or determine how best [humans] can accomplish their desires. In the NASA project, we used a very simple model of these cognitive attitudes: the 'desires' of the system were limited to the goals of closing valves, testing fuel pressure, and so on. The system had no emotions."

For weAttract, on the other hand, the company has developed "a very sophisticated model" of the cognitive and emotional attitudes underlying human behavior, based on a large number of psychological studies over many years. Its approach is to give the person it is seeking to assist (in this case, a person who has a desire to find an appropriate partner) a number of questions and tests. The company uses the output from these tests to logically and statistically deduce the most likely cognitive and emotional model for the person. Once it has this model, it can then determine the best way for that person to achieve his or her desires. In other words, by observing the person's responses to the tests, weAttract is able to deduce a psychological model of that person, which—just like the system for the space shuttle—the company can then use to determine how best they can achieve their desires or goals. According to Georgeff, the methods weAtrract uses to do this are quite different from those used for the shuttle, but the underlying scientific approach is the same.

The company then goes one step further. By questioning the person on what type of partner they are seeking, weAttract can also build a psychological model of the preferred partner. This allows weAttract to find prospective partners that match not only on basic demographic and behavioral attitudes (e.g., non-smoking), but on a "rich model of their cognitive and emotional makeup."

By having the psychological models of both the seeker and the potential partner, weAttract can then predict how these two models would interact and behave together. In this way, the company can identify potential strengths and weaknesses in the partnership, and suggest means for modifying behaviors to avoid problems and reducing the impact of any incompatibilities.

"This is an incredibly exciting project," Georgeff proclaims. "I believe it is breaking new ground in understanding how we, as humans, interact with one another and how we can realize our personal and social potential."

Match.com, the highly popular dating site with over 10 years of experience, began using weAttract's software in 2003. The result was a sophisticated personality matching program that uses "smart" algorithms to customize a test for each user, so that each answer leads to a tailored follow-up question; no two tests are exactly alike.

"The Match.com Personality Test was a quantum leap beyond the pop-psych questionnaires you'll find on other personals sites," says Dr. Mark Thompson, the founder and chief executive officer of weAttract, as well as a Stanford University-trained clinical psychologist. "There were no pre-canned reports," he adds. "In fact, there were over 100 million possible customized reports that went into great detail about the user's strengths and quirks, and how to find someone who really 'gets you' on a deep level."

In 2004, weAttract launched its second-generation product for Yahoo! Personals, which includes the Personality & Love Style Test and the Relationship Test. Based on weAttract's mathematical and scientific prowess, these tests use interactive reenactments of real-life relationship scenarios, instead of static multiple-choice questions.

The Personality & Love Style Test, which takes approximately 10 minutes to complete, provides singles with a customized report of their personality type, love style, biggest challenges, and suggestions on which type of person would be a good fit for them. The Relationship Test, which takes roughly 30 minutes to complete, provides a personalized, in-depth report that measures compatibility with others, relationship skills, and much more.

Presently, the insights gained from weAttract's matching endeavors have led it to form two new spinoff companies. The first, called SciencePlanet.com, aims to expand weAttract's focus on educational tools and engines for the general public. The second, yet to be named, will work to apply the advances weAttract has made in facial recognition and personality profiling to areas of national security and defense. ❖

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Affordable Space Tourism: SpaceStationSim

Originating Technology/NASA Contribution

For over 5 years, people have been living and working in space on the International Space Station (ISS), a state-of-the-art laboratory complex orbiting high above the Earth. Offering a large, sustained microgravity environment that cannot be duplicated on Earth, the ISS furthers humankind's knowledge of science and how the body functions for extended periods of time in space—all of which will prove vital on long-duration missions to Mars.

On-orbit construction of the station began in November 1998, with the launch of the Russian Zarya Control Module, which provided battery power and fuel storage. This module was followed by additional components and supplies over the course of several months. In November 2000, the first ISS Expedition crew moved in.

Since then, the ISS has continued to change and evolve. The space station is currently 240 feet wide, measured across the solar arrays, and 171 feet long, from the NASA Destiny Laboratory to the Russian Zvezda Habitation Module. It is 90 feet tall, and it weighs approximately 404,000 pounds. Crews inhabit a living space of about 15,000 cubic feet.

SpaceStationSim allows players to create and manage their very own International Space Station and crew.

In New Station Mode, players have the freedom to build the International Space Station any way they want, within, of course, the connection rules governing the actual space station.

To date, 90 scientific investigations have been conducted on the space station. New results from space station research, from basic science to exploration research, are being published each month, and more breakthroughs are likely to come.

It is not all work on the space station, though. The orbiting home affords many of the comforts one finds on Earth. There is a weightless "weight room" and even a musical keyboard alongside research facilities. Holidays are observed, and with them, traditional foods such as turkey and cobbler are eaten—with lemonade to wash them down.

Partnership

Vision Videogames, LLC, of Towson, Maryland, completed a Space Act Agreement with NASA to create the interactive video game, SpaceStationSim, in which players role-play as the NASA "Chief Administrator," managing astronauts on the ISS in a 3-D simulated environment. The agreement was a continuation of one between NASA and GRS Games before Vision Videogames management bought the company in March 2004.

The agreement provided, for a set time, the company with information from, and access to, NASA personnel, so that it could make the most accurate game possible. NASA personnel even volunteered to be beta testers for the new game.

Bill Mueller, president of Vision Videogames, said of the project, "The assistance and support from NASA were invaluable, and the enthusiasm of the NASA personnel was great."

The company also received volunteers of assistance from a variety of space experts and international agencies, including the Japan Aerospace Exploration Agency (JAXA).

With this level of interest, expertise, and involvement, Vision Videogames managed to create a game that is so accurate and realistic that NASA is even exploring aspects of the game for mission planning.

Early in 2005, Vision Videogames worked with Raytheon Company, of Waltham, Massachusetts, to demonstrate the viability of using a simulated systems engineering and integration visualization platform for collaborative development environments. In fall 2005, Vision Videogames completed a contract with NASA to use SpaceStationSim to simulate the creation of the Crew Exploration Vehicle and crew, appropriately named, SimCEV. It is significantly more affordable and safe to model and test equipment and programs in a simulated environment than it is to field test, especially when the field is the Moon or Mars. The SpaceStationSim software engine provided "virtual vehicle" assets, animation, and programming expertise for NASA to support the Vision for Space Exploration.

Product Outcome

SpaceStationSim is the latest in a long line of popular simulation (SIM) games. Precursors include games that

allow players to do everything from building a city, an island, or a planet, to attending college, going out on the town at night, or managing an amusement park, to masquerading as rock stars. There is even a SIM variation that allows players to practice looking after pets. While the ISS variation, then, is not that far-fetched, the difference is that it was built to NASA technical specifications and holds all the excitement and intrigue that goes with actually living in space.

"We believe that one real day at NASA is more exciting than an imaginary day anywhere else," Mueller explains. "We intend to bring to a whole generation of young people a sense of ownership in, and dedication to, NASA."

As the "Chief Administrator" of NASA, the player creates crewmembers with unique needs, abilities, and personalities, and manages their activities and relationships.

In this game, as in real life, the astronauts face mission-critical situations, including meteor strikes and decompression, while conducting microgravity experiments and dealing with troublesome space tourists. The space tourists, included to offer a bit of comic relief, appear on the station dressed for the beach or boardwalk, in full Hawaiian tourist attire. They disrupt the astronauts as the crew goes about its chores repairing machinery, conducting experiments, and trying to keep happy and healthy in the confines of the space station.

The Astronaut Builder allows players to create and recruit new astronauts for their stations, choosing everything from whether the astronaut will have a green or blue shirt to whether he or she will be skilled in astrotechnology or biomedicine.

The player monitors the crew as it performs experiments and completes simple repairs. According to the game's instruction manual, "Through strategy, design, management, discovery, and care of your crew, your ISS may usher in the dawn of a new age for man among the stars or fail in a burning inferno!"

The game begins in the Mission Control Center, which is also where the player returns regularly to launch new modules and components, recruit crewmembers, organize supply missions, and monitor the game's currency, which is international goodwill, measured in the form of international flags.

The player determines the astronaut's strengths and weaknesses, and then these factors later come into play on the ISS. If an astronaut is excessively playful and has a poor work ethic, repairs might not be made. If the astronaut, on the other hand, is too focused on work and is not interested in having fun, he may burn out over time and become unhealthy and depressed. The skills and specialties of the astronauts also come into play, as certain specialists are the only ones qualified to perform certain tasks. A biomedical payload specialist, for example, can perform high-level biomedical experiments, whereas an astrotechnology expert may be more adept at certain onsite repairs.

After the astronauts are blasted off to the station on a Russian Soyuz vehicle, the player must manage the astronaut's activities by assigning tasks to keep them happy, healthy, and productive. The astronauts are able to choose tasks on their own, but initially, they need more guidance or they will make mistakes. Once they have developed more experience, though, they become more self-sufficient, and the player can focus on building the station.

To keep the astronauts in peak condition and the station in orbit, players must give astronauts tasks that fulfill their needs as well as those of the station.

As the game progresses, the player constructs the station, adding additional sections and bringing needed equipment and supplies to the virtual astronauts. The player coordinates with Mission Control to determine which vehicles are available to carry different machinery to the station. A player can choose between dozens of modules and stylized components from NASA and its four exploration partners, JAXA, the Russian Space Agency, the Canadian Space Agency, and the European Space Agency.

Players can add experimental equipment, items to make their lives and stay more comfortable, and can construct their own unique station by building additions and components.

Currently, the game can be played on a personal computer, and a PlayStation 2 version is in development. ❖

PlayStation® is a registered trademark of Sony Computer Entertainment America, Inc.

SpaceStationSim™ is a trademark of Vision Videogames, LLC.

Preventing Ice Before it Forms

Originating Technology/NASA Contribution

NASA has always been on the cutting edge of aviation safety research, though many of the technologies the Agency develops also find practical application in ground transportation safety. One of the most prominent examples of this type of technology transfer is the grooved pavement developed by NASA in the early 1970s. While researching runway conditions, NASA scientists discovered that cutting narrow grooves into the surface of runways allowed rainwater to flow off of the tarmac, decreasing the troubles associated with wet, slick runways, including slipping, hydroplaning, poor handling, and reduced braking times.

This knowledge has aided airports around the world, and highway engineers have realized its benefits for slippery roadways, as well. This is just one of dozens of examples of how NASA technology with roots in flight safety has helped drivers on the ground.

As a more recent example, in the late 1990s, a team of engineers at Ames Research Center invented an anti-icing fluid to keep ice from building up on airplane wings. Ice on wings can be a serious safety hazard, especially during takeoff, when a sheet of ice the thickness of a compact disc can reduce lift by 25 percent or more. The typical approach to clearing off the ice is to use a deicing solution once the ice has built up. The fluid created by the Ames team, though, when applied to a dry surface, prevents the ice from even forming a surface bond, which saves deicing time and money, while also preventing excessive use of chemical solvents. If, however, the solution is not applied before ice forms, it also serves as a traditional deicing formula.

The formula contains propylene glycol, which has a very low freezing point, and a thickener, which helps the fluid adhere to the surface. Ice gathers on top of the formula, and then it can be wiped off with little effort. This thickening agent, a pseudo-plastic, sprays on as a liquid, like lemonade, gels like a lemon sherbet, turns back to a liquid when wiped, and then gels again into its sherbet consistency when left to solidify. The sherbet-gel stage is especially important when the formula is sprayed onto a vertical or steeped surface, as it clings better than a liquid would.

This anti-icing agent adds an extra level of safety to air travel. Created at Ames Research Center, it contains food-grade ingredients, making it safe for the environment as well.

The sherbet analogy is not that far-fetched. In fact, when the solution was originally introduced, it was so environmentally safe that it was deemed "food grade," because its ingredients were approved by the U.S. Food and Drug Administration for use in food—ice cream, to be specific. This safety feature is a serious advantage over methyl alcohol- and ethylene glycol-based solutions, which are commonly used for deicing, but have negative environmental effects. Exposure to large amounts of

ethylene glycol can damage the kidneys, heart, and nervous system of people and animals. Pools of the toxic solution are also dangerous for fish and wildlife. The toxic effects can be widespread if it enters streams, rivers, or other bodies of water that support life.

When the nontoxic anti-icing solution was announced in 1997 by Ames co-inventors Leonard Haslim, John Zuk, and Robert Lockyer, the fluid was said to be able to prevent ice buildup on airplane wings. The first example application in the patent, though, was for use as an anti-icing agent on automobile windshields. Although working in the sunny climate of California, Zuk had grown up in the American Northeast, attended college in the Midwest, and was all too familiar with cold mornings spent scraping ice from windshields.

Partnership

This fluid had such obvious widespread application that NASA sought to find and issue a license to a commercial partner with the background and resources to market and distribute this wonder.

WorldSource, Inc., of Palm Desert, California, a developer and distributor of products for the consumer marketplace, was just the right fit. It has an experienced management team with considerable expertise in the development, manufacturing, marketing, and distribution of consumer products. WorldSource is now the sole manufacturer and distributor of the formula for windshield applications.

"NASA aviation and space research have helped mankind by finding epic discoveries in our skies and far into the heavens," said Brian Jue, chief executive officer of WorldSource. "WorldSource is proud to license a piece of NASA's aviation safety technology for our Ice Free anti-icing product. Ice Free's ability to prevent ice from bonding to a vehicle's glass windows could make winter life easier for millions of people on roadways around the world." The inventors also recommended its use on railway switches and on monorail electrical connections. The technology is currently being leveraged by another licensee, Midwest Industrial Supply, Inc., of Canton, Ohio, where it is prized for its anti-icing qualities, as well as its lubricating properties for preventing the development of ice buildup.

"As we continue to explore the universe, we are proud that NASA's pioneering efforts keep fueling American creativity, innovation, and technology development," said David Morse, acting chief, Technology Partnerships Division at Ames. "This new product is yet another example of the additional dividends Americans reap from their investment in space exploration."

Product Outcome

Ice Free is a spray for automobile windshields that can provide protection down to 20 °F. Applied prior to inclement weather with a standard spray bottle, it is a simple and safe treatment that prevents ice or snow from bonding on a glass surface, such as a car's windshield, side or rear windows, and mirrors.

The spray makes it fast and easy to get started on a wintry morning, as it eliminates waiting for defrosters to help thaw ice and, as is even more appreciated, eliminates the need to stand outside in cold weather, scraping and chipping away at the ice. It is so simple that one swipe of the windshield wipers is all it takes to clear front windshields treated with the solution. For side windows and mirrors, a stroke of a squeegee is all it takes.

It has the additional benefit of deicing, instead of just being an anti-icing agent. If the formula is not applied before the ice sets, the solution can still be used, because when sprayed on ice, it helps the thawing process.

"We've had an extraordinary reception to Ice Free in initial marketing tests from consumers, distributors, and the media from across the United States, and have been receiving worldwide inquiries," said Bob Harrick, WorldSource president. "We're working on putting Ice Free onto retailers' shelves in every region where cold weather forces people to scrape their icy windows when trying to get their vehicle ready for driving. Ice Free saves people time, and some of their body heat, too."

Now that Ice Free is commercially available, people everywhere can experience the advantages of this NASA-derived technology.

Lockyer said of the product in its newfound commercial application, "It's a good use for it, and it will work. We sprayed some on a windshield here, let it ice over, turned the windshield wipers on the next morning, and the ice came right off." ❖

Microspheres in Plasma Display Panels

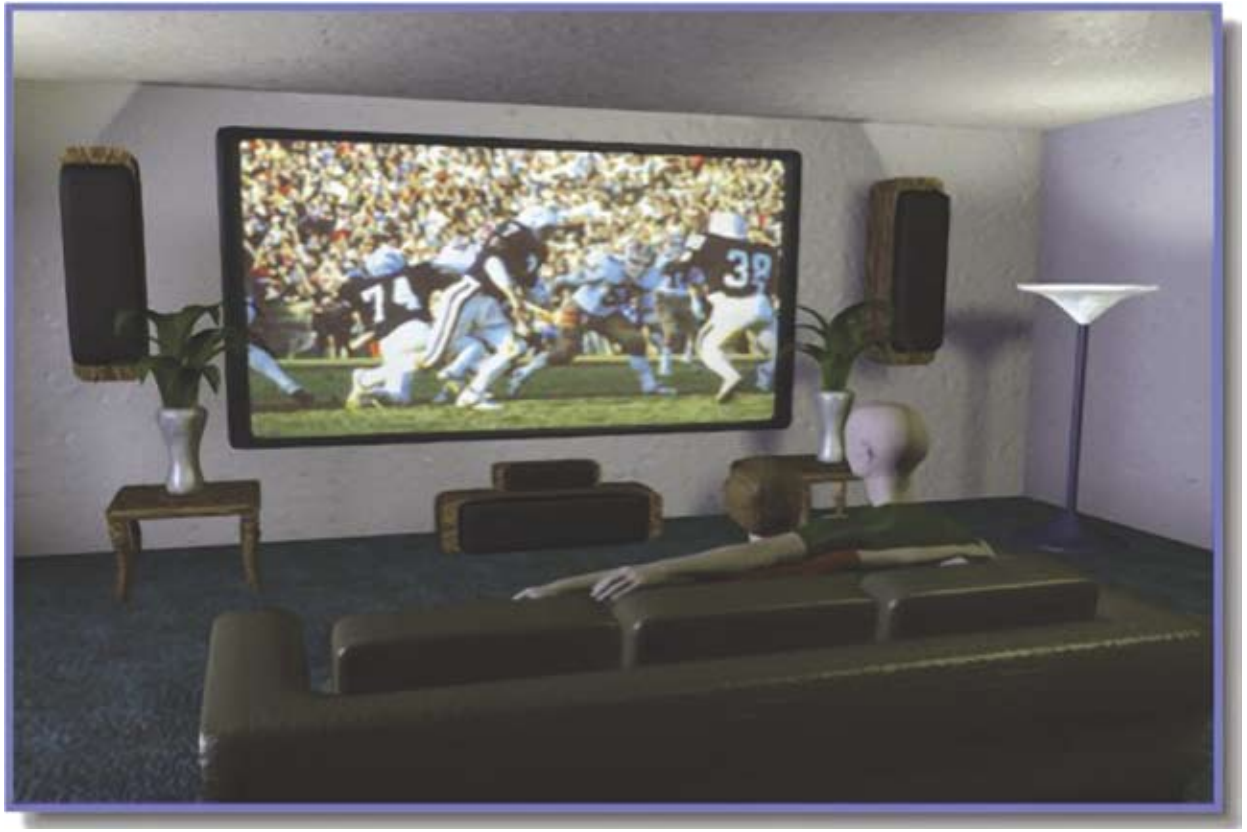
Originating Technology/NASA Contribution

NASA does things that have never been done before—sending spacecraft to other planets, sending people to the Moon, and exploring the limits of the universe. To accomplish these scientific missions, engineers at work within the Space Agency build machines and equipment that have never been made before—rockets that can send advanced instruments across the solar system, giant telescopes that watch the stars from space, and spacecraft that can keep astronauts safe from the perils of space flight. To do these never-before-done deeds with these never-before-made materials, NASA often needs to start at the basics and create its own textiles and materials. The engineers and materials specialists at the Space Agency are, therefore, among the best in the world.

It is not surprising then, that oftentimes, when industry engineers have difficulties with their designs or processes, they turn to NASA for assistance and NASA teams are happy to oblige.

Partnership

Filling small bubbles of molten glass with gasses is just as difficult as it sounds, but the technical staff at NASA is not known to shy away from a difficult task.



When Microsphere Systems, Inc. (MSI), of Ypsilanti, Michigan, and Imaging Systems Technology, Inc. (IST), of Toledo, Ohio, were trying to push the limits of plasma displays but were having difficulty with the designs, NASA's Glenn Garrett Morgan Commercialization Initiative (GMCI) assembled key personnel at Glenn Research Center and Ohio State University for a brainstorming session to come up with a solution for the companies.

They needed a system that could produce hollow, glass micro-sized spheres (microspheres) that could be filled with a variety of gasses. But the extremely high temperature required to force the micro-sized glass bubbles to form at the tip of a metal nozzle resulted in severe discoloration of the microspheres. After countless experiments on various glass-metal combinations, they had turned to the GMCI for help.

NASA experts in advanced metals, ceramics, and glass concluded that a new design approach was necessary. The team determined that what was needed was a phosphate glass composition that would remain transparent, and they went to work on a solution.

Six weeks later, using the design tips from the NASA team, Tim Henderson, president of MSI, had designed a new system in which all surfaces in contact with the molten glass would be ceramic instead of metal. Meanwhile, IST was able to complete a Phase I **Small Business Innovation Research (SBIR)** grant supported by the National Science Foundation (NSF) and supply a potential customer with samples of the microspheres for evaluation as filler materials for high-performance insulations.

In 2002, MSI received a $35,000 GMCI "Commercialization Assistance Award" to upgrade and implement its production system to evaluate customer and investor

Conceptual drawing of a large-area, thin flat-panel display television in a home setting. Imaging Systems Technology, Inc., engineers were among the first to begin work in the field of developing plasma displays, and they are continuing to push the boundaries of this field.

Imaging Systems Technology, Inc., is leading the way in the areas of plasma design, development, and testing.

reactions to a new plasma display panel; and IST was able to continue to develop the flexible display technology using microspheres.

In addition to the Phase I SBIR, IST went on to receive NSF Phase II and Phase IIB grants, as well as a National Institute of Standards and Technology Advanced Technology Program grant for $2 million and two additional research grants from the State of Ohio, totaling nearly $800,000.

Product Outcome

Under the direction of its president, Carol Ann Wedding, IST specializes in microspheres for flat-panel displays and related devices—with a strong focus and capability in plasma display design, development, and analysis. The staff at IST can trace its roots back to the development of the very first plasma displays created; and microspheres are the key component for IST's novel plasma displays, since they can be made into a variety of contours and shapes without distorting the image.

IST markets the microspheres as Plasma-spheres, tiny hollow spheres encapsulating an ionizable gas that glows when charged. The spheres, which can be applied to both flexible and rigid panels, form the basis of an addressable pixel element—a Plasma-sphere display. The display offers the same bright, full color as a conventional plasma display, but it is very rugged and can be a low-cost solution for large-area flexible displays.

These displays have commercial application in the markets of large venue displays, large conformable displays, and even home theaters.

The company continues to stay on the cutting edge of this field, thanks in part to the NASA partnership. It has worked on many designs, products, and services in the area of imaging and display technology, including product tear-downs, analysis and correction of false contour and motion artifacts, as well as development of custom test equipment. It has even designed a line of large-area touchscreens, including the world's largest, which measures in at 32 by 8 feet.

In October 2005, IST received the prestigious "R&D 100 Award," making it the third time that plasma display research teams led by the Wedding family have received this honor. In 1982, Donald K. Wedding with Dr. Donald R. Willis of Magnavox had received the award for the development of the world's first 1-meter plasma panel. In 1990, Carol Ann Wedding had received the award for the development of the first video addressable color plasma display. The company received the R&D 100 award, which recognizes its cutting-edge technology as one of the most technologically significant products of the year, for its innovative work in flexible Plasma-sphere displays. That same year, IST was also awarded the "State of Ohio 2005 Emerging Technology Award." ❖

Plasma-sphere™ is a trademark of Imaging Systems Technology, Inc.

Look Sharp While Seeing Sharp

Originating Technology/NASA Contribution

While fashion styles are known to come and go, a certain "shade" from the past has proved otherwise.

Developed in the 1980s, the original SunTiger, Inc., sunlight-filtering lens has successfully withstood the test of time. It is alive and well today in the form of eyewear that caters to the needs of any lifestyle. The technology, first featured in *Spinoff* 1987, sprung from breakthrough research carried out by Jet Propulsion Laboratory (JPL) scientists James B. Stephens and Dr. Charles G. Miller. The two scientists were tasked with studying the harmful properties of light in space, as well as the artificial radiation produced during laser and welding work, for the purpose of creating an enhanced means of eye protection in industrial welding applications.

While working to apply their space research to these terrestrial applications, Stephens and Miller became engrossed with previously discovered research showing evidence that the eyes of hawks, eagles, and other birds of prey contain unique oil droplets that actually protect them from intensely radiated light rays (blue, violet, ultraviolet) while allowing vision-enhancing light rays (red, orange, green) to pass through. These oil droplets absorb short wavelength light rays which, in turn, reduce glare and provide heightened color contrast and definition for optimal visual acuity. Accordingly, birds of prey possess the ability to distinguish their targeted prey in natural surroundings and from great distances.

Pairing the findings from their initial studies with what they learned from the bird studies, the scientists devised a methodology to incorporate the light-filtering/vision-enhancing dual-action benefits into a filtering system, using light-filtering dyes and tiny particles of zinc oxide. (Zinc oxide, which absorbs ultraviolet light, is also found in sunscreen lotions that protect the skin from sunburn.)

Over the course of 3 years, Stephens and Miller—with help from several other JPL researchers—used this methodology to create and commercialize a transparent welding curtain technology that absorbs, filters, and scatters light to maximize protection of human eyes from the harmful blue and ultraviolet radiation that emanates during welding. If the eyes are not protected during welding, the intense light that is produced can lead to a condition called arc eye, in which ultraviolet light causes inflammation of the cornea and long-term retinal damage.

Intense light emitted during welding can be harmful to the eyes if they are not properly protected. Jet Propulsion Laboratory researchers developed a welding curtain in the 1980s to absorb, filter, and scatter this light and, ultimately, provide optimum eye protection.

Partnership

Following completion of the welding project, Stephens and Miller turned their attention to the related matter of protective glasses. They used computer analysis to design sunglasses for various light environments, including mountain, desert, and fluorescent-lighted office settings. What resulted was a spinoff of a spinoff: the SunTiger lens for every natural and artificial environment. SunTiger, Inc., of Calabasas, California, was formed to market a full line of sunglasses that promised 100-percent elimination of harmful wavelengths and a sharp, crisp viewing perspective.

Product Outcome

Over the past few years, the company, now doing business as Eagle Eyes Optics, has extended its product line to over 40 styles of sunglasses that appeal to both genders, no matter the age. There is, for example, the Aviator model that preserves the 1980s retro look and feel and is the number one choice of pilots and police officers; the Classics model that commemorates a variety of eras with its timeless styling; the Tuscan and Forenza models, each crafted in an Italian unisex style with a tortoiseshell frame; the UltraLite Metro model, which weighs less than a half-ounce and features a comfortable wrap-around wire frame; and the Redtail model, which the company says is inspired by styles regularly seen on the ski slopes of Mont Blanc in the French Alps. Regardless of model preference, all Eagle Eyes sunglass products feature the company's patented TriLenium Gold lenses with complete ultraviolet protection, dual-layer scratch-resistant coating, polarized filters for maximum protection against glare, and high visual clarity to make scenery more vivid.

As the brand expanded, so did the product categories. Eagles Eyes has spent the last couple of years reviewing advancements in optical research. Knowing that diminished eyesight due to conditions such as glaucoma, macular degeneration, cataracts, and low lighting can be both physically detrimental and expensive to treat, Eagle Eyes has developed an advisory board with renowned ophthalmologists and other vision specialists, including expert lens developers. The board has turned up sufficient research showing that damage to the eye, especially to the retina, starts much earlier than most people realize. Therefore, the company has invested in educating members of the general public—particularly those who are exposed to a lot of sunlight on a daily basis—to protect their eyes a lot earlier in life.

Eagle Eyes' Solare sunglasses, modeled here, are one of the latest styles available in the company's line of total-protection, vision-enhancing sunglasses. The southwestern-styled, semi-rimless copper frames feature a soft silicon layer for added comfort around the temples and indiscernible, flexible hinges, while the scratch-resistant lenses shield ultraviolet light and glare.

The Aviator style—Eagle Eyes' original product—is the number one choice of pilots and police officers. Millions of others worldwide are also sporting Aviators for their timeless style.

The results of this research can now be enjoyed by consumers seeking to improve their vision in environments with poor lighting. The latest product is called StimuLights. Designed specifically for low-light environments, StimuLights can be worn outdoors while driving in hazy, foggy, dusk and dawn conditions and indoors while working on computers under fluorescent lights, watching television, or reading in dimly lit areas. Special cut-on and cut-off filters in the lenses relax the eyes and provide improved clarity, definition, and color contrast under these conditions. The filters cut on to let the eyes receive useful, vision-enhancing red, yellow, and green light rays and cut off to prevent blue and violet light rays from entering and focusing on the retina. The ultraviolet light is blocked by the lenses, therefore protecting the purple pigment in the eye, called rhodopsin, that promotes vision in low-light conditions. Lack of protection from rhodopsin leaching can lead to night blindness.

Industry-specific lenses are also available. For example, Eagle Eyes manufactures a lens that provides dentists protection against the ultraviolet light they are exposed to when operating curing systems for dental materials.

Eagle Eyes is also launching a line of special lenses and glasses that fall within specific ranges of the wavelength spectrum, at varied nanometer interval cut-ons, to meet specific vision needs for both general and industrial use. These offerings intend to help the eyes transition from one environment to another.

In February, Eagle Eyes earned recognition as a Certified Space Technology from the Space Foundation. "The Space Foundation is pleased to certify Eagle Eyes' lens technology for its application of this innovative technology that enhances and protects human vision," said Kevin C. Cook, director of Space Technology Awareness for the Space Foundation.

Eagle Eyes is also eyeing up skin protection. The company currently has clinical studies underway for a unique ultraviolet sunscreen.

"We are most proud that the Eagle Eyes brand has become a household name to millions of customers across the world. Now, with our upcoming launch of the ultraviolet sunscreen application, we feel most excited to take our company to the next level in whole body protection," stated Alan Mittelman, Eagle Eyes president. ❖

Eagle Eyes® is a registered trademark of SunTiger, Inc.

UltraLite™, TriLenium™, and StimuLights™ are trademarks of SunTiger, Inc.

Raised Relief Mars Globe Brings the Red Planet Closer

Originating Technology/NASA Contribution

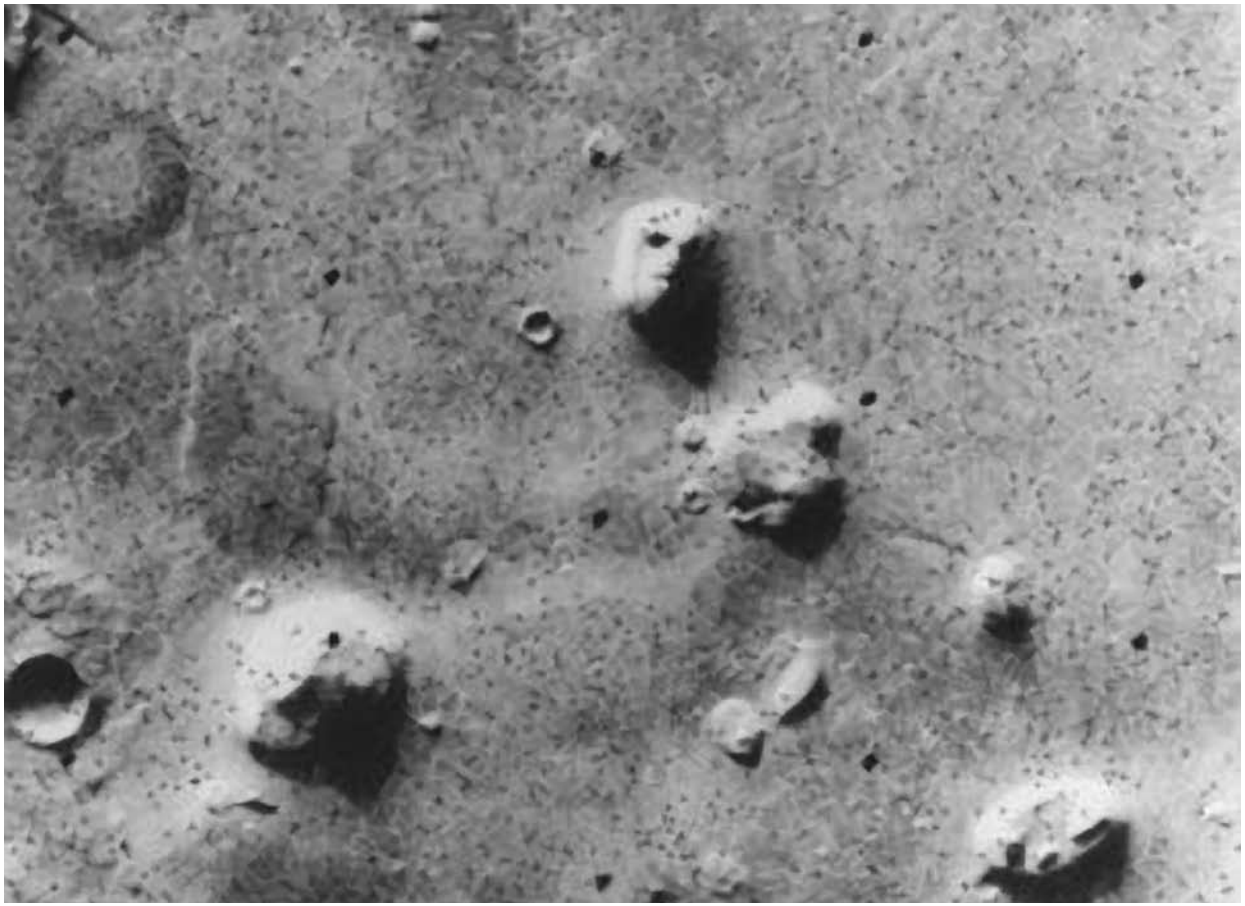
When the Mars Reconnaissance Orbiter (MRO) entered the Red Planet's atmosphere in March 2006, it joined the ranks of other noble explorers studying the planet over the past 2,000-plus years. This new NASA orbiter will study the Martian atmosphere and surface, and probe underground in search of past and present water, making it one of the most advanced studies of the planet to date. People have been aware of the existence of Mars and in awe of its presence for centuries, ever since early humans noticed that it did not shimmer like the surrounding stars.

The Babylonians, around 400 BCE, called the planet Nergal after their god of war. Around this same time, the Ancient Egyptians, also gazing upward, noticed the planet and named it "Har Decher," the Red One. The Greeks called the planet Ares after their swaggering, blood-thirsty god of war. The Romans named the fourth planet from the Sun "Mars" after their mythological god of war.

Whatever the name, the Red Planet has forever captured people's imaginations. With its blood-red, rocky surface, and its pronounced visibility, Mars has sparked the imaginations of people for generations, and speculations that there is life on the surface have never ceased. There is even a topographical feature that makes it look as if there is a face on the planet, which many have taken as a sign that the "people" of Mars are trying to communicate with Earth. Beliefs that other beings live on Mars have been so rampant that the term "Martian," meaning from Mars, is now synonymous with space alien.

For example, since 1948, when he was first introduced to audiences, the Warner Bros. animated character Marvin the Martian has been attempting to blow up the Earth with his Illudium Q-36 Explosive Space Modulator, since our Blue Planet blocks his view of Venus.

And then, there is always the classic CBS television science fiction comedy that ran from 1963 to 1966, "My Favorite Martian," in which the lovable Uncle Martin, an English-speaking Martian, appears very human—despite retractable antennae and the abilities to move objects with the point of a finger, turn invisible at will, and send telepathic messages.



The face on Mars, actually just a series of craters and hills that, when viewed from a distance, look like the features of a human face, fueled speculation for years that the Red Planet housed some form of life and that Martians were trying to communicate with Earthlings.

It has not always been fun and hijinks coming down from the seventh largest planet in the solar system, though. People have been afraid of Mars and its "Martians." The most famous example of this fear dates back to October 31, 1938, when nearly 2 million Americans sat down to their evening's entertainment of news and a musical score, and were scared out of their wits when a young radio personality, Orson Wells, interrupted their scheduled programming with a news-style drama that convinced many that Earth was being invaded by Martians. The radio play

was Orson Wells' adaptation of H.G Wells' "War of the Worlds," updated and set in present day (1930s) United States, as opposed to Victorian England.

It began with a meteor strike, followed by a burst of incandescent gas, and the next thing listeners knew, the Martians had landed in rural New Jersey and were beating a devastating path toward New York City. Despite having pre-warned the audiences that the story was a dramatic presentation, the show still caused mass pandemonium.

Decades later, NASA determined to discover if there is or ever was life on Mars.

In the 1960s, the Mariner 4, an unmanned flyby spacecraft, gave scientists their first glimpse of Mars at close range, finally putting to rest the myths that the Red Planet may have harbored an advanced civilization. Mariner 4 cruised for 228 days before it reached Mars, passing at an altitude of 9,846 kilometers from the planet's surface. An onboard television camera recorded 21 images of the surface, bringing to Earth the first close-up pictures of Mars.

Mariners 6 and 7 were designed to fly over the equator and southern hemisphere of Mars. Geologic features—including cratered deserts, huge concentrically terraced impact regions, collapsed ridges, and craterless depressions—were among the Mariners' many revelations.

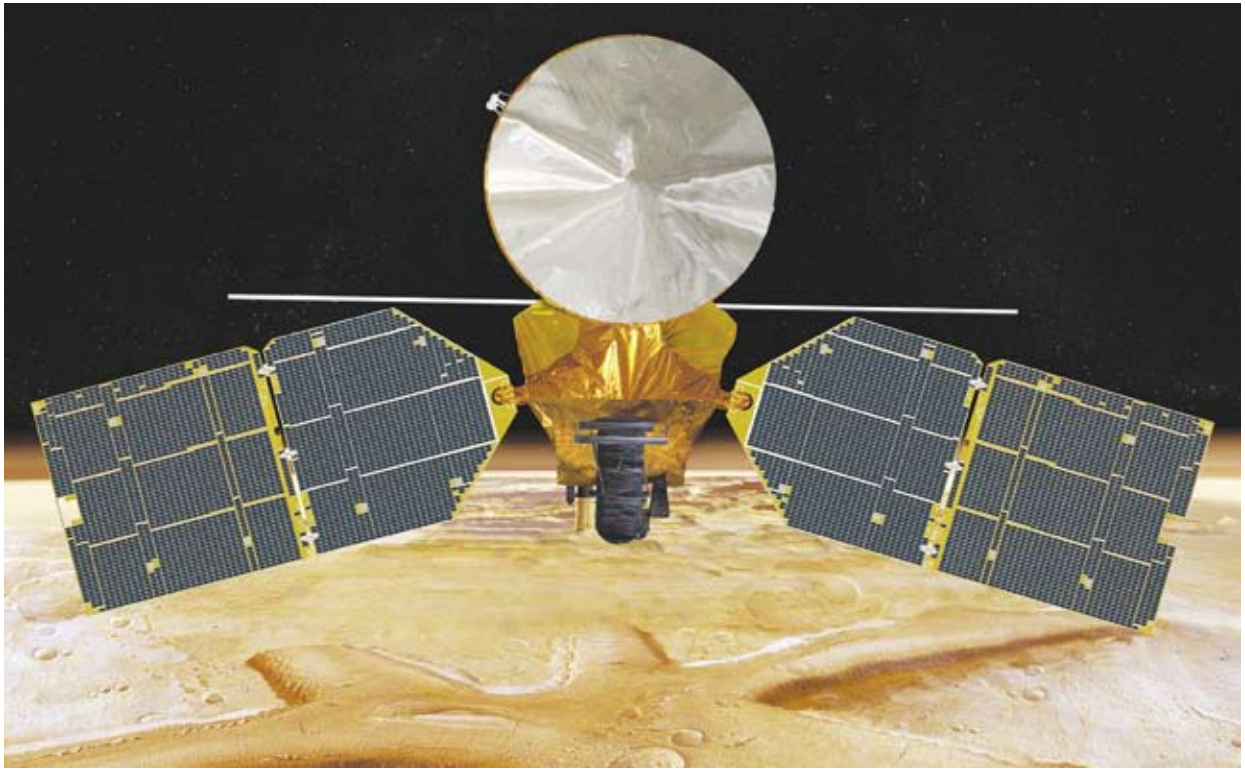
In 1971, Mariner 9 became the first spacecraft to orbit another planet. The spacecraft circled Mars twice daily for a full year, photographing the surface and analyzing the atmosphere with infrared and ultraviolet instruments. When Mariner 9 first arrived, Mars was almost totally obscured by dust storms, which persisted for a month. After the dust cleared, Mariner 9 revealed the true surface of Mars, with gigantic volcanoes and a canyon stretching 3,000 miles across its surface.

In 1976, the Viking Mission inserted two probes into the planet's atmosphere. The Viking probes each consisted of two primary pieces, a lander and an orbiter. The Viking landers separated from the orbiters upon arrival, and then descended onto the Martian surface, each at a different location. Among some of the orbiter's discoveries were that Mars had numerous features of geologic interest.

Mars Global Surveyor became the first successful mission to the Red Planet in 2 decades when it launched November 7, 1996, and entered orbit on September 12, 1997. After a year and a half trimming its orbit from a looping ellipse to a circular track around the planet, the spacecraft began its prime mapping mission in March 1999. The mission has, with its primary instrument, the Mars Orbiter Laser Altimeter (MOLA), studied the entire Martian surface, atmosphere, and interior, and has returned more data than all previous Mars missions combined.

This same year, Mars Pathfinder landed on the planet's surface and managed to collect and transmit 2.3 billion bits of information, including more than 16,500 images from the lander and 550 images from the rover, Sojourner, as well as more than 15 chemical analyses of rocks and soil and extensive data on winds and other weather factors.

Currently, as part of the Mars Exploration Rover program, Spirit and Opportunity have been roving about the Martian landscape for years beyond their expected survival dates, exploring the surface and sending pictures back to Earth. The robot geologists landed on the rocky surface in 2003 with an expected lifespan of 90 days, but continue to



This is an artist's concept of NASA's Mars Reconnaissance Orbiter. This orbiter is the latest in a series of spacecraft to visit Mars in order to broaden our understanding of the mysterious planet.

this day to crest hills and scoot through the valleys of the dusty, red terrain.

NASA has brought people closer to the surface of this fascinating planet and it even intends to send people to explore its surface; but people have never really been able to see Mars up close or touch its surface—until now. Thanks to a clever use of NASA geographical data, in the form of a super-accurate globe, it now takes just a matter of seconds to orbit Mars—a far cry shorter than the 2 years it normally takes for a Martian year to pass. Similarly, the surface can now be within arm's reach instead of the varying 35 to 250 million miles that must otherwise be traversed.

Partnership

When Alan Folmsbee retired from his position at a computer company in 2003, he had plenty of energy and some expendable income with which he wanted to purchase a globe collection. Not finding the quality or scope of globes that he had hoped to purchase, Folmsbee founded The Relief Globe Company, in Boulder Creek, California, to produce raised relief globes based on specifications from actual databases. While the average globe is smooth, its depictions miss the opportunity to show topographical features. It denies the ability of the globe to show features and details in a 3-D display. The topographical maps create landmarks not accessible with a map or a non-relief globe. A raised relief globe, however, allows the mountains and canyons to become real and tangible in ways that a cardboard globe covered in numbers and letters just cannot.

He purchased databases online for ocean globes, as well as those for the Moon, Venus, and Mars. The Mars data, the complete recordings taken by the Mars Global Surveyor's MOLA instrument, filled 15 CD-ROMs. After trying to use those CD-ROMs, he downloaded the more up-to-date data from the NASA Planetary Data System archives maintained by the Earth and Planetary Remote Sensing Laboratory in the Department of Earth and Planetary Sciences at the Washington University in St. Louis. Folmsbee then used his computer background to write a program that would take the data and run simulations—a process that went remarkably smooth due to the large amount of detailed data supplied him by MOLA. Within 2 weeks, Folmsbee had a fully functional model of Mars, the first digitally produced 3-D depiction of the planet ever created.

He then contacted Spectrum 3D, Inc., a state-of-the-art prototyping, low-run, injection molding, and rapid-tooling production company located in Tustin, California. Spectrum 3D had a history of making precision products from computer designs—it made the robots for

The Relief Globe Company creates raised relief globes using the most up-to-date information available, exaggerated to bring out the unique characteristics. From left to right are a globe of Earth with an exaggerated seafloor, the Mars globe, and a raised relief land globe of Earth.

The Mars Globe 20x, with elevations calculated from the Mars Orbiter Laser Altimeter database.

the Twentieth Century Fox motion picture "I, Robot," the futuristic adaptation of Isaac Asimov's novel by the same name, as well as special effects for a handful of other major motion pictures and independent films.

Spectrum 3D accepted the task of manufacturing the raised relief Mars globe. The first step was to work with The Relief Globe Company to determine which level of relief was the most appealing. The 7-times exaggeration was too bland, while the 40 times was, perhaps, too much, though they did present several 40-times raised relief Mars globes to the National Federation of the Blind to share with blind students who would otherwise have no idea what the surface of the Red Planet was like. The National Federation of the Blind, working with NASA's Jet Propulsion Laboratory (JPL) to set up summer internships in technical fields for blind students as part of NASA's Achieving Competence in Computing, Engineering, and Space Science program, introduced the globe to JPL Mars education and engineering staff who would be mentoring the students. The JPL team met with Spectrum 3D and The Relief Globe Company and provided guidance for their future models. They suggested toning down the exaggeration, as they felt that perhaps 20-times raised relief was more subtle, yet still allowed the topographical features to stand out. They also suggested a revised color scheme based upon some imagery from the Viking Mission. The final test, though, came when blind NASA interns at JPL were able to identify the major topographical features of the globe.

Product Outcome

The Mars Globe 20x is the first digitally produced raised relief globe to be sold at retail establishments. The rises and dips of the Martian landscape have been multiplied by 20 to make the shapes more noticeable to human touch and sight. They make this globe, with its over 1 million elevation points, a visually stunning introduction to the planet.

Spectrum 3D used the NASA digital land elevation data to aim lasers that then shaped and defined the master globe's surface. Subsequent copies were then made by creating a master globe mold. The molded copies are hand finished by workers who remove errant edges or lines that may appear on the raw globes and then paint the surfaces. The result is a globe that measures in at 18 inches in diameter, roughly 1:15,729,473 scale of the actual planet.

The exaggerated raised relief is like having a 3-D digital microscope for planetary shapes. This makes the landmarks easier to learn and understand, as it provides easy visuals for orientation. People have a natural propensity for understanding 3-D shapes more easily than numbers or words. The 3-D globes appeal to both the kinetic and visual learning aspects of the brain, making it easy for people to readily memorize the landmarks and to make a mental model that they will remember for a long time.

