National Aeronautics and Space Administration

Spinoff

Ohio

2005-2007

Inspiration Innovation Discovery Future

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Secure Networks for First Responders and Special Forces

Originating Technology/ NASA Contribution

When NASA needed help better securing its communications with orbiting satellites, the Agency called on Western DataCom Co., Inc., to help develop a prototype Internet Protocol (IP) router.

Westlake, Ohio-based Western DataCom designs, develops, and manufactures hardware that secures voice, video, and data transmissions over any IP-based network. The technology that it jointly developed with NASA is now serving as a communications solution in military and first-response situations.

Partnership

In early 2000, Glenn Research Center approached Western DataCom to develop the prototype IP router. This was part of NASA's "IP in Space" initiative, which looked to employ commercial off-the-shelf products to support reliable, fast, and secure communications between NASA and its orbiting satellites. The company signed a Space Act Agreement with Glenn and delivered a prototype device that met the three requirements set by the NASA research center, namely speed, security, and reliability. The router employed advanced data-compression techniques (to improve throughput and meet the speed requirement) and encryption (to meet the security requirement), and operated with commercial protocols (to meet the reliability requirement).

Because of the work it had done for Glenn, Western DataCom was approached by Cisco Systems, Inc., in 2001, to participate in the development of an IP encryptor for the Cisco Mobile Access Router (3200 Series), for military use. According to Western DataCom, it offered Cisco two distinct advantages: 1) Western DataCom had leading encryption and compression technologies, from working with NASA, as well as the National Security Agency; and 2) Western DataCom code developers possessed the military clearances needed to perform the work required. Cisco created its "Advance Technology Partner" classification and named Western DataCom the first of such partners. Cisco also joined Western DataCom in working with Glenn to develop the reliable, fast, and secure mobile router system for military and first-response use.

The technology was not commercially available at the time that the September 11 attacks took place, but will prove invaluable to emergency and rescue personnel in averting any potential future threats.

This van served as the mobile test bed when the IP router technology was field-tested at Glenn Research Center.

Product Outcome

In the hours and days after September 11, communications between first responders and emergency-management officials from Federal, state, and local agencies were severely disrupted. New York City's Emergency Operations Center, designed to coordinate rescue efforts in a major terrorist attack, was housed in the 47-story "7 World Trade Center" building and destroyed.

The World Trade Center was a node of central communications for all forms of voice and data traffic and was utilized by business and private customers, as well as the city's first responder and emergency-management agencies. Communications systems for the police and fire departments were temporarily disabled as a result of the damage caused by the collapsing of the building and senior emergency-management officials were unable to contact first responders in the early hours of the tragedy.

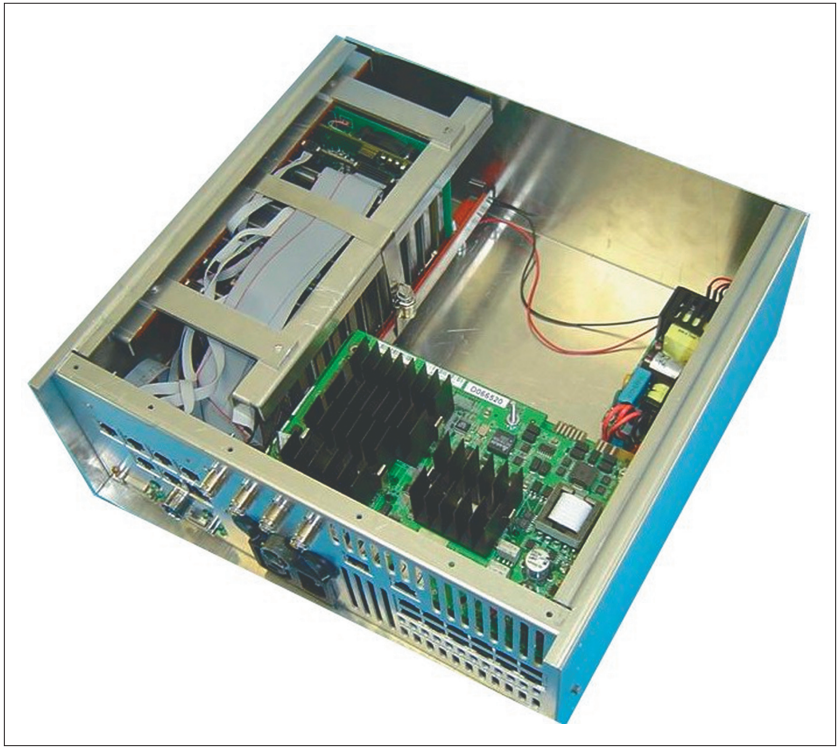
Because police and firefighters could not communicate directly with each other, many firefighters within striking distance of safety never received a police warning on the impending collapse of the South Tower. A report from the University of New Hampshire* concluded that this lack of interoperability between the police and fire communications systems were "at least, partially responsible for