The polar caps on the north and south poles lend visual contrast to the otherwise blanketing palette of reds and browns, but the real excitement is in the richly varying landscape. The globe helps show the landmarks in relative sizes and positions. Olympus Mons, the highest point on Mars, is 78,000 feet tall, 2.6 times taller than Mount Everest. There are also 5 other giant volcanoes, plus about 15 major volcanoes, that are each about the entire size of Hawaii. It is a captivating, busy landscape. On a topographical map, coloring tends to blur these dramatic features—but not so on the raised relief globe. A giant crack runs down one side of the planet. It is half as deep as Olympus Mons is tall—29,000 feet. This "Grand Canyon" runs the distance from what would be Los Angeles to New York, here on Earth.

Most striking about the globe's appearance, though, is that Mars is not perfectly round. In fact, it appears quite lopsided. On the side opposite the large volcano clusters is a deep crater—the largest in the solar system. This great depression, when viewed simultaneously with the exaggerated mountains, gives the appearance that something large struck the planet, creating the crater and forcing the volcanoes out of the surface on the opposite side. This striking feature was one of the elements that the JPL staff members were so excited to see. They had been studying the planet for years and this was the first time they had ever had this perspective available to them on a globe. Other globes of Mars had just been round or showed the topography in such low scale that it was hardly noticeable.

The Mars Globe 20x is being distributed in the United States and throughout Europe. It has myriad uses, including as an educational display in classrooms, museums, and lobbies. It can serve just as well as a piece of art with the ability to captivate and amaze the viewer just as the early civilizations were amazed when they first gazed up and started wondering about that red, glowing orb. ❖

Marvin the Martian™ is a trademark of Warner Bros. Entertainment, Inc.

Modern Exploration of the Lewis and Clark Expedition

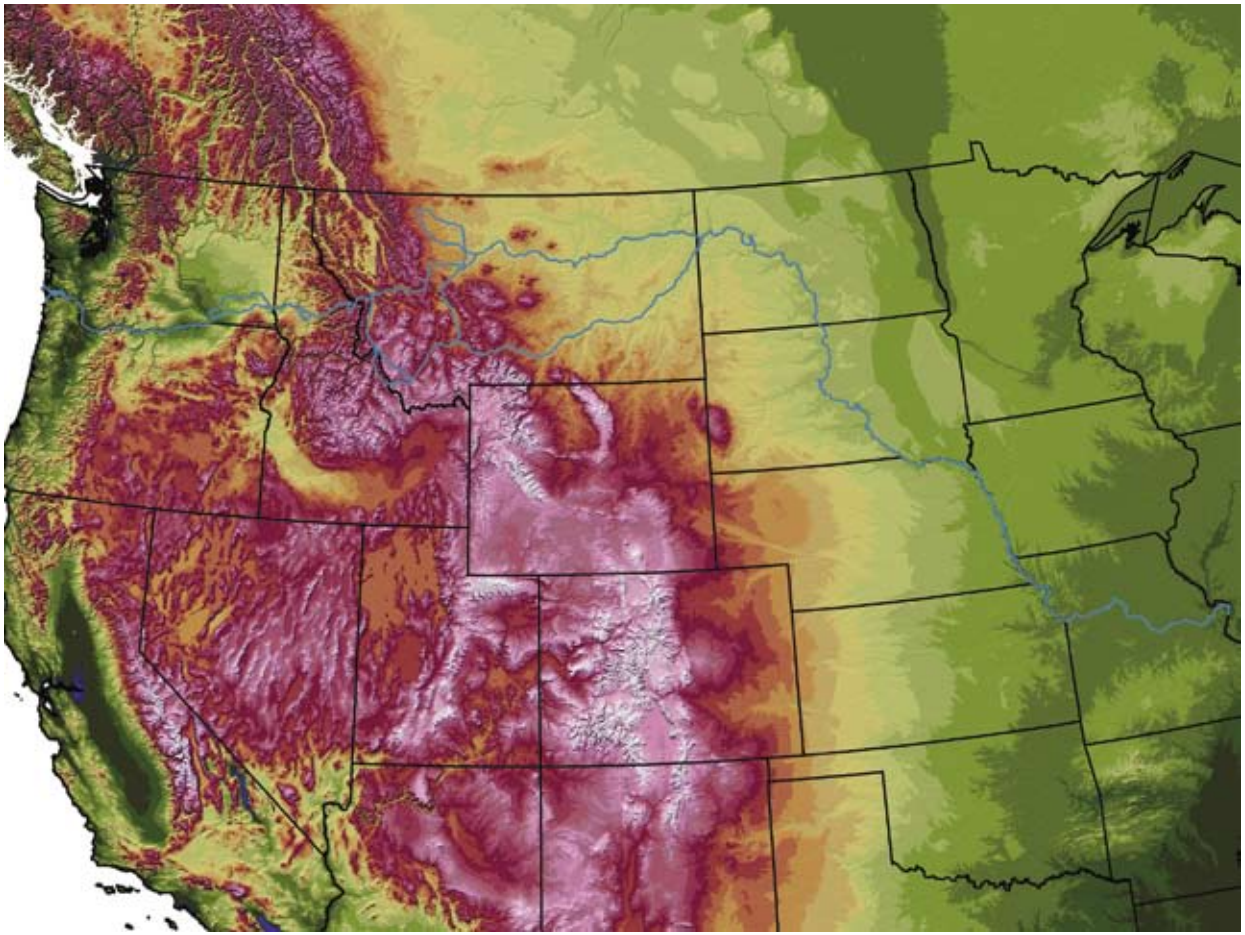
Originating Technology/NASA Contribution

One of the forces that propels scientific and cultural advancement is exploration. The mission of NASA is to pioneer the future of space exploration, scientific discovery, and aeronautics research. Through this mission, NASA leads the Nation in pushing the boundaries of exploration and discovering new frontiers, and, as a secondary benefit, pushing scientific and cultural advancement.

Much as the early American frontiersmen charted new territory and created the new independent American culture, NASA is at the forefront of the continuation of this pioneering spirit. It is not surprising, then, that NASA Administrator Michael Griffin is fond of drawing the comparison between the work done under his stewardship of the Space Program and the expeditions of such trailblazers as Captain Meriwether Lewis and Lieutenant William Clark and their Corps of Discovery.

In an address to the 2005 graduating class of the Georgia Institute of Technology, Griffin told the students of a plan to use available atmospheric elements on Mars to fuel rockets. He made this comparison: "The requirement to live off the land will be crucial to our future in space, just as it was to Lewis and Clark and the Corps of Discovery as they made their way from St. Joseph, Missouri, to the West Coast and back, from 1803 to 1806."

Four months later, while addressing a group at the 22nd National Space Symposium, a commercial space meeting hosted annually by the Space Foundation in Colorado Springs, Colorado, Griffin went on to say, "I believe that the benefits of exploration are, similarly, an emergent property of our inquisitive human behavior. We can study the great explorations of the past, and we can conclude that such ventures did in fact benefit the societies which sponsored them. But no society can reasonably predict that a given venture will prove to be worth its cost. Sponsorship of such a quest is always an act of faith, not an act of science.



The Lewis and Clark Geosystem is an online collection of private, state, local, and Federal data resources associated with the geography of the Lewis and Clark Expedition.

"In this regard I enjoy recalling that, as expressed in his instructions to the Lewis and Clark Expedition, President Jefferson's primary goals for that venture concerned the expedition's diplomatic mission to the Indian nations, the establishment of the United States as the sovereign power in the region, and the enhancement of the fur trade. Particularly important to the latter was the effort to find a route between the headwaters of the eastward-flowing Missouri River and the westward-flowing Columbia, thus (it was hoped) enabling a waterborne route for the fur trade between the east and west coasts. Who, today, believes that these purposes—though they were accomplished—constitute the most significant results to have come from the Lewis and Clark Expedition?"

It is not only the Administrator who is in awe of the explorations of Lewis and Clark. Their story inspires many. In a preflight interview with Dr. Kalpana Chawla, mission specialist aboard STS-107, when asked what had inspired her throughout her life, she answered, "Lewis and Clark's incredible journey across America to find a route to water, if one existed. And, the perseverance and incredible courage with which they carried it out."

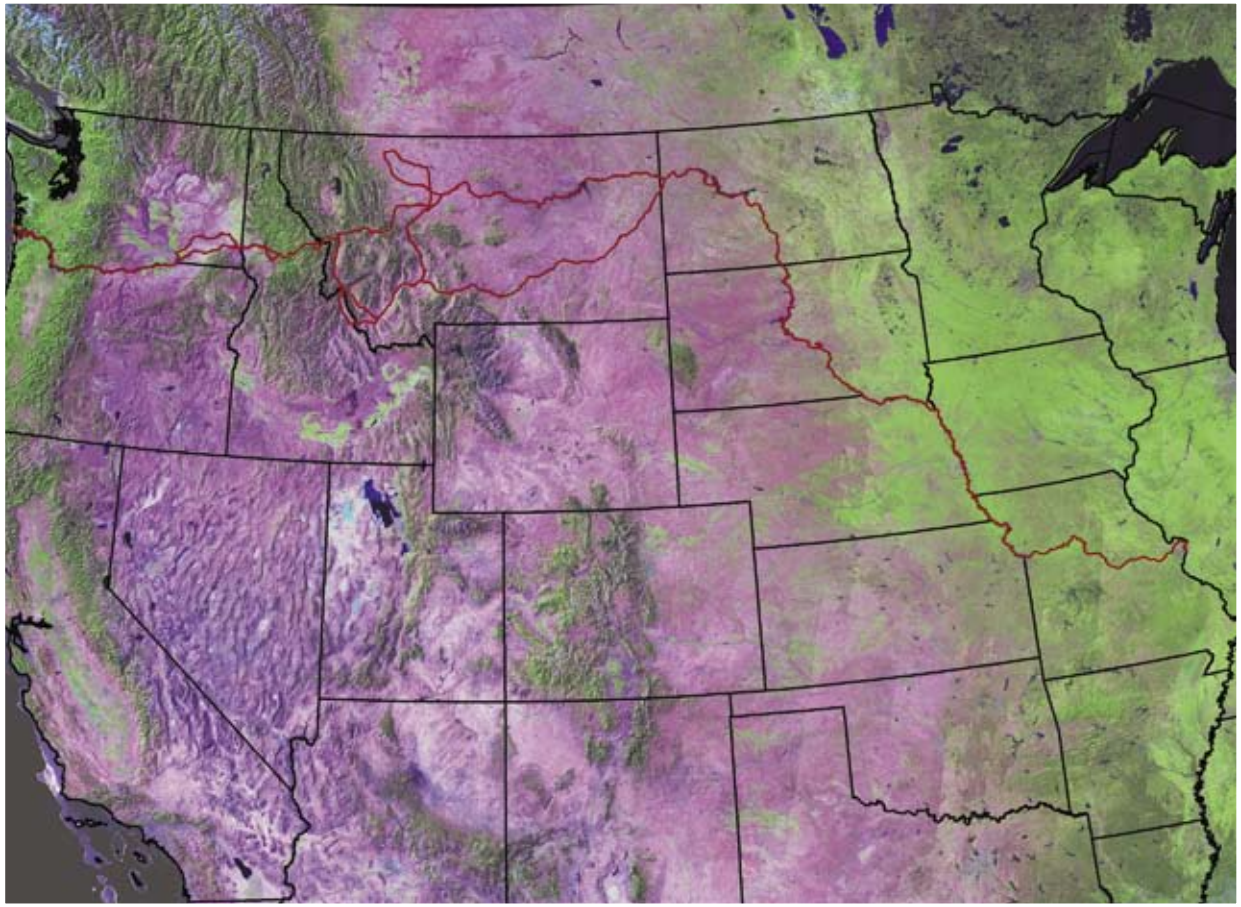
Just as Lewis and Clark faced the great unknown, harsh conditions, and unexplored territories, which secured their page in history among the world's great explorers, so too, have NASA's astronauts and visionary scientists. Through its endeavors, over 200 years later, NASA has managed to contribute to modern recording and understanding of Lewis and Clark's historic expedition through a unique, collaborative initiative with other government agencies, academia, and private industry. NASA provided a wealth of satellite imagery to help preserve and explain the route taken by Lewis and Clark.

Partnership

The Lewis and Clark Geosystem is an online collection of private, state, local, and Federal data resources associated with the geography of the Lewis and Clark Expedition. Data were compiled from key partners including NASA's Stennis Space Center, the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the U.S. Geological Survey (USGS), the University of Montana, the U.S. Department of Agriculture Forest Service, and from a collection of Lewis and Clark scholars. It combines modern views of the landscape with historical aerial photography, cartography, and other geographical data resources and historical sources, including: The Journals of the Lewis and Clark Expedition, the Academy of Natural Science's Lewis and Clark Herbarium, high-resolution copies of the American Philosophical Society's primary-source Lewis and Clark Journals, The Library of Congress Lewis and Clark cartography collection, as well as artifacts from the Smithsonian Institution and other sources.

The Stennis contribution to the Lewis and Clark Geosystem consisted of providing access to a variety of different satellite resources. Most notably, the system employs comprehensive national land coverage from the Moderate Resolution Imaging Spectroradiometer, a key instrument aboard NASA's Terra and Aqua satellites. It also employs imagery from the Advanced Thermal and Land Applications Sensor remote sensing instrument flown on the Stennis Lear jet to show select campsites along the Lewis and Clark Trail, as well as Landsat 5 TM (Thematic Mapper) data and the highly accurate Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) coverage of the trail.

Stennis also worked with a Lewis and Clark historian, Dr. Robert Bergantino, and GCS Research LLC, a geospatial information technology firm based out of Missoula,



The Lewis and Clark Geosystem combines modern views of the traversed landscape with historical aerial photography, cartography, and other geographical data resources and historical sources.

Montana, that currently has a Space Act Agreement with the NASA center. GCS Research has done work as varied as producing imagery for secure airport management to watermarking of digital imagery and was the perfect fit for this historic endeavor.

At this time, The Lewis and Clark Geosystem also serves as a primary historical geospatial component of the Federal geospatial One-Stop (GOS II) Portal that makes geospatial information available to the public The geosystem was included during the launch ceremony for the earlier GOS I and was highlighted during the 2004 National Governors Association Conference in Washington, D.C. Similarly, Alex Philp, president of GCS Research, had the opportunity to discuss the creation, formation, and historical geospatial components of the Lewis and Clark Geosystem at the 2003 Geological Society of America Annual Conference in Seattle, where he was invited to present at the distinguished USGS-sponsored Pardee Symposium, hosted by Dr. Jim Tate, Science Advisor to the U.S. Secretary of Interior.

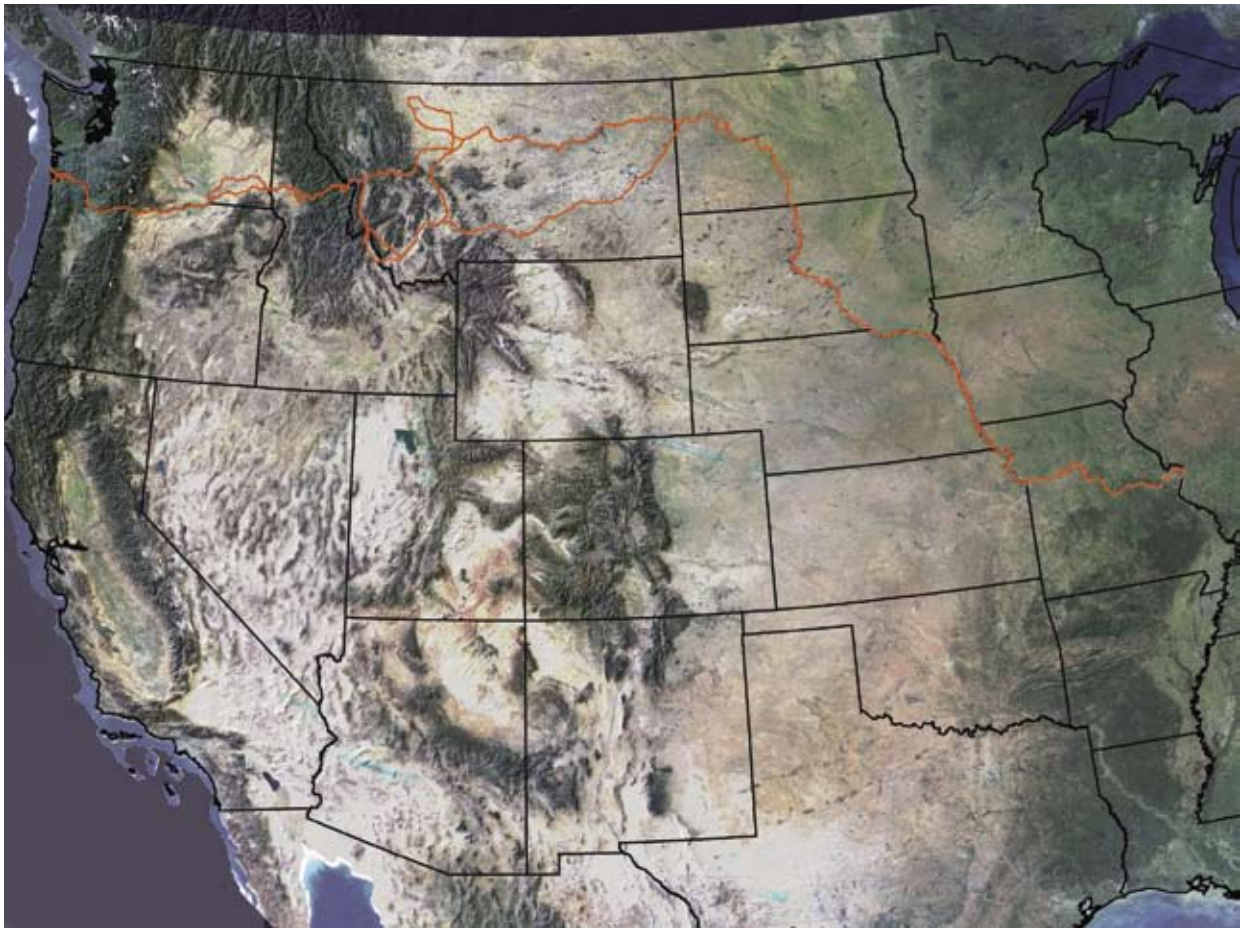
The Lewis and Clark Geosystem, managed by GCS Research, is intended for educational and research purposes, and its primary goal is to provide a Web-based geospatial system wherein concepts of historical landscape change can be explored on an interactive map.

Philp said of the project, "The Lewis and Clark geosystem was born out of shared vision between NASA and GCS Research regarding the significance of the Lewis and Clark geographical odyssey and the modern parallels to continued planetary exploration. Technically, the geosystem demonstrates the ability to share and combine NASA's rich geospatial archives in distributed geospatial systems. Conceptually, the Lewis and Clark Geosystem helps us understand landscape change in terms of human exploration both in the present and future."

Product Outcome

The Lewis and Clark Geosystem, managed by GCS Research, is intended for educational and research purposes, and its primary goal is to provide a Web-based geospatial system wherein concepts of historical landscape change can be explored on an interactive map.

The geosystem provides multiscale and multitemporal examination of the Lewis and Clark Trail's geography. The purpose is twofold. It provides a way to view historical landscape change and a way to examine the networking of a variety of geospatial data sources. Covering 200 years of change, it presents a variety of spatial data—historical, ecological, climatological—in a way that allows for examination of historical landscape change as a result of anthropogenic and non-anthropogenic effects. It also explores the deployment and networking of a variety of geospatial Web services, each of which provides unique geospatial data types of interest to the study of the trail's



The Lewis and Clark Geosystem provides multiscale and multitemporal examination of the Lewis and Clark Trail's geography.

geography, representing significant, cumulative advancements in geospatial information technology.

Perhaps the most notable feature of the interactive map is that the user can superimpose or hide a series of layers over it to help users form analytical perspectives of the various trail landscapes. Like transparent slides, the layers cover the map and show a variety of different features. Landmarks can be added and taken away. For example, a user can select a slide that superimposes markers showing the trail in different colors, each color depicting a different leg of the expedition, or a layer that shows all of the places the expedition camped.

The user can superimpose the state borders, or take them off for authenticity and to have a more contextually accurate view of the trip. The user can also choose whether to show the borders of Canada and Mexico, or even the Louisiana Purchase. There is even a feature on the map that will highlight or hide bodies of water. In short, the user can modify the map in a variety of ways according to interest, course of study, and intended use.

The online map has a bevy of additional features and capabilities that make navigation easy.

The user is able to zoom in or out and pan across the map, bringing the view as close as needed to examine details or as far out as needed to gain perspective. Crossing the terrain on this geospatial map is as simple as dragging the cursor, which is a far cry easier than how the early pioneers crossed the land. In fact, the expedition averaged 15 miles per day by land and 25 miles per day by river, with the explorers carrying all of their equipment and supplies. Now it only takes the modern researcher a flick of the wrist to cross terrain on this map.

Similarly, while the explorers had to set up their astrolabes and compasses to calculate coordinates, users of the Lewis and Clark Geosystem have it easier. By clicking on the map, it will re-center on that point. This tool gives the same results as the panning tool, except the user just needs to click where he wants the map to re-center. This feature can be used for an accurate coordinate calculation. Unlike the original explorers, the computer-bound user can measure any distance on the map in miles or even feet, with just the drag of the mouse.

And, while the expedition cartographers would have to unfold a table, unroll a sheet of paper, and dip quill into ink to make a new map, the system has a tool that rescales the map with a ratio set by the users and then allows them to print the map. The early pioneers would have appreciated the technology today just as much as the people of today appreciate the exploration efforts of the early pioneers. ❖

Reflecting on Space Benefits: A Shining Example

Originating Technology/NASA Contribution

NASA has long been known for having developed the thin, shiny reflective material used to insulate everything from the Hubble Space Telescope to hikers, from the Mars rovers to marathon runners, from computers to campers, from satellites to sun shields, and from rockets to residences. It is one of the simplest, yet most versatile spinoffs to come out of the Agency.

The insulating material, a strong, plastic, vacuum-metallized film with a highly-efficient, infrared-reflective, vapor-deposited coating of aluminum, was created to be very lightweight in order to minimize weight impact on vehicle payload while also protecting spacecraft, equipment, and personnel from the extreme temperature fluctuations of space.

It has been employed on virtually all manned and unmanned NASA missions. The shiny insulation which coated the base of the Apollo lunar landing vehicles is perhaps one of the most memorable early displays of this technology, and the bright, reflective honeycomb on the James Webb Space Telescope prototype is a testament to its lasting usefulness.

During the first days Skylab was in space, the station was besieged by problems caused when the meteoroid shield that was designed to protect it from micro-meteorites and the Sun's intense heat tore off during launch. Scientists, engineers, astronauts, and management personnel at Marshall Space Flight Center and elsewhere worked to devise the means for its rescue. Their solution was to deploy a reflective parasol-like sunshield. Concern over the possibility that the parasol would deteriorate with prolonged exposure to the Sun's rays prompted the installation of a second sunshield (pictured here) during the Skylab-3 mission.

Partnership

The material is created by depositing vaporized aluminum onto thin plastic substrates. The result is a thin, flexible material that provides superior thermal-reflective properties. The highly pure aluminum coatings are carefully matched to their substrates to efficiently redirect infrared energy—infrared waves being the chief component of thermal energy in the near-vacuum conditions of outer space—to create either first- or second-surface reflecting. In some instances, the material is intended to deflect the infrared rays, and in other cases, it is meant to conserve them as a passive warming system.

Early in the Space Program, the National Metallizing Division of Standard Packaging Corporation, headquartered in Cranbury, New Jersey, was a supplier of this reflective material to NASA. In fact, it was one of the original subcontractors NASA turned to for design and supply of the material, and it was able to branch off from this work into the more general, terrestrial insulating applications, like building insulation.

It was National Metallizing that NASA turned to for assistance when, in May 1973, during the first few days that Skylab was in orbit, it was malfunctioning and overheating. A heat shield broke off during launch, and air temperature inside the orbiting station began approaching 130 °F. NASA was concerned about the condition of food, film, and other equipment inside, as well as plastic insulation and possible toxic gases if the temperature rose too high. The staff at National Metallizing was called upon by engineers at Marshall Space Flight Center to help create an emergency parasol-type sunshield that helped save millions of dollars worth of equipment, years of research, and allowed, for the first time, a habitat for astronauts to live and work in space.

Through a series of mergers, acquisitions, and transfers of ownership, National Metallizing's factory doors

eventually closed. A former employee, though, David Deigan, took advantage of the remarkable material the company had been manufacturing for NASA and founded a company to continue producing it, branding it as Heatsheets. The company, AFMInc, was originally founded as JSC Enterprises, a solely owned proprietorship, in Ridgewood, New Jersey. The "J" stood for Jennifer, "S" for Stephanie, and the "C" for Christopher, the names of Deigan's three children.

He incorporated in 1982 as AFMInc (Advanced Flexible Materials), because the name JSC, Inc. was already taken, but the company's story actually goes back a few decades further than this.

Product Outcome

In 1959, the Russians were the first to successfully launch a probe to the far side of the moon—and return pictures—thus firing the starter pistol for the Space Race. Meanwhile, back in New York, a high schooler, David Deigan, heard a similar shot ring out, and on a lark with some friends, fell in step with a crowd running a marathon. With little prior training, he still managed to finish the event, and even though he paid for it with muscle aches and soreness, he had caught the marathon bug.

Granted, the illness remained dormant for 20 years, as it wasn't until 1978 that Deigan attempted another marathon—this time with more training and preparation. It was a marathon in New York City that stretched its 26.2 miles throughout Manhattan's five boroughs: Staten Island, Brooklyn, Queens, the Bronx, and Manhattan, where it finished in Central Park at the Tavern on the Green.

When the runners finished, one of the problems they ran into was keeping themselves warm. The race is held in the fall of each year, either in October or November, and weather in New York, like in many places around the country during these months, can be rather fickle. It might be balmy. It might snow. With masses of people crossing the finish line, it was taking each person an average of 20 minutes to get to their clothes. Hypothermia was settling in when the runners stopped running, and more people were making it to the first aid tent than were to their street clothes.

Runners winding down after the 2005 Boston Marathon. When they stop running, body temperatures drop rapidly. The reflective blankets, which have become standard at marathons worldwide, help stabilize body temperatures.

The Association of International Marathons and Road Races, a nonprofit group that organizes races, met to discuss this problem. They tested several products and settled on the original "Space Blanket" from Metallized Products, an early company that had taken advantage of the NASA technology. Although fine for many situations, and ideally suited for this use in many ways, the blankets were each folded and packaged, a seemingly small detail that had severe impact on their usefulness in this situation—with hundreds of runners crossing the line every few minutes, the blankets just took too long to dispense, unwrap, and unfold, but they were still, at that time, the most viable solution.

Still running, during the 1979 New York City Marathon, Deigan crested a hill in Central Park and crossed the finish line. What stood out to him was not that

AFMInc supplied the Marine Corps Marathon with 24,000 camouflage printed Heatsheets for the 2005 run.

he had made it 26.2 miles; rather, he was marveling at the silver caterpillar of people wiggling away from the finish line. As he recalls "I crossed the finish line and followed the runners in front of me as we were wrapped in metallized polyester sheets and guided onto and over a hilly path to the reunion area." He recalls that it looked like a dragon from a Chinese New Year's celebration. He had the idea at that point that the New York Road Runners Club, Inc., the group that organizes the New York City Marathon, could transform the expense of the silver blankets into racing revenue through branding.

Deigan, the former employee of National Metallizing, also thought of a solution to the problem of having to unwrap and unfold the blankets. The insulating material could be shipped flat and unwrapped on a pallet, thus eliminating the time-consumption problem.

During the first few years, the blankets were branded with the Road Runners logo, a bright red apple; but in 1982, industry had taken notice of the advertising opportunity and major corporations branded the marathon as well as 10 smaller races, and the idea really took hold. That following year, the Chicago and Boston Marathons took interest in the new product and found sponsors to brand their races as well.

Now, most major marathons in the United States, many in other parts of the world, and a number of smaller races employ the blankets, mostly for the purposes of preventing hypothermia, but also because runners have come to expect them. They have become synonymous with finishing a race.

The blanket printing process has, over the last few years, gotten increasingly sophisticated. This past year, for the Marine Corps Marathon, in Arlington, Virginia, AFMInc shipped 24,000 camouflaged finish line Heatsheets to cover the runners as they finished the race. The product has also advanced over time and is now manufactured in a variety of ways, including on rolls and perforated at 6-foot intervals for quick dispensing. Most notably, though, the sport has really progressed. It has taken on mass appeal as a sport where amateurs line up with Olympians. In fact, it is estimated that 700,000 marathoners cross the finish line in the United States alone each year, in the dozens of races taking place around the country.

In 1996, Runner's World, a monthly publication devoted to news of interest to joggers, ran an article on Deigan and AFMInc's endurance in the marathon safety culture. Deigan received a call from a plant manager at Encompass Group, of Addison, Texas, who had just started running marathons and had read the article. The plant manager, Lloyd Burnett, told Deigan about Thermo-Lite, an advanced variation of the infrared-reflective aluminized material that his company was manufacturing.

At the time, Thermo-Lite was being used as bed sheets in hospital settings as passive hypothermia prevention for pre- and post-operational patients, for staff in scrubs who work in chilled environments, and as surgical drapes, often including a cut-out access area, giving surgeons access to specific areas of the body while covering the rest. The sheets were softer and quieter than most reflective insulating materials, as they did not have the crinkle and rustle of metallized plastics.

Burnett and Deigan saw potential for the Thermo-Lite and Heatsheets in a line of adventure and extreme weather gear, which AFMInc then sold through Adventure Medical Kits, of Oakland, California. The products, emergency bivvies and rescue blankets, made their way to Alaska where they were purchased by Becky and Doug Bowers.

The Bowers live at the Tolovana Roadhouse in the outreaches of Alaska, 50 miles from the nearest road and the small town of Nenana. They grow their own vegetables, hunt, fish, and trap. Since public utilities do not run to their remote outpost, their power is generated by wind mills and solar collectors. They use this power, in part, to run a small business, Midnight Mushing Outdoor Gear, making the types of rugged, cold-tolerant outdoor gear needed for their climate, where, on a nice day, temperatures run well into the negative digits.

Most of the year, they are confined to their home, where Doug conducts the marketing and business side of their enterprise, while also making the buttons and pulls for their line of parkas and anoraks out of caribou bone and antlers, and Becky designs the garments. Each item, including the vests, mittens, parkas, walking bags (a type of mobile sleeping bag), and pullovers, is made by hand, with added details that make each one unique, but still representative of traditional Alaskan designs.

At the Tolovana Roadhouse in Alaska, 50 miles from the nearest road, Doug and Becky Bowers live with their 25 sled dogs and operate their small company, Midnight Mushing Outdoor Gear, via solar electricity.

All of the items in the Midnight Mushing catalog are handmade, and several contain an advanced variation of the infrared-reflective material used by NASA to control temperatures on spacecraft and equipment.

In addition to their aesthetics, though, the garments are tested thoroughly for high performance. Becky and Doug use everything for a full season before offering them for sale. As might be imagined, one of the key factors they test is an item's insulating ability. Many contemporary insulating fabrics are wicking, which draws the perspiration away from the body; but after it has been wicked, the insulating barrier is then wet. The ideal solution is to combine the insulating material with a vapor barrier. Unfortunately, many of the different materials traditionally used as vapor barriers are bulky or noisy. This is where Thermo-Lite enters the picture.

On one of their trips into Nenana, Becky purchased one of the Thermo-Lite blankets. She cut it into pieces and sewed it into the linings of several pairs of mittens.

The mittens were put to the test in the winter of 1999, shortly after Christmas, when Becky and Doug left Nenana to trek the 50 miles back to their home after conducting some routine business. Doug was leading the way on the snowmobile with a load of gear, and Becky was following with a team of sled dogs. The two were enjoying the unseasonably warm weather, and the trip was uneventful.

Two days later, the temperature started to drop, reaching -55 °F by the time night fell and continued dropping through the night. The thermometer in their woodshed the next morning read -65 °F. The weather was expected to hold at this temperature for at least a week, and the Bowers had only enough food for their 25 sled dogs to last another 4 days.

They determined to make the trek back, through the bitter cold, into Nenana, so they made makeshift dog coats out of squirrel-damaged blankets, fired up the snowmobile, and left. The trip took 7½ hours, with temperatures nearing -72 °F, 144 degrees below room temperature!

During that time, the starter pull rewind failed on the snowmobile, which meant Doug had to run the engine idle high to avoid stalling and then drive extra slowly so as not to overheat the engine. Meanwhile, Becky's chemical hand warmer failed near the halfway point. She wore

her new, experimental Heat Barrier Mitts the rest of the way, and to her surprise, and great relief, her hands stayed warm. Ahead on the snowmobile, which is not equipped with heated grips, Doug wore a pair of work gloves under a pair of the mitts, and his hands, too, stayed warm.

After this event, Becky and Doug decided to add the Thermo-Lite mittens to their Midnight Mushings product line. Becky eventually worked her way through a line of phone calls and got through to Deigan, then asked if she could buy seconds of the material. After hearing her story, not only did Deigan agree to supply Becky with factory seconds, he took a plane up the West Coast to see the Tolovana Roadhouse where the Bowers live.

Midnight Mushing's resulting Heat Barrier Mitts employ a 330-denier Supplex Cordura outer shell, a material that owes its origin to work done by DuPont in the 1920s to make super-strong tires for Army vehicles. It has been refined to the point now, where it is as supple as cotton. The mittens also have Tuff-Grip palms, which stay flexible even in extreme cold, and, of course, the Thermo-Lite insulation. They are very popular with the trappers who turn the mittens inside out when perspiration builds inside, wait a few seconds for the moisture to freeze, give the mittens a whack to crack off the ice, and then put them back on.

Becky has been wearing the mittens for several seasons now, and with the money she has saved from not having to purchase a case of chemical warmers each season, the mittens paid for themselves within the first year. She had had considerable tissue damage to her hands from repeated frostbite, and wearing these mittens for the past few years, her hands have had a chance to start healing—a considerable boon considering that she is a seamstress by trade.

Midnight Mushing also incorporates the space-age Thermo-Lite into a line of vests, which is handy not only for activities like running the dogs in extreme cold, but for sedentary activities, like sewing, where the body has the tendency to lose heat.

The Bowers are not the only people who have bought this space-age material from AFMInc; many have realized its potential and then wanted it for their own unique use. What is remarkable, though, is the extent to which this space technology can be applied and that it has worked its way into such remote locations.

In October 2005, an earthquake registering 7.6 on the Richter scale caused widespread destruction in northern Pakistan, as well as in Afghanistan and northern India. The following day, the area felt 147 aftershocks, the strongest of which registered 6.2. During the first 4 days after the initial quake, 28 aftershocks occurred with a magnitude greater than 5. Even 11 days later, there were still major quakes.

It is estimated that over 79,000 people died, 135,000 people were injured, and 400,000 houses were destroyed—a true natural disaster. The area was devastated, and the aid started pouring in to assist in relief efforts.

Stateside, Richard Berger, an avid hiker, was so moved by the plight of the people in the remote villages of Pakistan that he literally got into his car and started a search for products that might help relieve their suffering. He found his way to a large REI (Recreational Equipment, Inc.) retail store in his hometown of Seattle. REI is a supplier of specialty outdoor gear and equipment. There, Berger sorted through as many products as he could and settled on the Heatsheets rescue blanket AFMInc and Adventure Medical Kits had created. It is a larger version of the finish line blanket. At finish lines, where tripping hazards are a problem, the blankets measure 48 by 72 inches. These emergency blankets, though, are big enough for two people to wrap up and share body heat. They measure 60 by 96 inches, and the retail version is printed

The Emergency Sleeping Bag by Adventure Medical Kits weighs only 2.5 ounces and reflects up to 90 percent of a person's body heat, making it ideal for survival situations.

with a complete set of illustrated survival instructions in two languages.

Berger, like the Bowers, worked his way from the supplier to the distributor, to the manufacturer, and eventually to Deigan, asking what AFMInc could do to help. With the cooperation of a network of small companies, and a remarkable Internet fundraising effort through friends and acquaintances, Berger began to generate a buzz. The efforts were successful, and the newly formed collective received e-mails and letters from nurseries and day schools, from various nonprofit organizations, and from individuals willing to assist the refugees of the Pakistani earthquake.

Through this fundraising campaign, they produced approximately 150,000 60- by 90-inch Heatsheets out of a special performance resin polyethylene with the standard infrared-reflective coating. All of the work was done at cost, with no profit, and they went through two production runs to produce enough Heatsheets to reach as many people as possible.

Once the campaign had grown quite sizeable, Berger contacted Mercy Corps, of Portland, Oregon, to assist in the final, but most critical, stage—distributing the materials. Mercy Corps has a 25-year history of disaster relief response around the world and had already been conducting aid work in Pakistan for over 20 years. It was integral to the earthquake response and the ideal group to manage the next stages of the effort.

The group supplied both folded Heatsheets and Heatsheets-on-a-Roll for this effort, and suggested ways to employ Heatsheets as structural insulation and as emergency blankets. AFMInc also donated thousands of smaller Thermo-Lite blankets that were tremendously helpful, especially for smaller children and the elderly. These doubled as ground covers during the day and much-needed blankets at night.

Dan McHugh, a senior vice president at DHL International, Ltd., assisted the group by arranging for the large shipping firm to provide air shipments of the relief supplies at no charge, on three separate occasions. This generosity made it possible to nearly double the amount of Heatsheets supplied and provided some relief to people halfway around the world.

Mercy Corps coordinated with individuals and institutions, large and small, to deploy tens of thousands of the reflective emergency blankets to Pakistan in fall of 2005, after earthquakes devastated the region.

Both the Heatsheets and Thermo-Lite have been named Certified Space Technologies by the Space Foundation. The Space Foundation, in cooperation with NASA, created the Space Certification Program to promote the extraordinary products and services that bring the benefits of space technology home to Earth and enhance public interest and awareness in space. ❖

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PRP: The Proven Solution for Cleaning Up Oil Spills

Originating Technology/NASA Contribution

The Exxon Valdez, an oil tanker exporting millions of gallons of oil, ran aground just after midnight on March 24, 1989 in Alaska, creating what is, to this day, the worst environmental disaster in American history. The affected area of coastal Alaska continues to feel the toxic results of that disaster that killed more than 250,000 seabirds, thousands of marine mammals, and countless numbers of other coastal marine organisms in just its first months. Oil is notoriously difficult to clean from water, and it is still emerging from subsurface reservoirs. Salmon caught in that region are, even now, 16 years later, showing signs of long-term contamination from the devastating oil spill.

While disasters of this magnitude happen rarely, with large spills making up less than 5 percent of the oil spilled into water each year, tens of thousands of smaller oil spills are occurring all around the world. Oil enters the water supply from road runoff; refuse from routine engine maintenance; emptying of boat wastewater and other ship operations; air pollution that settles into bodies of water after rains; and through offshore oil production, which can cause ocean oil pollution from spills, leaks, and routine, operational discharges.

Water can, thankfully, be cleaned or remediated and made safe again for drinking, swimming, fishing, and boating, a task made significantly easier if the oil is caught before it has the chance to settle into the depths. A product using NASA technology is available to consumers and industry that enables them to safely and permanently clean petroleum-based pollutants from the water. It is almost alchemical in its perfection, as it is comprised of beeswax microcapsules that act as a food source that stimulates the indigenous microbes to consume the oil.

The product makes use of NASA microencapsulation technology. Work was done at the Jet Propulsion Laboratory (JPL) to demonstrate the feasibility of encapsulating live cells, while technology developed at the Marshall Space Flight Center for experiments in orbital production of microspheres provides the basic design of the delivery system.

The BioSok Bilge Maintenance System is an easy-to-use "sock" (approximately 3 by 10 inches) that captures and biodegrades the oil and fuel that leaks into a boat bilge and can be accidentally pumped overboard.

Partnership

Industry scientists worked with researchers at JPL and Marshall in the early 1990s to develop the microencapsulated wonder, PRP, or Petroleum Remediation Product, for the company Petrol Rem, Inc. In 2004, Universal Remediation, Inc. (UniRemInc), of Pittsburgh, purchased the assets of Petrol Rem, Inc., and has rapidly expanded the uses of the original microencapsulating technology. UniRemInc has broadened production and availability of PRP, making it accessible to more clients and in a variety of different forms.

Product Outcome

The basic technology behind PRP is thousands of microcapsules—tiny balls of beeswax with hollow centers. Water cannot penetrate the microcapsule's cell, but oil is absorbed right into the beeswax spheres as they float on the water's surface. This way, the contaminants—chemical compounds that originally come from crude oil such as fuels, motor oils, or petroleum hydrocarbons—are caught before they settle.

PRP works well as a loose powder for cleaning up contaminants in lakes and other ecologically fragile areas. The powder can be spread over a contaminated body of water or soil, and it will absorb contaminants, contain them in isolation, and dispose of them safely. In water, it is important that PRP floats and keeps the oil on the surface, because, even if oil exposure is not immediately lethal, it can cause long-term harm if allowed to settle. Bottom-dwelling fish exposed to compounds released after oil spills may develop liver disease, in addition to reproductive and growth problems. This use of PRP is especially effective for environmental cleanup in sensitive areas like coral reefs and mangroves.

This ecological wonder has also been packaged for specific uses by UniRemInc to create a variety of different commercial products, including the BioSok Bilge

Maintenance System, the BioBoom, the WellBoom, and OilBuster.

One of the most popular uses for PRP is the BioSok Bilge Maintenance System. It allows boaters to clean up small spills. Boats take on water, either from rain, washing, or waves splashing over the sides. This water often mixes with cleaning fluids, and oil and gas from a boat's motor. The water collects in a bilge, the area inside a boat's bottom designed to collect and hold the errant water. A bilge needs to be pumped overboard regularly to prevent the boat from taking on too much water. This bilge water, though, is often contaminated.

The BioSok is a small, 3- by 10-inch "sock" with PRP encased in polypropylene that floats in the bilge, absorbing and bioremediating any hydrocarbons, thus, decontaminating the water. Each BioSok can immediately absorb twice its weight and can degrade more than 20 times its weight in oil over time. One BioSok will generally last for an entire boating season. It requires no maintenance or monitoring, and it safely eliminates the pollutants and fumes associated with spilled oil and gasoline.

The U.S. Coast Guard is always on the prowl for any boaters who expel oil-contaminated water from their bilges. Fines are often thousands of dollars, which makes sense, knowing that every year bilge cleaning and other ship operations release millions of gallons of oil into navigable waters from thousands of discharges of just a few gallons each. The BioSok is such an effective antidote to polluted bilge water, that even the Coast Guard has used it on its boats.

UniRemInc also manufactures the BioBoom, essentially a longer BioSok that can be used to enclose larger oil spills. It is especially effective for emergency containment of spilled oil in large areas, like in marinas, ponds, lakes, or open waters; but can also be effective in tanks, storm runoff systems, electrical utility vaults, and anywhere that requires the containment, absorption, and biodegredation of leaking petroleum hydrocarbons. The BioBoom acts as a perimeter around spills and prevents them from spreading. The snake-like tube is 3 inches in diameter and can be produced at any length up to 10 feet.

The WellBoom facilitates groundwater monitoring by absorbing floating petroleum more effectively and less expensively than traditional bailing methods. UniRemInc makes the standard WellBoom by filling a weighted polypropylene sock, 36 inches long and up to 3 inches in diameter, with PRP. The product is then lowered into the groundwater monitoring wells where it absorbs and accelerates the biodegradation of any floating petroleum hydrocarbon contaminants. WellBoom is typically used at petroleum storage facilities, gasoline stations, and other locations where there is a potential for groundwater contamination.

OilBuster is yet another product using PRP that UniRemInc has developed. It is the beeswax PRP mixed with several grades of ground corncob and is for use on land or hard surfaces where no natural microbial population is present. It is ideal for cleaning oil spills that have not yet reached the water and that hopefully never will.

PRP has proven effective in facilities conducting railroad repair, where ballasts, ties, and the ground can be saturated with diesel fuel and oil. It is a safe, cost-effective way for these types of contaminated facilities to get quick results that restore the environment and help them avoid the steep U.S. Environmental Protection Agency fines.

UniRemInc is continuing to find uses for this amazing bioremediation technology and to supply consumers and industry with safe, natural, and effective ways to keep oil out of our water. ❖

PRP Powder is especially well-adapted for moderate-to-small spills in areas such as industrial plant settings (cooling ponds and tanks), shorelines (whether rocky or sandy), marinas, railroad tracks, oil wells and fields, maintenance facilities, truck roll-overs, and for marsh and wetlands remediation where it can mitigate the collateral damage to the ecosystem caused by cleanup crews.

BioSok Bilge Maintenance System™, BioBoom™, WellBoom™, and OilBuster™ are trademarks of Universal Remediation, Inc.

Progressive Plant Growing Has Business Blooming

Originating Technology/NASA Contribution

Soil, water, and light. According to prevailing dogma, these are the three main ingredients for growing and maintaining healthy plants. But what if you take soil completely out of the equation and limit the presence of water significantly? Can you still nurture plants in such an environment?

Call it an agricultural anomaly if you will, green thumbers, but plants are getting the tender loving care they need by way of an environmentally friendly process that is devoid of dirt and uses very little water. This process, known as aeroponics, enables plants to grow in an air/mist environment that is free from soil or an aggregate media. Though not rooted in soil, some aeroponically grown plants are actually rooted in NASA.

In 1997, AgriHouse, Inc. (d.b.a. Aeroponics International), a leading agri-biology company, united with NASA and BioServe Space Technologies, a non-profit, NASA-sponsored partnership research center, to design a soil-less plant-growth experiment to be performed in microgravity, aboard the Mir space station. This experiment aimed to gauge the effectiveness of a non-pesticide solution on the immune responses of bean plants. In essence, the research consortium was looking for a means of keeping plants free from infection, without having to rely on the use of pesticides.

This research, combined with follow-on grants from NASA, has helped Berthoud, Colorado-based AgriHouse gain credibility in the commercial marketplace with related technology and gross the capital necessary to conduct further research in a new-age field known as bio-pharming.

Partnership

Richard Stoner II, president and founder of AgriHouse, began using aeroponics in the late 1980s to grow herbs in a greenhouse. Utilizing his own patented aeroponic process, Stoner was one of the only people in the United States employing the aeroponic plant-propagating technique at the time.

Several years later, Stoner began working with Colorado State University researchers on perfecting an all-natural, organically derived, disease control liquid formula called Organic Disease Control, or Organically Derived Colloidals (ODC). This formula could cooperate with a plant's immune system, in an aeroponic environment, to boost growth and ward off disease and infection. Dr. Jim Linden, a Colorado State University professor in the Department of Microbiology and co-inventor of the ODC technology, claimed that previous approaches by other researchers to stimulate a plant's immune system had "fallen short of sustainable results." He added that the newly developed ODC formula stimulates a plant's ability to fight off diseases during its entire life cycle. News of this triumphant effort was spreading, and NASA caught wind of it.

With great interest, NASA sought Stoner's experience in 1997 for an experiment to be carried out aboard Mir. The Space Agency immediately became interested in the low-water requirements of the aeroponic growing method. Using aeroponics to grow plants in space could reduce the amount of water carried during flight, thus, reducing the overall weight of the payload. Additionally, NASA has strict regulations concerning the use of pesticides within closed space habitats, so it was equally interested in experimenting with the ODC formula Stoner had been working on.

Stoner assented to NASA's request for assistance, and BioServe was brought on board to help direct the research, in light of having flown a multitude of payload experiments on previous missions.

The goal of the NASA research was to determine whether or not the antifungal response of the plants was maintained during space flight. Looking at the bigger picture, the results could ultimately lead to new strategies for growing and maintaining healthy food plants on long-term space flights or for future bases on other planets and moons.

Richard Stoner II, president and founder of AgriHouse, Inc., with a prototype of the inflatable aeroponic system for space and microgravity food production.

For the actual microgravity experiment, astronauts worked with adzuki bean seeds and seedlings, a high-protein Asian food crop. Along with the space-based experiment, concurrent ground control experiments were being conducted on adzuki bean seeds and seedlings back on Earth. This was done to investigate the plants' responses in two different gravitational environments.

In general, the adzuki bean seeds and seedlings sprouted quite well both on Earth and aboard the space station. The Mir-grown seeds and seedlings, however, exhibited more growth than those grown on Earth. Though no fungal challenge was intentionally introduced into the plants, the researchers did witness fungal infection of several of

the seedlings on both Earth and Mir. Preliminary visual analysis indicated that the seeds and seedlings that were treated with the ODC method grew more robustly and exhibited less fungal infection than the untreated seeds and seedlings. This was true for both flight and ground experiments. Post-biochemical analysis supported this finding and further showed that these plants retained their fungal-fighting abilities and the ODC method maintained its effectiveness in microgravity.

The success of this NASA experiment led to others, designed by Stoner and his company under numerous NASA **Small Business Innovation Research (SBIR)** contracts from Kennedy Space Center. Stoner took advantage of the SBIR support to create for NASA a high-performance, gravity-insensitive, enclosed aeroponic system for food production in space, as well as a low-mass, inflatable aeroponic system for rapid crop production of pesticide-free herbs, grains, tomatoes, lettuce, peppers, and other vegetables.

These plants have developed healthy root systems, all while growing in the soil-less environment of the Genesis Series V rapid-growth aeroponic system.

The high-performance, gravity-insensitive, enclosed aeroponic system can be used to produce various food crops that NASA intends to grow in space. The SBIR award contributed to the development of several methods that allow a plant's only by-product to be the plant itself. This system is now being used by commercial growers and producers for clean, efficient, and rapid food production. Crops can be planted and harvested in the system year round without interruption, and without contamination from soil, pesticides, and residue.

The low-mass, inflatable aeroponic system has not yet been used in the Space Program, but does have potential for integration into future Moon and Mars applications. The inflatable and deflatable nature of the SBIR innovation makes it lightweight, so it takes up less volume during transportation and storage. Even more, it improves upon the preceding enclosed aeroponic system in that its design allows for a significantly larger crop yield. Spinoffs of the design and materials used are now being introduced for commercial agricultural applications.

Product Outcome

AgriHouse's aeroponics and ODC research on Mir and its ensuing first SBIR contract made way for the commercialization of the Genesis Series V aeroponic system. With this rapid-growth system, plants can be started from cuttings from an already-mature plant placed in the openings on top of the growing chamber. The stems are suspended in this chamber. If starting with seeds, they can be placed on specially designed mesh holders that are inside of the chamber. For both the cuttings and the seeds, the resulting plants rapidly develop root systems and grow in an enclosed, air-based environment, made moist by a hydro-atomized, nutrient-rich spray that is released in timed

A grower clips the leaves of plants grown in the openings of a Genesis chamber.

Despite the drastic reduction in water and fertilizer usage, those employing the aeroponics growing method are witnessing robust crop yields and healthy, vibrant coloring.

intervals by a microcomputer and finely misted onto the growth subjects.

This clean, sterile environment greatly reduces the chances of spreading plant disease and infection that is commonly associated with other growing media. Each growing chamber has 161 openings. The grower can place one to five cuttings in each opening. Plants do not stretch or wilt while they are developing their roots. Once roots are developed, the plants can be easily removed for transplanting into any type of media without experiencing transplant shock or setback to normal growth.

The Genesis system can grow many different plant types, including nursery stock, fruits, vegetables, and houseplants. Hundreds of varieties have been cultivated by researchers, farmers, commercial greenhouse growers, and nursery operators. In the case of tomatoes, for example, growers can utilize the soil-less method to get a jumpstart on their production. Tomato growers traditionally start their plants in pots, having to wait at least 28 days before transplanting them into the ground. With the Genesis system, growers can start the plants in the aeroponic growing chamber, then transplant them to another medium just 10 days later. This advanced aeroponic propagation technology offers tomato growers six crop cycles per year, instead of the traditional one to two crop cycles. It also

eliminates the need for stage one and two tissue culture transplants, thus, reducing labor and handling costs.

According to AgriHouse, growers choosing to employ the aeroponics method can reduce water usage by 98 percent, fertilizer usage by 60 percent, and pesticide usage by 100 percent, all while maximizing their crop yields by 45 to 75 percent. By conserving water and eliminating harmful pesticides and fertilizers used in soil, growers are doing their part to protect the Earth. Moreover, the NASA SBIR results demonstrated that this aeroponic technology delivers an 80-percent increase in dry weight biomass per square meter, when compared to hydroponic and soil-based growing techniques. (When a dry weight measurement is taken, all water is removed from roots, leaves, and stems—thereby, removing water from the biomass.) These results essentially proved that aeroponically grown plants uptake more minerals and vitamins compared to other growing techniques.

The high-performance crop-production technology recently reached to the other side of the world to help potato production in East Asia. With assistance from the U.S. Department of Commerce, the World Trade Center in Denver, and the Export-Import Bank of the United States, AgriHouse installed an aeroponic system at the Hanoi Agricultural University's Institute for Agrobiology, in Hanoi, Vietnam.

According to AgriHouse, potato production in East Asia lags behind North America due to poor performance of seed potato crops. Utilizing the closed-loop features developed under the NASA grants, the company designed and installed a state-of-the-art aeroponic potato laboratory at the Institute for Agrobiology, for potato tuber seed production.

"AgriHouse's advanced technology gives the Institute of Agrobiology the opportunity for a direct replacement of labor-intensive, in vitro tissue culture potato production," said Dr. Nguyen Quang Thach, the institute's director. "Furthermore, the economic impact in the region from the seed potato-production features of this NASA technology will give our underdeveloped country a tremendous boost."

AgriHouse's Beyond is yet another environmentally conscious, crop-boosting commercial product stemming from the Mir research and the first SBIR contract. Based on the ODC formula tested and proven in space, Beyond is considered "nature's natural health booster for all plants" by the company. The all-natural product is derived from natural aquatic materials, and therefore contains no enzymes, hormones, petrochemicals, acids, or manure, and does not affect the natural mineral uptake of plants. As a multipurpose cure-all for any garden—no matter what growing method is used—Beyond eliminates the need for pesticides; promotes faster seed germination; increases the survival rate of seeds; revives sick or infected plants; increases growth and yields; adds natural nitrogen to soil-based flora; is 100-percent biodegradable; and has an indefinite shelf life.

Beyond is also super-concentrated, so it does not take a large application of the liquid to realize positive results. At 16 ounces, each bottle makes over 160 gallons of plant-treating solution when mixed with water. This balances out to be enough treatment for over 1 acre of field crops. In stand-alone applications of a smaller nature, such as plant revival, pre-planting, or plant-potting, users can simply pour about an ounce of the solution directly on plants, seeds, and sprouts, once or twice a week.

Beyond customers are expressing their satisfaction with the product left and right, whether it be a potato farmer who experienced a 45-percent growth rate in potato stock, or one of the thousands of shoppers who saw it for sale on the HSN shopping channel (formerly recognized as the Home Shopping Network channel) and purchased it for domestic purposes.

AgriHouse's most recent NASA spinoff is its Flex aeroponic system, which incorporates the lightweight material from the low-mass inflatable system that was developed for NASA during a succeeding SBIR contract. Like the Genesis system, the Flex system is a closed-loop aeroponic system. The Flex system, however, possesses a chamber that contains 1,000 plant holders, offering a tenfold increase in fresh crop production per square meter over the Genesis system. It is capable of delivering 12 growing cycles per year and eliminates the need for a greenhouse.

Beyond, a nature-friendly, nontoxic product that promotes faster seed germination, strengthens root systems, and increases growth and yields, all while eliminating the need for pesticides.

With an eye to the future, AgriHouse is now exploring advanced bio-pharming techniques in which natural compounds derived from botanicals may be used in place of chemicals to product pharmaceuticals. Specifically, Stoner and his company are focusing on creating controlled environments to produce bountiful crops to be used in bio-pharming. ❖

Beyond™ is a trademark of AgriHouse, Inc.
HSN® is a registered trademark of HSN LP.

FLIPPER: Validation for Remote Ocean Imaging

Originating Technology/NASA Contribution

In order to better understand our solar system and the ways it supports life, scientists and researchers at NASA study the planets. Of course, one of the planets on which NASA focuses most of its research is the Blue Planet, Earth, since this is the only one currently known to support life; and it is also, for all practical purposes, the most accessible. These scientists and researchers know that one of the determining factors in the planet's ability to support life is the same factor that makes the Blue Planet blue: water. Therefore, NASA researchers have a focused interest in understanding Earth's oceans and their ability to continue sustaining life.

A critical objective in this study is to understand the global processes that control the changes of carbon and associated living elements in the oceans. Since oceans are so large, one of the most widely used methods of this research is remote sensing—using satellites to observe changes in the ocean color that may be indicative of changes occurring at the surface. Major changes in carbon are due to photosynthesis conducted by phytoplankton, showing, among other things, which areas are sustaining life. Although valuable for large-scale pictures of an ocean, remote sensing really only provides a surface, and therefore incomplete, depiction of that ocean's sustainability.

True and complete testing of the water requires local testing in conjunction with the satellite images in order to generate the necessary algorithm parameters to calculate ocean health. For this reason, NASA has spearheaded research to provide onsite validation for its satellite imagery surveys.

Partnership

Under a NASA **Small Business Innovation Research (SBIR)** grant with Stennis Space Center, Ciencia, Inc., of East Hartford, Connecticut, developed the Fluorescence Lifetime Profiler of Photochemical Efficiency in Real-time, or FLIPPER, to assist in understanding the global processes controlling the fluxes of carbon and associated biogenic elements in the oceans. Biologists and oceanographers benefit from this new device that provides real-time data of water properties essential to understanding water on a global scale. Now being used to monitor the Earth's oceans, the results of this technological partnership are also finding homes in applications as broad as agricultural analysis and pharmaceutical manufacturing.

The many shades of blue and blue-green in this image indicate that marine plant life (phytoplankton) is in full bloom around Iceland. This image is from NASA's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Project, whose goal is to provide quantitative data on global ocean bio-optical properties to the Earth science community.

Dr. Salvador Fernandez, president of Ciencia, Inc., praises the NASA SBIR program and how it has helped bring the technology to fruition. "This project is exemplary of the goals of the SBIR program," he said. "On one hand, we have been able to provide NASA with a unique technology, essential to meeting its mission, while at the same time creating core technology that [is enabling] us to develop new products for very different applications, such as drug discovery and process analysis in the pharmaceutical industry."

While not all of these goals have been fully realized, they are still in the works and quite near fruition; the NASA technology and funding will help them come to life, while, in the meantime, the oceanographic surveying tool, FLIPPER, is already advancing the study of the Earth's oceans.

Product Outcome

FLIPPER is a fully submersible oceanographic vertical profiler for in situ, or onsite, measurements. It is being assessed by NASA researchers and the oceanographic research community to determine its ability to monitor photosynthetic parameters in marine phytoplankton for oceanographic, estuarine, limnological, and riverine research; environmental monitoring of phytoplankton populations; ocean optical properties research; and studies of fisheries and ecosystems.

FLIPPER is an effective vertical profiler for these types of research. Other vertical profiling methods can be inaccurate and confusing. Instruments based on chlorophyll fluorescence intensity, for example, cannot provide accurate information on chlorophyll concentration; the quantum yield of chlorophyll fluorescence is variable, and intensity alone does not provide any information about photosynthesis status. FLIPPER permits, for the first time, direct determination of in vivo chlorophyll fluorescence quantum yield in situ. This is an essential parameter in the study of ocean and coastal ecosystems, one that has been shown to be inversely related to the rate at which phytoplankton biomass is formed.

The concentration of chlorophyll in the oceans presents a major detection challenge, because in order to obtain accurate values of photosynthetic parameters, the intensity of light used to excite fluorescence must be kept very low so as not to disturb the photosynthetic system. Several innovations in fluorometric instrumentation were made

in order to make it possible for FLIPPER to reach the required low-detection limit. These innovations include a highly efficient optical assembly with an integrated flow-through sample interface, and a high-gain, low-noise electronic detection subsystem.

The instrument also incorporates means for self-calibration during operation and electronic hardware and software for control, acquisition, and analysis of data and communications. The electronic circuitry is highly miniaturized and designed to minimize power demand. The instrument is housed in a package that can withstand the water pressure at the maximum depth of 300 meters. All of these innovations allow FLIPPER to perform as other ocean-profiling devices cannot.

Within FLIPPER, a light-emitting diode excites fluorescence in the sample flow cell, which is placed at one focal point of an ellipsoidal reflector. A photomultiplier tube is placed at the other focal point. This optical arrangement enables highly efficient collection of fluorescence emitted over all polar directions. The excitation is modulated at a specific frequency, and the phase shift between the excitation light and the emitted fluorescence is measured by a detection method in which the signal is down-converted. The fluorescence lifetime can be computed from the known relationship among the fluorescence lifetime, phase shift, and modulation frequency.

In operation, the instrument measures fluorescence intensity and lifetime repeatedly, according to a schedule established during an instrument set-up process, in which the instrument is connected to a host computer. Once programmed, the instrument is disconnected from the computer and remains in an inactive, quiet state as it is placed in the ocean. The measurement process is started by use of a magnetically actuated switch.

Measurements taken by the instrument are recorded in a memory module that can hold data from more than 28,000 measurements. The set of data from each measurement is time-stamped and includes a pressure/depth datum. Switching the instrument off terminates the measurements and prepares the instrument for the next series. At the end of a series of measurements, the instrument is reconnected to the host computer and the measurement data are uploaded from the instrument's memory module to the computer. These data provide researchers with never-before-seen accuracy.

FLIPPER is a fully submersible oceanographic vertical profiler for onsite measurements. The electronic circuitry is designed to minimize power demand, and the instrument housing can withstand water pressure at a maximum depth of 300 meters. The instrument also incorporates means for self-calibration, and highly miniaturized electronic hardware and software for control, acquisition, and analysis of data and communications.

The development of FLIPPER is an important advance for biological oceanographic research, for phytoplankton ecology studies, and for ground truth of primary production estimates made from satellite ocean color measurements, but the technologies developed for these experiments are rapidly finding uses in other fields as well.

Based on the core technological development for FLIPPER, Ciencia has entered into two commercialization agreements that represent non-equity investments in research and development and engineering services directed at new product creation.

Ciencia has received a significant investment from HTS Biosystems, Inc., of Hopkinton, Massachusetts, for a product development effort that will incorporate frequency-domain technology developed under the NASA work into instrumentation for drug discovery.

In addition, Ciencia has also entered into another product development agreement with an international company for the making of a sensor for online process analysis of powder mixtures in the pharmaceutical industry. A feasibility study funded by this commercialization partner has been completed, and design of a system for beta site testing is underway.

This research has generated a significant amount of interest and already has investors clamoring to get involved. Additional applications include precision farming; noninvasive clinical instrumentation and analytical instrumentation for food safety testing; environmental analysis; and noninvasive, real-time, online processing monitoring for food manufacturing.

Ciencia recently signed an agreement with Global Imaging of Japan, based in Chiba, that now controls international distribution of FLIPPER. ❖

Paper-Thin Plastic Film Soaks Up Sun to Create Solar Energy

Originating Technology/NASA Contribution

A solar cell is a semiconductor device that converts photons, or light, into electricity. The most widely used solar cells today are made from wafers of mono- or poly-crystalline silicon.

Mono-crystalline silicon, or single-crystal silicon, is produced by growing a large pure crystal of silicon in a furnace. The pure crystal is then sawed into wafers and assembled in an array. The resulting silicon is highly efficient, but expensive and time-consuming to mass-produce. Further, because the silicon has to be cut prior to assembly, approximately 50 percent of material goes unused, and is therefore wasted.

Poly-crystalline silicon, or multi-crystal silicon, is created by casting molten silicon in blocks. While this process is a little less expensive and faster than the process used for growing a single crystal, the resulting multi-crystal silicon is less efficient than its single-crystal counterpart.

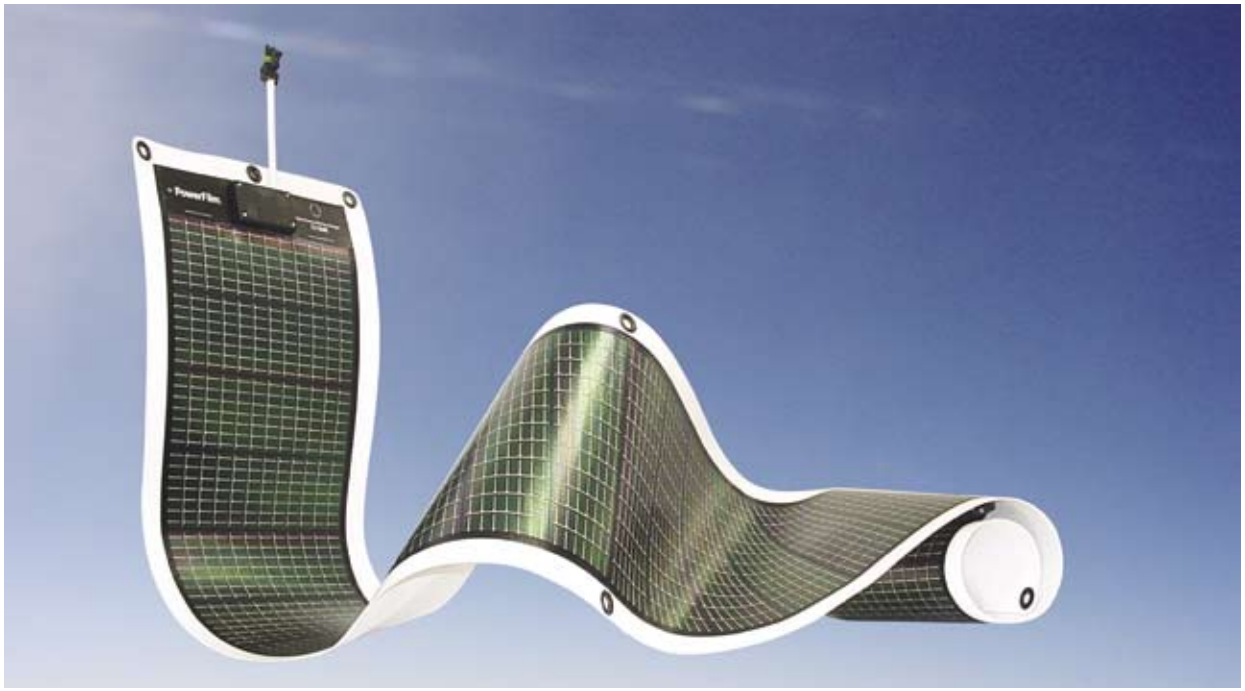
Thin film solar cells derived from amorphous silicon, pictured here, are gaining more and more attention in a market otherwise dominated by mono- and poly-crystalline silicon solar cells.

Although less commonly used, a third type of solar cell, called a thin film solar cell, can counterbalance many of the disadvantages associated with mono- and poly-crystalline silicon manufacturing by using only a fraction of pure silicon. Thin film solar cells are made by depositing a very thin layer of silicon (or another semiconductor substance, depending upon the application) on a very thin supporting material, such as glass, plastic, or metal foil. This process is known as chemical vapor deposition.

A non-crystallized silicon known as amorphous silicon is the semiconductor material most frequently chosen for deposition, because it is a strong absorber of light. According to the U.S. Department of Energy, amorphous silicon absorbs solar radiation 40 times more efficiently than single-crystal silicon, and a thin film only about 1-micrometer (one one-millionth of a meter) thick containing amorphous silicon can absorb 90 percent of the usable light energy shining on it. Peak efficiency and significant reduction in the use of semiconductor and thin film materials translate directly into time and money savings for manufacturers.

Thanks in part to NASA, thin film solar cells derived from amorphous silicon are gaining more and more attention in a market that has otherwise been dominated by mono- and poly-crystalline silicon cells for years. At Glenn Research Center, the Photovoltaic & Space Environments Branch conducts research focused on developing this type of thin film solar cell for space applications. Placing solar cells on thin film materials provides NASA with an attractively priced solution to fabricating other types of solar cells, given that thin film solar cells require significantly less semiconductor material to generate power. Using the super-lightweight solar materials also affords NASA the opportunity to cut down on payload weight during vehicle launches, as well as the weight of spacecraft being sent into orbit.

Iowa Thin Film Technologies, Inc., of Boone, Iowa, worked closely with the Photovoltaic & Space Environments Branch so that both parties could broaden



PowerFilm Solar manufactures thin, flexible solar panels by way of a proprietary, low-cost, "roll-to-roll" process. The rollable solar panels are monolithically integrated, which eliminates the need for damage-prone manual connections of individual solar cells.

their understanding of thin film solar cells made from amorphous silicon. The commercial payoff of this alliance has now been realized, with terrestrial trickle-downs coming in the forms of solar-powered headset radios for recreational use and battery chargers and solar tents for military operations.

Partnership

In November 1989, Glenn awarded Iowa Thin Film Technologies with a $50,000 Phase I **Small Business Innovation Research (SBIR)** contract to research the potential for a lightweight and flexible thin film solar cell that uses amorphous silicon as a semiconductor source, for air and space applications. With this initial-phase funding, Iowa Thin Film Technologies demonstrated that development of the solar technology was viable and, thus, was awarded a $500,000 Phase II contract to move ahead with the manufacturing process, which then occurred over the course of 2 years. Funding from Glenn supported the research and development programs of Iowa Thin Film Technologies in the early years of the company and helped improve the company's process for depositing solar cells on rolls of thin, flexible plastic substrate.

Iowa Thin Film Technologies also received funding for this project from several other government agencies, as well as from private resources. The private investments provided the financing necessary for the company to build a complete production facility. In addition to expanding its workspace, the company expanded its workforce, growing from just a few employees to 12 full-time and 8 part-time employees.

Because of the NASA SBIR support that led to new technology and helped create new jobs, the company today shines as a leading producer of thin film photovoltaics.

Product Outcome

PowerFilm Solar, the solar division of PowerFilm, Inc. (the company previously known as Iowa Thin Film Technologies), manufactures and markets a differentiated line of next-generation, amorphous silicon, thin film solar panels that can easily and economically be integrated with consumer and military products. The amount of amorphous silicon used in the panels is as low as 1 percent of the amount used in traditional crystalline silicon solar panels, according to PowerFilm Solar.

These thin film solar panels, branded as PowerFilm solar panels, are constructed using a process called monolithic integration, which is the automatic, built-in connection of individual solar cells. According to the company, monolithic integration improves durability and reduces cost by eliminating the need for expensive and failure-prone manual collection of individual solar cells. It further noted that it is the first and only company in the world to manufacture and sell monolithically integrated semiconductors on a flexible polymer substrate. During the manufacturing process, PowerFilm Solar uses its proprietary "roll-to-roll" manufacturing technology platform. (Roll-to-roll processing is the action of creating electronic devices on a roll of flexible plastic or metal foil.)

"Imagine taking paper-thin plastic film and making it generate power again and again. That's what PowerFilm is and does," claimed Michael Coon, the company's chief operating officer. "This is not your father's solar technology from the '70s. PowerFilm's durable plastic base is superior to fragile glass or corrosive metal," he added.

Available in a variety of standard and custom configurations to meet specific voltage, current, and

The Soltronix HR-1 solar-rechargeable AM/FM Headphone Radio eliminates the cost and inconvenience of replacing batteries. The portable and powerful system automatically recharges itself when in sunlight, even while listening.

environmental needs, the rollable PowerFilm products boast a durable and aesthetically pleasing design, and are quickly adaptable within their intended market, be it commercial or military. Moreover, they are not hazardous to human health, since amorphous silicon is completely free of cadmium (a naturally occuring metallic element known to produce toxic effects in humans), unlike many other solar technologies.

Across the board, PowerFilm Solar's PowerFilm commercial products are experiencing very strong sales.

The PowerFilm AA Foldable Solar Charger provides portable power for charging AA rechargeable batteries. The charger automatically begins charging once unfolded, and a light informs the user when the batteries are fully charged.

One of the company's first offerings sprung from its research partnership with NASA was the HR-1 Soltronix Solar Rechargeable AM/FM Headphone Radio. Featuring a breakthrough combination of PowerFilm solar technology and premium sound, the HR-1 headphone radio automatically recharges itself when in sunlight, even while the user is listening to it. (One hour of charging in full sunlight provides 1 to 3 hours of listening.) It will even recharge under interior house lighting or on cloudy or rainy days, albeit at much slower rates. When fully charged, the headphone set will play for more than 20 hours, even in the dark.

Other features include an internal antenna for powerful reception, a dual headband for added comfort, all-weather durability (Some users have remarked on the usefulness of the headset while walking/jogging in the rain or while boating.), and an extended bass range for setting graphic equalization to a listener's liking.

The sophisticated solar cells also serve as precision chargers for AA batteries. In 2005, PowerFilm Solar

launched the PowerFilm Foldable Solar Charger that can recharge up to four AA batteries at a time, to optimum level, without inducing damage associated with overcharging. "Unlike other solar chargers for AA batteries, this new charging circuit does not get confused from variations in current typically seen from a solar panel," noted Frank Jeffrey, PowerFilm's chairman.

The technology, comprised of a rugged fabric that houses the lightweight, flexible solar panels, is being marketed in partnership with Johnson Outdoors, Inc., a recreational product manufacturer. In addition to this commercial version, PowerFilm Solar has introduced a military version that is ideal for soldiers in the field, especially in remote locations.

Also in 2005, PowerFilm Solar teamed up with the U.S. Army to supply PowerFilm-equipped tents. The largest tent ordered by the Army is a canopy that can provide up to 2 kilowatts of power. "This is enough energy to power up to 66 laptop computers or 260 cell or satellite phones [when the sun is shining]," said Steve Martens, the president of PowerFilm. "A second, smaller model can produce enough power for 5 laptop computers or 24 cell or satellite phones," he added. The power generated by each tent is stored in a bank of batteries.

The PowerFilm 60-Watt Foldable Solar Charger, the largest in PowerFilm, Inc.'s line of foldable solar chargers, is very lightweight (2.6 pounds), considering the amount of power it produces (3.6 amps at 15.4 volts).

The flexible, thin film solar cell can be a source of power for laptops, MP3 players, portable televisions, and other items that might be used during outdoor recreational activities.

The solar tents help meet the Army's growing demand for rapid-response rates and portable, remote power, and eliminate the need for noisy generators, spare batteries, and excessive fuel storage. ❖

PowerFilm® and Soltronix HR-1® are registered trademarks of PowerFilm, Inc.

Saving Space and Time: The Tractor That Einstein Built

In this photo, the Gravity Probe B (GP-B) space vehicle is being assembled. The GP-B progam is among the most thoroughly researched programs ever undertaken by NASA.

Originating Technology/NASA Contribution

In 1984, NASA initiated the Gravity Probe B (GP-B) program to test two unverified predictions of Albert Einstein's theory of general relativity—hypotheses about the ways space, time, light, and gravity relate to each other. To test these predictions, the Space Agency and researchers at Stanford University developed an experiment that would check, with extreme precision, tiny changes in the spin direction of four gyroscopes contained in an Earth satellite orbiting at a 400-mile altitude directly over the Earth's poles.

When the program first began, the researchers assessed using Global Positioning System (GPS) technology to control the attitude of the GP-B spacecraft accurately. At that time, the best GPS receivers could only provide accuracy to nearly 1 meter, but the GP-B spacecraft required a system 100 times more accurate.

To address this concern, researchers at Stanford designed high-performance, attitude-determining hardware that used GPS signals, perfecting a high-precision form of GPS called Carrier-Phase Differential GPS that could provide continuous real-time position, velocity, time, and attitude sensor information for all axes of a vehicle.

The researchers came to the realization that controlling the GP-B spacecraft with this new system was essentially no different than controlling an airplane. Their thinking took a new direction: If this technology proved successful, the airlines and the Federal Aviation Administration (FAA) were ready commercial markets. They set out to test the new technology, the "Integrity Beacon Landing System," using it to automatically land a commercial Boeing 737 over 100 times successfully through Real-Time Kinematic (RTK) GPS technology.

The thinking of the researchers shifted again—from automatically landing aircraft, to automating precision farming and construction equipment.

Partnership

The Stanford/NASA precision aircraft landing system had such clear-cut commercial applications that a group of the Stanford researchers in Menlo Park, California, created their own company, Novariant Corporation (originally called IntegriNautics Corporation), and submitted a proposal to NASA's **Small Business Technology Transfer (STTR)** program at Langley Research Center.

In 1994, the company was awarded the STTR contract. In partnership with NASA, the FAA, and Stanford, the firm planned to research and develop a "highly reliable navigations system for precision approach and landing, using navigation signals transmitted by satellites and similar signals transmitted by low-cost 'Integrity Beacons' on the ground."

The STTR contract had also identified other potential applications, including commercial ones for automated agricultural and construction equipment. In 1996, Novariant spawned a subsidiary, AutoFarm, to focus on agricultural applications of its GPS auto-steering technology, and a tractor-steering technology was trademarked with the name, RTK (Real-Time Kinematic) AutoSteer. RTK AutoSteer was released in 1999 to farmers in California, Arizona, and Australia.

Product Outcome

For traditional farming, when using human-steered tractors, it is nearly impossible to create repeatable straight rows. Tractors shift and wobble, and farmers and operators make natural digressions from the exact rows they try to cultivate. Despite these dilemmas, farmers know the advantages of accurately planting seeds, distributing fertilizers, and watering. Seeds planted directly in the centers of rows, then sprayed accurately with fertilizer and water, will yield increased crops, reduced chemical use, and less wasted water. It is, therefore, to the benefit of the farmer to be as precise as possible.

RTK AutoSteer technology mounts to most standard farm equipment set-ups and delivers accurate steering of tractors to within 1 inch. It is ideal for the preparation of fields, the laying of beds, planting, cultivating, and tilling.

It eliminates skipped rows or unnecessary overlaps by creating perfect rows with repeatable accuracy. In addition, it can run any time of day or night, and even on weekends—in dust, fog, wind, and extreme heat.

The device has the capability to change the face of farming forever by speeding field operations and

maximizing productivity, which reduces operating costs as well as capital equipment expenditure.

The AutoSteer system uses a steering wheel-mounted control, multiple GPS antennas on the tractor cab roof, and an RTK base station antenna/transmitter. The GPS antennas in the roof module directly measure position (latitude, longitude, and altitude) plus orientation (roll, pitch, and yaw) of the tractor for steering corrections. The base station allows GPS signals to be improved to consistently repeatable sub-inch accuracy.

The multiple-GPS roof module allows vehicle steering to be corrected before a guess row error or overlap is created. The roof module is all-weather rated, which means it is both water- and dust-proof, a definite plus for equipment that will be exposed to the elements.

The intuitive AutoSteer touchscreen display is simple to operate, similar to using an ATM, and is designed with a transreflective screen for ease of readability in the sunshine. Additionally, a quick-connect design makes it easy to move between vehicles, which helps it seamlessly integrate across fleets of mixed makes and models. Easy-access connectors and quick-release latches make it simple to transfer the AutoSteer system between tractors, floaters, and sprayers, and it connects in minutes without tools.

Unlike the one-size-fits-all approach of other GPS steering systems, the AutoSteer system adjusts for changes in the vehicle's performance profile as a result of changes in implements and cargo, terrain, or even through normal wear over time. The system has tuning and calibration "wizards" that enable tuning it to the operating characteristics of a specific vehicle, and it adjusts as the machine's performance changes. It is even accurate over uneven terrain. The system can directly measure the roll of the vehicle frame as it passes over such terrain. The multiple antennas calculate and compensate for vehicle tilt, whereas a single antenna system will mistakenly assume the vehicle has shifted over.

The technology is now found on farms across the world, and in April 2006, Novariant was inducted by the Space Foundation into the prestigious Space Technology Hall of Fame. ❖

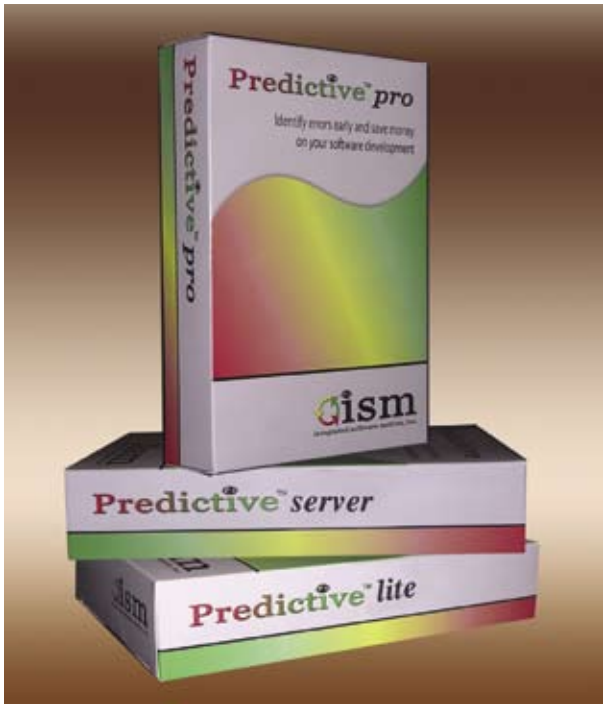
AutoFarm® is a registered trademark of Novariant Corporation.
RTK AutoSteer™ is a trademark of Novariant Corporation.

RTK AutoSteer helps farmers reduce fuel costs, decrease driver fatigue, and eliminate overlap. Pictured here are GPS system antennas roof-mounted on a farming tractor and the touchscreen controls for the GPS guidance system installed in the cockpit.

A Predictive Approach to Eliminating Errors in Software Code

Originating Technology/NASA Contribution

NASA's Metrics Data Program Data Repository is a database that stores problem, product, and metrics data. The primary goal of this data repository is to provide project data to the software community. In doing so, the Metrics Data Program collects artifacts from a large NASA dataset, generates metrics on the artifacts, and then generates reports that are made available to the public at no cost. The data that are made available to general users have been sanitized and authorized for publication through the Metrics Data Program Web site by officials representing the projects from which the data originated.



The Predictive product suite analyzes and predicts defects in software projects, allowing the user to identify the best metrics and thresholds to apply across one or more projects.

The data repository is operated by NASA's Independent Verification and Validation (IV&V) Facility, which is located in Fairmont, West Virginia—a high-tech hub for emerging innovation in the Mountain State. The IV&V Facility was founded in 1993, under the NASA Office of Safety and Mission Assurance, as a direct result of recommendations made by the National Research Council and the Report of the Presidential Commission on the Space Shuttle Challenger Accident. Today, under the direction of Goddard Space Flight Center, the IV&V Facility continues its mission to provide the highest achievable levels of safety and cost-effectiveness for mission-critical software.

By extending its data to public users, the facility has helped improve the safety, reliability, and quality of complex software systems throughout private industry and other government agencies. Integrated Software Metrics, Inc., is one of the organizations that has benefited from studying the metrics data. As a result, the company has evolved into a leading developer of innovative software-error prediction tools that help organizations deliver better software—on time and on budget.

Partnership

Since 2002, Integrated Software Metrics has not only studied NASA's metrics data, but has contributed to the maturation of the Agency's Metrics Data Program, through a contract with Galaxy Global Corporation, Inc.; both Integrated Software Metrics and Galaxy Global reside nearby the IV&V Facility in Fairmont. This contract enabled Integrated Software Metrics to work together with Glenn Research Center to generate metrics for the Metrics Data Program's data repository. NASA is now leveraging what was learned from this collaboration to better identify error-prone computer code and, hence, assure mission success.

Commercially, Integrated Software Metrics has tapped into everything it has learned from its partnership with NASA to create a new, artificially intelligent product suite called Predictive. Prior to introducing the software to market, the company tested it on very large NASA software projects consisting of over a million lines of computer code, in order to ensure its efficacy.

Product Outcome

The Integrated Software Metrics Predictive suite of software products predicts where errors will occur in software code. Such a capability enables users to uncover any errors in the early stages of software development, thus saving time and money.

Software errors are usually not found until the late stages of the development cycle, when it becomes very costly to go back and fix them. Addressing these errors, however, is essential; otherwise, software developers build a reputation for delivering faulty products or, even worse, create life-critical situations when the software is part of larger systems or devices, such as power plant-monitoring systems or medical equipment.

Integrated Software Metrics is addressing these problems on the front end, before it becomes too late. The three products that make up its new Predictive suite are: Predictive Lite, Predictive Pro, and Predictive Server.

Predictive Lite was launched in February 2005 and provides basic metrics analysis and error prediction across one or more projects, for those who develop and manage software, including project managers, individual developers, and software quality assurance professionals. While identifying error-prone code, Predictive Lite will create color-coded reports that highlight risk areas. The user can then focus attention on the flawed code and assign resources to check and potentially fix the code before the project is completed.

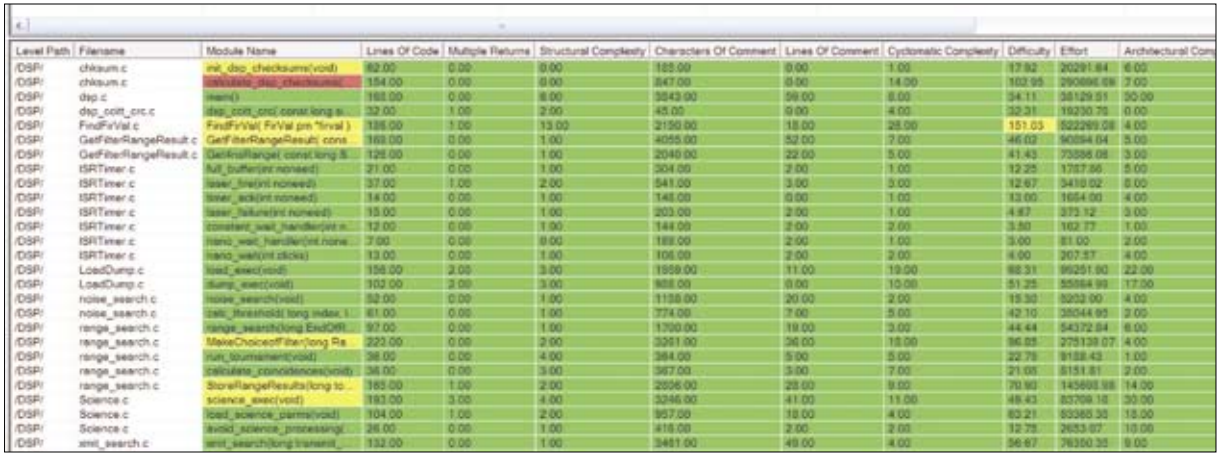
The Lite version of the software, designed for C, C++, and Java source codes, was made to be deployed on the same PC where the code resides, making it a streamlined tool that is easy to use. The user just directs Predictive Lite to the target code, and the metrics are automatically applied. This simple interface also allows the user to

monitor progress as the tool performs its analysis. When the analysis is completed, all error-prone code is organized hierarchically. A user can typically expect to see a complete analysis within minutes, as Predictive Lite possesses an average processing speed of 1,500 lines of code per second (on a standard system with a 2.8 GHz processor and 512 MB of RAM).

In an example of application, Houston-based GB Tech, Inc., a technical services company providing engineering services to government, recently managed a small but critical software project for the U.S. Department of Defense (DOD), using Predictive Lite. The project involved software code, consisting of only 5,000 lines, that operated a battery management system for the DOD's Joint Strike Fighter manned airplane. Despite the diminutive number of lines, hazard criticality was rated extremely high. This code had to be tested extensively to ensure safety, given that the battery was a lithium ion battery, which can overcharge and possibly explode.

GB Tech first used a more expensive tool for structural code coverage before trying Predictive Lite. Later, it ran both tools on the same code to perform a comparison, which demonstrated that Predictive Lite produced consistent results and exceeded the abilities of the more expensive tool, in terms of architectural complexity and calculations.

Predictive Pro, the second product belonging to the Predictive portfolio, was launched in June 2005 and includes standard and heuristics modes, as well as a trend-identification mode that analyzes historical code to find patterns and trends. The standard mode is used early in the software life cycle, before error data are accumulated. As such data pile up, the heuristics mode can be employed to identify the error-prone code. This problem-solving mode uses an artificially intelligent engine to analyze the metrics and associated error data to learn what metric thresholds predict error within a specific project. (Integrated Software Metrics reports that results are very stable and more precise than those of domain experts



Level Path	Filename	Module Name	Lines Of Code	Multiple Returns	Structural Complexity	Characters Of Comment	Lines Of Comment	Cyclomatic Complexity	Difficulty	Effort	Architectural Com
/DSP/	chksum.c	init_dsp_checksums(void)	82.00	0.00	0.00	185.00	0.00	1.00	17.92	20291.84	6.00
/DSP/	chksum.c	calculate_dsp_checksums(	154.00	0.00	0.00	847.00	0.00	14.00	102.95	290886.09	7.00
/DSP/	dsp.c	main()	168.00	0.00	8.00	3843.00	59.00	8.00	34.11	38129.51	30.00
/DSP/	dsp_coff_crc.c	dsp_coff_crc(const long s...	32.00	1.00	2.00	45.00	0.00	4.00	32.31	19230.75	0.00
/DSP/	FindFirVal.c	FindFirVal(FirVal pm *final)	186.00	1.00	13.00	2150.00	18.00	28.00	151.05	522269.08	4.00
/DSP/	GetFilterRangeResult.c	GetFilterRangeResult(cons...	168.00	0.00	1.00	4055.00	52.00	7.00	46.02	90094.04	5.00
/DSP/	GetFilterRangeResult.c	GetFirstRange(const long S...	126.00	0.00	1.00	2040.00	22.00	5.00	41.43	75886.08	3.00
/DSP/	ISRTimer.c	full_buffer(int noneed)	21.00	0.00	1.00	304.00	2.00	1.00	12.25	1767.86	5.00
/DSP/	ISRTimer.c	laser_fire(int noneed)	37.00	1.00	2.00	541.00	3.00	3.00	12.67	3410.02	8.00
/DSP/	ISRTimer.c	laser_ack(int noneed)	14.00	0.00	1.00	146.00	0.00	1.00	13.00	1654.00	4.00
/DSP/	ISRTimer.c	laser_failure(int noneed)	15.00	0.00	1.00	203.00	2.00	1.00	4.67	373.12	3.00
/DSP/	ISRTimer.c	constant_wait_handler(int n...	12.00	0.00	1.00	144.00	2.00	2.00	3.80	162.77	1.00
/DSP/	ISRTimer.c	rand_wait_handler(int none...	7.00	0.00	0.00	189.00	2.00	1.00	3.00	81.00	2.00
/DSP/	ISRTimer.c	rand_wait(int clicks)	13.00	0.00	1.00	106.00	2.00	2.00	4.00	207.57	4.00
/DSP/	LoadDump.c	load_exec(void)	158.00	2.00	3.00	1959.00	11.00	19.00	88.31	99251.90	22.00
/DSP/	LoadDump.c	dump_exec(void)	102.00	2.00	3.00	808.00	0.00	10.00	51.25	55564.99	17.00
/DSP/	noise_search.c	noise_search(void)	52.00	0.00	1.00	1158.00	20.00	2.00	15.30	5252.00	4.00
/DSP/	noise_search.c	cell_threshold(long index, l...	61.00	0.00	1.00	774.00	7.00	5.00	42.10	38044.95	2.00
/DSP/	range_search.c	range_search(long EndOff...	97.00	0.00	1.00	1700.00	19.00	3.00	44.44	54372.84	6.00
/DSP/	range_search.c	MakeChoiceOffSet(long Re...	222.00	0.00	2.00	3251.00	36.00	13.00	96.05	275138.07	4.00
/DSP/	range_search.c	run_tournament(void)	36.00	0.00	4.00	384.00	5.00	5.00	22.75	8158.43	1.00
/DSP/	range_search.c	calculate_coincidences(void)	36.00	0.00	3.00	367.00	3.00	7.00	21.05	8151.81	2.00
/DSP/	range_search.c	StoreRangeResults(long to...	165.00	1.00	2.00	2606.00	28.00	9.00	70.90	145669.98	14.00
/DSP/	Science.c	science_exec(void)	193.00	3.00	4.00	3246.00	41.00	11.00	48.43	83709.18	30.00
/DSP/	Science.c	load_science_parms(void)	104.00	1.00	2.00	957.00	18.00	4.00	60.21	93360.30	18.00
/DSP/	Science.c	avoid_science_processing(	26.00	0.00	1.00	416.00	2.00	2.00	12.75	2653.07	10.00
/DSP/	xmit_search.c	xmit_search(long transmit_...	132.00	0.00	1.00	3481.00	49.00	4.00	56.67	76350.30	9.00

Earning 9 out of 10 stars from CRN magazine, Predictive Pro gives quality assurance managers "a tool with teeth." The software is deployed on the same PC where the targeted code resides. The user just directs Predictive Pro to the code and metrics are generated. The output shows every module in the project, the associated metrics, its location, and error data for that module. Predictive Pro's color-coding scheme of red, yellow, and green readily identifies the code modules of high, medium, and low risk, so that errors can be found easily.

who have a strong technical understanding of software analysis.) A user can then continue to use the heuristics mode through most of the software development cycle. Near the end of the cycle, the user can switch to the trend-identification mode to identify trends and find the chronic problems in the system.

The final product, Predictive Server, was released in September 2005. Predictive Server contains all of the features of Lite and Pro, and is scalable for network or distributed deployment. Unlike its predecessors, however, it was developed as a Web-based risk management tool for multiple software projects, and it facilitates collaboration among project managers, developers, and software quality assurance professionals. Essentially, the software aims to meet the demands of having to manage multiple software projects in a networked environment.

When Predictive Server is used on a software project, error data and metrics are compiled and stored in the software's knowledge database from the very beginning of the project until the end. Thereafter, this historical database of metrics can be used for other software projects in the enterprise. Because Predictive Server is Web-based, all authorized software project teams can access and update the database, helping the organization deliver better software and save development costs.

In late 2005, Integrated Software Metrics announced a 200-percent surge in sales of its Predictive error-prediction tools. Driving this boost were new customers in the telecom, energy, technology, and government markets, including organizations such as Compagnie Financière Alcatel (Alcatel); Chevron Corporation; LogLogic, Inc.; and Northrop Grumman Corporation.

Spinning back to NASA, the Glenn and Goddard field centers are currently using the entire Predictive suite. Both centers rely on the products for critical code that supports NASA's Earth-orbiting spacecraft. ❖

Predictive™ is a trademark of Integrated Software Metrics, Inc.
Java™ is a trademark of Sun Microsystems, Inc.

Scheduling Software for Complex Scenarios

Often considered the most complex machine ever built, the space shuttle requires intricate planning and scheduling to prepare for launch. Pictured here is the Space Shuttle Columbia on April 12, 1981, preparing for the very first shuttle launch.

Originating Technology/NASA Contribution

Preparing a vehicle and its payload for a single launch is a complex process that involves thousands of operations. Because the equipment and facilities required to carry out these operations are extremely expensive and limited in number, optimal assignment and efficient use are critically important. Overlapping missions that compete for the same resources, ground rules, safety requirements, and the unique needs of processing vehicles and payloads destined for space impose numerous constraints that, when combined, require advanced scheduling.

Traditional scheduling systems use simple algorithms and criteria when selecting activities and assigning resources and times to each activity. Schedules generated by these simple decision rules are, however, frequently far from optimal. To resolve mission-critical scheduling issues and predict possible problem areas, NASA historically relied upon expert human schedulers who used their judgment and experience to determine where things should happen, whether they will happen on time, and whether the requested resources are truly necessary.

Partnership

NASA selected Stottler Henke Associates, Inc., a software design firm with a long history of solving NASA's unique dilemmas, to capture and encode the knowledge embodied by these human experts. Located in San Mateo, California, the company is a leader in innovative artificial intelligence software applications. For this project, the company was contracted through a **Small Business Innovation Research (SBIR)** award facilitated by Kennedy Space Center.

As a result of the partnership, Stottler Henke developed Aurora, an intelligent planning and scheduling system that enables NASA to solve complex scheduling problems quickly, by encoding and applying sophisticated, domain-specific decision-making rules.

The proof-of-concept prototype was completed in the summer of 2001, and the Aurora scheduling system entered operational use at Kennedy in late 2003. It is being used to schedule the use of floor space and other resources at the Space Station Processing Facility, where International Space Station components are prepared for space flight. Aurora is also at the core of a system that generates short- and long-term schedules of the ground-based activities that prepare space shuttles before each mission and refurbish them after each mission. This system

replaced the Automated Manifest Planner, also developed by Stottler Henke and used by NASA since 1994.

The software Stottler Henke designed for NASA applies a combination of artificial intelligence techniques to produce a system capable of rapidly completing a near-optimal schedule. It combines sophisticated scheduling mechanisms with domain knowledge and a bevy of expert conflict-resolution techniques to solve scheduling problems. It also takes into account a number of problems unique to Kennedy, such as the need to schedule floor space and maintain certain spatial relationships among the tasks and components. Aurora then graphically displays resource use, floor space use, and the spatial relationships among different activities. Scheduling experts can interactively modify and update the schedule, and can request detailed information about specific scheduling decisions. This allows them to supply additional information or verify the system's decisions and override them, if necessary, to resolve any conflicts.

The company has modified the software and released it as a commercial scheduling tool that is usable in non-NASA situations, allowing the general public to solve a plethora of industry scheduling problems.

Product Outcome

Although there are a number of commercially available scheduling systems, none, according to Stottler Henke, offers all of the features and advantages of Aurora. Furthermore, the degree of domain knowledge required for decisions and the unusual sets of unnatural constraints set by the traditional scheduling software makes them of limited use for truly complex scenarios. The level of complexity the Aurora software was designed to handle, however, is quite useful in a variety of industries. It is practical for solving planning problems for which human expertise can be encoded and applied to generate near-optimal scheduling solutions automatically. It reduces, then, reliance on domain experts, and it changes the scheduling process from a painstaking exercise that takes days and weeks to one that can be accomplished in hours.

It is currently being incorporated into two major systems. One is for the United Space Alliance, LLC, to provide space crews with onboard scheduling capability for the Crew Exploration Vehicle. The second is for a major aircraft manufacturer to help schedule assembly operations of its next-generation airliner.

With Aurora, users can define attributes for individual tasks, groups of tasks, resources, resource sets, and constraints. These attributes can be considered by user-supplied or built-in scheduling decision rules that are invoked at key scheduling decision points within single- or multipass algorithms, such as determining which task to schedule next, selecting the overall best time window and resources, or handling the situation where not all of the required resources are available at the required time. Additional attributes of each resource can be considered when making intelligent resource selection decisions in order to generate schedules that are as close to optimal as possible.

Aurora's graphical user interface enables users to enter domain-specific knowledge and specify their scheduling requirements quickly and easily. Interactive displays enable users to visualize and edit the schedule's resource allocations and the temporal relationships among activities. Scheduling problems, such as unresolved conflicts, are highlighted to attract the user's attention.

Aurora allows users to export reports about resource use, which can then be opened in a standard spreadsheet program. It can also export any of its schedule displays as an image the size of the schedule display itself, allowing the user to include the schedule in presentations or otherwise distribute it. The software can also print any of its schedule displays.

One of the biggest advantages of the Aurora software, though, is that it is cost-efficient. It used to be that, in order for a company to develop a customized scheduling system, the company would have to pay hundreds of thousands or even millions of dollars. Aurora can be customized for far less. It eliminates the need for costly, time-consuming experts and can produce accurate, dependable results. ❖

Aurora™ is a trademark of Stottler Henke Associates, Inc.

On June 16, 2005, the Space Shuttle Discovery rested on a mobile launcher platform that sat atop a crawler-transporter, on its way to Launch Pad 39B, while the canister that delivered the mission STS-114 payloads to the launch pad departed.

Difficult Decisions Made Easier

Originating Technology/NASA Contribution

NASA missions are extremely complex and prone to sudden, catastrophic failure if equipment falters or if an unforeseen event occurs. For these reasons, NASA trains to expect the unexpected. It tests its equipment and systems in extreme conditions, and it develops risk-analysis tests to foresee any possible problems.

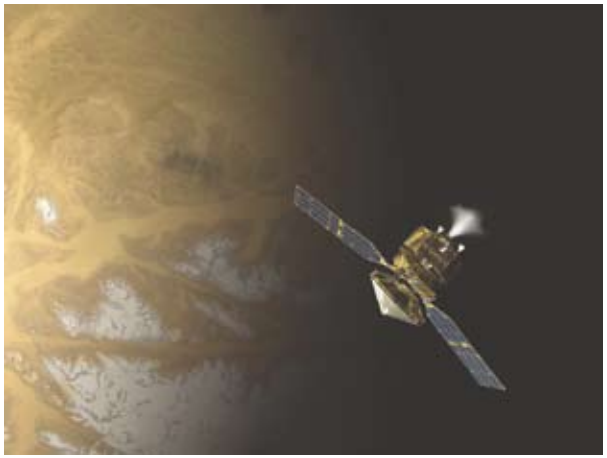
The Space Agency recently worked with an industry partner to develop reliability analysis software capable of modeling complex, highly dynamic systems, taking into account variations in input parameters and the evolution of the system over the course of a mission.

The goal of this research was multifold. It included performance and risk analyses of complex, multiphase missions, like the insertion of the Mars Reconnaissance Orbiter; reliability analyses of systems with redundant and/or repairable components; optimization analyses of system configurations with respect to cost and reliability; and sensitivity analyses to identify optimal areas for uncertainty reduction or performance enhancement.

Partnership

For this work, NASA turned to GoldSim Technology Group LLC, of Issaquah, Washington, a privately held software company that delivers software and services to help people understand complex systems and make better decisions. GoldSim, the company's namesake simulation software, was originally developed for long-term safety analyses of nuclear waste disposal, and is currently used by the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission, among others. It is the company's flagship product and is widely used for performance assessment in the nuclear arena, most notably at the Yucca Mountain Project in Nevada, the Nation's first long-term geologic repository for spent nuclear fuel and high-level radioactive waste.

The company worked with NASA through a **Small Business Innovation Research (SBIR)** grant with the Jet Propulsion Laboratory to develop and demonstrate a new module for the GoldSim software: an integrated, total-system risk and reliability analysis approach based on dynamic, probabilistic simulation. This new module (the Reliability Module) added features to the software to facilitate simulation of space missions.



Artist's concept of the Mars Reconnaissance Orbiter (MRO) during the critical process of Mars orbit insertion. GoldSim software helped make this part of the mission a success.

Previously, most NASA studies of mission risk and reliability used a methodology known as fault tree analysis, which was often difficult to implement for complex systems that changed over time. Instead of using fault trees, the GoldSim methodology actually simulates the behavior of the mission components over the full duration of the mission, explicitly representing how the various components evolve over time and the probabilities involved. The analysis is intensive and computes the possible ways that the mission may fail, along with their probabilities.

This approach now provides a valuable new systems analysis capability to complement current NASA systems analysis approaches. In particular, it is useful for impact studies, risk/cost/benefit analyses, risk/uncertainty analyses, model integration, and model-based design/model-based engineering.

The development of the new module marked the successful completion of the NASA-funded research project to demonstrate the suitability of the GoldSim software for evaluating the risk and reliability of future NASA missions.

The company released the Reliability Module to the public in September 2005.

Product Outcome

GoldSim is used to create computer models that simulate the performance of complex systems in business, engineering, and science. In general, the purpose of such models is to simulate the future behavior of a system and then determine what can be done to improve its performance. These models are used to gain a diagnostic understanding of the system, ask "what if" questions about it, and evaluate alternative designs, policies, and plans. It is used by organizations worldwide.

The software is highly graphical and extensible, able to quantitatively represent the uncertainty inherent in complex systems, and allows users to create compelling models that are easy to communicate and explain to diverse audiences. Users build a model in an intuitive manner by literally drawing a picture (an influence diagram) of their system. In a sense, GoldSim is like a "visual spreadsheet" that allows users to graphically create and manipulate data and equations. It moves beyond spreadsheets, however, by making it much easier for users to evaluate how systems evolve over time and predict their future behavior.

The primary applications for the software fall into three categories: engineered systems modeling, environmental systems modeling, and business modeling.

For many complex engineered systems (such as space and defense systems, industrial facilities, mines, power plants, and computer networks), it is necessary to predict measures such as the system's reliability or risk. GoldSim

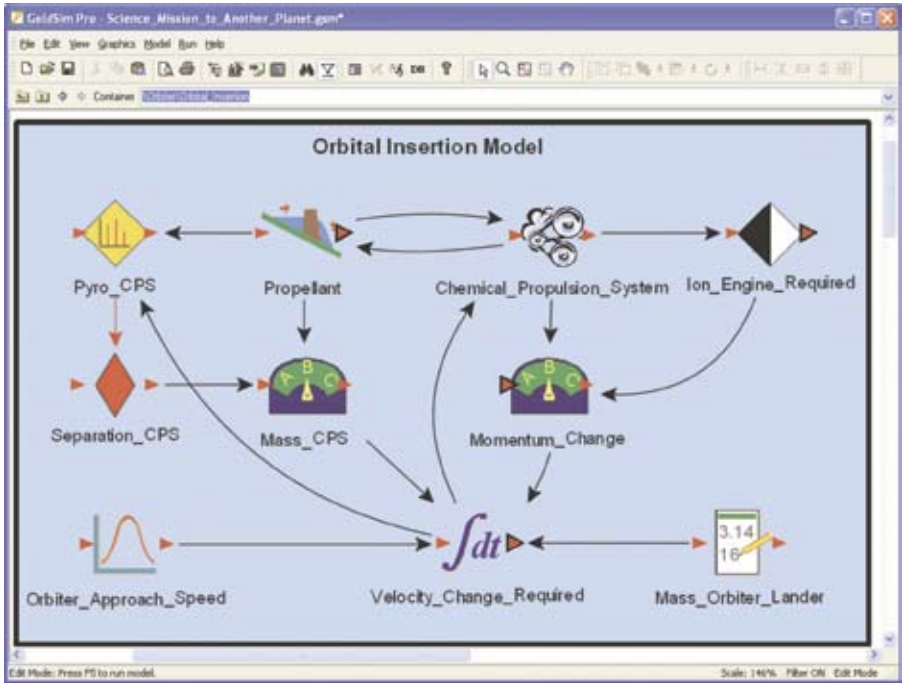
can be used to simulate the reliability and performance of complex engineered systems over time.

The Reliability Module (the result of the NASA SBIR grant) supports the software's ability to perform engineering systems analysis, as it consists of predicted reliability metrics (e.g., reliability and availability) for the overall system and for individual components within that system. The Reliability Module can also be used to compute the probability of specific consequences (e.g., catastrophic failure of the system) to support risk analysis. GoldSim catalogs and analyzes failure scenarios, which allows for key sources of unreliability and risk to be identified.

GoldSim can also be used to create realistic models of complex, real-world, multimedia environmental systems. Users can explicitly represent the uncertainty inherent in these systems, in order to carry out risk analyses, evaluate potential environmental impacts, and make better resource management decisions. According to the company, GoldSim is, for this purpose, the premier tool in the world for carrying out performance assessments of proposed and existing radioactive waste management sites.

GoldSim is also useful for a wide range of other environmental systems modeling applications, including water balances and water quality management at mines and other constructed facilities; municipal water resources management and planning; the performance of existing or proposed landfills, hazardous waste sites and engineered disposal facilities; environmental impacts associated with various mine development and closure options; the transport and fate of contaminants in aquifers, wetlands, lakes, and other ecosystems; transmission of infectious diseases; and the transport and fate of pharmaceuticals and other compounds within biological systems.

Another arena where GoldSim has found a home is in business modeling. Most business modeling today relies on the use of spreadsheets and/or project management software to create project schedules, do simplified risk analysis calculations, carry out cost and revenue projections, and perform other simple financial analyses. Although such tools are useful and applicable in many cases, they generally do not have the ability to represent the complex dynamics and uncertainties present in real-world business systems. As such, the projections produced by these tools often do not provide a realistic representation of the future. This can lead to poor decisions. GoldSim provides users with the ability to transform business modeling into a more quantitative, rational, and defensible analysis.



The GoldSim software aids in uncertainty reduction and performance enhancement by providing decision makers with a highly graphical, multidimensional analysis tool. This screen shot is a seemingly simple depiction showing some of the elements that came into play while planning the complex orbital insertion of the Mars Reconnaissance Orbiter.

It provides business planners with the tools to evaluate alternative strategies and policies, and identify those that offer the greatest potential for success; determine the optimal portfolio of projects, resources, and/or investments; develop program plans that provide the highest likelihood of meeting objectives on time and under budget; and evaluate risks, and then identify cost-effective preemptive measures and contingency plans that minimize adverse impacts. Business planners can also use this software to evaluate the performance of supply chains or design and evaluate financial instruments.

All of the engineering systems modeling, environmental systems modeling, and business modeling applications can benefit from the collaborative research performed by NASA and GoldSim. In fact, the company sees this software being beneficial in even more arenas.

"We also think it has a lot of potential in other fields where risk and reliability are important—areas such as defense, automotive, and electronics. It isn't just a matter of doing risk calculations; it's important to really understand the sources of risk or unreliability in order to be able to design optimal solutions. That's what our GoldSim software is all about," said Ian Miller, president of GoldSim. ❖

GoldSim® is a registered trademark of GoldSim Technology Group LLC.

The Echoes of Earth Science

Originating Technology/NASA Contribution

NASA's Earth Observing System Data and Information System (EOSDIS) acquires, archives, and manages data from all of NASA's Earth science satellites, for the benefit of the Space Agency and for the benefit of others, including local governments, first responders, the commercial remote sensing industry, teachers, museums, and the general public. EOSDIS is currently handling an extraordinary amount of NASA scientific data. To give an idea of the volume of information it receives, NASA's Terra Earth-observing satellite, just one of many NASA satellites sending down data, sends it hundreds of gigabytes a day, almost as much data as the Hubble Space Telescope acquires in an entire year, or about equal to the amount of information that could be found in hundreds of pickup trucks filled with books.

To make EOSDIS data completely accessible to the Earth science community, NASA teamed up with private industry in 2000 to develop an Earth science "marketplace" registry that lets public users quickly drill down to the exact information they need. It also enables them to publish their research and resources alongside of NASA's research and resources. This registry is known as the Earth Observing System ClearingHOuse, or ECHO.

The charter for this project focused on having an infrastructure completely independent from EOSDIS that would allow for more contributors and open up additional data access options. Accordingly, it is only fitting that the term ECHO is more than just an acronym; it represents the functionality of the system in that it can echo out and create interoperability among other systems, all while maturing with time as industry technologies and standards change and improve.

Earth-observing satellites that have provided/will provide data to better understand how the planet is changing: Quick Scatterometer (QuikSCAT) will record sea-surface wind speed and direction data; Earth Observing-1 (EO-1) is part of a land-imaging mission; Landsat 7 provides images of continental/coastal areas; ACRIMSAT measures the Sun's light energy for climate and global warming predictions; GRACE I/II are mapping gravity fields; SAGE-III measures ozone, aerosols, water vapor, and other atmospheric parameters; UARS measured chemical compounds found in the ozone layer; Jason-1 improves climate predictions and monitors global ocean circulation and eddies, plus El Niño conditions; TOMS-EP (Total Ozone Mapping Spectrometer onboard an Earth Probe satellite) measures total column ozone and sulfur dioxide from volcanic eruptions; the TRMM (Tropical Rainfall Measuring Mission) satellite was designed to study tropical rainfall; TOPEX/Poseidon monitored ocean circulation, improved climate predictions, and tracked El Niño conditions; Aqua is designed to collect water cycle information, including ocean evaporation and atmospheric water vapor.

Partnership

In streamlining the public access path to Earth science data and materials culled by EOSDIS, NASA's Goddard Space Flight Center joined ranks with Global Science & Technology, Inc., a science, engineering, and information technology company serving Federal and corporate clients, and Blueprint Technologies, Inc., formerly a woman-owned, small business specialist in providing architecture-based solutions that was recently acquired by Pearson Government Solutions, Inc. (The company is now recognized as Pearson Blueprint Technologies, Inc.)

From 2000 to 2002, Goddard worked with Global Science & Technology (the prime contractor on the project) and Blueprint Technologies (the subcontractor) to develop the ECHO registry platform. A public version was released in November 2002. Feedback from early adopters on this initial operational system led to a new set of enhancements, considering the data access needs and expectations of America's Earth science ring were changing before its very eyes. The development team refined the original version to expand the capabilities offered to the community.

The expansion of the project took place through 2004, with a strong emphasis on data collection. By 2005—and several software versions later—a much-improved ECHO service registry was in place, complete with more

than 60 million pieces of Earth science metadata and customized client interfaces for improved searching capabilities. Furthermore, this metadata registry allowed users to publish and exchange their services, algorithms, and models.

Product Outcome

Today, the Earth science solution developed in part by NASA and for NASA is fully live and operational as ECHO version 8.0. The public registry is officially a Web-based brokering system that enables information and resource sharing that ultimately leads to improvements in research and analysis, as well as copious societal benefits. For example, local governments can use ECHO 8.0 to make key decisions about adverse weather conditions facing their regions, such as floods and hurricanes. Having access to the latest satellite imagery via ECHO can give them a leg up in taking any precautions they can to become fully prepared.

"ECHO poses an exciting example of how technology can be used to solve real-world challenges and create important foundations of change for generations to come," said Jeanne O'Kelley, general manager of Pearson Blueprint Technologies. "Indeed, what makes this particularly relevant is the use of Web-services technology that can be applied not only within the geospatial realm, but across numerous sectors—including homeland security—making any set of data easier to record, access, and share."

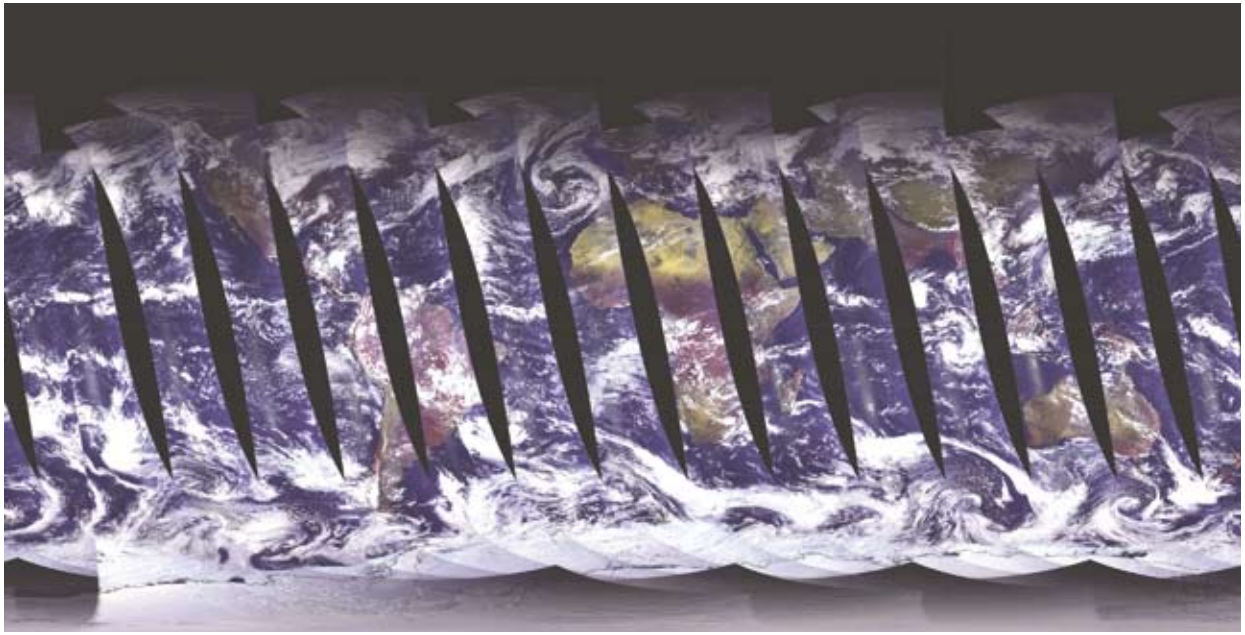
Version 8.0 provides a mechanism of interoperability between organizations who offer Earth observation data and independent organizations who offer tools, algorithms, and models that utilize this data, essentially serving as "middleware" between data and client partners. With this feature, Earth scientists have a basic infrastructure to leverage resources from global partners and, hence, build dynamic applications.

"The future of a global exchange of Earth-observing resources allows for effective use of the resources for current science applications and enables future innovation in putting together these data, algorithms, models, and other services in new and unintended ways," said Pearson Blueprint Technologies' Michael Burnett, the lead ECHO architect. "ECHO is built as infrastructure for a service-oriented enterprise, the future of enterprise-level exchange in many domains, including that of Earth observation."

In order to retrieve data stored in ECHO, a user can search for specific metadata using keywords or certain spatial or temporal parameters. In performing a spatial search, for instance, a user can enter geographic parameters, such as the name of a state or an exact latitudinal/longitudinal location. The search will then generate a set of results for access within the user's application.

Because ECHO is a Web-brokering system, the user can order information in a manner similar to how he or she would go about purchasing items from traditional online retailers. The user can simply add any data items of interest to a personal online shopping cart and then proceed to checkout. If the data items retrieved by the ECHO-generated report are not of any interest to the user, he or she can then initiate a new search based on new keywords or parameters.

With Web-based services continuing to expand and reaching new users as a result, the developers of ECHO anticipate that publicly available Earth science data will proliferate for tomorrow's Earth science generation, all because of the synergy between today's data contributors and customers. ❖



Available to the public, the ECHO Web-based brokering system is filling gaps in Earth science data. The global-exchange registry lets scientists everywhere share important resources to help solve real-world challenges.

GPS Eye-in-the-Sky Software Takes Closer Look Below

Originating Technology/NASA Contribution

The Global Positioning System (GPS) is a satellite navigation system developed and maintained by the U.S. Government. Though initially designed for military applications, GPS is also a public information service that protects the environment, improves productivity, and increases safety. It can be used as an instrument to map and survey boundaries; improve crop production; track storms and the spread of wildfires; and monitor any land movement and deformation of the Earth's crust resulting from earthquake activity. It also offers navigational assistance for cars, airplanes, and boats. For example, cars equipped with GPS-based navigational systems can direct drivers to their intended destination points, steering them away from longer routes, traffic, and road construction, and preventing them from getting lost.

Just as vehicles can be tracked and steered in the right directon by GPS, so can people. Hikers, hunters, mountain climbers, and cross-country skiers commonly depend on it to navigate their routes, and to let others track their whereabouts, in case they get lost or find themselves in danger and in need of rescue. Telephone companies are also manufacturing GPS-enabled cell phones. The Federal Communications Commission now requires cell phone companies to be able to pinpoint a customer's location within 100 meters, so emergency responders can reach them in a crisis. While not all cell phones contain actual GPS chips, the ones that do can actually find an individual's location to within a few feet.

At NASA, GPS is a vital resource for scientific research aimed at understanding and protecting Earth. The Agency employs the band of GPS satellites for such functions as mapping Earth's ionosphere and developing earthquake-prediction tools. Extending this worldly wisdom beyond Earth, NASA researchers are even discussing the possibility of developing global positioning satellites around Mars, in anticipation of future manned missions.

Despite all of its terrestrial accomplishments, traditional GPS still has its limitations. The Space Agency is working to address these with many new advances, including a "Global Differential GPS" technology that instantaneously provides a position to within 4 inches horizontally and 8 inches vertically, anywhere on Earth. According to NASA's Jet Propulsion Laboratory, no other related system provides the same combination of accuracy and coverage.

The GI-Eye software-based system, used to collect aerial mapping data for commercial and military applications.

Furthermore, traditional GPS cannot communicate beyond latitudes of 75°. That means that most of Greenland and Antarctica cannot receive GPS signals. The Global Differential GPS technology approaches this area of the world using several different GPS signals. These signals overlap to compensate for the gaps in coverage. Now, scientists working in the extreme northernmost and southernmost areas of the world can have access to the same GPS technology that other scientists around the world rely on.

NASA partnered with private industry to address another GPS limitation and, therefore, enhance the technology for better surveying of urban areas prone to signal blockages. The result of this collaboration led to a new aerial mapping and targeting system with myriad benefits.

Partnership

NAVSYS Corporation, a Colorado Springs, Colorado-based provider of technical products and services in GPS hardware design, systems engineering, systems analysis, and software design, was awarded a **Small Business Innovation Research (SBIR)** contract in 1993 by NASA Headquarters to develop a GPS/inertial mapping system. The SBIR aimed to address the unreliability of GPS surveying in urban environments and the amount of time it took to collect large quantities of data for geographic information systems.

NAVSYS Corporation's proposed solution to this problem was developing a tightly-coupled GPS/inertial/video-mapping system that could add precise position and attitude metadata to digital camera images. This could also allow the digital images to be post-processed and the coordinates of objects of interest to be collected, plus high-accuracy GPS/inertial integration algorithms could continue mapping operations through short GPS drop-outs, without noticeable performance degradation.

The original system developed for NASA was a van-based unit. NAVSYS Corporation took this system and developed a smaller, airborne version of the product, termed GI-Eye, which was then used to collect aerial mapping data for commercial and military applications.

Product Outcome

The commercial GI-Eye system is a software platform that integrates GPS with inertial and digital camera data. It is designed to collect high-resolution imagery for precise visual navigation or accurate geolocation of target coordinates. It takes advantage of differential or kinematic GPS positioning to provide the precise location of each camera image and uses NAVSYS Corporation's

proprietary InterNav kinematic alignment algorithm to measure the precise attitude of the camera using the inertial sensor data.

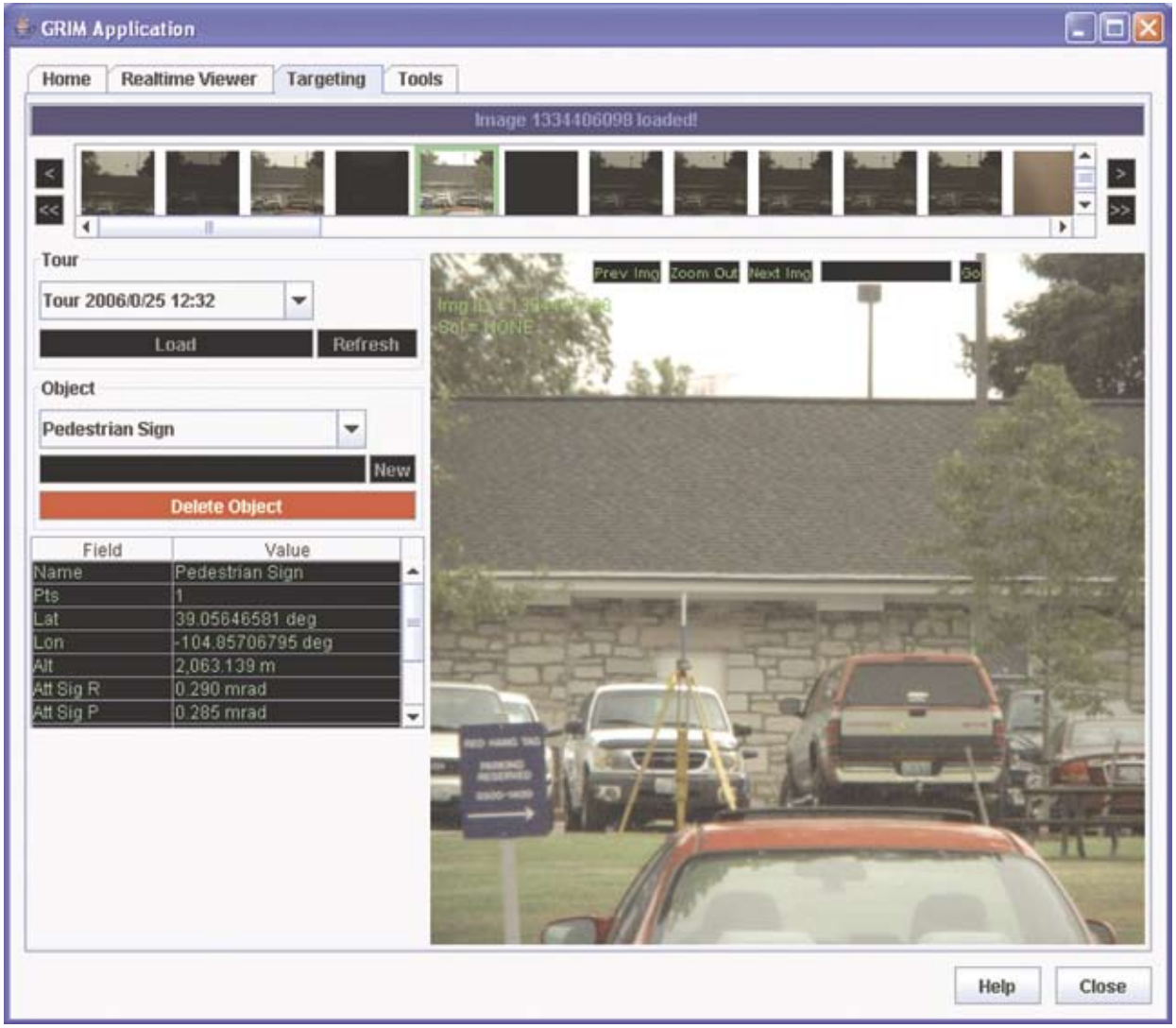
By recording the precise location and attitude of the video images, the extraction of feature location data is simplified and streamlined. According to the company, this results in rapid and more efficient data processing, thus eliminating the need for expensive and time-consuming processing currently needed to generate the orthorectified and registered overhead images used by many Web services.

The GI-Eye technology has been integrated into FLIR Systems, Inc.'s Star SAFIRE III airborne electro-optic thermal imaging system. Currently, there are approximately 800 Star SAFIRE III units deployed on more than 35 different types of rotary- and fixed-wing aircraft. The pairing of GI-Eye's precision mapping abilities and Star SAFIRE III's long-distance, 360-degree, day or night scoping abilities presents a truly unprecedented vantage point for aerial surveillance associated with search and rescue, reconnaissance, law enforcement, border patrol, news gathering, land-use planning, and environmental monitoring.

GI-Eye also registers sensor data collected from unmanned aerial vehicles (UAVs) such as the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) UAV, the first unmanned craft ever to carry out a scientific research flight. In the military, the system was also selected by the U.S. Navy for use in an advanced technology demonstration to provide real-time target coordinates on a battlefield.

"We have been very impressed with targeting results provided by the NAVSYS GI-Eye product and are now also pursuing approaches to GPS-denied navigation of unmanned air vehicles using this technology," said James R. Buss, of the Office of Naval Research.

Targeting systems have additionally been developed for several other U.S. military branches, including the U.S. Marine Corps. ❖



Proprietary algorithms are used for point-and-click computation of object locations from selected pixel coordinates. In this ground-based demonstration, the GI-Eye software sets its target coordinates to lock directly onto a pedestrian sign, demonstrating its precise targeting capabilities.

A History of High-Performance Computing

Originating Technology/NASA Contribution

Faster than most speedy computers. More powerful than its NASA data-processing predecessors. Able to leap large, mission-related computational problems in a single bound. Clearly, it's neither a bird nor a plane, nor does it need to don a red cape, because it's super in its own way. It's Columbia, NASA's newest supercomputer and one of the world's most powerful production/processing units.

Named Columbia to honor the STS-107 Space Shuttle Columbia crewmembers, the new supercomputer is making it possible for NASA to achieve breakthroughs in science and engineering, fulfilling the Agency's missions, and, ultimately, the Vision for Space Exploration.

Shortly after being built in 2004, Columbia achieved a benchmark rating of 51.9 teraflop/s on 10,240 processors, making it the world's fastest operational computer at the time of completion. Putting this speed into perspective, 20 years ago, the most powerful computer at NASA's Ames Research Center—home of the NASA Advanced Supercomputing Division (NAS)—ran at a speed of about 1 gigaflop (one billion calculations per second). The Columbia supercomputer is 50,000 times faster than this computer and offers a tenfold increase in capacity over the prior system housed at Ames. What's more, Columbia is considered the world's largest Linux-based, shared-memory system.

The system is offering immeasurable benefits to society and is the zenith of years of NASA/private industry collaboration that has spawned new generations of commercial, high-speed computing systems.

Partnership

To construct Columbia, NASA tapped into years of supercomputing experience, dating as far back as the early 1980s, when computational fluid dynamics (CFD) computer codes originated, and as recent as 2004, when the Agency adopted novel immersive visualization technologies to safely pilot the Spirit and Opportunity Mars Exploration Rovers. In addition, NASA looked to Silicon Valley for some extra support and found a friend it had helped back in the heyday of early microprocessing technology.

In the first few years of the 1980s, Ames scientists and engineers assisted Mountain View, California-based Silicon Graphics, Inc. (SGI), by providing technical input to improve the company's high-performance workstation product line. NASA had purchased 18 of SGI's IRIS workstations and helped make them commercially viable with several improvements. By 1984, NASA was SGI's biggest customer.

"NASA was a huge help to us as a young company, not only by being our biggest customer at a time when a lack of sales would have been disastrous, but they were one of our best customers in the sense that the engineers there gave us all sorts of valuable feedback on how to improve our product. Many of the improvements to the original workstations are still part of our most modern products," according to Tom Davis, former principal scientist and a founding member of SGI.

A bird's-eye view of the 10,240-processor SGI Altix "Columbia" supercomputer located at Ames Research Center. While Columbia is helping NASA achieve breakthroughs and solve complex problems in support of its missions, it has also been made available to a broader national science and engineering community.

SGI's payback to NASA was helping to build the behemoth Columbia supercluster. Santa Clara, California-based Intel Corporation, the world's largest computer chip maker and a leading manufacturer of computer, networking, and communications products, also assisted in the effort. Through extraordinary dedication and uncompromising commitment, the Columbia project team achieved what many in the supercomputing community considered impossible: conceiving, planning, and constructing the world's largest Linux-based, shared-memory system in just over 4 months.

The resulting system is an SGI Altix supercomputer system, based on SGI's NUMAflex shared-memory architecture for high productivity. It is comprised of 20 SGI Altix integrated superclusters, each with 512 processors; 1 terabyte of memory per 512 processors, with 20 terabytes total memory; 440 terabytes of online storage; and 10 petabytes of archive storage capacity (1 petabyte is equal to 1,024 terabytes, and 1 terabyte is equal to 1,024 gigabytes).

"NASA's indomitable spirit of exploration has led us to the Moon, to the surface of Mars, and even to the rings of Saturn," said Bob Bishop, vice chairman of SGI. "With Project Columbia, NASA will not only carry mankind further into space, but into new worlds of knowledge and understanding. After 2 decades of collaboration, NASA and SGI are on the cusp of a new age of scientific method and scientific discovery."

Product Outcome

A portion of the Columbia system has been made available on a broad basis to ensure the Nation's entire science and engineering community has access to the highly advanced supercomputer architecture. For example, throughout the 2004 hurricane season, the finite-volume General Circulation Model (fvGCM) running on Columbia had cranked out valuable, real-time numerical weather-prediction data targeted at improving storm tracking and intensity forecasts. A team at Goddard Space Flight Center is utilizing the data to predict landfall up to 5 days in advance.

Additionally, Jet Propulsion Laboratory, Massachusetts Institute of Technology, and Scripps Institution of Oceanography scientists from a consortium called Estimating the Climate and Circulation of the Ocean (ECCO) teamed with the NAS Division to use the supercomputer to dramatically accelerate the development of a highly accurate analysis of global-ocean and sea-ice circulations. The ECCO team produces time-evolving, three-dimensional estimates of the state of the ocean and of sea-ice. These estimates, obtained by incorporating into a numerical model vast amounts of data gathered from instruments in the ocean and from space satellites—such as sea level, current speed, surface temperature, and salinity—serve as a practical tool to better understand how the ocean currents affect Earth's climate, to study the role of the ocean in the Earth's uptake of carbon dioxide, and to more accurately predict events like El Niño and global warming.

Meanwhile, NASA continues to lend technical advice to support the advancement of SGI's products. The lessons learned while SGI provides NASA with engineering prototype systems is helping to improve the scalability and reliability of the machines. When SGI developed a 256-processor high-performance system for Ames, the experience directly benefited the company's commercial 128-processor machines. When NASA doubled its 256-processor system to operate on a 512-processor system, SGI made the 256-processor system commercially available. Ames again doubled up (prior to having Columbia) by moving to a 1,024-processor system, leading SGI to make the 512-processor system an official commercial product.

"The main product outcome has been the development of larger and larger general purpose, single-system image machines that are practical and usable, not just curiosities," said Bron Nelson, a software engineer with SGI. "This is driven by Ames and SGI's belief that these large, single-system image machines help to improve programmer productivity and ease-of-use, as well as ease of system administration."

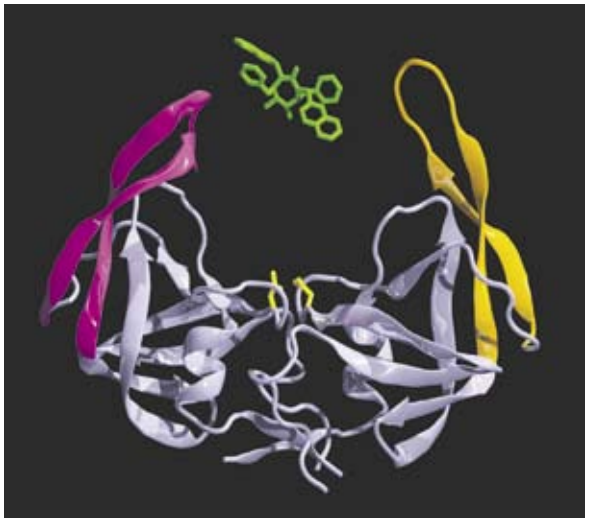


Image courtesy of Silicon Graphics, Inc., and Stoney Brook University.

Using an SGI Altix system to successfully model how the HIV protease molecule works across time, researchers hope to determine how best to target it with drugs that could stop it from doing its job and thus prevent the HIV virus from developing altogether.

Whether it is sharing images to aid in brain surgery, finding oil more efficiently, enabling the transition from analog to digital broadcasting, helping to model Formula 1 race cars and Ford Motor Company vehicles, or providing technologies for homeland security and defense, SGI has committed itself to working with NASA to ensure that it is putting out the best product possible and committed its resources to addressing the next class of challenges for scientific, engineering, and creative uses. ❖

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Cryogenic Cooling for Myriad Applications—A STAR Is Born!

Originating Technology/NASA Contribution

Cryogenics, the science of generating extremely low temperatures, has wide applicability throughout NASA. The Agency employs cryogenics for rocket propulsion, high-pressure gas supply, breathable air in space, life support equipment, electricity, water, food preservation and packaging, medicine, imaging devices, and electronics. Cryogenic liquid oxygen and liquid hydrogen systems are also replacing solid rocket motor propulsion systems in most of the proposed launch systems—a reversion to old-style liquid propellants.

In the late 1980s, NASA wanted a compact linear alternator/motor with reduced size and mass, as well as high efficiency, that had unlimited service life for use in a thermally driven power generator for space power applications. Prior development work with free-piston Stirling converters (a Stirling engine integrated with a linear actuator that produces electrical power output) had shown the promise of that technology for high-power space applications. A dual use for terrestrial applications exists for compact Stirling converters for onsite combined heat and power units.

The Stirling cycle is also usable in reverse as a refrigeration cycle suitable for cryogenic cooling, so this Stirling converter work promised double benefits as well as dual uses. The uses for cryogenic coolers within NASA abound; commercial applications are similarly wide-ranging, from cooling liquid oxygen and nitrogen, to cryobiology and bio-storage, cryosurgery, instrument and detector cooling, semiconductor manufacturing, and support service for cooled superconducting power systems.

Partnership

NASA entered into a **Small Business Innovation Research (SBIR)** contract with Clever Fellows Innovation Consortium, Inc. (CFIC), of Troy, New York, through Glenn Research Center, to develop a lighter, more robust linear alternator based on CFIC's novel STAR architecture. This resulted in a 15-kilowatt prototype alternator for NASA's Space Power Research Engine (SPRE) that reduced overall Stirling converter mass by 21 percent. The work accomplished through this partnership was later extended to a line of linear alternators and motors, used mainly in cryogenic refrigerators that are marketed by Qdrive, formed in 2001 as the cryogenic cooler development and manufacturing arm of CFIC.

Qdrive's mission is to fill the need for quiet, low-vibration, no-maintenance, long-life, complete cryogenic cooling systems that are easy to use and economically attractive. Its work with NASA has aided in its ability to meet this goal. Qdrive's acoustic Stirling cryocooler line is now the industry's widest capacity range of unitary coolers, with 77 kelvin capacities from 10 watts to over a kilowatt.

Product Outcome

One of the advances the SBIR contract spawned was the establishment of the manufacturing capabilities of Qdrive, which resulted in the direct sales of the company's STAR-based equipment. STAR motor/alternators are now the driving force behind all Qdrive products. STARs are linear reciprocating devices that combine the unique commuter flexing axial suspension, with plunger-mounted, high-energy magnets and a robust coil-over-iron stator (the stationary portion of a motor). These motors can be considered a hybrid of motor and loudspeaker. Like loudspeakers, they move in and out in response to an electrical input, but like motors, they operate at a preferred speed (frequency), and are powerful and efficient. Qdrive's current STAR line has powers from 100 to over 10,000 watts-per-unit, with efficiencies ranging from mid-80s to well over 90 percent (the best loudspeakers are under 50 percent).

STAR motors have a unique wear-free suspension system—with unlimited life and extremely pure linear motion without rubbing, rolling, sliding, or any other wearing contact—a feature that eliminates lubrication requirements. They utilize an innovative interlocking, moving magnet design with low-cost block magnets, also enabled by the single-degree of freedom suspension.

Qdrive's 1S102M/A linear reciprocating motor/alternator. All of the company's products benefit from the STAR motor/alternators advanced under the NASA contract.

The noncontact STAR motors are combined with acoustic Stirling coldheads in Qdrive coolers, so there are no moving parts operating at the cold temperatures. This design eliminates oils and other condensibles that would otherwise foul the cold parts of conventional mechanical coolers. A compact, balanced configuration of twin STAR motors in the machines produces minimal vibration.

Qdrive's technological strength is sustained by key alliances. For manufacturing and distribution of, and continued improvements to, its larger systems, the company has allied with Praxair, Inc., of Danbury, Connecticut—the largest air separation and industrial gas company in

Qdrive's water-cooled 2S102K L-form configuration desktop cryocooler.

the Americas, with offices worldwide. Praxair also designs, engineers, and constructs cryogenic supply systems using Qdrive's STAR motors.

Qdrive has also licensed Helix Technology Corporation, of Mansfield, Massachusetts (recently acquired by Brooks Automation, Inc., of Chelmsford, Massachusetts), to make and sell its coolers for the demanding fields of semiconductor and flat panel display manufacturing. The CTI-Cryogenics division of Helix Technology is the global leader in cryogenic high-vacuum products, where reliability and low-vibration are paramount.

Other development customers include the Los Alamos National Laboratory and the Applied Research Laboratory at Penn State University—both global leaders in thermoacoustics—as well as other superconducting products companies, major international refrigeration manufacturers, NASA, the U.S. Department of Energy, the U.S. Department of Defense, and laboratory and university researchers globally.

Future applications will include cooling in more familiar situations. CFIC-Qdrive has just completed the world's first compact and efficient thermoacoustic food refrigerator (STAR driven) for mobile use by the U.S. Army. The modifications required for efficient operation at noncryogenic conditions are applicable to many other refrigeration tasks and even to air-conditioning without environmental risks, suggesting that this SBIR spinoff may become one of the coolest innovations yet! ❖

Qdrive's shrouded, air-cooled 2S102K desktop cryocooler.

Temperature Sensing for Oil, Gas, and Structural Analysis

Originating Technology/NASA Contribution

With retirement of the space shuttle imminent, and the commercial space industry burgeoning, NASA is searching for safe and innovative methods for carrying payload and passengers to the Moon, Mars, and beyond. The search for new vehicles has been going on for some years now, with a variety of plans being pursued and countless technologies being developed.

One of the early quests for a shuttle replacement involved the X-33 program, initiated in 1996. The goal of the X-33 program was to reduce the business and technical risks associated with space travel so that private industry could build and operate the next-generation reusable launch vehicle (RLV) by first designing, constructing, and flying a half-scale prototype that would demonstrate (in flight) the technologies needed for the new RLV.

The X-33 was intended to pave the way for a full-scale, commercially developed RLV to be built by the Lockheed Martin Corporation after the turn of the century. The full-scale RLV would dramatically reduce the cost of putting payloads into space and, ultimately, replace the space shuttle.

The Lockheed Martin design for the X-33 was selected from three designs submitted to NASA. The concept used a wedged shape coupled with an aerospike rocket engine to propel the vehicle, and a rugged metallic thermal protection system to shield against the extreme variations in temperature the craft would endure during take off and reentry.

It was designed to take off vertically like a rocket and land horizontally like an airplane after having reached hypersonic speeds and altitudes of up to 50 miles.

The X-33 program was managed by the Marshall Space Flight Center and the craft would have been launched at a special site on Edwards Air Force Base, in California.

Due to technical problems with the vehicle's composite liquid hydrogen tanks, though, the X-33 program was cancelled in February 2001, with Lockheed Martin given the option by NASA to continue development of the craft on its own.

Science developed for the vehicle prototype proceeded in many directions, including toward advancing knowledge needed to create the next-generation RLV, and toward creating a small fiber-optic-based temperature sensor that has found uses as widespread as automating the oil and gas industry to ensuring the structural integrity of large concrete dams.

This artist's rendering depicts the three designs submitted to NASA for the X-33 reusable launch vehicle, an early program addressing the eventual replacement of the space shuttle fleet. NASA considered design submissions (pictured left to right) from Rockwell Collins, Lockheed Martin Corporation, and the McDonnell Douglas Company. NASA selected Lockheed's Martin's Design.

Partnership

In 1996, Systems and Processes Engineering Corporation (SPEC), of Austin, Texas, undertook a NASA **Small Business Innovation Research (SBIR)** contract with Langley Research Center to develop a compact and lightweight digital thermal sensing (DTS) system for monitoring the cryogenic tanks on the X-33 prototype aircraft. That technology, along with a processor developed by SPEC for Goddard Space Flight Center, was space-qualified and integrated into several NASA missions.

SPEC formed an ancillary organization, SensorTran, Inc., to continue work developing the DTS technology for a variety of commercial and industrial applications.

Product Outcome

By the year 2000, SensorTran was employing the DTS technology around the world in the oil and gas industry, the electrical power industry, in processing plants, and to test structural integrity of large structures.

Now in its second generation, the commercially available device, billed as the SensorTran 5100, is an industry leader because of its performance, ruggedness, and cost-effectiveness. The device measures temperature along an optical fiber by monitoring the amplitude of backscatter from a laser pulse through the fiber, with temperature profiles accurate to half a degree Celsius along full kilometers of optical fiber. By measuring temperature over the entire surface of an area, the SensorTran 5100 provides thousands of measurement points to monitor actual conditions. These extensive real-time data allow operators to make better decisions about performance, to reduce operating costs, and to increase performance and return on investment.

In the oil industry, it helps companies make the right decisions for the operation of their oil wells by giving them clear depictions of downhole conditions. Often when downhole information is available, it is limited or vague, leaving oil companies with high levels of uncertainty, which could potentially cost valuable time and resources. The SensorTran 5100 instrument reduces this uncertainty by providing clearer pictures of well conditions, which allows for better decisions and maximizes overall productivity. Using the installed optical fiber, it measures temperature over the entire length of the well, detecting conditions at any location. It also permanently monitors conditions over time, capturing critical events as they occur, while helping reduce the risk and cost of well intervention.

The device enables users to better see conditions and events anywhere in their wells at any time, allowing them to make the right decisions.

An artist's conception of a half-scale X-33 demonstrator, one of the first visions for a space shuttle replacement, flying over a southwestern desert. The vehicle had a wedge-shaped lifting body, with two vertical fins and a pair of stub wings. At the rear was the aerospike engine, an experimental design that lacked the nozzles of conventional rockets.

Oil industry users can:

- troubleshoot wellbore conditions without intervention and identify problems before they become serious;
- locate tubing and equipment leaks;
- detect flow behind casing;
- identify cross-flow and water or gas breakthrough;
- optimize multizone production over the life of a well;
- monitor changes in zone contributions;
- monitor steam flood and steam-assisted gravity drainage (SAGD) efficiency;
- verify effectiveness of downhole operations in real time;
- confirm injection profiles;
- monitor cementing jobs; and
- verify cement tops and gas-lift valve operation.

In the power cable monitoring industry, the SensorTran device also offers a host of benefits. Traditional methods for calculating load ratings rely on estimates for cable heat dissipation under different loads and conditions. The downside of this method is that it produces overly conservative load ratings, leaving cables with significant unused capacity. The SensorTran instrument allows engineers to increase load ratings by directly measuring temperature over the entire length of a cable and under actual conditions. This provides a much more accurate picture of cable heat dissipation, which, in turn, produces a more accurate cable rating. Estimates suggest that utilizing DTS measurements can increase cable ratings by as much as 25 percent.

These higher ratings available with DTS can provide significant benefits for power companies, because they can defer new capital expenditures, deliver more power with existing infrastructure, and defer millions of dollars in planned new construction. The ratings also allow them to reduce load-shedding events and the number of blackouts and brownouts on their systems, which translate into internal benefits that help to greatly improve customer service and support future customer growth. The need for additional investment is reduced by extending the life of existing underground cables.

The SensorTran 5100 DTS unit is rugged, cost-effective, and precise.

When problem areas in power cable lines, called hotspots, are not known or change over time, power cable operators may be routinely loading cables above thermal limits. With the SensorTran 5100, engineers can accurately pinpoint the location and severities of all hotspots, helping extend cable life by ensuring temperature limits are not exceeded. The device can even provide automatic alarms, giving operators greater confidence under critical load conditions.

SensorTran 5100 can ameliorate new cable design and operation. By designing new cables with an expected higher rating from DTS data, less expensive cables can be used. In addition, with the sensor installed from the very beginning, the conditions of the cable for its entire life can be tracked, helping better estimate cable life and optimize cable maintenance.

The benefits of this technology also extend into monitoring processing plants. With the SensorTran 5100, plant operators now have the ability to thoroughly monitor their processing vessels and plant pipelines in real time. Using standard optical fiber, the device can monitor the entire surface of any vessel, such as a reactor vessel or cryogenic tank, helping operators pinpoint the location and

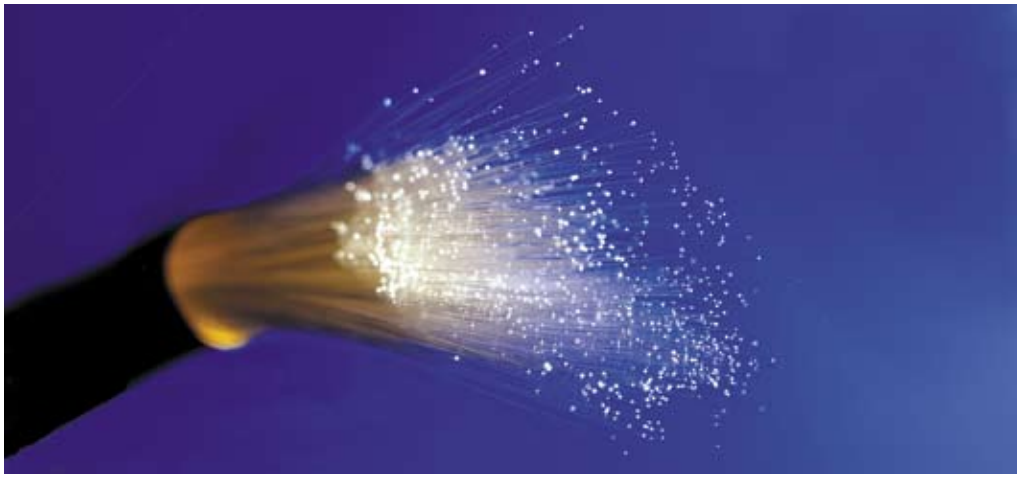
severity of impending insulation failure or catastrophic leaks—even on internal surfaces. The entire length of any plant pipeline can also be monitored for potential leaks.

By monitoring vessels and pipelines in real time, operators can respond quickly to leaks or spills, thus reducing downtime and improving plant safety. In addition, maintenance schedules can be optimized based on actual conditions instead of estimated guesses.

DTS can also be used to monitor the strength of large cement structures. With the SensorTran 5100, engineers now have the ability to monitor critical dam structures from the inside out, to ensure proper cement curing and sufficient integrity throughout the life of the structure. Using standard optical fiber installed throughout and around the dam structure during construction, the SensorTran 5100 can provide initial insight into the progress of cement curing to help locate any significant flaws for reinforcement. In addition, the sensor can be used over the life of the dam to precisely locate any emerging leaks throughout the dam structure. With an accurate location of leaks, corrective action can be taken to stop or reduce potential damaging effects. ❖

SensorTran 5100™ is a trademark of SensorTran, Inc.

A group of engineers gathers to collect temperature data using the SensorTran 5100 on the Yu River dam construction project in the Guizhou Province of China.



The SensorTran unit relies on advanced fiber optics. The device measures temperature along an optical fiber by monitoring the amplitude of backscatter from a laser pulse through the fiber, with temperature profiles accurate to half a degree Celsius along full kilometers of optical fiber. By measuring temperature over the entire surface of an area, the SensorTran 5100 provides thousands of measurement points to monitor actual conditions. This precision is useful in myriad industries.

Robust, Thin Optical Films for Extreme Environments

Originating Technology/NASA Contribution

The environment of space presents scientists and engineers with the challenges of a harsh, unforgiving laboratory in which to conduct their scientific research. Solar astronomy and X-ray astronomy are two of the more challenging areas into which NASA scientists delve, as the optics for this high-tech work must be extremely sensitive and accurate, yet also be able to withstand the battering dished out by radiation, extreme temperature swings, and flying debris. Recent NASA work on this rugged equipment has led to the development of a strong, thin film for both space and laboratory use.

Partnership

Through a **Small Business Innovation Research (SBIR)** contract with Goddard Space Flight Center, Luxel Corporation, of Friday Harbor, Washington, developed key materials that will help NASA researchers as they explore the unforgiving environment of space. With NASA's assistance, the company developed a novel manufacturing process for ultra-thin films that have application in enhancing X-ray and extreme ultraviolet (EUV) filter technology.

The films incorporate composite polymer support mesh with polyimide or metallic ultra-thin films, which makes them stronger and more durable, while still maintaining their optical filtering integrity. The mesh was specially characterized for adhesion, mechanical and vibration strength, X-ray transmittance, and throughput gain.

This is the fourth successful NASA SBIR contract that Luxel has completed in this area, with others including "Applications of Thin Polyimide Films to X-ray Optics," "High Throughput Thin Foil Filters with Enhanced Durability for the Soft X-ray and EUV Regions," and "Polyimide X-ray Filters Optimized for Strength at Cryogenic Temperatures."

While NASA will find use for these filtering films in a variety of optical and plasma research venues during future missions, Luxel's customers have been finding uses for this new technology in government and commercial laboratories.

Product Outcome

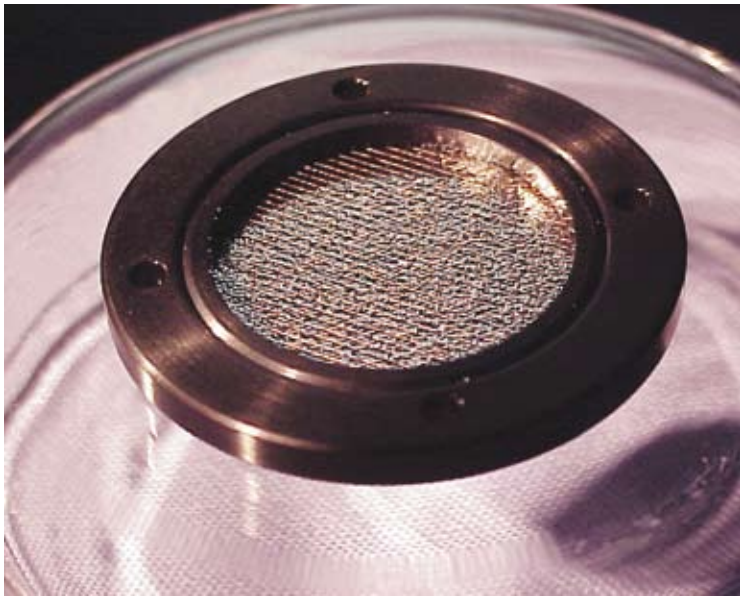
In the 30 years that Luxel has been in operation, it has pioneered development of new filter materials and techniques for the fabrication of the filtering films, and with its years of industry experience, it can produce filters and windows larger and stronger than previously thought possible.

Its filters are cutting edge. Many of the new Luxel designs are allowing researchers to better discriminate regions of the electromagnetic spectrum, and its filters routinely demonstrate remarkable strength for their size. Many of them are able to withstand spacecraft launch, pressure differentials, and maintain gas cell integrity. Luxel delivers some of the highest quality foil filters available, produced from over 70 different materials, compounds, and organics, supplied on both standard and custom frames. The polyimide and metallic foil filters that were advanced under the NASA contracts are now part of Luxel's commercial offerings and being used by a plethora of researchers.

The new filters, combined with Luxel's new manufacturing process—a late discovery in the SBIR work that resulted in a radical new method for producing composite polymer supports using photolithography and polyimide—are a viable option for many of Luxel's customers. This new manufacturing capability is a boon to customers, as it allows Luxel to provide large quantities of the ultra-thin films.

The researchers also increased the performance of the films. They discovered that by incorporating either high-modulus polymer fibers or tungsten filaments into a filter's construction, the average burst strength increases by 200-percent more than that of the baseline electroformed nickel mesh; and the ultra-fine diameter filaments used in filter construction have the ability to reduce obscuration effects by 10 to 15 percent over those same existing mesh systems.

These filters fabricated for X-ray and EUV applications using polymer composite support mesh are highly transparent in the high-energy wavelengths, even in extreme conditions. They are hardy enough to survive rough handling, which makes them ideal for a variety of research applications. ❖



Luxel Corporation is a top supplier of thin foil filters. The company supports customer requirements for X-ray and extreme ultraviolet (EUV) research programs. Its work with NASA under a Small Business Innovation Research (SBIR) contract helped to create key filtering materials for protecting optics in harsh environments. These materials are now helping researchers everywhere.

The Cutting Edge of High-Temperature Composites

Originating Technology/NASA Contribution

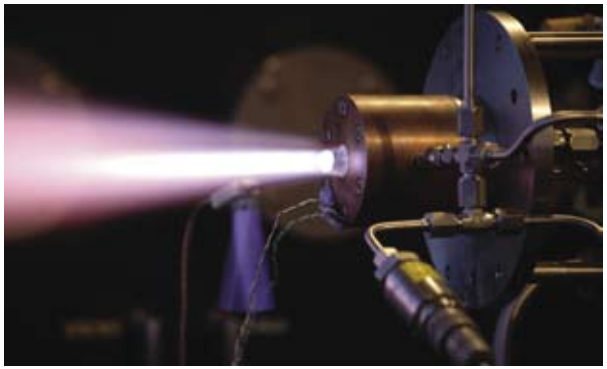
NASA's Ultra-Efficient Engine Technology (UEET) program was formed in 1999 at Glenn Research Center to manage an important national propulsion program for the Space Agency. The UEET program's focus is on developing innovative technologies to enable intelligent, environmentally friendly, and clean-burning turbine engines capable of reducing harmful emissions while maintaining high performance and increasing reliability.

Seven technology projects exist under the program, with each project working towards specific goals to provide new technology for propulsion. One of these projects, Materials and Structures for High Performance, is concentrating on developing and demonstrating advanced high-temperature materials to enable high-performance, high-efficiency, and environmentally compatible propulsion systems. Materials include ceramic matrix composite (CMC) combustor liners and turbine vanes, disk alloys, turbine airfoil material systems, high-temperature polymer matrix composites, and lightweight materials for static engine structures.

Partnership

Hyper-Therm High-Temperature Composites, Inc. (Hyper-Therm HTC), is a worldwide leader in producing high-temperature ceramic composite materials. In the mid-1990s, the Huntington Beach, California-based company created a silicon-doped boron nitride (BN) fiber coating for advanced CMCs. This development was geared towards demanding applications that require increased durability and longevity, as well as demanding environments, such as space.

By participating in NASA's **Small Business Innovation Research (SBIR)** program with Glenn, Hyper-Therm HTC is helping the UEET program reach its goals to "develop and hand off revolutionary turbine engine propulsion technologies that will enable future-generation vehicles over a wide range of flight speeds." Hyper-Therm HTC's ceramic composites are also being evaluated by other NASA programs that require improved materials for next-generation launch and flight vehicles.



Hyper-Therm High-Temperature Composites, Inc., is developing advanced composite materials for a variety of high-temperature aerospace applications, including hypersonic aircraft thermal structures and advanced rocket propulsion thrust chambers.

Additionally, Hyper-Therm HTC was contracted (SBIR) by Glenn's neighbor to the south, Marshall Space Flight Center, to devise a unique and cost-effective methodology for manufacturing axisymmetric ceramic composite structures. According to the company, this project helped to facilitate the world's first actively cooled, continuous fiber-reinforced silicon carbide (SiC)-matrix composite thrust chambers for liquid rocket propulsion systems. These propulsion devices were designed to be cooled with cryogenic liquid hydrogen, to provide protection from severe, high-temperature combustion environments (greater than 6,500 °F liquid hydrogen/oxygen). Hot-fire testing of the devices was performed by Glenn.

By working with NASA's Glenn and Marshall centers, as well as other branches of government, Hyper-Therm HTC was able to further develop and optimize its composite technology for government and commercial aerospace, plus commercial industrial applications.

Product Outcome

Hyper-Therm HTC has experienced sales in excess of $4 million, thanks to its advanced composite materials, coatings, and components. The technology has been folded into everything from hypersonic airframe and thermal reentry structures, to turbine disks, laser mirror substrates, heat-engine devices, ballistic penetrators, micro-rotary cutting tools, and free-standing refractory metal components for nuclear, medical, and materials research applications.

The cutting-edge composites are produced via isothermal/isobaric and forced-flow chemical vapor infiltration (CVI) processing techniques. The company's most popular high-temperature structural material systems are composed of carbon and SiC fiber reinforcements in a CVI SiC matrix. Available fiber coatings include silicon-doped BN, pyrolytic BN, pyrolytic carbon (PyC), and duplex PyC-B_4C, all of which have been developed to impart an optimum balance of strength, fracture toughness, and strain-to-failure.

For applications demanding increased durability and life in aggressive environments, Hyper-Therm HTC offers its multilayer SiC fiber coating system and its pseudo-porous SiC system. The multilayer fiber coating system is composed of very thin (about 100 nanometers), weakly bonded layers of stoichiometric SiC and was developed to mitigate the inherent problems of oxidation and moisture instability plaguing currently available PyC and BN fiber coatings. (In its work with NASA, the company achieved a hundredfold improvement in moisture stability over standard, low-temperature-derived BN fiber coatings.) The pseudo-porous fiber coating system is composed of a thin (less than 1 micrometer), breakable monolayer network of porous SiC—also developed to mitigate the associated problems with PyC and BN.

Looking ahead, the stirring demand for stronger-but-lighter, high-temperature, cost-effective materials will fortify Hyper-Therm HTC's business opportunities in existing markets, as well as new ones. ❖

Nano Goes Magnetic to Attract Big Business

Glenn Research Center engineers assemble a NASA Evolutionary Xenon Thruster (NEXT) for testing. This thruster is a next-generation propulsion system that could revolutionize the way NASA sends science missions deep into the solar system. The thruster is built to use xenon gas and electrical power to drive spacecraft.

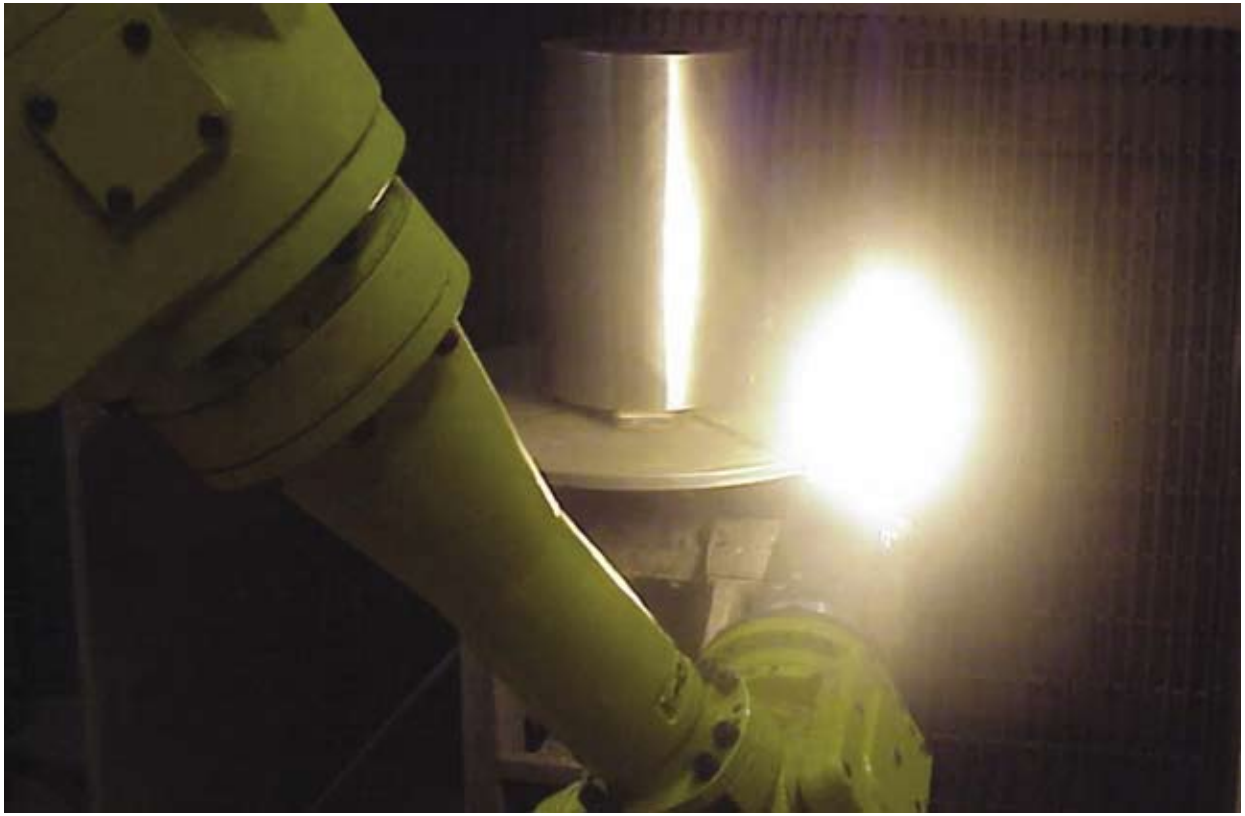
Originating Technology/NASA Contribution

Glenn Research Center has combined state-of-the-art electrical designs with complex, computer-aided analyses to develop some of today's most advanced power systems, in space and on Earth. The center's Power and On-Board Propulsion Technology Division is the brain behind many of these power systems. For space, this division builds technologies that help power the International Space Station, the Hubble Space Telescope, and Earth-orbiting satellites. For Earth, it has woven advanced aerospace power concepts into commercial energy applications that include solar and nuclear power generation, battery and fuel cell energy storage, communications and telecommunications satellites, cryocoolers, hybrid and electric vehicles, and heating and air-conditioning systems.

Whether it is energizing the latest space-bound propulsion systems or providing energy for terrestrial purposes, Glenn's power-generation technology gives NASA the boost it needs to achieve its missions in both realms.

Partnership

In 1999, Inframat Corporation received funding and technical support from Glenn, in the form of Phase I and Phase II **Small Business Innovation Research (SBIR)** contracts, to fabricate high-frequency, soft magnetic/ceramic nanocomposites in order to advance the magnetic performance of the Space Agency's electronic, power-generating equipment. According to the Farmington, Connecticut-based company, if these nanocomposites could feasibly be developed, they could yield improved properties over conventional ferrites, including a combination of higher magnetic permeability, higher electrical resistivity, and lower magnetic loss. (Found in electronic devices, a ferrite is any group of magnetic substances that consist essentially of ferric oxide combined



Inframat Corporation is an emerging technology company founded in 1996 to develop nanostructured materials to improve performance and extend the life of coated components used throughout the global infrastructure. These materials include magnetic nanocomposites with superior magnetic properties and a plasma spray nanocoating, seen here being applied by a spray gun onto a steel roller.

with the oxides of one or more metals and have high magnetic permeability and electrical resistivity.) Inframat claimed that, over the past half-century, conventional ferrites have been the only type of magnetic material for high-frequency applications, adding that they perform relatively poorly at high frequencies. These ferrites are also known to deteriorate when exposed to large demagnetizing fields at low temperatures.

Inframat went to work on manufacturing nanocomposite materials with various magnetic frequencies, using a wet-chemical synthesis technique. The intent was to create technology that could have a major impact on NASA's power management and distribution applications, as well as within the commercial market.

While the technology did not come to fruition during the NASA SBIR effort, Inframat was able to make the most out of what it had learned during this entire experience, as well as the funding it received, to later resolve some outstanding technical issues and create an enabling technology for commercial applications.

Product Outcome

While electronic systems are trending toward multifunctionality and increased miniaturization at higher speeds and lower costs than ever before, they can still have their limitations. For example, current inductive (power) components in a traditional semi-conducting chip can be a major impediment for the mass miniaturization of electronics, due to the fact that conventional, micro-sized, magnetic materials can only be used properly at very low frequencies.

The limitations of conventional magnets become significant in high-frequency applications (above 1 megahertz), because their permeability, or magnetic-quality factor, starts to decrease as frequency increases, thereby increasing their deterioration exponentially.

To transcend these limitations and propel to a new level the manufacturing, cost, weight, performance, and reliability improvements demanded of high-frequency

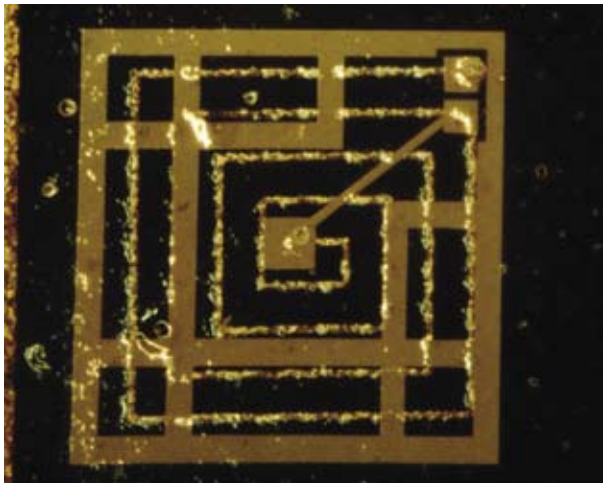


Image courtesy of Drs. P.M. Raj and Lixi Wan.

Telecommunications is a part of Embedded Nanomagnetics, Inc.'s initial market focus. Pictured here is a microtransformer for DC-DC converters in cell phone applications.

electronic devices and inductors, Inframat has spun off a company called Embedded Nanomagnetics, Inc. This new enterprise is commercializing Inframat's revolutionary nanocomposite advancements under the brand name M-power. According to Inframat, the M-power brand name is representative of one of the key power advantages of Embedded Nanomagnetics products: "…the fact that they deliver up to 10 times more inductive value and efficiency than conventional magnetic materials of the same size."

For the designing and manufacturing of M-power nanocomposites, Inframat and Embedded Nanomagnetics have a proprietary process in place that enables extremely dense packing of nanoscale magnetic particles into a magnetic paste or film. When configured as a nanomagnetic paste, for instance, the material is capable of achieving the high-inductance values that are required for embedded power circuit board applications (applications for which high-inductance values cannot be accomplished using thin film techniques). In this case, the paste can simply be silk-screened onto a circuit board. On the other hand, when configured as a thin film, the material can achieve high-inductance values for applications that are dependent on semiconductor wafers, instead of circuit boards.

The M-power magnetic material has demonstrated that it can maintain high permeability with extremely low core loss (loss caused by a magnetization of the core and its resistance to magnetic flux) and excellent electrical properties, even at high frequencies extending into the gigahertz range (1,000 megahertz equals 1 gigahertz). This design possesses soft magnetic properties that Inframat considers "far superior" to those of conventional ferrites, thus, it enables "much greater flexibility" in tailoring magnetic and electric parameters in a wide range of applications.

Device use for M-power materials include: power converters, antennas, broadband filters, sensors, digital packing converters, radiofrequency switches, microwave and millimeter wave circulators, sound-suppressors, hybrid integrated circuits, and semiconductor wafers. These applications cover a broad spectrum of commercial markets, such as telecommunications, computers, consumer electronics, automotives, aerospace, defense, power generation, and industrial operations.

Embedded Nanomagnetics is initially focusing on the electronics, telecommunications, and defense markets, as it has attracted the attention of several market leaders in these industries. One of these leaders, Tagent Corporation, is working to integrate the M-power materials into small, cost-effective radio frequency identification systems intended for fully automated electronic tag reading and item tracking. ❖

Inframat® is a registered trademark of Inframat Corporation.
M-power™ is a trademark of Inframat Corporation.

Laser Mapping for Visual Inspection and Measurement

Originating Technology/NASA Contribution

Each space shuttle orbiter has 38 Primary Reaction Control System (PRCS) thrusters to help power and position the vehicle for maneuvers in space, including reentry and establishing Earth orbit. Minor flaws in the ceramic lining of a thruster, such as a chip or crack, can cripple the operations of an orbiter in space and jeopardize a mission. The ability to locate, measure, and monitor tiny features in difficult-to-inspect PRCS thrusters improves their overall safety and lifespan.

These thrusters have to be detached and visually inspected in great detail at one of two NASA facilities—the White Sands Test Facility or the Kennedy Space Center—before and after each mission, which is an expense of both time and money.

Partnership

Laser Techniques Company, LLC (LTC), of Bellevue, Washington, builds customized laser-based measurement and inspection devices to help improve the safety, reliability, and useful life of high-value, safety-critical equipment and industrial machinery for the commercial, defense, and aerospace industries.

In 2002, James Doyle, president of LTC, successfully demonstrated that a miniature, high-performance laser could locate and map hidden flaws in PRCS thrusters that were smaller than the head of a pin, to an accuracy of 0.0003 inches.

Through the NASA-sponsored Montana State University TechLink Center, Doyle delivered a presentation of his work at White Sands, which led to the issuance of a NASA contract to build a full-scale, portable, in situ thruster mapping system.

The project was successful, resulting in the development of an automated laser-based scanning system that included a miniature, high-performance laser sensor. With the scanning laser system, the area of a thruster can be quickly inspected and mapped, providing technicians with accurate 3-D data for evaluating the ceramic surface condition. The portable laser scanner system was sent to White Sands, where it is used in thruster life-testing projects and routine thruster overhaul and refurbishment programs.

James Doyle, Laser Techniques Company, LLC, president, kneels to examine the thrusters on Space Shuttle Atlantis.

NASA is interested in extending the use of LTC's portable scanning system to on-shuttle applications, enabling inspectors to detect and map flaws in the lining of the thrusters while they are attached to the shuttle. This would be a significant improvement over the current visual methods of inspection, which require removal and shipping of the thrusters.

The successful results of the thruster mapping project resulted in positive exposure of LTC's capabilities to other branches of NASA. Working with the technical staffs of NASA; the United Space Alliance, of Houston; and Hamilton Sundstrand Corporation, of Windsor Locks, Connecticut, LTC developed an automated, laser-based corrosion mapping system for the gas generators used in the auxiliary power units on both the solid rocket boosters and the main orbiter. This system, which is being put into full production this year, will eliminate the laborious and difficult task of measuring corrosion and pitting on the external surface of the gas generator units.

A significantly more difficult challenge was then presented to LTC by the same group of NASA researchers. As Doyle recalls, "They basically said 'Okay, you did a great job on the external surface of the gas generator unit, but can you build a microsensor that maps the inside surface of the gas generator injector stem? Oh, by the way, its inner diameter is only 0.095 inches, and it is only 3 inches deep!'"

The inside surface of the injector stem is the most difficult area to inspect. Even tiny flaws in the gas generator can result in the condemnation of these expensive parts, and since they are considered flight critical, no flaws can be allowed.

Approximately 4 months after receiving a contract to develop a proof-of-principle gas generator stem-mapping sensor, LTC notified NASA that it was ready to demonstrate the device.

Not only was LTC ahead of schedule, the sensor exceeded the design goals, providing high-resolution, 3-D images of pits as small as 0.005 inches deep. It will be put into full production for inspection of all gas generators during the refurbishment process at the Hamilton Sundstrand facility, in Rockville, Illinois. This system, which will be capable of mapping both the gas generator external surface and the injector stem, will significantly improve the inspection process by automating the onerous task of manually inspecting these critical parts.

The TechLink center provides assistance for small businesses, such as LTC, to get exposure to NASA and the U.S. Department of Defense—a task that is otherwise particularly difficult for small businesses. For LTC, that is all it needed.

To date, LTC has successfully introduced its technology to NASA's Marshall Space Flight Center, Glenn

Research Center, White Sands Test Facility, and Kennedy Space Center.

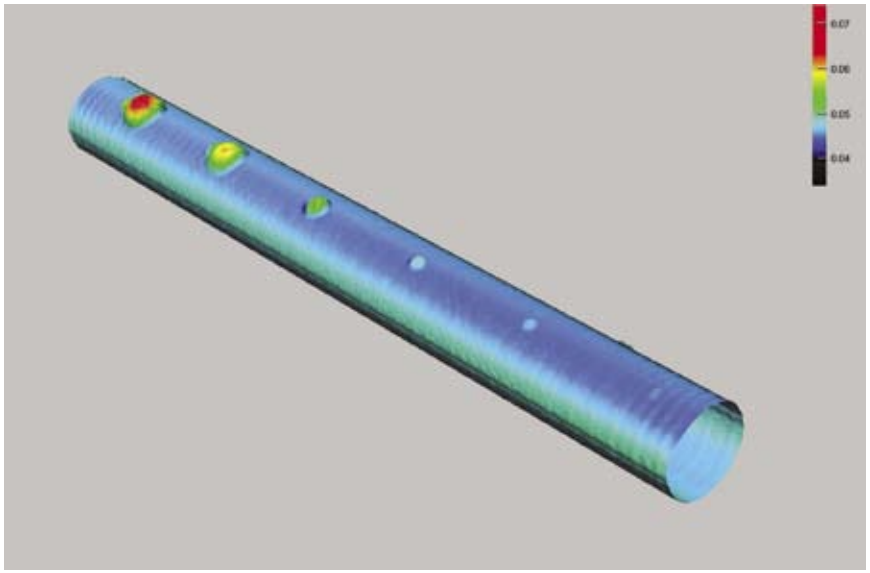
Product Outcome

The developments accomplished through the projects conducted for NASA are being directly extended to the commercial industry and for military defense applications. Conventional visual inspection and measurement methods can be time-consuming, laborious, and inaccurate. "Our objective," stated Doyle, "is to eliminate the possibility of missing a potentially crucial flaw due to the effects of operator subjectivity, visual acuity, or fatigue."

LTC's laser-based scanning measurement and inspection systems, advanced under the NASA contracts, are ideal and cost-effective solutions to these problems. Their small size allows them to scan otherwise inaccessible areas, and they can map virtually 100 percent of a target surface in a matter of minutes. In addition, the unique LaserVideo image dataset from the laser-scanning probe provides valuable qualitative visual information about surface condition. These laser-generated visual images provide nearly photographic image quality of surfaces that would be impossible to photograph using conventional bore scopes, and expose flaws such as scratches, scuffs, and discoloration.

LTC offers a variety of noncontact measurement and inspection solutions using laser-based sensors. For inspection of critical components, LTC has developed a wide range of products based on three core technologies: laser profile mapping, LaserVideo imaging, and Laser-Scanned Fluorescent Penetrant Inspection (LSPI). All of the company's technologies are supported by its Laser MicroMap data acquisition system and utilize its LaserViewer software for flexible data acquisition, real-time display of collected data, and data analysis. It has developed a standard product line to meet the needs of a number of diverse applications, and can, as it proved with the variety of work it performed for NASA, quickly adapt those products to new requirements.

Laser profile mapping involves a group of sensors that provide precise, noncontact measurement and 3-D images of tubes, bores, plates, and complex surfaces. These sensors are high-resolution "laser calipers" that take a rapid succession of single-point distance measurements while scanning over the target surface. The result is a 3-D image that provides a quantitative map of the inspected part. Features such as pits, erosion, and deformation can be rapidly located and accurately measured. LTC also develops systems that integrate eddy current sensors, complementary nondestructive testing technology that can detect subsurface flaws.



A 3-D image of corrosion generated using the laser sensor developed under the NASA-funded partnership.

With LaserVideo imaging, a highly focused laser spot provides high-resolution, undistorted images of hard-to-access surfaces such as tubes and bores, revealing features like cracks, scratches, stains, and variations in surface roughness. These images are acquired along with the profile data and provide a visual image that complements the topographical data set.

The patented LSPI technique provides automated fluorescent penetrant inspection for real-time detection and mapping of surface-breaking cracks and other defects. Like LaserVideo imaging, this noncontact inspection method is ideal for detecting surface defects in difficult-to-access components.

Using these three core technologies, LTC offers an in-house laser inspection service, as well as a fully equipped laboratory, including multi-axis, computer-controlled scanning fixtures; optical breadboard tables; and a full cadre of test instruments and sensors. The company can quickly set up and test samples that clients provide for evaluation. It also offers remote or onsite consulting to customers, to develop solutions for challenging inspection and measurement applications.

LTC practices its trade in the defense, aerospace, and energy industries. Defense applications of this laser-sensing technology include detecting and mapping erosion, deformation, and pitting in weapons ranging from small caliber rifles, to mortars, to large caliber cannons. Aerospace applications, in addition to detecting chips in the space shuttle thrusters, include detecting cracks in aircraft engine parts and measuring thruster erosion. In the energy industry, this technology is useful for dent measurement, quality measurement, and crack detection in nuclear steam generator tubes, and underwater mapping of piping. ❖

LaserVideo™, LSPI™, and Laser MicroMap™ are trademarks of Laser Techniques Company, LLC.

Electrical Conductivity in Textiles

Originating Technology/NASA Contribution

Copper is the most widely used electrical conductor. Like most metals, though, it has several drawbacks: it is heavy, expensive, and can break. Fibers that conduct electricity could be the solutions to these problems, and they are of great interest to NASA.

Conductive fibers provide lightweight alternatives to heavy copper wiring in a variety of settings, including aerospace, where weight is always a chief concern. This is an area where NASA is always seeking improved materials.

The fibers are also more cost-effective than metals. Expenditure is another area where NASA is always looking to make improvements.

In the case of electronics that are confined to small spaces and subject to severe stress, copper is prone to breaking and losing connection over time. Flexible conductive fibers eliminate that problem. They are more supple and stronger than brittle copper and, thus, find good use in these and similar situations.

While clearly a much-needed material, electrically conductive fibers are not readily available. The cost of new technology development, with all the pitfalls of troubleshooting production and the years of testing, and without the guarantee of an immediate market, is often too much of a financial hazard for companies to risk.

NASA, however, saw the need for electrical fibers in its many projects and sought out a high-tech textile company that was already experimenting in this field, Syscom Technology, Inc., of Columbus, Ohio. Syscom was founded in 1993 to provide computer software engineering services and basic materials research in the areas of high-performance polymer fibers and films. In 1999, Syscom decided to focus its business and technical efforts on development of high-strength, high-performance, and electrically conductive polymer fibers. The company developed AmberStrand, an electrically conductive, low-weight, strong-yet-flexible hybrid metal-polymer yarn. The company, however, had not yet developed methods for mass production of its product. Several design features, as well, needed collaborative improvements from NASA engineers.

Recognizing the need for this technology, NASA encouraged the development and advancement of this advanced fiber for its use in future missions, while also pushing Syscom into the commercial marketplace with advanced manufacturing abilities. The U.S. Air Force Research Laboratory and the University of Dayton also contributed expertise and funding to this revolutionary endeavor.

Today, the hybrid metal-polymer wire is replacing signal wiring in several NASA applications, as well as being considered for use as space tethers, space antennas, for electromagnetic interference (EMI) shielding, and for a plethora of applications where lightweight wiring is essential. Meanwhile, Syscom is experiencing unprecedented growth and finding countless applications for its product.

Partnership

Syscom teamed with the Space Agency through a **Small Business Innovation Research (SBIR)** contract that was geared toward developing the ability to manufacture AmberStrand on a large scale. After a successful Phase I of the research grant, in which the company proved the validity of the project, NASA awarded a second grant, a lucrative Phase II award that allowed Syscom to pursue large-scale manufacturing by building a machine to mass-produce the wire. The company is now capable of producing up to 8.5 million feet of product per year, with one 8-hour shift per day.

Syscom attended an invitation-only conference for NASA SBIR recipients in San Diego, where the company was introduced to dozens of potential users from the military, aerospace, and other high-tech fields. This conference increased the exposure of AmberStrand and gave Syscom the credibility with the key investors that it needed to make use of its new, large-scale manufacturing abilities.

High production volumes and greater product diversity, combined with significantly lower product pricing, will remove most of the entry barriers to the electronic textiles market.

Product Outcome

To create AmberStrand, Syscom covers a high-performance polymer fiber with a metallized coating, producing strong-but-flexible strands. The strands are then wrapped together to form strong, lightweight wiring. According to Syscom, the polymer fibers from which AmberStrand is woven are actually twice as strong as KEVLAR. While somewhat less conductive than copper, the final product is still more than capable of carrying virtually any current it would be called upon to handle.

It is ideal for lightweight EMI shielding, space and aerospace wiring, and other applications requiring high-strength, low-weight, and superior conductivity.

Syscom offers AmberStrand as a series of yarn fibers that are readily available in inventory, but also manufactures custom fibers to meet specific criteria. It comes in a variety of metal coatings, conductive coating thicknesses, and in any number of base filaments and strands. It passes a series of necessary tests for strength, resistance, fluid immersion, flammability, smoke tolerance, and toxicity with high rankings.

Current customers include NASA, the U.S. Air Force, and the aerospace industry, since this advance in wiring technology reduces the maintenance cost of commercial and military aircraft, as well as spacecraft.

Potential applications include power distribution lines; additional aircraft and aerospace wiring systems; automotive wiring harnesses; missile guidance wires; electrotextiles for military, medical, and consumer applications; lightweight deployable antennas; thermal blankets and clothing; flexible keyboards; giant-area flexible circuits for energy harvesting; electrostatic charge dissipation; and battlefield monitoring and reporting of vital signs and wound locations on soldiers.

Syscom is spinning AmberStrand in anticipation of dozens more terrestrial uses for the fibers. These applications are becoming more apparent everyday, with items like heated clothing, wiring for airbag sensors, and electronic textiles (electrotextiles) for military and civilian uses coming into sharp demand.

The electrotextile applications, previously not feasible with standard textiles because of limitations in their ability to conduct current, are now becoming practical. Although the electrotextile industry is still in its infancy, it is almost certain that, in the near future, fabrics will not only protect the wearer from the environment, but will also have intelligent built-in features, such as multifunctional sensors or computing devices. In contrast to rigid electronic components, the electrotextile will be truly flexible, soft, and comfortable to wear and touch.

Electrotextiles will allow wearers a variety of functions, ranging from listening to MP3s to controlling temperature. Like so many electronic entertainment trends, when this catches on, it has the potential to change the electronics industry and make electrotextiles and electronically conductive fibers commonplace, which would create further demand and likely drive down manufacturing costs even further. It may, therefore, likely be common in the near future to see people wearing clothes that are wired with electronic devices like cell phones, PDAs, gaming devices, and music players.

These devices are already being woven into innovative, but experimental, medical apparel—whole jackets or vests that patients wear to transmit vital signs to health care personnel. For military and law enforcement applications, uniforms and body armor can be equipped with built-in sensors and computing devices. The woven textiles allow these technologies to be readily available, but there would not be a sacrifice in flexibility or comfort.

The NASA partnership with Syscom is one of the first steps in bringing these products to market. Previously, lightweight, flexible electrotextiles were not a viable option for manufacturing and building, because they were not available in large quantities. This partnership allows Syscom to offer this technology at reduced cost and at greater quantity, which will spearhead the movement to making this much anticipated technology more accessible. ❖

AmberStrand™ is a trademark of Syscom Technology, Inc.

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

AmberStrand metal-clad polymer fibers can be used to incorporate electronic conductivity into otherwise traditional textiles.

Spatial Phase Imaging

Originating Technology/NASA Contribution

In 1928, Alexander Fleming, a young Scottish scientist with a side practice of discretely treating the syphilis infections of prominent Londoners, was researching agents that could be used to combat such bacterial infections. He left his practice for a 2-week vacation, inadvertently leaving several bacterial culture plates unwashed and out of the incubator. When he returned, what immediately struck him was that the plates had grown mold, but the bacteria Fleming had been working with was being fended off by the mold, which he called penicillin, after the mold *Penicillium notatum*. Although unable to refine or purify the penicillin, Fleming had discovered the archetype of modern antibiotics.

The days of chance drug discovery and extensive trial-and-error testing are over, though. Drugs are not really discovered in this fashion anymore; rather, they are now designed.

Understanding proteins, the basic biological building blocks for all animals (including humans) and the regulators of biochemical processes in plants, helps researchers design these new drugs, combat diseases, and even improve agricultural products, such as pesticides. Researchers are unlocking this knowledge by studying the growth of protein crystals.

Through such study, researchers can now target a specific protein of a pathogen to maximize a drug's effectiveness, while at the same time work to minimize possible side effects. This process, known as rational drug design, has one major downside: The exact structure of the target protein must be determined, down to the last molecule.

To uncover this molecular structure, scientists often use X-ray crystallography. A crystal of the protein is bombarded with X-rays to produce a pattern, which, much like a fingerprint, reveals the identity of the protein's atomic structure. To get an accurate pattern, though, the crystal must be as free of imperfections as possible. Growing such crystals can be extremely difficult—even impossible—on Earth, because gravity causes the crystals to settle on top of one another, which results in structural flaws.

Since 1985, to take advantage of the ability of crystals to grow free of imperfections in microgravity, a variety of protein crystal growth experiments have flown on the space shuttle, and several have flown on the International Space Station (ISS).

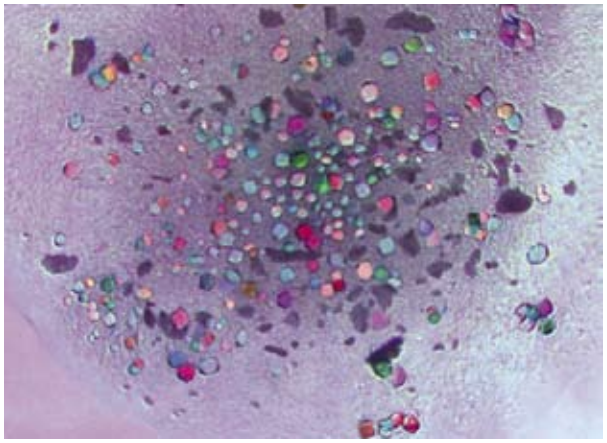
Data collected from the ISS experiments allowed the comparison of growth rates and crystal quality of microgravity versus Earth-grown crystals. The crystals that are grown in microgravity are able to grow larger and better organized than on Earth. The research that is done on these crystals may further human space exploration efforts by technological and biological advancements developed as a direct result from this research and will likely lead to the newest generations of wonder drugs.

Partnership

Frequently, scientists grow crystals by dissolving a protein in a specific liquid solution, and then allowing that solution to evaporate. The methods used next have been, variously, invasive (adding a dye that is absorbed by the protein), destructive (crushing protein/salt-crystal mixtures and observing differences between the crushing of salt and protein), or costly and time-consuming (X-ray crystallography).

In contrast to these methods, a new technology for monitoring protein growth, developed in part through NASA **Small Business Innovation Research (SBIR)** funding from Marshall Space Flight Center, is noninvasive, nondestructive, rapid, and more cost effective than X-ray analysis. The partner for this SBIR, Photon-X, Inc., of Huntsville, Alabama, developed spatial phase imaging technology that can monitor crystal growth in real time and in an automated mode.

Spatial phase imaging scans for flaws quickly and produces a 3-D structured image of a crystal, showing volumetric growth analysis for future automated growth. It can measure the characteristics of a crystal and the crystal's 3-D volumetric properties, and can also discriminate between salt and protein crystals.



Crystallization trial of the glucose isomerase enzyme pseudo-colored by the phase of light from a slurry/crystal mixture and captured in 3-D.

The spatial phase imaging involves the use of proprietary filters. The operator uses a single camera to acquire a series of spatial phase images of a specimen—which could include one or more protein crystals mixed with one or more salt crystals. The next step is to digitally process the image data using algorithms that extract information on the 3-D properties of the protein crystal of interest, including its volume and some aspects of its crystalline structure. This information can be processed further to extract information about the symmetry of the crystal and to detect flaws.

The method is not expected to eliminate the need for X-ray crystallography at the later stages of research. However, as a means of identification and preliminary analysis of protein crystals, it could eliminate or greatly reduce the need for X-ray crystallography as a screening technique in the early stages. In addition to being noninvasive and nondestructive, the new method yields results so rapidly that it is suitable for real-time monitoring

and, hence, for providing process control feedback. This method is expected to accelerate the search for conditions to optimize the growth of proteins and to be a means of automation of the growth of high-quality protein crystals.

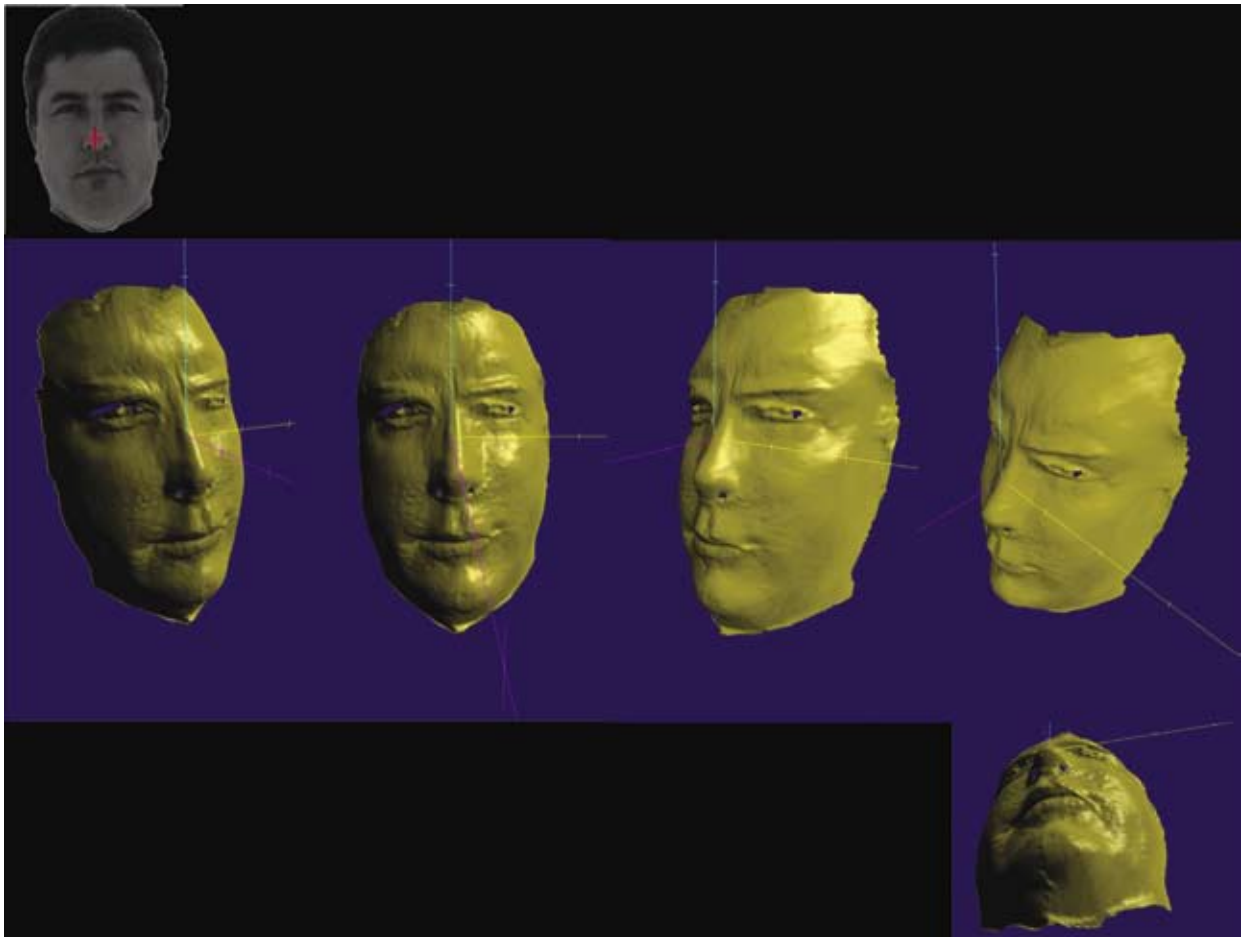
Product Outcome

While the target market for Photon-X's spatial phase imaging technology includes pharmaceutical companies, as well as laboratories at the academic, commercial, structural, and governmental levels, this technology is very desirable to anyone who routinely sets up hundreds or thousands of crystallization experiments on a daily basis, and it is more cost effective than X-ray analysis.

Photon-X has also used this innovative technology to develop commercial 3-D cameras for various machine vision and automated 3-D vision systems. Its Spatial Phase Video Camera is able to extract 3-D information passively without scanned or structured lighting. This technology requires a single camera, a single-image capture, and is independent of range. The 3-D output is smooth and connected, with versatility and depth precision often exceeding that of triangulation-based methods. Plus, by eliminating the need for multiple camera angles, laser illumination, or moving targets to generate usable data, machine vision systems based on the sensor technology can be less expensive and easier to install, and as passive devices, present no laser radiation hazard to personnel.

The Photon-X 3-D spatial phase imaging system can rapidly provide highly accurate data about the surface features of its target. This information can be processed by existing applications to determine the area, volume, or height of surface features. This patented, innovative approach to characterizing surface elements is angle-invariant and easily scaled to suit a variety of applications, meaning that surface features can be recognized at a variety of distances and angles.

By simply changing its field of view, the technology has been successfully demonstrated in systems whose imaged targets range in size from microscopic crystals, to faces, automobiles, and aircraft; even to terrain features measuring hundreds of yards in width at distances up to several miles from the sensor unit itself.



Photon-X's 3-D camera technology can capture a 3-D image in single camera frame time. One application, face verification software, has been successfully demonstrated and shown to be a strong 3-D face verification tool.

Specific applications include machine vision, many different types of inspection, rapid prototyping, target or object recognition, surface damage assessments, deformation analysis, defect detection and characterization, terrain mapping, and biometric facial recognition, which analyzes a person's facial characteristics through digital video input. The images can be used to construct intricate composites, which are then stored in a database. This method of identification is currently being used for security systems, but law enforcement agencies are now exploring its application in terrorist and criminal recognition. ❖

Miniature Wireless Sensors Size Up to Big Applications

Originating Technology/NASA Contribution

Like the environment of space, the undersea world is a hostile, alien place for humans to live. But far beneath the waves near Key Largo, Florida, an underwater laboratory called Aquarius provides a safe harbor for scientists to live and work for weeks at a time.

Aquarius is the only undersea laboratory in the world. It is owned by the National Oceanic and Atmospheric Administration (NOAA), administered by NOAA's National Undersea Research Program, and operated by the National Undersea Research Center at the University of North Carolina at Wilmington. Aquarius was first deployed in underwater operations in 1988 and has since hosted more than 200 scientists representing more than 90 organizations from around the world.

For NASA, Aquarius provides an environment that is analogous to the International Space Station (ISS) and the space shuttle. As part of its NASA Extreme Environment Mission Operations (NEEMO) program, the Agency sends personnel to live in the underwater laboratory for up to 2 weeks at a time, some of whom are crew members—or "aquanauts"—who are subjected to the same tasks and challenges underwater that they would face in space. In fact, many participants have found the deep-sea diving experience to be much akin to spacewalking.

To maintain Aquarius, the ISS, and the space shuttle as safe, healthy living/research habitats for its personnel—while keeping costs in mind—NASA, in 1997, recruited the help of Conroe, Texas-based Invocon, Inc., to develop wireless sensor technology that monitors and measures various environmental and structural parameters inside these facilities.

Partnership

This project, funded through a Johnson Space Center **Small Business Innovation Research (SBIR)** contract, focused on developing wireless sensors to help cut back on the integration costs associated with wired sensors. It included the conceptual design, fabrication, and demonstration of a battery-powered, miniature, wireless temperature sensor. NASA and Invocon agreed to take Invocon's existing wireless network communication system and combine it with various microelectromechanical systems (MEMS) sensors. The innovation consisted of a PC interface unit, a graphical user interface, and multiple wireless sensors that are each equivalent in size to a stack of five quarters.

Upon completion of the miniature wireless sensor technology, Johnson's Human Exploration and Development of Space program (now part of the Space Operations Mission Directorate) sought to apply it to the space shuttle to acquire temperature data from several fundamental locations in and around the shuttle crew compartment and avionics equipment. High above the depths of Aquarius, the sensor system has flown and operated successfully on space shuttle missions STS-92, STS-96, STS-97, STS-100, STS-101, STS-104, STS-106, and STS-108. Further use of the technology is being investigated for monitoring carbon dioxide concentrations onboard the ISS, in the crew's sleeping quarters, and in regions of reduced airflow.

Crew members for the ninth NASA Extreme Environment Mission Operations (NEEMO) excursion arrive at their underwater home: the Aquarius Underwater Laboratory, off the coast of Key Largo, Florida. Canadian astronaut Dave Williams led the crew of four, which included NASA astronauts Ronald Garan and Nicole Stott, and University of Cincinnati physician Tim Broderick.

Product Outcome

After emerging from the sea and shooting high into the heavens, Invocon's wireless sensor system has made a terrestrial landing as a product called MicroWIS-CO_2. This commercial offspring is a wireless, remote, low-power, carbon dioxide data-acquisition system for near-static sensing and recording applications. It uses a non-dispersive infrared diffusion method for carbon dioxide measurement. Carbon dioxide diffuses into the sensor's optical chamber, and molecules of the gas absorb infrared light. This absorption is measured to derive the carbon dioxide concentration.

MicroWIS-CO_2 offers three modes of data transfer once the carbon dioxide level is determined. The unit can transmit data in real time to an associated receiver; store information in a memory bank for later downloading, via radiofrequency, to either the receiver or a PC; or conveniently combine both of these modes to stream real-time information while backing it up in memory.

Invocon has also spun off several "next-generation" MicroWIS products that are configured for applications other than carbon dioxide sensing. The latest of these products, the MicroWIS-XG, can be used for sensing environmental, temperature, strain, and pressure parameters, for example.

In the area of construction, one of these next-generation systems was used to monitor external grout pressure during the building of three tunnels in the Netherlands.

The miniature wireless sensor developed for NASA is equivalent in size to a stack of five quarters. The technology has helped NASA acquire important data to keep astronauts' remote living quarters safe and has been applied to a variety of sensing applications on Earth.

When boring tunnels through the ground, proper grout pressure is critical, because it controls the amount of grout that is deposited on the exterior of the tunnel, which ultimately determines the strength of the water-seal and durability of the tunnel throughout its useful life. Another important reason to maintain proper grout pressure is that it influences surface elevation of the ground directly above the tunnel. When the grout pressure becomes too low during construction, the surface can sink. This becomes problematic in areas where much of the land is at or below sea level.

Dutch Government regulations required that strict controls were used during construction in order to ensure that the tunnels would maintain their integrity for 100 years or longer. The MicroWIS technology was called upon to monitor grout pressure at several locations during the building phase to verify that the project met quality and safety requirements. The wireless nature of the system greatly simplified the building process and eliminated any risks that could have come from wires and power cables that could have been cut when exposed to the boring machines used to dig through the ground to assemble the tunnels.

In 2002, MicroWIS systems were used by the University of Houston to study stresses during construction and testing of a local bridge. This application stemmed from concerns that certain sections of a bridge may actually be compromised in the construction process due to inadequate support during handling and installation.

To test this theory, 112 MicroWIS units were mounted at key locations on the bridge—between main box girders and on temporary k-frames—to determine stress loads during the 6-month construction process. Data sampling took place once every 8 minutes or once every 30 minutes, depending on the stage of construction. The units measured the strains induced on the bridge beams by both mechanical loads and diurnal temperature effects. The measurements taken and the resulting data produced by the units prevented the builders from adding any unnecessary loads or strains to the sections of the bridge in question.

Since developing the sensors for NASA, Invocon has gone on to manufacture monitoring solutions that have flown on 20 space shuttle missions, including the latest STS-114 mission. By continuing to support NASA with new technologies bound for space, the company is reaping the benefits of bringing new ideas down to Earth. ❖

MicroWIS™ is a trademark of Invocon, Inc.

Research and Development at NASA

The success of the Vision for Space Exploration 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 formed four Mission Directorates: Space Operations, Exploration Systems, Science, and Aeronautics Research. These directorates provide NASA Headquarters and the field centers with a streamlined approach to continue exploration in space and on Earth.

Research and Development at NASA

NASA Will Crash an Impactor on the Moon in Search of Water

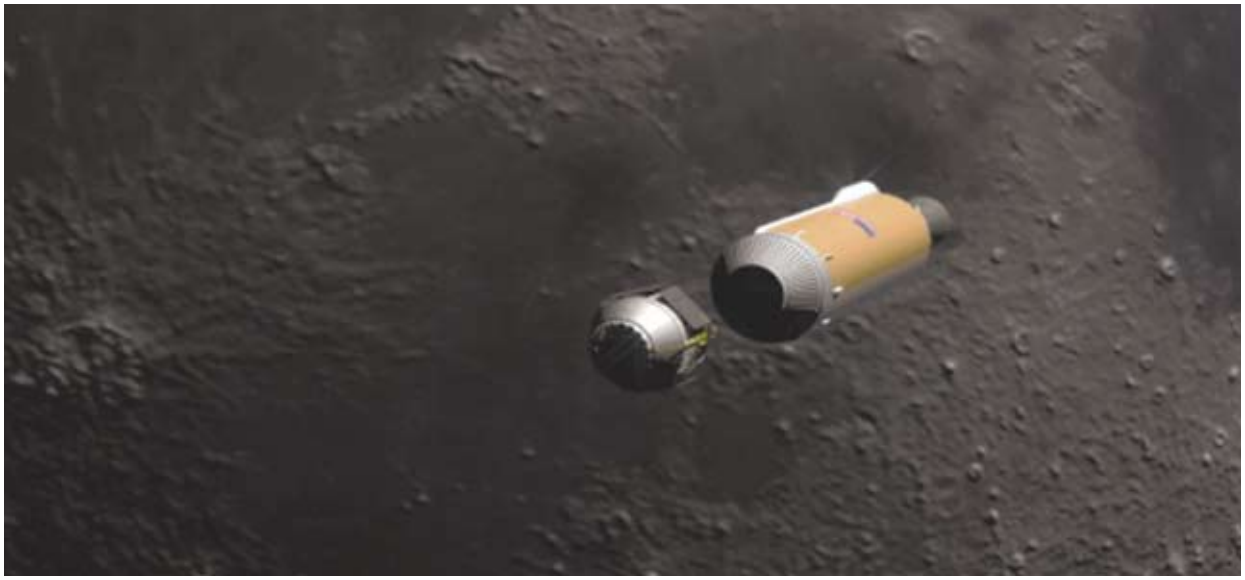
To kick off the quest for lunar water ice, NASA announced that a small, secondary payload spacecraft to be developed by Ames Research Center will begin a trip to the Moon in October 2008 to look for precious water.

The water-seeking spacecraft is called the Lunar CRater Observation and Sensing Satellite (LCROSS). It is known as a secondary payload spacecraft because it will begin its trip to the Moon on the same rocket as the Lunar Reconnaissance Orbiter (LRO), which is on a different mission to the Moon. The rocket, the Evolved Expendable Launch Vehicle, will launch from Kennedy Space Center.

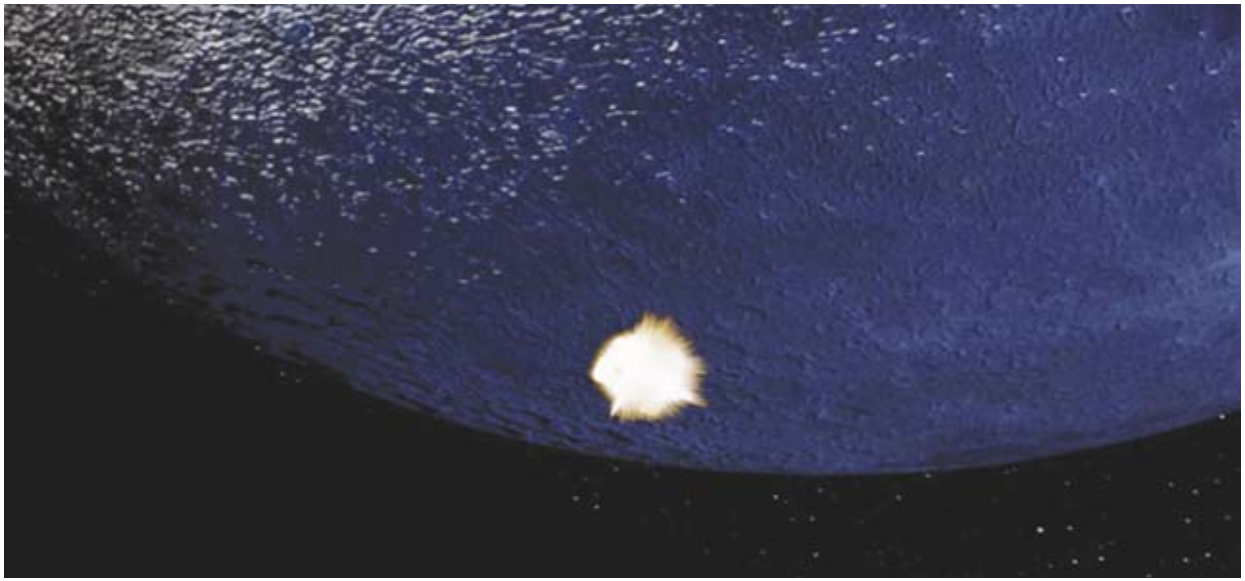
The LCROSS spacecraft will arrive in the lunar vicinity independent of the LRO satellite. Prior to impacting the Moon, LCROSS will orbit Earth twice for about 80 days, and will then strike the lunar south pole in January 2009.

On the way to the Moon, the LCROSS spacecraft's two main parts, the Shepherding Spacecraft and the Earth Departure Upper Stage, will remain coupled. As the spacecraft approaches the Moon's south pole, the Earth Departure Upper Stage will separate, and will then impact a crater in the south pole area. A 2.2-million-pound plume from the Earth Departure Upper Stage crash will develop as the Shepherding Spacecraft heads in toward the Moon.

The Shepherding Spacecraft will fly through the plume, and instruments on the spacecraft will analyze the cloud to look for signs of water and other compounds. At the end of its mission, the satellite will itself become an impactor, creating a second plume visible to lunar-orbiting spacecraft and Earth-based observatories.



In this artist's concept, the Earth Departure Upper Stage and the Shepherding Spacecraft approach the Moon (above); the Earth Departure Upper Stage impacts at the south pole (below).



How We Will Get Back to the Moon

Before the end of the next decade, NASA astronauts will again explore the surface of the Moon. This time, they

are going to stay, building outposts and paving the way for eventual journeys to Mars and beyond.

This journey begins soon, with the development of a new spaceship. Building on the best of past and present technology, NASA is creating a 21st century exploration system that will be affordable, reliable, versatile, and safe.

The centerpiece of this system is a new spacecraft designed to carry four astronauts to and from the Moon, deliver up to six crewmembers and supplies to the International Space Station (ISS), and support future missions to Mars.

The new Crew Exploration Vehicle (CEV) will be shaped like an Apollo capsule, but it will be significantly larger and include solar panels for power. The new ship will be built to minimize life-cycle costs. Designers are looking at the pros and cons of a variety of different systems that will ensure that the crew vehicle, as well as the launch and landing systems, are sustainable for long-term use by the next generation of space explorers.

A rocket fires for translunar injection, carrying the Crew Exploration Vehicle and lunar lander toward the Moon.

Coupled with the new lunar lander, the system will send twice as many astronauts to the lunar surface as Apollo, and they can stay longer, with the initial missions lasting 4 to 7 days. While Apollo was limited to landings along the Moon's equator, the new ship will carry enough propellant to land anywhere on the Moon's surface.

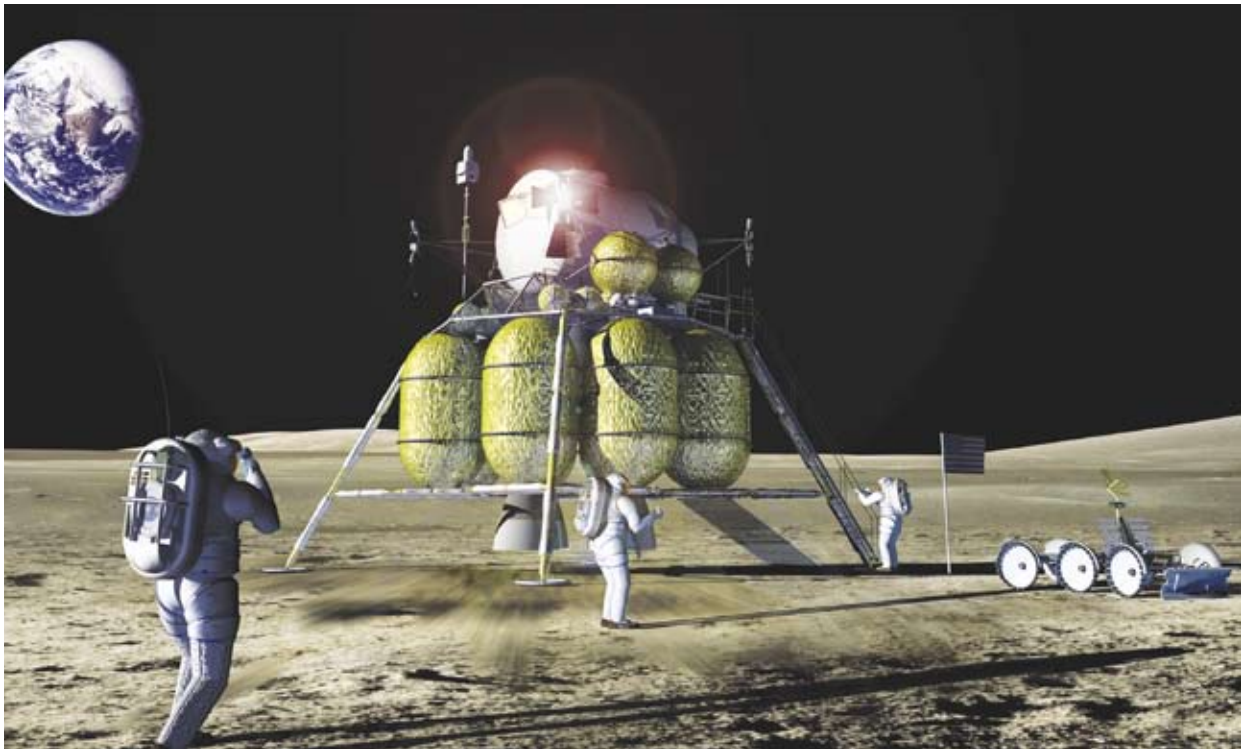
Once a lunar outpost is established, crews could remain on the surface for up to 6 months. The capsule will also operate for up to 6 months in lunar orbit without a crew, eliminating the need for one astronaut to stay behind while others explore the surface.

The launch system that will get the crew off the ground builds on powerful, reliable propulsion elements. Astronauts will launch on a rocket made up of a longer shuttle solid rocket booster, with a second stage powered by a J-2X engine, like the kind used on the Apollo Saturn V rockets.

A second, heavy-lift system will use a pair of the longer solid rocket boosters and five liquid-fueled engines to put up to 125 metric tons in orbit—slightly more than the weight of a shuttle orbiter. This versatile system will be used to put the components needed to go to the Moon and Mars into orbit. The heavy-lift rocket may be modified to carry crew as well.

Best of all, the capsule will be 10 times safer than the shuttle because of an escape rocket on top that can quickly blast the crew away if launch problems develop. There also will be little chance of damage from launch vehicle debris, since the capsule will sit on top of the rocket.

Early in the next decade, the new ship will begin to ferry crew and supplies to the ISS. Plans call for as many as six trips to the station a year. In the meantime, robotic missions will lay the groundwork for lunar exploration.



As many as four astronauts could land on the Moon in the new lunar lander, a spacecraft that recalls the Apollo era but would be leagues more advanced.

NASA plans to return humans to the Moon as early as 2018. Here is how a mission will unfold:

A heavy-lift rocket blasts off, carrying a lunar lander and a "departure stage" needed to leave Earth's orbit. The crew launches separately, docks its capsule with the lander and departure stage, and then heads for the Moon.

Three days later, the crew enters lunar orbit. The four astronauts climb into the lander, leaving the capsule to wait for them in orbit. After landing and exploring the surface for 7 days, the crew blasts off in a portion of the lander, docks with the waiting capsule, and then travels back to Earth. After a de-orbit burn, the service module portion of the capsule is jettisoned, exposing the heat shield for the first time in the mission. After a fiery descent through Earth's atmosphere, parachutes deploy, the heat shield is dropped, and the capsule lands.

With a minimum of two lunar missions per year, momentum will build quickly toward a permanent outpost. Crews will stay longer and learn to exploit the Moon's resources, while landers make one-way trips to deliver cargo. Eventually, the new system could rotate crews to and from a lunar outpost every 6 months.

Planners are already looking at the lunar south pole as a candidate for an outpost, because of concentrations of hydrogen thought to be in the form of water ice and an abundance of sunlight to provide power.

These plans give NASA a huge head start in getting to Mars. The United States will already have the heavy-lift system needed to get there, as well as a versatile crew capsule capable of taking the crew to and from a Mars vehicle in low-Earth orbit. A lunar outpost just 3 days away from Earth will give NASA the needed practice of living on another world away from Earth, before making the longer trek to Mars.

NASA Team Develops Spacecraft Armor

Six NASA centers from across the country are joining together with one common goal: advanced development of a heat shield that will protect the next generation of

Astronauts living at the lunar outpost, likely to be located on the Moon's south pole, will use the site for scientific data collection and, eventually, as a stopover on a trip to Mars.

space vehicles. The final flight version of the heat shield and ancillary support systems will be designed and manufactured by the CEV prime contractor when that contract is awarded.

As the CEV returns from future missions to the Moon, it will bore through Earth's atmosphere at speeds exceeding 6.8 miles per second. Those speeds can generate temperatures that exceed 4,800 °F.

The space shuttle, by comparison, enters at a speed of 4.7 miles per second and sees a maximum temperature of 2,900 °F. The crew vehicle will see temperatures of up to 3,400 °F when reentering from low-Earth orbit.

The faster entry velocities, and especially the higher temperatures, will make providing for the safe return of NASA's crew vehicle a real challenge. To reach this goal, a team comprised of engineers from six of NASA's field centers will conduct atmospheric reentry materials and structures tests leading to the design and development of a new heat shield.

"You can think of the CEV heat shield as a large Frisbee-like disc that is attached to the bottom of the crew vehicle," said James Reuther, Thermal Protection System Advanced Development Project (TPS ADP) manager at Ames.

The TPS ADP is led by Ames for the CEV Project Office. Teams from Langley Research Center, Johnson Space Center, Glenn Research Center, Kennedy Space Center, and the Jet Propulsion Laboratory (JPL) are collaborating in this effort.

NASA's two large arcjet facilities at Ames and Johnson are home to experiments specifically designed to test heat shield materials under conditions that simulate the searing heat and pressure experienced during reentry. These arcjet tests will determine whether a current set of candidate TPS materials will provide the crew vehicle enough protection during its fiery descent back to Earth.

Thermal mechanical testing at Langley is leading toward a better understanding of the structural aspects of the TPS materials. Langley is also designing the attachment and separation system, as well as the carrier structure (used to hold onto the TPS material), for the heat shield.

Glenn researchers are working with Ames and Langley to develop the main seal for the heat shield. They are doing a state-of-the-art review of previously and currently used seal options, seal manufacturers, potential risks, and pros and cons for each option in order to provide recommended seal options with corresponding attributes and risks.

Engineers at Kennedy will conduct various nondestructive tests to analyze the quality of full-size manufactured demonstration units for the crew vehicle's heat shield.

JPL engineers are working with Ames engineers to develop and document a robust set of TPS requirements and associated verification and validation plans for evaluating contractor implementations. They are also working with Langley engineers to design the attachment and separation system for the heat shield. They have completed a state-of-the-art review of previously and currently used mechanical attachment and separation options, and are now refining and analyzing one option being considered.

To remain on the proposed schedule of launching the CEV in 2014, NASA's widespread TPS team is working to complete the advanced development and select the final TPS material and overall design of a durable heat shield by 2009.

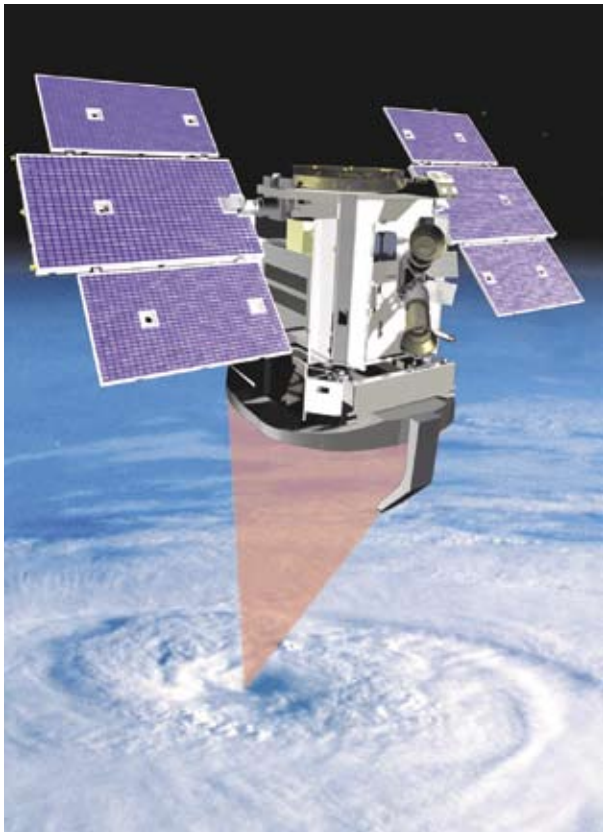
"Unlike some of the other elements of the CEV design, the heat shield material selection and design is being run as an open competition," said Reuther. "It is a real challenge to produce a heat shield design that can both protect the CEV from the extreme heat of entry and simultaneously be produced as a single 16.5-foot-diameter lightweight and robust dish."

This advanced development is under the direction of the CEV project at Johnson. George Sarver, manager of Ames's CEV/Crew Launch Vehicle Support Office, concluded, "NASA's expertise in the field of thermal protection, across all of NASA's centers, is world class."

NASA Launches Satellites for Weather, Climate, and Air Quality Studies

Two NASA satellites were launched in April from Vandenberg Air Force Base, California, on missions to reveal the inner secrets of clouds and aerosols, tiny particles suspended in the air.

Artist's concept of NASA's CloudSat spacecraft, which will provide the first global survey of cloud properties to better understand their effects on both weather and climate.



This artist's concept shows NASA's CloudSat spacecraft and its Cloud-Profiling Radar using microwave energy to observe cloud particles and determine the mass of water and ice within clouds. The mission will collect information about the vertical structure of clouds that will help answer key questions about how they form, evolve, and affect our weather, climate, and water supply.

CloudSat and CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) thundered skyward atop a Boeing Delta II rocket. The two satellites will eventually circle approximately 438 miles above Earth in a Sun-synchronous polar orbit, which means they will always cross the equator at the same local time. Their technologies will enable scientists to study how clouds and aerosols form, evolve, and interact.

"Clouds are a critical but poorly understood element of our climate," said Dr. Graeme Stephens, CloudSat principal investigator and a professor at Colorado State University. "They shape the energy distribution of our climate system and our planet's massive water cycle, which delivers the fresh water we drink that sustains all life."

"With the successful launch of CloudSat and CALIPSO, we take a giant step forward in our ability to study the global atmosphere," said Dr. David Winker, CALIPSO principal investigator at Langley. "In the years to come, we expect these missions to spark many new insights into the workings of Earth's climate and improve our abilities to forecast weather and predict climate change."

Each spacecraft will transmit pulses of energy and measure the portion of the pulses scattered back to the satellite. CloudSat's Cloud-Profiling Radar is over 1,000 times more sensitive than typical weather radar. It can

detect clouds and distinguish between cloud particles and precipitation. CALIPSO's polarization lidar can detect aerosol particles and distinguish them from cloud particles. Lidar, similar in principle to radar, uses reflected light to determine the characteristics of the target area.

The satellites will fly in formation as members of NASA's "A-Train" constellation, which also includes NASA's Aqua and Aura satellites and a French satellite known as Parasol, for Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar. The satellite data will be more useful when combined, providing insights into the global distribution and evolution of clouds to improve weather forecasting and climate prediction.

CloudSat is managed by JPL, which developed the radar instrument with hardware contributions from the Canadian Space Agency; Colorado State University provides scientific leadership and science data processing and distribution; Ball Aerospace and Technologies Corporation, of Boulder, Colorado, designed and built the spacecraft; the U.S. Air Force and U.S. Department of Energy contributed resources; and American and international universities and research centers support the mission science team.

CALIPSO is a collaboration between NASA and the French space agency, Centre National d'Etudes Spatiales (CNES). Langley is leading the CALIPSO mission and providing overall project management, systems engineering, and payload mission operations; Goddard Space Flight Center is providing support for system engineering and project and program management; CNES is providing a Proteus spacecraft developed by Alcatel Space, a radiometer instrument, and spacecraft mission operations; Hampton University, in Hampton, Virginia, is providing scientific contributions and managing the outreach program; Ball Aerospace developed the lidar and onboard visible camera; and NASA's Launch Services Program at Kennedy procured the mission's launch and provided management for the mission's launch service.

NASA Scientists Achieve Breakthrough in Black Hole Simulation

NASA scientists have made a breakthrough in computer modeling that allows them to simulate what gravitational waves from merging black holes look like. The 3-D simulations, the largest astrophysical calculations ever performed on a NASA supercomputer, provide the foundation to explore the universe in an entirely new way.

According to Albert Einstein's math, when two massive black holes merge, all of space jiggles like a bowl of gelatin as gravitational waves race out from the collision at light speed. Previous simulations had been plagued by computer crashes, as the necessary equations, based on Einstein's theory of general relativity, were far too complex. Scientists at Goddard, however, have found a method to translate Einstein's math in a way that computers can understand.

"These mergers are by far the most powerful events occurring in the universe, with each one generating more energy than all of the stars in the universe combined. Now we have realistic simulations to guide gravitational wave detectors coming online," said Joan Centrella, chief of the Gravitational Astrophysics Laboratory at Goddard.

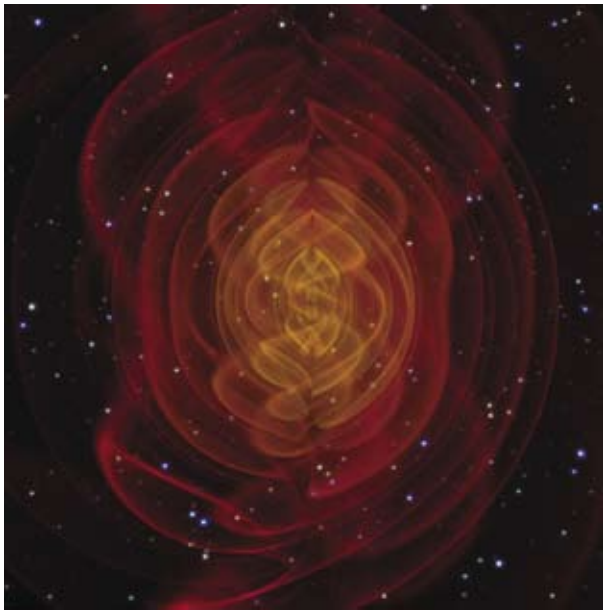
Similar to ripples on a pond, gravitational waves are ripples in space and time, a four-dimensional concept that Einstein called spacetime. They have not yet been directly detected. Furthermore, gravitational waves hardly interact with matter and, thus, can penetrate the dust and gas that block the view of black holes and other objects. They offer a new window to explore the universe and provide a precise test for Einstein's theory of general relativity. The National Science Foundation's ground-based Laser Interferometer Gravitational-Wave Observatory and the proposed Laser Interferometer Space Antenna, a joint NASA-European Space Agency project, hope to detect these subtle waves.

Black hole mergers produce copious gravitational waves, sometimes for years, as the black holes approach

Gravitational Astrophysics Laboratory team members. From left to right: Michael Koppitz, Jim Van Meter, Joan Centrella, and John Baker.

each other and collide. Black holes are regions where gravity is so extreme that nothing, not even light, can escape their pull. They alter spacetime. Therein lies the difficulty in creating black hole models; space and time shift, density becomes infinite, and time can come to a standstill. Such variables cause computer simulations to crash.

These massive, colliding objects produce gravitational waves of differing wavelengths and strengths, depending on the masses involved. The Goddard team has perfected the simulation of merging, equal-mass, non-spinning black holes starting at various positions corresponding to the last two to five orbits before their merger.



This visualization shows what Albert Einstein envisioned. Researchers crunched Einstein's theory of general relativity on the Columbia supercomputer at Ames Research Center to create a 3-D simulation of merging black holes. The simulation provides the foundation to explore the universe in an entirely new way, through the detection of gravitational waves.

With each simulation run, regardless of the starting point, the black holes orbited stably and produced identical waveforms during the collision and its aftermath. This unprecedented combination of stability and reproducibility assured the scientists that the simulations were true to Einstein's equations. The team has since moved on to simulating mergers of nonequal-mass black holes.

Einstein's theory of general relativity employs a type of mathematics called tensor calculus, which cannot easily be turned into computer instructions. The equations need to be translated, which greatly expands them. The simplest tensor calculus equations require thousands of lines of computer code. The expansions, called formulations, can be written in many ways. Through mathematical intuition, the Goddard team found the appropriate formulations that led to suitable simulations.

The simulations were performed on the Columbia supercomputer at Ames. Progress also has been made independently by several other groups, including researchers at the Center for Gravitational Wave Astronomy at the University of Texas, Brownsville, which is supported by NASA's Minority University Research and Education Programs.

Stardust Mission Findings May Alter View of Comet Formation

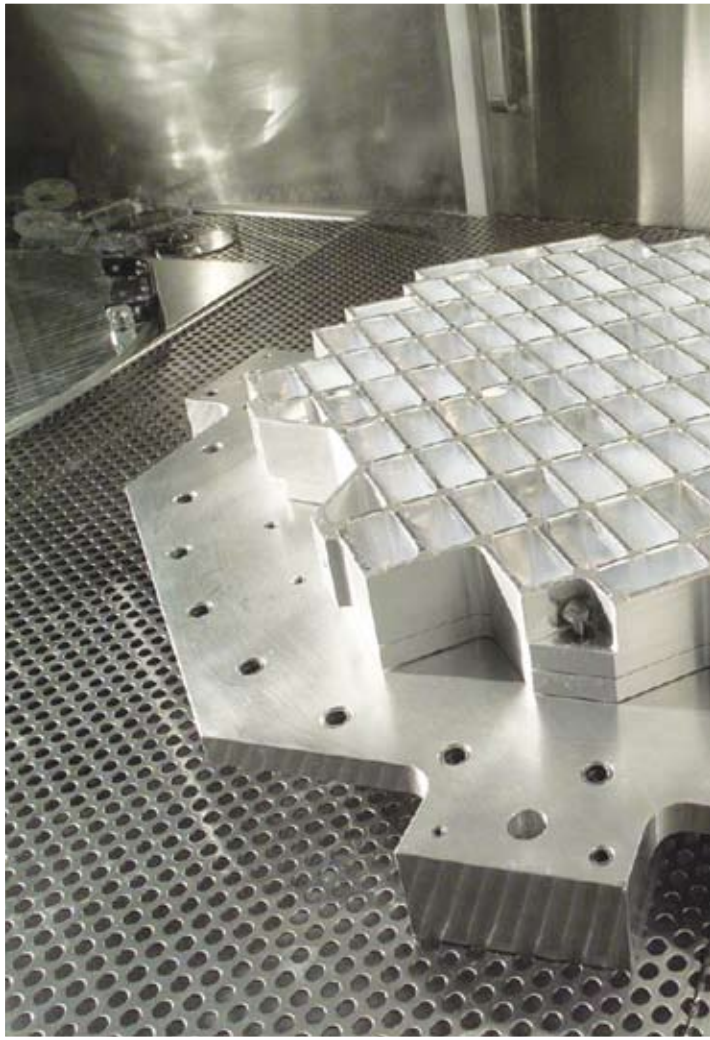
To scientists' surprise, samples from comet Wild 2 indicate that the formation of at least some comets may have included materials ejected by the early Sun to the far reaches of the solar system.

Scientists have found minerals formed near the Sun or other stars in the samples returned to Earth by NASA's Stardust spacecraft in January. The findings suggest materials from the center of the solar system could have traveled to the outer reaches where comets formed. This may alter the way scientists view the formation and composition of comets.

"The interesting thing is we are finding these high-temperature minerals in materials from the coldest place in the solar system," said Donald Brownlee, Stardust principal investigator from the University of Washington, Seattle.

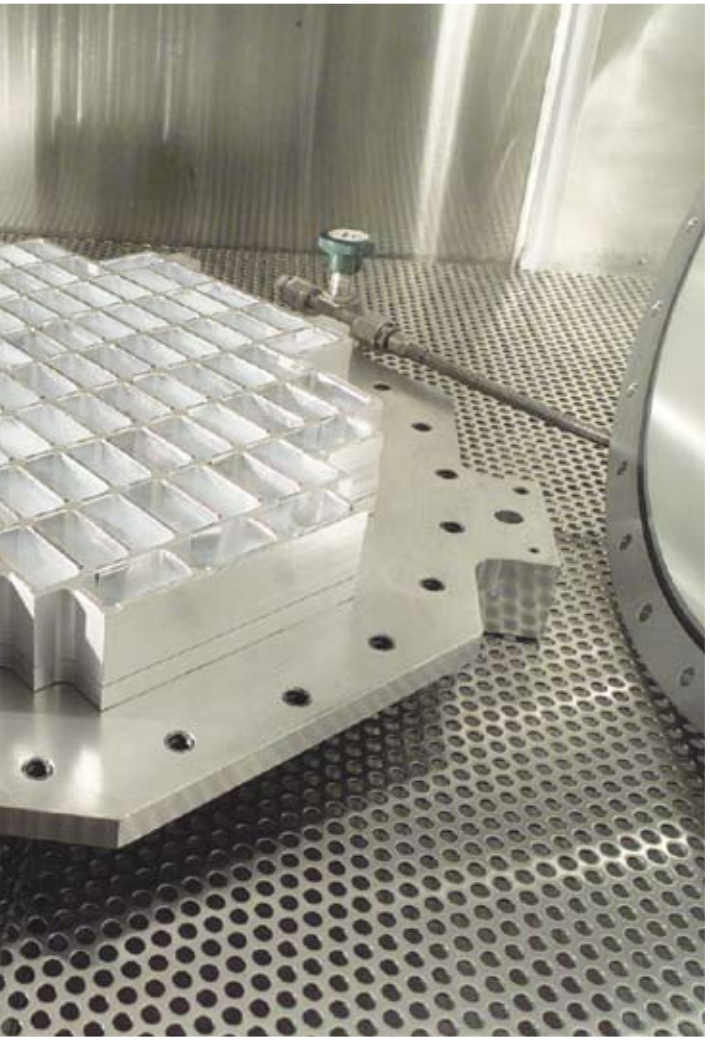
Scientists have long thought of comets as cold, billowing clouds of ice, dust, and gases formed on the edges of the solar system. But comets may not be so simple or similar; they may prove to be diverse bodies with complex histories. Comet Wild 2 seems to have had a more complex history than thought.

"We have found very-high-temperature minerals, which supports a particular model where strong bipolar jets coming out of the early Sun propelled material formed near to the Sun outward to the outer reaches of the solar system," said Michael Zolensky, Stardust curator and co-investigator at Johnson. "It seems that comets are not



composed entirely of volatile-rich materials but rather are a mixture of materials formed at all temperature ranges, at places very near the early Sun, and at places very remote from it."

One mineral found in the material brought back by Stardust is olivine, a primary component of the green sand



found on some Hawaiian beaches. It is among the most common minerals in the universe, but scientists were surprised to find it in cometary dust.

Olivine is a compound of iron, magnesium, and other elements. The Stardust sample is primarily magnesium. Along with olivine, the dust from Wild 2 contains high-temperature minerals rich in calcium, aluminum, and titanium.

To collect particles without damaging them, the Stardust spacecraft used an extraordinary substance called aerogel, seen above in the form of a 2-gram piece supporting the weight of a much heavier 2.5-kilogram brick. Aerogel is a silicon-based solid with a porous, sponge-like structure in which 99.8 percent of the volume is empty space. It was fitted into the tennis racquet-shaped collector, on the left. One side of the collector faced towards the particles in Comet Wild 2, while the reverse side faced the streams of interstellar dust encountered during the journey.

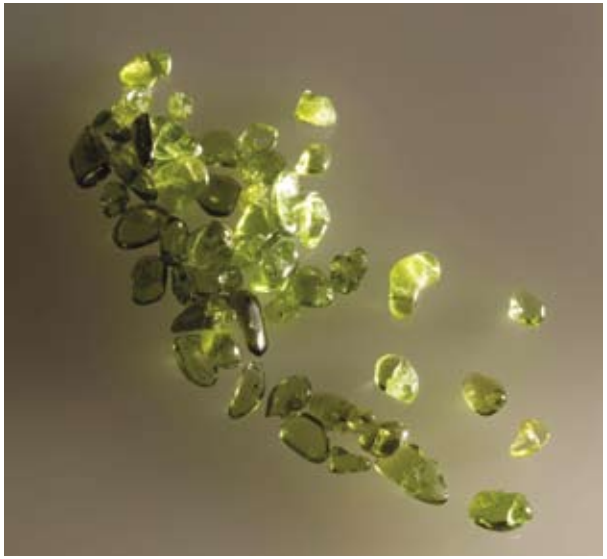
Stardust passed within 149 miles of comet Wild 2 in January 2004, trapping particles from the comet in an exposed gel. Its return capsule parachuted to the Utah desert 2 years later, on January 15 of this year. The science canister with the Wild 2 sample arrived at Johnson on January 17. Samples have been distributed to approximately 150 scientists for study.

"The collection of cometary particles is greater than we ever expected," said Peter Tsou, Stardust deputy principal investigator at JPL. "The collection includes about two-dozen large tracks visible to the unaided eye."

The grains are tiny, with most being smaller than a hair's width. A single grain of 10 microns, only one-hundredth of a millimeter, can be sliced into hundreds of samples for scientists.

In addition to cometary particles, Stardust gathered interstellar dust samples during its 7-year, 2.88 billion-mile journey. A team at Johnson's curatorial facility is carrying out a detailed scanning of the interstellar samples. In doing so, it will initiate the "Stardust@Home" project, which will enable volunteers from the public to help scientists locate particles.

The velocity of the sample return capsule that entered the Earth's atmosphere in January was the fastest of any human-made object on record. It surpassed the record



One mineral found in the material brought back by Stardust is olivine, a primary component of the green sand found on some Hawaiian beaches.

set in May 1969 during the return of the Apollo 10 Command Module.

JPL manages the Stardust mission for the Science Mission Directorate.

Cassini Discovers Potential Liquid Water on Enceladus

NASA's Cassini spacecraft may have found evidence of liquid-water reservoirs that erupt in Yellowstone National Park-like geysers on Saturn's moon, Enceladus. The rare occurrence of liquid water so near the surface raises many new questions about the mysterious moon.

"We realize that this is a radical conclusion—that we may have evidence for liquid water within a body so small and so cold," said Dr. Carolyn Porco, Cassini imaging team leader at the Space Science Institute, of Boulder, Colorado. "However, if we are right, we have significantly broadened the diversity of solar system environments where we might possibly have conditions suitable for living organisms."

High-resolution Cassini images show icy jets and towering plumes ejecting large quantities of particles at high speed. Scientists examined several models to explain the process. They ruled out the idea that the particles are produced by or blown off the moon's surface by vapor created when warm water ice converts to a gas. Instead, scientists have found evidence for a much more exciting possibility: the jets might be erupting from near-surface pockets of liquid water above 0 °C, like cold versions of the Old Faithful geyser in Yellowstone.

"We previously knew of, at most, three places where active volcanism exists: Jupiter's moon, Io; Earth; and possibly Neptune's moon, Triton. Cassini changed all that, making Enceladus the latest member of this very exclusive club, and one of the most exciting places in the solar system," said Cassini scientist Dr. John Spencer, of Southwest Research Institute.

"Other moons in the solar system have liquid-water oceans covered by kilometers of icy crust," said Dr. Andrew Ingersoll, imaging team member and atmospheric scientist at the California Institute of Technology. "What is different here is that pockets of liquid water may be no more than tens of meters below the surface."

Other unexplained oddities now make sense. "As Cassini approached Saturn, we discovered that the Saturnian system is filled with oxygen atoms. At the time, we had no idea where the oxygen was coming from," said Dr. Candy Hansen, Cassini scientist at JPL. "Now we know that Enceladus is spewing out water molecules, which break down into oxygen and hydrogen."

This enhanced color view of Enceladus was created from 21 false-color frames taken during the Cassini spacecraft's close approaches to the Saturnian moon on March 9 and July 14 of this year. The south polar terrain is marked by a striking set of fractures and encircled by a conspicuous and continuous chain of folds and ridges.

Scientists are also seeing variability at Enceladus. "Even when Cassini is not flying close to Enceladus, we can detect that the plume's activity has been changing through its varying effects on the 'soup' of electrically charged particles that flow past the moon," said Dr. Geraint H. Jones, Cassini scientist, magnetospheric imaging instrument, Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany.

Scientists still have many questions: Why is Enceladus currently so active? Are other sites on Enceladus active? Might this activity have been continuous enough over the moon's history for life to have had a chance to take hold in the moon's interior?

"Our search for liquid water has taken a new turn," said Dr. Peter Thomas, Cassini imaging scientist at Cornell University, in Ithaca, New York. "The type of evidence for liquid water on Enceladus is very different from what we've seen at Jupiter's moon, Europa. On Europa, the evidence from surface geological features points to an internal ocean. On Enceladus, the evidence is direct observation of water vapor venting from sources close to the surface."

In the spring of 2008, scientists will get another chance to look at Enceladus when Cassini flies within approximately 220 miles of the moon, though much work remains after Cassini's 4-year prime mission is over.

"There is no question that, along with the moon Titan, Enceladus should be a very high priority for us. Saturn has given us two exciting worlds to explore," said Dr. Jonathan Lunine, Cassini interdisciplinary scientist at the University of Arizona, Tucson.

The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency, and the Italian Space Agency. The Cassini orbiter was designed, developed, and assembled at JPL.

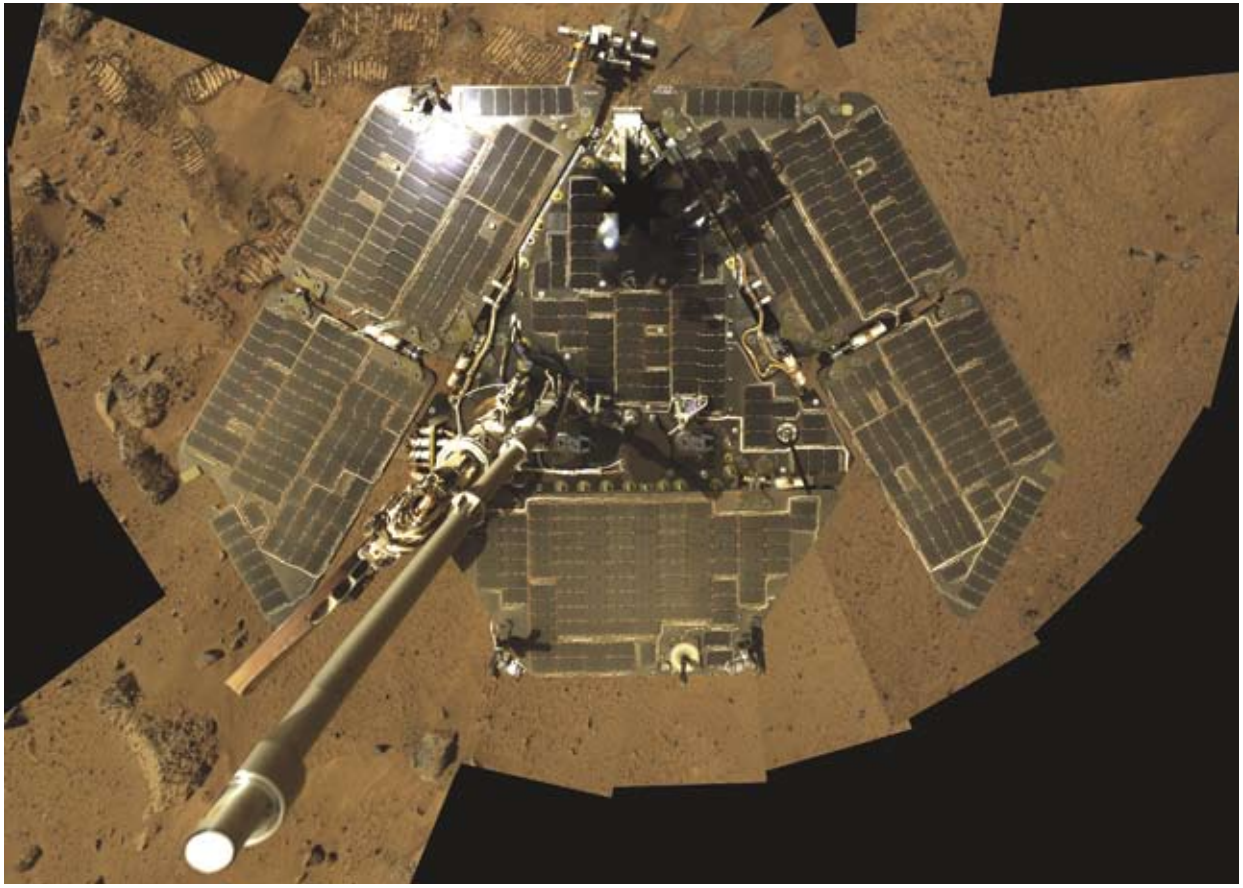
Mars Rovers Advance Understanding of the Red Planet

Still going…

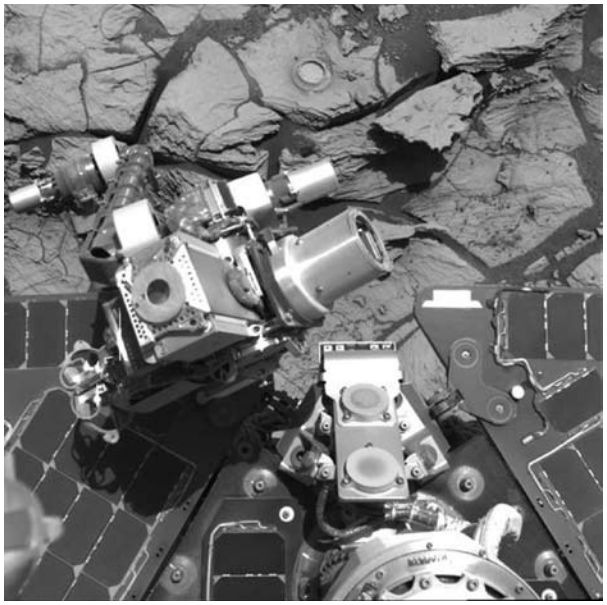
Mars rovers Spirit and Opportunity have been working overtime to help scientists better understand ancient environmental conditions on the Red Planet. The rovers are also generating excitement about the exploration of Mars outlined in the Vision for Space Exploration. They continue to find new variations of bedrock in areas they are exploring on opposite sides of Mars. The geological information they have collected adds evidence about ancient Martian environments that included periods of wet, possibly habitable conditions.

"The extended journeys taken by the two rovers across the surface of Mars have allowed the science community to continue to uncover discoveries that will enable new investigations of the Red Planet far into the future," said Mary Cleave, associate administrator for the Science Mission Directorate.

The rovers are currently on their third mission extension. During their 3-month primary missions, the rovers drove farther and examined more rocks than the prescribed criteria for success.



This self-portrait of Spirit reveals that the rover's solar panels are still gleaming in the Martian sunlight and are carrying only a thin veneer of dust more than 2 years after it landed and began exploring the Red Planet.



In January 2006, NASA's Mars Exploration Rover team adopted a new strategy for carrying Opportunity's robotic arm (the instrument deployment device with its turret of four tools at the end) when the rover is driving. On short drives over smooth terrain, Opportunity now holds the arm in a "hover-stow" position as shown in this image taken by the navigation camera during the rover's 706th Martian day. On longer or rougher drives, Opportunity still holds the arm in the original stow position, tucked underneath the deck. Symptoms began appearing that have been diagnosed as a broken wire in the motor windings at the shoulder joint. The motor still works when given extra current, but the change in strategy results from concern that, if the motor were to completely fail with the arm in the original stow position, the arm could no longer be unstowed for use.

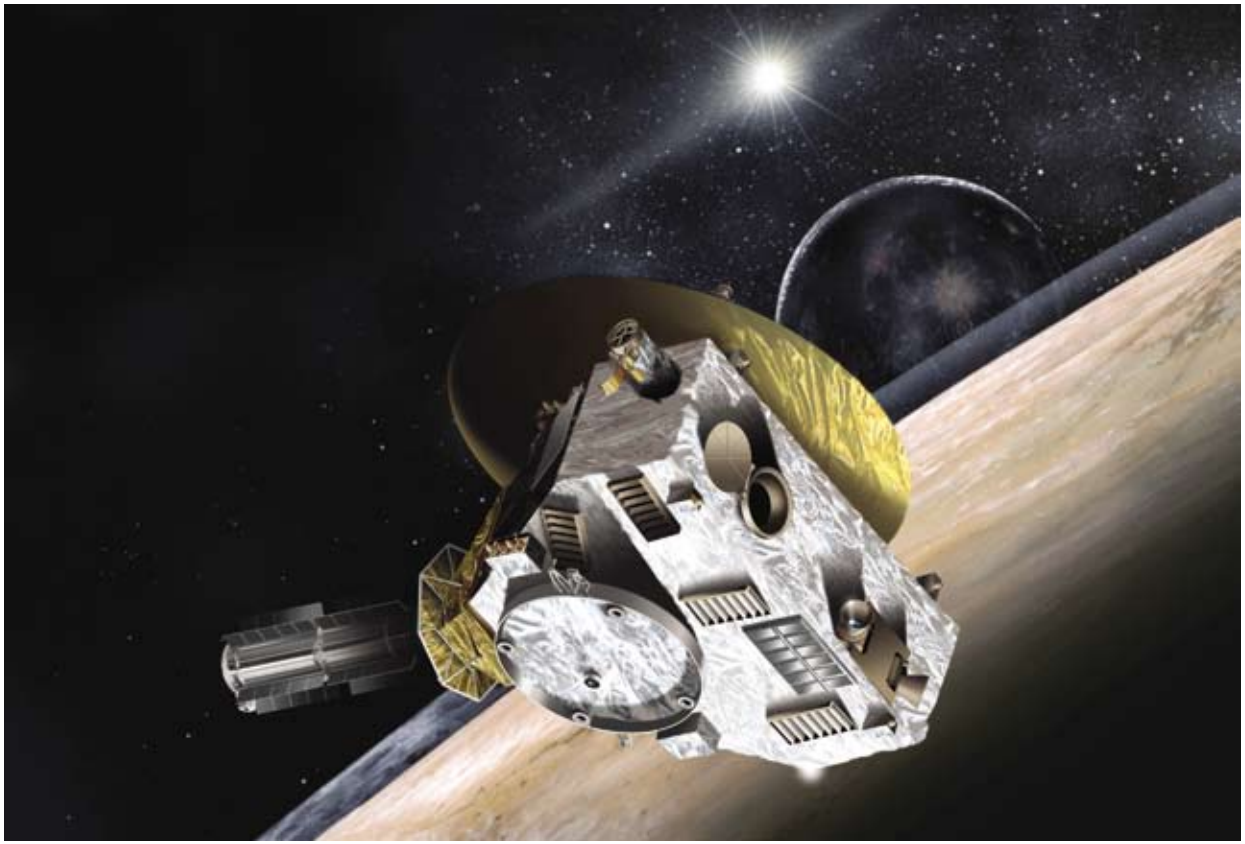
Opportunity has spent some considerable time this year examining bedrock exposures along a route between two craters coined Endurance and Victoria. Opportunity also found evidence of a long-ago habitat of standing water on Mars.

Early this year, Spirit passed its second anniversary inside the Connecticut-sized Gusev Crater. Initially, Spirit did not find evidence of much water, and hills that might reveal more about Gusev's past were still mere bumps on the horizon. By operating eight times as long as planned, Spirit was able to climb up those hills, examine a wide assortment of rocks, and find mineral fingerprints of ancient water.

While showing signs of wear, Spirit and Opportunity are still being used to their maximum remaining capabilities. On Spirit, the teeth of the rover's rock abrasion tool are too worn to grind the surface off any more rocks, but its wire-bristle brush can still remove loose coatings. The tool was designed to uncover 3 rocks, but it actually exposed the interiors of 15 rocks.

On Opportunity, the steering motor for the front right wheel stopped working. A motor at the shoulder joint of the rover's robotic arm showed symptoms of a broken wire in the motor winding. Opportunity can still maneuver with its three other steerable wheels, however. Its shoulder motor still works when given extra current and the arm is still useable without that motor.

JPL manages the Mars Exploration Rover mission for the Science Mission Directorate.



Artist's concept of the New Horizons spacecraft during its planned encounter with Pluto and its moon, Charon. Image courtesy of Johns Hopkins University Applied Physics Laboratory and Southwest Research Institute.

NASA's New Horizons Mission Launched toward Pluto

The first mission to Pluto, recently designated as a dwarf planet by the International Astronomical Union, is under way after the successful January launch of NASA's New Horizons spacecraft from Cape Canaveral Air Force Station.

"Right now, what we know about Pluto could be written on the back of a postage stamp," explained Dr. Colleen Hartman, deputy associate administrator for the Science Mission Directorate. "After this mission, we'll be able to fill textbooks with new information."

The 1,054-pound, piano-sized spacecraft is the fastest ever launched. It sped away from Earth at approximately 36,000 miles per hour, on a trajectory that will take it more than 3 billion miles toward its primary science target in what is considered the "third zone" of our solar system. New Horizons will zip past Jupiter for a gravity assist and science studies in February 2007, and conduct the first close-up, in-depth study of Pluto and its moons in summer 2015. As part of a potential extended mission, the spacecraft would then examine one or more additional objects in the Kuiper Belt, the region of ancient, icy, rocky bodies (including Pluto) far beyond Neptune's orbit.

"This is the gateway to a long, exciting journey," said Glen Fountain, New Horizons project manager from the Johns Hopkins Applied Physics Laboratory (where the mission is managed and where the spacecraft was designed and built). "The team has worked hard for the past 4 years

to get the spacecraft ready for the voyage to Pluto and beyond; to places we've never seen up close. This is a once-in-a-lifetime opportunity, in the tradition of the Mariner, Pioneer, and Voyager missions, to set out for first looks in our solar system."

After the Jupiter encounter—during which New Horizons will train its science instruments on the large planet and its moons—the spacecraft will "sleep" in electronic hibernation for much of the cruise to Pluto. Operators will turn off all but the most critical electronic systems and check in with the spacecraft once a year to check out these systems, calibrate the instruments, and perform course corrections, if necessary. Between the in-depth checkouts, New Horizons will send back a beacon signal each week to give operators an instant read on spacecraft health. The entire spacecraft, drawing electricity from a single radioisotope thermoelectric generator, operates on less power than a pair of 100-watt household light bulbs.

New Horizons is the first mission in NASA's New Frontiers Program of medium-class spacecraft exploration projects. The mission team also includes Goddard, JPL, the U.S. Department of Energy, Ball Aerospace, The Boeing Company, Lockheed Martin Corporation, Stanford University, University of Colorado, and KinetX, Inc., among a number of other partners.

The National Academy of Sciences ranked the exploration of the third zone—Pluto, its moons (Charon, in particular), and the Kuiper Belt—among the highest priorities for space exploration, citing the fundamental scientific importance of these bodies to advancing understanding of our solar system.

Mars-Orbiting Cameras Make Debut as NASA Craft Adjusts Orbit

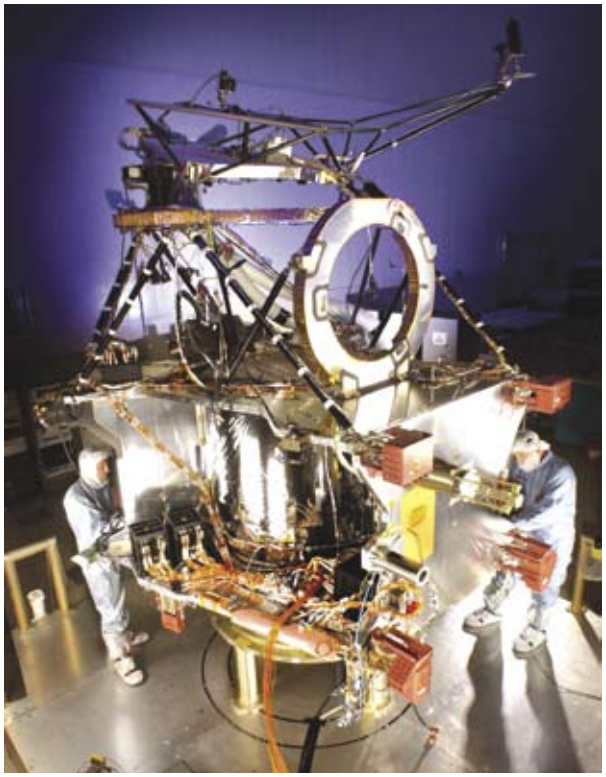
In other Mars news, researchers are now releasing the very first Mars images taken from the science cameras on NASA's Mars Reconnaissance Orbiter, launched in August 2005 to study whether the fourth planet from the Sun offered enough water to ever provide a habitat for life and to identify potential landing sites for future Mars missions.

Images taken by the orbiter's Context Camera and Mars Color Imager during the first tests of those instruments confirm the performance capability of the cameras—even though the test images were taken from nearly 10 times as far from the planet as the spacecraft will be once it finishes reshaping its orbit.

"The test images show that both cameras will meet or exceed their performance requirements once they're in the low-altitude science orbit. We're looking forward to that time with great anticipation," said Dr. Michael Malin of San Diego-based Malin Space Science Systems, Inc. Malin is team leader for the Context Camera and principal investigator for the Mars Color Imager.

The cameras took the test images 2 weeks after the orbiter's March 10 arrival at Mars and before the start of aerobraking, a process of reshaping the orbit by using controlled contact with the Martian atmosphere. In mid-April, the spacecraft began its dip into the upper atmosphere of Mars. The orbiter also took this time to fly in very elongated loops around the planet. Each circuit lasted about 35 hours and took the spacecraft about 27,000 miles away from the planet before swinging it back in close.

After the spacecraft gets into the proper orbit for its primary science phase, the six science instruments onboard will begin their systematic examination of Mars. The Mars Color Imager will view the planet's entire atmosphere and surface everyday to monitor changes in clouds, wind-blown dust, polar caps, and other changeable features. Images from the Context Camera will have a resolution of 20 feet per pixel, allowing surface features as small as a basketball court to be discerned. The images will cover swaths 18.6 miles wide. The Context Camera will also show how smaller areas examined by the High Resolution Imaging Science Experiment camera (which will have the best resolution ever achieved from Mars orbit) and by the mineral-identifying Compact Reconnaissance Imaging Spectrometer fit into the broader landscape. This will ultimately allow scientists to watch for small-scale changes in the broader coverage area.



Assembly and testing of the Mars Reconnaissance Orbiter spacecraft bus in a cleanroom environment.

"Mars Reconnaissance Orbiter is a quantum leap in our spacecraft and instrument capabilities at Mars," said James Graf, the mission's project manager at JPL. "Weighing 4,806 pounds at launch, the spacecraft will be the largest ever to orbit Mars. The data rate from the orbiter at Mars back to Earth will be three times faster than a high-speed residential telephone line. This rate will enable us to return a tremendous amount of data and dramatically increase our understanding of this mysterious planet."

Work Continues on Ultra-High Bypass Ratio Turbofan Engines

In aviation research, the Subsonic Fixed Wing project is pushing engine and airframe architectures beyond today's "tube and wing" configurations by optimizing the integration of airframe and propulsion systems. A key to improving performance and lowering aircraft noise is the development of higher bypass ratio engines for higher efficiency and reduced engine noise. NASA has worked closely with Pratt & Whitney for 15 years to develop technologies needed to enable ultra-high bypass ratio engines.

In the 1990s, the Advanced Ducted Propulsor was developed through scale model fan tests in wind tunnels at Glenn and Langley and an engine demonstrator in the 40- by 80-foot wind tunnel at Ames. (During this time, the emphasis was on large and medium twin-engine aircraft performing long-duration flights.) Higher efficiencies were obtained by lowering the rotational fan tip speeds to about 840 feet per second during takeoff, which reduced the shock-related losses associated with current turbofan engines. The noise was reduced by lowering the fan pressure ratio to about 1.29 (compared to > 1.53 from today's engines) and lowering the jet exhaust velocity. Variable pitch fans were developed to provide reverse thrust for landing and taxi operations.

Within the last 5 years, the emphasis for new technology development shifted to small twin-engine aircraft. Based on Advanced Ducted Propulsor technologies, a new engine was identified by Pratt & Whitney called the Advanced Geared Turbofan. The engine cycle parameters were similar to the Advanced Ducted Propulsor, but the fan tip speed was increased to about 1,030 feet per second and the variable pitch fan was replaced with a variable area nozzle. Fan noise predictions and data obtained by NASA from several tests showed that the fan pressure ratio was controlling the broadband noise and the overall noise levels could be comparable to the Advanced Ducted Propulsor, as long as the tip speed did not increase to where the shock-related noise sources dominated. Pratt & Whitney anticipated additional noise and performance benefits from using a fixed-pitch fan that reduced losses at the hub and tip. NASA tested a model fan (representative of the GE90 cycle) and showed that variable area nozzles can provide additional noise reduction and performance benefits that are expected to help the new Advanced Geared Turbofan.

In August 2006, NASA conducted a cooperative model fan test with Pratt & Whitney in a 9- by 15-foot wind tunnel at Glenn to quantify the aerodynamic and acoustic characteristics of the Advanced Geared Turbofan. The results are being used for an engine demonstrator that Pratt & Whitney will fund and test in late 2007.

Through the Subsonic Fixed Wing project, NASA will continue working with Pratt & Whitney to test advanced technologies for additional noise, emissions, and performance improvements, with the possibility of testing them in engines that will be developed for future small twin-engine aircraft. NASA projects it may be possible to reduce the noise levels from the current 14 cumulative Effective Perceived Noise Level in decibels (EPNdB) below Stage 3, to levels ranging from 38 to 42 EPNdB below Stage 3. Specific fuel consumption will be reduced by about 8 percent relative to engines flying

3-D depiction of Distributed National Flight Operational Quality Assurance flights.

today and advanced combustor designs will reduce emissions such as nitrogen oxide by about 70 percent relative to the Committee on Aviation Environmental Protection standards.

The Advanced Geared Turbofan represents a significant advance to engine architectures that will be viewed as a technology breakthrough for ultra-high bypass ratio turbofans, just as the introduction of the GE90 engine in the 1990s paved the way for higher bypass ratio engines.

Information-Sharing Initiative

The Aeronautics Research Mission Directorate's Aviation Safety Program is working with the Federal Aviation Administration (FAA) and the commercial aviation community to develop and test new data-mining tools that will enable users to proactively identify, analyze, and correct systemic safety issues that affect commercial aviation. This activity also contributes to the Joint Planning and Development Office's (JPDO) safety initiative to assess the safety of the Next Generation Air Transportation System.

The Commercial Aviation Safety Team, which represents the aviation industry, the JDPO, and the FAA, and NASA, saw a need to move beyond the current historic, accident-based information to a diagnostic analysis of information extracted from Flight Operational Quality Assurance (FOQA) flight-recorded data and Aviation Safety Action Program (ASAP) incident reports being collected by air carriers. In recognition of this need, the industry established a Voluntary Aviation Safety Information-sharing Process (VASIP) to agree upon a process for the commercial aviation industry and the FAA to collect and share safety-related information. NASA clearly had the institutional background, resources and expertise necessary to develop the analytical tools for extracting and integrating information from large, distributed, and diverse (numerical and textual) data sources that were needed to enable the VASIP.

The Aeronautics Research Mission Directorate, working in a collaborative partnership with participating airlines, the FAA, and other organizations, started the Information-Sharing Initiative in June 2004. The goal of this initiative is to demonstrate operational programs for both Distributed National FOQA Archive data and Distributed National ASAP Archive data by September 30, 2006. Upon completion of the demonstration, aviation industry decision makers will use information from these two national databases to proactively correct systemic safety issues.

The FOQA and ASAP databases are only two of the many safety-related data sources currently being collected across the industry. Information must be extracted from these other sources and integrated to gain a better understanding of the problems and to determine appropriate interventions. The industry sees a successful demonstration as the foundation upon which to expand and enhance the national archives of aviation safety-related data.

Ultimately, the entire aviation industry will benefit from a proactive approach to managing systemic safety risks. The flying public will benefit from an airline industry that is able to maintain its phenomenal safety record despite projected increases in air travel.

Future ATM Concepts Evaluation Tool

The Future ATM Concepts Evaluation Tool (FACET) is a flexible Air Traffic Management (ATM) simulation environment technology that has been established for exploring, developing, and evaluating advanced ATM concepts under NASA's Airspace Systems Program. FACET can operate in a playback, simulation, live, or hybrid mode on a laptop computer, using the FAA's Enhanced Traffic Management System (ETMS) data along with wind and weather data from the National Oceanic and Atmospheric Administration.

Examples of advanced concepts that have been developed and tested in FACET include aircraft self-separation, integrated aircraft and space launch vehicle operations, aggregate flow models of the National Airspace System, and reroute conformance monitoring. These concepts were deployed in the FAA's operational ETMS system.

The success of FACET has lead to its adoption by the FAA, airlines, universities, and numerous companies. The most noteworthy example of FACET-derived technologies being adopted for commercial interests is the recent integration of FACET with the Flight Explorer software system, from Flight Explorer, Inc., of McLean, Virginia. Flight Explorer is the world's leading aircraft situation display with an installed base of over 5,000 systems, according to the company. Its customers include 80 percent of all major U.S. airlines, 22 regional airlines, all cargo carriers, and executive jet operators. The first two FACET features available for commercial use are the sector and airport demand overlays that alert airspace users to forecasted demand and capacity imbalances. With this new information, airspace users will be able to develop better flight-routing strategies that save fuel, preserve airline schedules, and reduce passenger delays and missed connections. Future releases of Flight Explorer will incorporate additional FACET capabilities, such as optimal route generation.

The integration of FACET with Flight Explorer was initiated in 2005 with the signing of a Space Act Agreement between NASA and Flight Explorer, Inc. Key FACET capabilities, such as sector demand overlays, were subsequently made available to the commercial market through a nonexclusive worldwide licensing agreement. Overall, the FACET-Flight Explorer integration effort has been an extremely successful venture and feedback from the user community has been very supportive. ❖

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Education News at NASA

NASA's unique missions to space are the result of scientific expertise and technical excellence, qualities that are dependent on sound educational backgrounds. NASA gives back to the educational community in order to groom the next generation of explorers. The following pages show some of the partnerships between the Space Agency and various educational communities.

Education News at NASA

NASA Explorer Schools Program Is Tops in Government Innovations

The NASA Explorer Schools program was chosen as one of the "Top 50 Government Innovations" for 2006 by the Ash Institute for Democratic Governance and Innovation. The selected programs represent the U.S. Government's most innovative and results-oriented efforts in various areas, including education and training.

"NASA's Explorer Schools program exemplifies the Agency's tradition of investing in the Nation's education programs and supporting educators who play a key role in preparing, inspiring, encouraging, and nurturing young minds," said Angela Phillips Diaz, NASA's acting assistant administrator for education.

The program establishes a 3-year partnership between the Agency and teams of teachers and education administrators from diverse communities across the country. In its fourth year, the program is designed for education communities to help improve teaching and learning in science, math, and technology. It aims to attract and retain students, teachers, and faculty through a progression of educational opportunities.

The Harvard University John F. Kennedy School of Government, home of the Ash Institute, announced the selections in March.

Newest Explorers Become Astronauts

After 18 months of intense training, NASA's latest astronaut candidates are now officially astronauts. The class of 11, including 3 educator astronauts selected from teachers across the Nation, received NASA astronaut pins in a February 2006 graduation ceremony. This is NASA's first astronaut class that is focused from the start on realizing the Vision for Space Exploration.

The candidates were selected in May 2004. They reported to Johnson Space Center that summer to begin training, which included water and land survival courses, T-38 flight instructions, and space shuttle and International Space Station systems training. The class also completed numerous qualifying exams and flight evaluations. They now join the rest of the astronaut corps in supporting space flight in technical roles and pursuing more specialized training for future assignments.

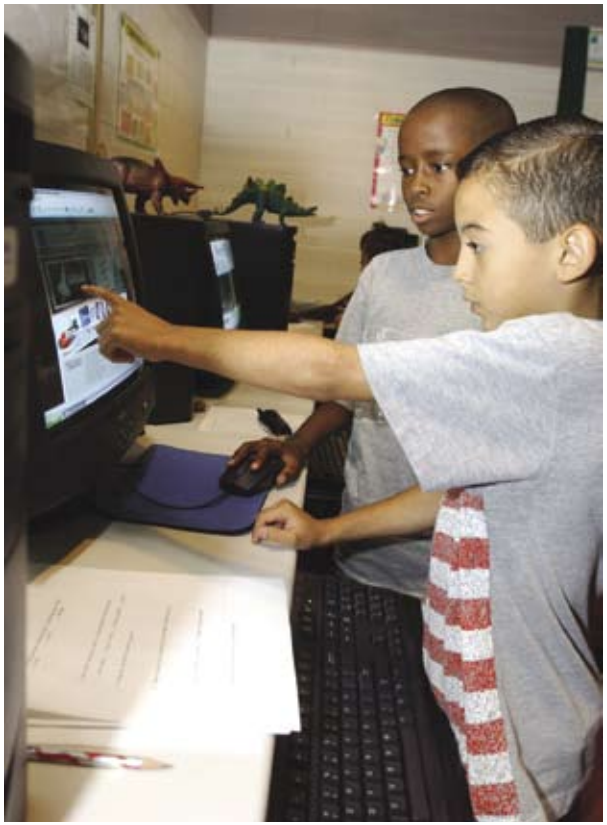
"What I'm looking forward to most is the future," said Jose Hernandez, astronaut candidate graduate. "I think it's a bright and exciting future for the Space Program."

Immediate duties include support roles in the space shuttle and space station programs, and positions in robotics and space flight medicine. The new astronauts and their work assignments are: Joe Acaba, mission specialist-educator, space station branch and education; Richard Arnold, mission specialist-educator, space station branch and education; Randy Bresnik, pilot, space station branch; Christopher Cassidy, mission specialist, space station operations branch and capcom branch; James Dutton, pilot, exploration branch; Jose Hernandez, mission specialist, shuttle branch; Shane Kimbrough, mission specialist, safety branch; Thomas Marshburn, mission specialist, space station branch and exploration branch; Dottie Metcalf-Lindenburger, mission specialist-educator, space station branch and education; Robert Satcher, mission specialist, robotics branch and space station branch; and Shannon Walker, mission specialist, space station operations branch and capcom branch.

NASA Launches Kids' Club

A team of NASA educators has helped create a dozen games that make up the first phase of the new NASA Kids' Club, which uses "stealth learning" to draw children in. In other words, while children are having fun launching rockets or driving across Mars, they are also learning about science and mathematics.

The games are divided into five levels, each associated with a grade from kindergarten through fourth. The games are based on national standards and involve skills appropriate for each grade level.



Student testers enjoyed the NASA Kids' Club Web site and gave feedback that helped in its development.

The following are some of the fun and educational games featured in the NASA Kids' Club:

- Grab It: This game lets children control the space shuttle's robotic arm to grab things that go together. It involves picking out which things begin with the same letter—a kindergarten-level skill.
- Airplane High-Low: This game challenges children to guess which number the game's airplane mascot is thinking of. It helps the players develop first grade-level number-order skills.

A brother-sister team of testers (above) worked together to solve a problem on the NASA Kids' Club site. The new NASA Kids' Club (left) has five levels of games, an art area, and updates of new missions and other exciting things that are happening at NASA.

- Star Fall: This fast-paced game involves clicking on groups of stars to clear as many of them off the board as possible. Not only does the game rely on pattern-recognition skills, children also learn about astronomy in the process.
- Flip Time: This memory game challenges players to match pictures of clocks in order to make an airplane take off. Children match digital and analog clocks with the same times, using third grade time-telling skills.
- Go to the Head of the Solar System: In this game, children test how much they know about space by picking the planets that best answer a series of questions. The child-friendly interface makes it both fun and educational.

"Our goal with the NASA Kids' Club is to provide a medium that will encourage children's interest in exploring the subjects that are important to developing their early skills in science, technology, engineering, and mathematics," said Jeff Ehmen, education specialist at Marshall Space Flight Center. "We hope they visit the site often to improve their gaming skills and knowledge. With their 'edutainment' value, these games and activities add to NASA's broad education resources."

The site was designed to be accessible to as many students as possible. It is compatible with screen readers and other assistive technologies for students with special needs. In addition to Flash-based games, the site features versions of its content that can be accessed in locations with slower Internet connections or computer equipment.

Goddard Scientists View Solar Eclipse With Tunisian Students

Under a science and technology agreement between the United States and Tunisia, sponsored by NASA and the U.S. State Department, NASA researchers flew to Tunisia in northern Africa to experience the October 3, 2005, solar eclipse with more than 80 Tunisian students. The Goddard Space Flight Center solar scientists, astrophysicist Joseph Davila and planetary research scientist Mehdi Benna, a native Tunisian, were invited to participate by the Tunisian Young Science Association (AJST).

Participating in this event was particularly important to Benna, because he was a member of AJST as a child. "I was delighted to have the chance to give something back to my country and perhaps influence the career choices of young people, since this group helped to steer me toward a career as a scientist," he said.

In preparation for the eclipse, two Tunisian students and a film crew visited Davila and Benna at Goddard to practice setting up some of the experiments to be carried out during the solar event.

Once the scientists arrived in Tunisia's capital city of Tunis, they participated in a press roundtable at the U.S. Embassy. Representatives attended from the major French language and Arabic newspapers in Tunis and from two major radio stations. In a series of lectures at the City of Science, a new science museum in Tunis, Benna and Davila spoke to approximately 100 students and members of the public.

Benna spoke about the history of Mars exploration and the anatomy of space missions, including how a spacecraft is built, tested, and launched; what kind of data scientists expect; and how long it takes to build and test such missions. Davila discussed the current state of space weather forecasting. Finally, Benna and Davila participated along with a professor of history at the University of Tunis in a public discussion that covered the history and mythology of solar eclipses in past civilizations.

Tunisian children were very interested in the Solarscopes brought from the United States.

The Goddard scientists then traveled to the southern city of Douz at the edge of the Sahara, where they set up a number of experiments to be carried out by the students. Several telescopes were also available for public viewing during the eclipse. Using these telescopes, along with solar scopes, models, and diagrams, the students explained the science of eclipses to hundreds of public observers.

Applause broke out as the Moon moved across the Sun, eventually covering 95 percent of it. "It was a beautiful twilight-covered desert, and all activity stopped for a few minutes. People gazed upward, while the camels, unimpressed, sat quietly on the ground," Davila said.

A major Tunisian movie studio, Cinetelefilms, is producing a documentary covering the collaborative event. This film is slated to become a pilot for a proposed series of science documentaries aimed at promoting mutual understanding between the West and the Arab world.

The NASA visit prepared the students for the March 29, 2006, total eclipse of the Sun, in northern Africa.

Student-Built Buoy Launches Ocean Studies

Over the winter holidays, high school sophomore Katie Nance painted her room a cool shade of blue; though, when she and her schoolmates had to paint the ocean buoy they recently constructed for an international oceanography program, they chose a much bolder color. Their bright-red buoy was launched off the coast of Antarctica in January. Through a satellite connection, the buoy sent back data on ocean temperatures that are available to scientists and students around the world.

The buoy project is part of an education program called Argonautica, organized by the French space agency, the Centre National d'Etudes Spatiales (CNES). With help from the Jet Propulsion Laboratory, a small group of students from a California-based French/American school, the Lycée International of Los Angeles, became the first U.S. participant. About a dozen team members were drawn from different classes, ranging in age from 9 to 17. Dr. Mohamed Abid, a senior systems engineer for NASA's Ocean Surface Topography Mission, served as their advisor.

Argonautica is designed to help students learn about the oceans and the role of satellites in oceanography. Participants are given an empty plastic shell from which they have to construct a functional buoy fitted with sensors capable of withstanding harsh ocean conditions, plus an anchor to keep the buoy in position as it drifts with the currents.

The first challenge, said seventh grader Turner Edwards, "was figuring out what we wanted to measure. Some wanted to measure the salt in the water, some temperature, and some currents. It was hard to decide."

Luckily, they had expert help. Abid is the author of a new book entitled "Spacecraft Sensors." "We had a number of options," he said, "so we made lists of the pros and cons of our different choices. We finally chose the temperature sensor."

The next steps were to understand how the sensors work, test them, and make sure they will survive in salt water. For Nance, the hardest part of the project was all the calculations that needed to be done. "We had to figure out where we were going to put the sensors, how much weight needed to be in the anchor, and how many volts we needed for the Argos card—the satellite transmitter."

The completed buoy was equipped with seven temperature sensors and an anchor, which was constructed from plastic piping and cement. The final step was the red paint. "It looked really good," said Nance, "but there's not much you can do with a buoy."

Students tracked their buoy and other Argonautica-built buoys from CNES's education Web site and correlated the data they collected with measurements of sea surface height made by the JASON satellite, which was launched as part of a joint U.S./French mission.

"It's great to see what they can accomplish," said Abid. "Now that they can see what they can do, their expectations get higher. They believe that next time they can build something even more complex."

Two Argonautica students work on a temperature sensor.

California Polytechnic State University student Abagail Liddle sits on Rogers Dry Lake and uses a laptop to collect noise data of a C-17's landing approaches.

NASA and Olympic Athletes Plan Lunar Games

With the help of several Olympic athletes, students this year were able to get a physics lesson from NASA about what it would be like to perform winter sports at the most extreme venue around—the Moon.

U.S. Olympic skier Eric Bergoust, snowboarder Hannah Teter, and bobsled team member Todd Hays were featured in 30- to 60-second NASA TV clips that explored the scientific concepts of their winning flips and rips.

Bergoust, a 1998 Olympic gold medalist, explored whether he could double his quadruple-twisting flip with a perfect landing in the Moon's gravity, which is one-sixth of the Earth's gravity. Teter, a gold medalist in this year's Olympic Games (the halfpipe), showed how her skills to hit a snowboarding move called a frontside five might be used to land a lunar spacecraft. Hays, a silver medalist in the 2002 Olympic Games, discussed the importance of launching spacecraft from Kennedy Space Center and compared such launches to the running starts he uses to jump-start his bobsled.

"U.S. Olympic athletes are helping to educate our youth by comparing the physics of sports with the physics of space exploration," said Phil West, the deputy director of education at Johnson. "We hope parents and teachers will use the clips to interest teens in math and science, because America will need them to become tomorrow's inventors."

Cal Poly Students Help NASA Reduce Aircraft Noise

Thirteen aerospace engineering students from the California Polytechnic State University (Cal Poly), San Luis Obispo, spent part of the 2005 summer on a lake. While this may be a normal summer activity for many college students, this group of 13 made its stay at Rogers Dry Lake, located in California's Mojave Desert, where it participated in the C-17 flight noise mitigation study, a NASA experiment that may one day make the world a quieter place.

Currently, a house within an airport's flight path needs triple-pane windows, special doors, and extra attic and wall insulation, in order to keep aircraft noise out. Researchers from Ames Research Center and Dryden Flight Research Center want to eliminate, or at least reduce, the need for these often-costly modifications.

To do so, NASA, through the Vehicle Systems Program, worked to reduce the "noise footprint" produced by aircraft. A key component of this plan is the development of extreme short takeoff and landing (ESTOL) aircraft and procedures. The ultimate goal is to keep aircraft noise within an airport's property. In September 2005, NASA demonstrated that aircraft capable of ESTOL could concentrate noise to a narrow area.

During the noise mitigation study, 17 microphones were positioned on the dry lakebed (covering approximately 15 square miles) to record the noise footprint of the U.S. Air Force Test Center's C-17 Globemaster III as it made various landing approaches. In addition to conventional straight-in approaches, a new type of simultaneous and non-interfering (SNI) approach was flown. This new approach is similar to a descending spiral over the landing site.

"Preliminary results indicate that the SNI approaches will concentrate the noise footprint into a narrow area," said John Zuk, the NASA manager who led the ESTOL research at Ames.

The tests also confirmed that the curved approaches posed no significant safety concerns and provided current commercial aircraft ride quality. "The landing approaches were simple and safe," said NASA research pilot Frank Batteas.

The successful tests were made possible by the extraordinary efforts and ingenuity of the team to meet the challenges of a limited budget and a shortened test schedule, according to Craig Hange, project manager and principal investigator for the study.

"The team came up with a totally new way of taking noise data over a large area that not only worked well, but was less expensive by using commercially available parts and software," said Hange. "They not only put in their ideas, but a lot of hard work made it a reality."

"The Cal Poly students and faculty also deserve a lot of credit for taking on this new task, doing most of the grunt work, and sharing an enthusiasm that you can only get from students," Hange added.

"Involvement in this NASA research project has taken the students' classroom curriculum and given it a hands-on application," said Cal Poly student lead Erika Berg.

The students also designed and built the portable workstations (made out of inexpensive plastic piping and heavy fabric) that stored the computer equipment while it was used on the lakebed.

The data collected during the tests will be very valuable for future research supporting ESTOL aircraft and may have a significant impact on airport operations around the country.

"An aircraft that could use the shorter runways of smaller regional and community airports could bring commercial air travel to approximately 97 percent of the U.S. population, because most Americans live within a half-hour of an airport," said Zuk.

The C-17 study team was comprised of members from Ames and Dryden, Cal Poly, the U.S. Air Force, Northrop Grumman Corporation, and CENTRA Technology, Inc., of Arlington, Virginia.

NASA Announces Solar System Ambassadors Class of 2006

What do a surfer, firefighter, teacher, neurosurgeon, and award-winning book author have in common? A love of space and a desire to share that passion. They have joined a growing number of private citizens in NASA's Solar System Ambassadors Program, which brings space information to the public through planetarium talks, telescope-viewing parties, mall displays, and other events.

Twenty-nine new ambassadors joined the program this year, bringing the total to over 450 ambassadors from all 50 states and Puerto Rico.

For swim coach and surfer Mike Olsberg, of Newport Beach, California, looking up at the stars overhead always captured his imagination, so becoming a NASA ambassador was a clear choice. "When Neil Armstrong and Buzz Aldrin walked on the Moon, it represented the culmination of all of man's technological achievements up to that moment. Since that day, space exploration has always has been a personal interest for me," Olsberg said.

For Kevin Kilkenny, a 15-year veteran of the New York City Fire Department, looking to the sky has been a favorite activity since he was 8 years old. "I like watching the faces of the youngsters as they learn about faraway planets and then go outside and see them through a telescope. Watching them make their own discovery is priceless," he said. Kevin was glued to the television that summer day in 1969 when Apollo 11 made its historic landing on the Moon.

"I have known since my early childhood that I was born to teach," said Judy M. Dominguez, a 33-year veteran retired teacher of math and science who lives in Downey, California. "I have been passionate about space, astronomy, and related subjects. I consider it a personal responsibility to communicate their importance and the wonder and joy of knowing to others," added Dominguez.

For Dr. Ronald Ignelzi, becoming an ambassador was a chance to speak about how space technology can help improve everyday lives. Ignelzi recently retired as a neurosurgeon and lives in La Jolla, California. "I believe space exploration and NASA are a great part of our planet's future and that already some of the technology developed for spacecraft has applications in medicine. These spinoffs have propelled medical technology and will continue to do so in the future."

"As a longtime space cadet, I loved the idea of becoming an ambassador for the solar system," said Dava Sobel, of East Hampton, New York, an award-winning author of popular science books.

Each ambassador agrees to hold at least four public events during the year. In 2005, ambassadors participated in 2,071 events that reached more than 1 million people. In its ninth year, the JPL-managed program prepares these volunteers through a series of Internet training courses and teleconferences. Ambassadors speak directly with scientists and engineers on missions like Cassini to Saturn, the Mars Exploration Rovers, and the Stardust mission that brought home comet samples. They also receive brochures, posters, DVDs, and other materials to help them in their presentations. ❖

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Partnership Successes

NASA cultivates relationships with private industry, academia, and other government agencies to bring its science back down to Earth. By contributing time, facilities, and a wealth of technical expertise, NASA enriches the lives of people everywhere—though not all of these partnerships result in a commercial spinoff. The following pages show some of the many benefits of these partnerships.

Partnership Successes

Industry Uses NASA Wind Tunnel to Design New Airplanes

NASA wind tunnel technology is being used by the aviation industry to improve new airplane designs throughout the entire development process.

The National Transonic Facility is a unique wind tunnel developed by NASA that uses super-cold nitrogen gas at high pressure to duplicate true flight aerodynamics. Located at Langley Research Center, the facility can accommodate models as small as one-fiftieth the size of the actual aircraft. Unlike conventional wind tunnels, it can adjust the characteristics of the airflow to match the size of the model. Results help engineers determine how new designs will work for real planes in flight.

The Boeing Company is purchasing wind tunnel time in the facility to test new aviation concepts before applying them in flight. The Seattle-based manufacturer is specifically evaluating high-lift system designs for its new 787 jet aircraft. High-lift systems include flaps and slats that increase the lift performance of the wing, allowing the airplane to take off and land more safely and efficiently.

Wing trailing edge design concepts for Boeing's new 787 aircraft are being tested on a 5.2-percent scale 777 semi-span model inside Langley Research Center's National Transonic Facility.

According to Rich Wahls, facility chief aerodynamicist, the wind tunnel's ability to duplicate the aerodynamics of the flight environment, even with small-scale models, can allow aircraft manufacturers to produce better-performing airplanes with less risk.

To test the high-lift concepts, Boeing developers designed the new 787-style trailing edge flaps and fit them to an existing 5.2-percent scale 777 semi-span model. This stainless steel model, which looks like one-half of an airplane cut down the middle, from nose to tail, is mounted on the sidewall of the wind tunnel.

Improvements in design and performance are always a challenge, because of the complex airflow issues encountered when flaps and slats are extended from a wing. Fortunately, even small improvements in performance of a high-lift system can significantly improve the take-off field length, weight-carrying capability, and range of a transport aircraft. The improvements can also help reduce aircraft noise.

"In the past, engineers have come to the National Transonic Facility to further understand and solve problems with systems that have already been developed," Wahls said. "Now we're also seeing this test capability being used during the aircraft design phase."

NASA Develops New Online De-Icing Training Course for Pilots

NASA has developed a free online course to help pilots avoid the hazards of ice contamination while their planes are on the ground. "A Pilot's Guide to Ground Icing" is intended primarily for professional pilots who make their own de-icing and anti-icing decisions. It is the eighth in a series of training aids developed at Glenn Research Center, and the first on ground icing.

"The pilot community has asked for training materials to cover the full spectrum of icing concerns," said Tom Bond, chief of Glenn's Icing Branch. "Ground icing

training complements our past work for in-flight icing training. NASA worked with an international group of aviation safety specialists from both regulatory and industry organizations to develop a training tool to aid pilots across international borders," he added.

The development team included experts from Ames Research Center, the Federal Aviation Administration, Transport Canada, the Civil Aviation Authority (United Kingdom), the Canadian Armed Forces, the University of Oregon, a fractional jet provider, and an airline.

This self-guided course provides pilots with general ground icing knowledge, an understanding of freezing precipitation hazards, and the ability to improve decision making for ground icing operations. It discusses the risks of contamination, provides cues to alert pilots to ground icing conditions, and offers actions pilots can take to help ensure safe operations. Imagery, case studies, aviator testimonials, and interactive elements are all used to inform and help pilots.

Ground icing accidents are often preventable. Pilots will receive training to improve the safety of their flights from this online course.

"We are committed to supporting NASA's goal to improve aviation safety. By helping pilots and operators understand the hazards of ground and in-flight aircraft icing, they can make better operational decisions," said Dr. Judith Van Zante, icing researcher with the Cleveland-based QSS Group, Inc., and a team member at Glenn who was instrumental in developing the course.

The activity was supported by NASA's Aviation Safety and Security Program Office, part of the Aeronautics Research Mission Directorate.

Previous training aids developed at Glenn focused on in-flight icing for various target pilot audiences. Titles include: Icing for Regional and Corporate Pilots; Icing for General Aviation Pilots; A Pilot's Guide to In-Flight Icing; Tailplane Icing; and Supercooled Large Droplet Icing.

Instrument Provides Pilots With Improved Weather Forecasts

Weather forecasters throughout the United States are making better local predictions for pilots and others, thanks to an airborne sensor being tested by aviation safety experts at Langley.

These experts led a team that designed, built, and equipped dozens of Mesaba Airlines aircraft with the Tropospheric Airborne Meteorological Data Report (TAMDAR) instrument. Headquartered in Eagan, Minnesota, Mesaba is a Northwest Airlines affiliate that mainly flies short commuter routes.

The TAMDAR instrument allows aircraft to automatically sense and report atmospheric conditions. Observations are sent by satellite to a ground data center that processes and distributes up-to-date weather information to forecasters and pilots.

Shown here is the TAMDAR instrument, a tiny sensor flown on commuter airliners to gather weather information.

"Initial research shows the airborne sensor makes a 10- to 20-percent improvement in forecast error in numerical models—and that's just with temperature," said Taumi Daniels, NASA project leader.

The sensor also measures humidity, pressure, winds, icing, and turbulence, with the help of location, time, and altitude provided by built-in Global Positioning System technology.

Large airliners fly above most weather and collect limited atmospheric data. When equipped with the weather sensor, regional aircraft, which typically fly below 25,000 feet, can provide more information. The information collected can also benefit weather models and forecasts, because it increases the number of observations in the lower atmosphere.

Currently, only 70 weather balloon sites in the continental United States collect temperature, wind, and moisture data from twice-daily atmospheric soundings. The TAMDAR experiment added 800 more daily atmospheric soundings.

"Meteorologists at the National Weather Service have found the Tropospheric Airborne Meteorological Data Report to be useful in forecasting severe thunderstorms, dense fog, precipitation types of winter storms, and low-level wind shear," said Richard Mamrosh, a National Weather Service meteorologist in Green Bay, Wisconsin. "In summertime, its best use is in determining if and when thunderstorms might develop. In wintertime, it really helps in determining whether a storm will bring sleet, freezing rain, or snow," he added.

The NASA partners analyzing the data are a mix of industry professionals, meteorologists, researchers, and scientists representing AirDat LLC, of Morrisville, North Carolina; the Federal Aviation Administration; the National Oceanic and Atmospheric Administration (NOAA); the National Center for Atmospheric Research; the Massachusetts Institute of Technology Lincoln Laboratory; the Meteorological Service of Canada, in Montreal; the Met Office, in London; and the

meteorological network of Europe (EUNETMET), in Toulouse, France.

The TAMDAR project is part of NASA's Aeronautics Research Mission Directorate.

Major Weather Forecasting Advancement

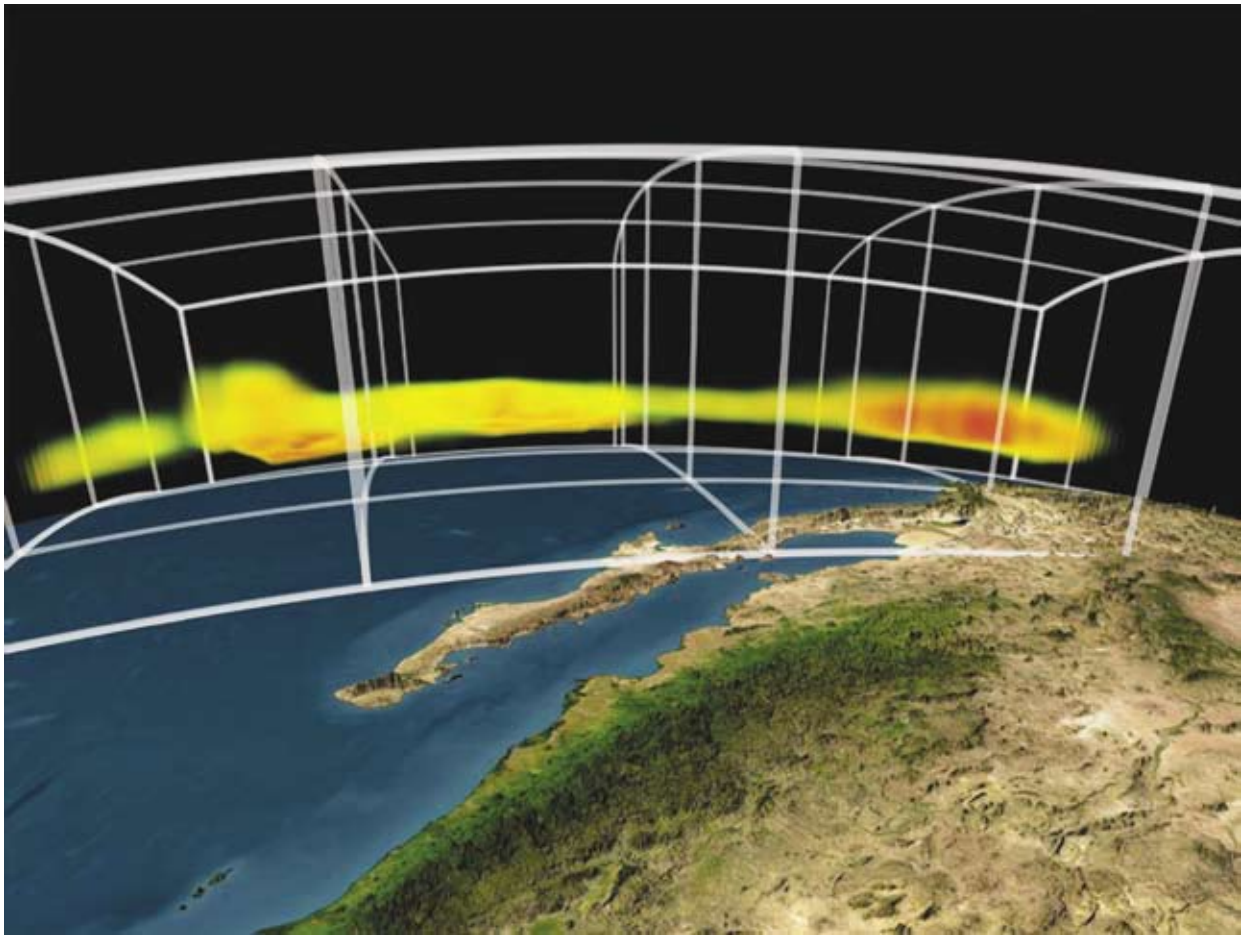
In another weather forecasting breakthrough, NASA and NOAA have outlined research that has helped to improve the accuracy of medium-range weather forecasts in the Northern Hemisphere.

NASA and NOAA scientists at the Joint Center for Satellite Data Assimilation, in Camp Springs, Maryland, came up with procedures to improve forecasting accuracy. The scientists worked with experimental data from the Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua satellite. AIRS is a high-spectral resolution, infrared instrument that takes 3-D pictures of atmospheric temperatures, water vapor, and trace gasses.

The scientists found that, by incorporating the instrument's data into numerical weather prediction models, they can improve the accuracy range of experimental, 6-day, Northern Hemisphere weather forecasts by up to 6 hours—a 4-percent increase.

"This AIRS instrument has provided the most significant increase in forecast improvement in this time range of any other single instrument," said retired Navy Vice Admiral Conrad C. Lautenbacher, Jr., Ph.D., undersecretary of commerce for oceans and atmosphere and NOAA administrator. "Climate and weather forecasts are dependent upon our understanding current global ocean and atmosphere conditions," added Lautenbacher. "If we want to be able to predict what the weather will be like in the future, we must adequately define the global conditions today. Satellite data, like AIRS provides, is a vital link for NOAA to take the pulse of the planet continuously."

"A 4-percent increase in forecast accuracy at 5 or 6 days normally takes several years to achieve," said Dr. John Le Marshall, Joint Center for Satellite Data Assimilation director. "This is a major advancement, and it is only the start of what we may see as much more data from this instrument are incorporated into operational forecast models at NOAA's Environmental Modeling Center."



NASA's Atmospheric Infrared Sounder instrument is able to peel back cloud cover to reveal 3-D data of a storm's water vapor content—information that can be used to improve weather forecast models.

"NASA is assisting the world's weather-prediction agencies by providing very detailed, accurate observations of key atmospheric variables that interact to shape our weather and climate," said Dr. Mary Cleave, associate administrator for NASA's Science Mission Directorate. "The forecast improvement accomplishment alone makes the AIRS project well worth the American taxpayers' investment."

The instrument's data have been officially incorporated into NOAA's National Weather Service operational weather forecasts. Elsewhere, the European Centre for Medium-Range Weather Forecasts began incorporating data from

AIRS into its operational forecasts in October 2003. The center reported an improvement in forecast accuracy of 8 hours in Southern Hemisphere 5-day forecasts.

The AIRS instrument is the result of more than 30 years of atmospheric research, led by Dr. Moustafa Chahine of the Jet Propulsion Laboratory (JPL).

The Joint Center for Satellite Data Assimilation is operated by NOAA, NASA, the U.S. Air Force, and the U.S. Navy. The goals of the center are to accelerate the use of observations from Earth-orbiting satellites to improve weather and climate forecasts, and to increase the accuracy of climate data sets.

Study Suggests Ways to Beat the Heat in New York City

The heat is on in New York City, whether it is summer or winter. This is due to a phenomenon called urban heat island effect that causes air temperatures in New York City and other major cities to be warmer than in neighboring suburbs and rural areas. In a big city, warmer air temperatures can impact air quality, public health, and the demand for energy.

Several innovative approaches developed by scientists, public officials, environmental activists, community organizations, and others have been put in place to take a bite out of the Big Apple's temperature problem. NASA researchers, using NASA satellite observations, weather pattern data, and computer models, conducted a study to assess how well those strategies are working.

"We need to help public officials find the most successful ways to reduce the heat island effect in New York. With ever-increasing urban populations around the world, the heat island effect will become even more significant in the future," said Stuart Gaffin, an associate research scientist at Columbia University and a co-author of the NASA study. "The summertime impacts are especially intense with the deterioration of air quality, because higher air temperatures increase ozone. That has health effects for everyone. We also run an increased risk of major heat waves and blackouts, as the heat island effect raises demand for electricity."

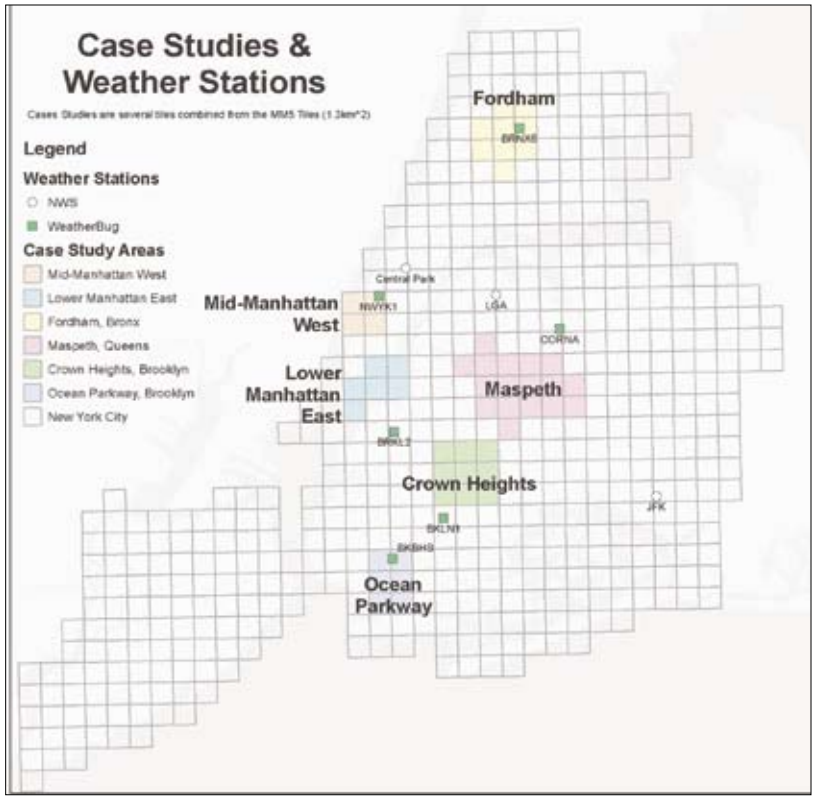
Land surfaces with vegetation are relatively sparse in large cities, dominated instead by non-reflective, water-resistant surfaces, such as asphalt, tar, and building materials that absorb most of the Sun's radiation, causing the urban heat island effect. These surfaces hinder the natural cooling that would otherwise take effect with the evaporation of moisture from surfaces with vegetation.

The urban heat island occurrence is particularly pronounced during summer heat waves and at night when wind speeds are low and sea breezes are light. During these times, New York City's air temperatures can rise 7.2 °F higher than temperatures in surrounding areas.

In the NASA project, researchers set out to recommend ways to reduce the urban heat island effect in New York City. Their recommendations included promoting light-colored surfaces—especially for roofs and pavements—that reflect sunlight, planting "urban forests," and creating "living roofs" on building tops where sturdy vegetation can be planted and can thrive. Using a regional climate computer model, the researchers wanted to calculate how these strategies could lower the city's surface and close-to-surface air temperatures, and how they would affect New York's energy system, air quality, and the health of its residents.

In addition to the city-wide case study, NASA researchers also conducted six smaller case studies across Lower Manhattan, the Bronx's Fordham section, Brooklyn's Crown Heights section, and the Maspeth area of Queens. These areas were chosen for the different ways land is used and their close proximity to other areas with high electrical use. They also had warmer-than-average near-surface air temperatures called "hot spots" and available spaces to test ways to reduce the urban heat island effect.

"We found that vegetation is a powerful cooling mechanism. It appears to be the most effective tool to reduce surface temperatures," Gaffin said.



This image indicates case study areas and weather stations used in the NASA study on urban heat island effect in New York City.

"Another effective approach is a manmade approach to cooling, by making very bright, high albedo, or reflected light, on roof tops. These light-colored surfaces, best made using white coatings, reflect the Sun's light and, thereby, its heat. Interestingly, more area is available to create the lighter surfaces than to add vegetation in a city such as New York."

This study was sponsored by the New York State Energy Research and Development Authority, the New York State Department of Environmental Conservation, and the U.S. Department of Agriculture Forest Service. Detailed results were presented during the 2006 American Meteorological Society's annual meeting.

Space-Rooted Telemedicine Aids Earthquake Victims

Scientists at a NASA research partnership center have put space medical-monitoring technology to humanitarian use in helping earthquake victims in Pakistan.

Drs. Ronald Merrell and Azhar Rafiq, of Virginia Commonwealth University's Medical Informatics and Technology Applications Consortium (MITAC), went overseas in January to teach telemedicine techniques in Rawalpindi, Pakistan, a region hit hard by an October 10, 2005 earthquake that killed more than 80,000 people and left 3.5 million homeless. The physicians taught medical practitioners from remote mountainous regions how to provide cutting-edge health care, using technology that was originally developed for astronauts on long-term missions to the Moon.

In addition to this work, Merrell and Rafiq were also invited by the U.S. Department of State and the U.S. Department of Defense Telemedicine and Advanced Technology Research Center to complete a telemedicine training program consisting of online and videoconference lectures for the medical college at Holy Family Hospital in Rawalpindi. Pakistani teams that complete this training program can become qualified to use electronic scopes and medical cameras for skin evaluations, the results of which can then be submitted to a hub at the medical college for consultation and treatment recommendations.

Scientists at a NASA research partnership center used space medical-monitoring technology to help earthquake victims in Pakistan. The tents pictured here served as field hospitals for patients who experienced "crush" injuries incurred from falling concrete caused by the earthquake.

"The skin reveals a lot about our health," said Rafiq, who, while in Pakistan, provided a daily log of his personal observations for NASA's Web site. "Clammy, cold skin can be a sign of hypothermia, while moist, hot skin may indicate fever from an infection. With the continuum of virtual information available through telemedicine, we can apply some of the same diagnostic techniques and treatment on Earth that we are developing for space exploration."

AMD Telemedicine, Inc., a leading provider of telemedicine equipment located in Lowell, Massachusetts, is an industry partner with MITAC and the donor of the medical equipment for the Pakistan project, including the electronic stethoscopes and medical cameras.

NASA and University Scientists Uncover Lost Maya Ruins—From Space

Remains of the ancient Maya culture, mysteriously destroyed at the height of its reign in the 9th century, have been hidden in the rainforests of Central America for more than 1,000 years. Now, NASA and university scientists are employing space- and aircraft-based remote sensing technology to uncover these ruins, using the chemical signature of the civilization's ancient building materials.

NASA archaeologist Dr. Tom Sever and scientist Dan Irwin, both from Marshall Space Flight Center, are teaming with Dr. William Saturno, an archaeologist at the University of New Hampshire, to locate the ruins of the ancient culture.

"From the air, everything but the tops of very few surviving pyramids [is] hidden by the tree canopy," said Sever, widely recognized for 2 decades as a pioneer in the use of remote sensing for archaeology. "On the ground, the 60- to 100-foot trees and dense undergrowth can obscure objects as close as 10 feet away. Explorers can stumble right through an ancient city that once housed thousands—and never even realize it."

Sever has explored the use of remote sensing, the science of collecting information about the Earth's surface using aerial or space-based photography, to serve archaeology. He and Irwin provided Saturno with high-resolution, commercial satellite images of the rainforest and collected data from NASA's Airborne Synthetic Aperture Radar, an instrument flown aboard a high-altitude weather plane, capable of penetrating clouds, snow, and forest canopies.

These resulting Earth observations have helped the team survey an uncharted region around San Bartolo, Guatemala. It discovered a correlation between the color and reflectivity of the vegetation seen in the images—their "signature," which is captured by instruments measuring light in the visible and near-infrared spectrums—and the location of known archaeological sites.

In 2004, the team ground-tested the data. Hiking deep into the jungle to locations guided by the satellite images, it uncovered a series of Maya settlements exactly where the technology had predicted they would be found. Integrating cutting-edge remote sensing technology as a vital research tool enabled the scientists to expand their study of the jungle.

The cause of the floral signature differences discerned in the imagery quickly became clear to the team. The Maya built their cities and towns with excavated limestone

Deep in the Guatemalan jungle, NASA archaeologist Dr. Tom Sever, right, and team member Rob Griffin, a graduate student at Penn State University, study a crumbled "stele," a stone pyramid used by the Maya to record information or display ornately carved art. Sever and Griffin found the stele—and other Maya ruins hidden for more than 1,000 years—during an expedition that relied on NASA remote sensing technologies to pinpoint sites of ancient settlements. Sever and fellow researcher Dan Irwin, both of Marshall Space Flight Center, have teamed with archaeologist Dr. William Saturno of the University of New Hampshire, to demonstrate how high-resolution satellite imaging can reveal variations in plant life indicative of ancient building sites.

and lime plasters. As these structures crumbled, the lack of moisture and nutritional elements inside the ruins kept some plant species at bay, while others were discolored or killed off altogether, as disintegrating plaster changed the chemical content of the soil around each structure.

"Over the centuries, the changes became dramatic," Saturno said. "This pattern of small details, impossible to see from the forest floor or low-altitude planes, turned out to be a virtual roadmap to ancient Maya sites when seen from space."

According to Irwin, scientists believe the Maya fell prey to a number of cataclysmic environmental problems, including deforestation and drought, that led to their downfall. "The world continues to battle the devastating effects of drought today, from the arid plains of Africa to the southern United States," he said. "The more we know about the plight of the Maya, the better our chances of avoiding something similar."

Another aspect of the research involved using climate models to determine the effects of Maya-driven deforestation on ancient Mesoamerican climate. The goal of this effort was to determine whether deforestation can lead to droughts and if the activities of the ancient Maya drove the environmental changes that undermined their civilization.

Extending benefits of remote sensing technologies is part of NASA's Earth-Sun System Division. NASA is conducting a long-term research effort to learn how natural and human-induced changes affect the global environment, and to provide critical benefits to society today.

Sever and Irwin conduct research at the National Space Science and Technology Center, in Huntsville, a joint science venture between Marshall, Alabama universities, industry, and Federal agencies.

Under a NASA Space Act Agreement with the University of New Hampshire, the science team will visit Guatemala annually through 2009, with the support of the Guatemalan Institute of Anthropology and History and the Department of Pre-Hispanic Monuments. The team will verify its research and continue refining its remote sensing tools to more easily lead explorers to other ancient ruins and conduct Earth science research in the region.

"Studies such as these do more than fulfill our curiosity about the past," Sever said. "They help us prepare for our own future."

NASA Responds to Coral Bleaching in the Caribbean

As part of a U.S. interagency response, a NASA-led team arrived in the Caribbean to assess a coral-bleaching event in early 2006.

Coral bleaching is associated with a variety of stresses, including increased sea surface temperatures. This causes the coral to expel symbiotic micro-algae living in their tissues—algae that provide it with food. Losing algae leaves coral tissues devoid of color, given them a bleached appearance. Prolonged coral bleaching (more than a week) can lead to coral death and the subsequent loss of habitats for a range of marine life.

"Coral reefs are considered 'canaries of the oceans,' acting as an early warning system for marine ecosystems," said Liane Guild, a scientist at Ames. Guild led the NASA emergency deployment to rapidly assess the damage before other changes could take place in the affected reefs.

"I'm very pleased to have NASA step up and bring its expertise and assets to help the scientific community understand and address this devastating event," said Timothy Keeney, deputy assistant secretary of commerce for oceans and atmosphere.

The NASA-led interagency team inspected reefs in Puerto Rico, including sites at La Parguera and Culebra Island, and sites in the U.S. Virgin Islands, including Buck Island, the north coast of St. Croix, and the south coast of St. John.

With financial support and staff from NOAA, the U.S. Department of the Interior, and other agencies, NASA conducted aircraft flyovers above the affected reefs to gather valuable data.

This aerial image of Buck Island, off of St. Croix, was taken with a Cirrus Digital Camera System. This camera system flew on NASA's Twin Otter aircraft, along with the NASA Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), to assist researchers in their efforts to better understand and predict coral bleaching.

The team's Twin Otter aircraft—supplied by Goddard Space Flight Center—inspected the bleached reef areas using a digital camera and the NASA Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), an instrument that captures visible and infrared light data. The aircraft-based sensors provide high spectral and spatial resolution data and can be used to enhance understanding of ocean biology satellite data.

"The importance of this research is that we will be concentrating on aspects that enhance both understanding and prediction of reef status in terms of the extent of bleached corals, coral mortality, evidence of recovery, evidence of algal overgrowth, and biodiversity, using AVIRIS data and field measurements," Guild said.

NASA, NOAA, and other organizations also supported field monitoring to complement the flyover. Guild's field team was in the water when the flights occurred, collecting data on the coral that related to the AVIRIS data.

Coral reefs are critical for marine fisheries, providing habitat and nursery grounds, according to experts. "The structure of coral reefs provides coastline protection from severe storms by dampening wave action," Guild said.

The research done by the team that assessed the potential impact of a changing climate on global ecology supports U.S. Climate Change Science Program and U.S. Ocean Action Plan objectives.

The NASA-NOAA effort was just one component of the response. Many other efforts were started to help document and track this bleaching event and its long-term impacts on Caribbean coral reef ecosystems and the communities that depend on them.

Other partners in this study included researchers from the University of Puerto Rico, NOAA's Coral Reef Conservation Program, and the National Park Service in the U.S. Virgin Islands.

NASA and Industry Test Aircraft Noise-Reducing Technologies

NASA and aerospace industry partners are flight testing new technologies to see if they can make aircraft quieter. Scalloped edges on engine exteriors and toboggan-like fittings on landing gear are some of the high-tech ideas being tested to reduce aircraft noise.

Experts at Langley and industry team researchers developed advanced noise-reduction concepts and tested them, initially, using wind tunnels and computer simulations.

With the initial conceptual testing completed, the team assessed the ideas and actual hardware at a test flight facility in Glasgow, Montana. The researchers used a large, specially equipped 777 passenger jet provided by The Boeing Company. The test facility was outfitted with sophisticated microphone arrays and other measurement devices to record noise levels.

The Quiet Technology Demonstrator 2 was a 3-week test flight program to validate the ideas, including two improved chevron designs on the engine and a cover that fits on the landing gear. Chevrons are scalloped or serrated edges already used on some newer jet engines. One improved chevron design included asymmetrical scallops around the engine.

"The new design tailors the chevrons to take into account the air flow and acoustic differences that occur when the engine is installed on the aircraft," said Charlotte Whitfield, NASA's Quiet Aircraft Technology manager of airframe system noise reduction.

Laboratory tests showed the advanced chevron shape will reduce noise as much as 4 decibels during takeoff and when flying at cruise altitude. Results of the flight tests may lead to changes in aircraft configurations, and future airplane engine and landing gear designs.

Goodrich Corporation's Aerostructures and Landing Gear divisions designed and built a toboggan-like shaped cover for the 777's main landing gear.

The cover streamlines the gear and makes it less noisy. NASA and Goodrich tested this concept in a wind tunnel on a 26-percent scale model of the 777 landing gear. NASA research indicated that, when landing, air rushing past conventional landing gear is almost as loud as engine noise. The covered gear concept could reduce landing noise by another 3 decibels.

After completing the testing, Boeing delivered the new technology-equipped 777 to All Nippon Airways (ANA), in Tokyo. The aircraft joined the ANA passenger fleet and will provide additional noise data based on regular operations. GE Transportation Aircraft Engines, of Cincinnati, also participated in the research.

NASA Helps Weed the National Garden

NASA and other Federal agencies are using satellites that circle the Earth to help weed out a plant that is affecting water supplies in the western United States.

NASA has been using its satellite and computer resources to help other organizations control invasive plant species. An invasive species is a non-native species or species that is alien to the ecosystem in which it is found. Often, invasive species cause economic or environmental harm, or pose risks to human health. Invasive species can be plants, animals, and other organisms (such as microbes). Human actions are the primary means of invasive species introductions.

Invasive plant species are traditionally located, identified, and monitored by manual ground surveys. Such surveys are effective, but expensive, time consuming, and difficult to manage over large areas. Now, a new tool developed by the U.S. Geological Survey (USGS) is taking advantage of observations from NASA satellites and NASA engineering to provide a service for land managers that predicts quickly and inexpensively the location and spread of invasive plants over regional areas. The tool, called the Invasive Species Forecasting System (ISFS), was recently used to make the first predictive map of tamarisk—sometimes called saltcedar—habitats in the United States. Tamarisk is a large deciduous shrub, sometimes growing to the size of a small tree, and native to Africa and Eurasia. It was introduced in the western United States in the early 1800s as "ornamental vegetation" and for wind and erosion control.

Tamarisk has since spread and can be found from Minnesota to California and from Mexico to Canada. The U.S. Department of Agriculture recently identified tamarisk as one of the most harmful invasive species in the Nation, because the plant's long roots tap into underground aquifers. Its groundwater-absorbing qualities may be adding to the severity of the drought in the western United States. Tamarisk also increases the salt concentration of the soil and degrades habitats for native species along river systems.

"The ISFS combines NASA satellite data with tens of thousands of field sampling measurements," said Tom Stohlgren, director of the USGS National Institute of

Researchers now estimate that tamarisk has infested more than 3.3 million acres in the western United States. With the invasion spreading like wildfire, this invasive species poses a serious threat to the West's water supply.

Invasive Species Science. All of the data are then used to look at where non-native plants existed in the past, or where they exist today. Then, the ISFS tool can help predict where the invasive plants may grow or spread. People that manage lands, especially water supplies in the U.S. West, can use the color-coded maps that the ISFS produces to help predict and manage the spread of troublesome invasive species.

ISFS uses data from NASA's Terra, Aqua, and Earth Observing-1 satellites, and the USGS Landsat satellites, together with field data from government and non-government contributors. All of these satellites observe and measure sunlight reflected by plants and the environments in which they are growing. The satellites are able to lock in on some of the reflected light to determine tamarisk's current locations, as well as places where it may spread.

"Satellite data and computer modeling helps us understand where tamarisk is likely to be growing, even in remote locations that field researchers cannot easily reach," said John Schnase, principal investigator of the ISFS project at Goddard.

Currently, USGS is using the ISFS to predict the spread of other invasive species, such as cheatgrass, Canadian star thistle, and certain aquatic species.

Scientists Get a Real 'Rise' Out of Breakthroughs in Understanding Changes in Sea Level

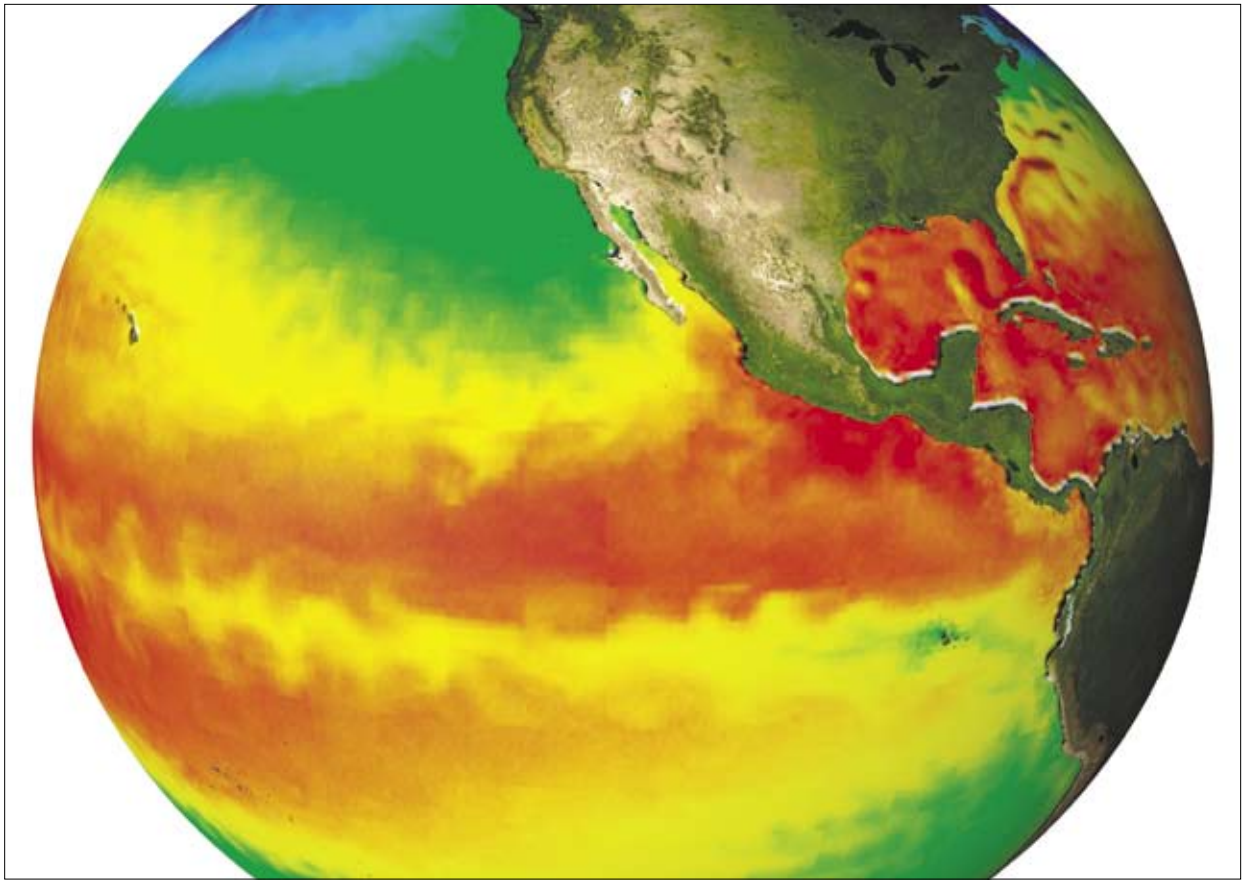
For the first time, researchers have the tools and expertise to understand the rate at which sea levels are changing and the mechanisms that drive that change.

Sea levels rise and fall as oceans warm and cool and as ice on land grows and shrinks. Other factors that contribute to sea level change are the amount of water stored in lakes and reservoirs and the rising and falling of land in coastal regions.

"From the Mississippi Delta, to the Maldives Islands off the coast of India, to the multitude of other low-lying coastal areas around the world, it is estimated that over 100 million lives are potentially impacted by a 3-foot increase in sea level," said Dr. Waleed Abdalati, head of the Cryospheric Sciences Branch at Goddard. "This is an ideal time, during the midst of a historic year of both related natural events and research developments tied to this critical global issue, to talk to the public about whether ice in our polar regions is truly melting, whether our oceans are indeed rising faster, and what these changes may mean to us."

NASA is taking advantage of its unique, space-based satellite observations of Earth's oceans and atmosphere, in combination with satellite observations and sea surface measurements from domestic and international partners, to learn more about why and how the world's waters are rising. In doing so, the Agency is hoping to determine more about factors leading to sea level change, indicators of change such as ocean expansion, changes in ice, impoundment of water, and movement of earth and coastal regions, and how the latest research developments contribute to our knowledge of sea level rise.

NASA is working with NOAA, the National Science Foundation, and others to explore and understand sea level change—to tell the story of what is happening. NASA satellite missions devoted to sea level research



Changes in sea level entail a complex array of conditions, from chemistry and temperature, to changes in the shape of the basins that hold the world's water. This advanced computer model shows the span of sea temperatures across the globe. Recent research indicates that ice cover is shrinking much faster than thought, with over half of recent sea level rise due to the melting of ice from Greenland, West Antarctica's Amundsen Sea, and mountain glaciers.

include: the Gravity Recovery and Climate Experiment (GRACE), which maps Earth's gravitational field with precision and resolution, and whose data helps us better understand movement of water throughout the Earth; the Ocean TOPography EXperiment (TOPEX/Poseidon), a joint U.S./French satellite that uses radar to map the precise features of the oceans' surfaces; The JASON Project, which measures ocean height and monitors ocean circulation; and the Ice, Cloud, and Land Elevation Satellite (ICESat), whose primary purpose is to study the mass of polar ice sheets and their contributions to global sea level change.

According to Dr. Laury Miller, chief of the NOAA Laboratory for Satellite Altimetry, the big news that has emerged over the past few years is that the rate of 20th century sea level rise is about 2 millimeters per year and that only a quarter of this is due to expansion caused by warming of the oceans. This provides an important context for these recent observations.

"We've found that the largest likely factor for sea level rise is changes in the amount of ice that covers Earth. Three-fourths of the planet's fresh water is stored in glaciers and ice sheets, or about 220 feet of sea level," said Dr. Eric Rignot, principal scientist for the Radar Science and Engineering Section at JPL. Research results by Rignot and partners, published in an October 2004 article in Science magazine, offer further evidence that ice cover is shrinking much faster than previously thought, with over half of recent sea level rise due to the melting of ice from Greenland, West Antarctica's Amundsen Sea, and mountain glaciers.

The latest sea level research conducted by Dr. Steve Nerem, associate professor at the Colorado Center for Astrodynamics Research at the University of Colorado at Boulder, and his colleagues, and published in a 2004 issue of Marine Geodesy, has found that recent TOPEX/Poseidon and JASON satellite observations show an average increase in global mean sea level of 3 millimeters a year, from 1993 to 2005. This rate is more than 50 percent greater than the average rate of the last 50 years.

"Now the challenge is to develop an even deeper understanding of what is responsible for sea level rise and to monitor for possible future changes. That's where NASA's satellites come in with global coverage, and ability to examine the many factors involved," said Miller. ❖

Innovative Partnerships Program Network

The Innovative Partnerships Program creates alliances with industry, academia, and other non-traditional sources to develop and transfer technology in support of national priorities and NASA's missions. The programs and activities resulting from the alliances engage innovators and enterprises to fulfill NASA's mission needs and promote the potential of NASA technology. This section recognizes the NASA organizations that assist in establishing these fruitful relationships.

Innovative Partnerships Program Network

The NASA Innovative Partnerships Program is comprised of the National Technology Transfer Center (NTTC) and a network of field center offices located around the country to provide a full range of technology transfer and commercialization services and assistance.

The **National Technology Transfer Center (NTTC) <http://www.nttc.edu>** was established in 1989 to expedite the commercialization of federally funded research and development. In that role, the NTTC links U.S. industry with Federal laboratories and universities that have the technologies, the facilities, and the world-class researchers that industry needs to maximize product development opportunities. Through these partnerships, the NTTC helps Federal agencies find companies that can commercialize technologies developed in the Federal laboratories and leverage research and development efforts across the public and private sectors to create collaborative research opportunities. The NTTC has worked with NASA since 1989, providing the services and capabilities needed to meet the changing needs of NASA for managing intellectual property and creating technology partnerships.

The NTTC, having developed as a full-service technology commercialization asset for federal and nonfederal funded technologies is now refocusing its NASA services to align with the Innovative Partnership Program's (IPP) Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) Program, but will continue to perform traditional technology transfer services as requested by NASA and for other clients.

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 **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 **Mississippi Enterprise for Technology (MsET) <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

The National Technology Transfer Center is located on the campus of Wheeling Jesuit University, in Wheeling, West Virginia.

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.

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 re-search 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.

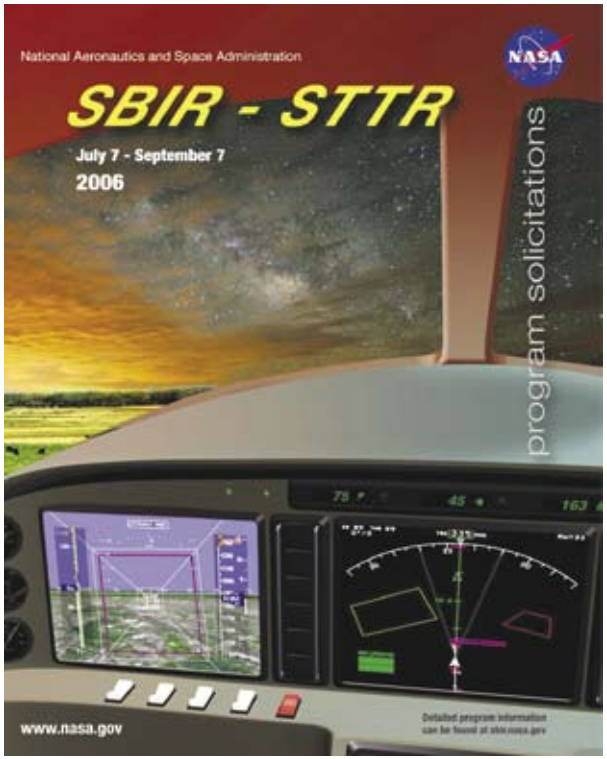
Although modeled after the SBIR program, STTR is a separate activity and is separately funded. The STTR program differs from the SBIR program in that the funding and technical scope is limited and participants must be teams of small businesses and research institutions that will conduct joint research.

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 IPP affiliated organizations devoted to the transfer of NASA technology are the **Research Triangle Institute (RTI)** and the **MSU TechLink Center**.



NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are a three-phased approach for the small business concern to develop a technology in response to a specific set of NASA mission-driven needs, as presented in the NASA SBIR/STTR Annual Solicitation.

The **RTI <http://www.rti.org>**, located in Research Triangle Park, North Carolina, provides a range of technology management services to NASA. RTI performs technology assessments to determine applications and commercial potential of NASA technology, as well as market analysis, and commercialization and partnership development. RTI works closely with all of NASA's Technology Transfer Offices.

The **MSU TechLink Center <http://techlinkcenter.org>** 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 Internet access to its database of over 3.9 million citations, as well as many in full text; online ordering of documents; and the NASA STI Help Desk (help@sti.nasa.gov) for assistance in accessing STI resources and information. Free registration with the program is available through the NASA Center for AeroSpace Information.

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.

Technology Innovation is one of NASA's magazines for business and technology, published by the Innovative Partnerships Program. The latest issue highlights Kennedy Space Center recognition for NASA invention for the year.

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.

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.nasa.gov/innovation>** is published quarterly by the NASA Office of Exploration Systems. 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> 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. ❖

NASA Innovative Partnerships Network Directory

The FY 2006 NASA Innovative Partnership Program Network (IPPN) extends from coast to coast. For specific information concerning technology partnering 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 at technology@nttc.edu.

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.

■ **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.

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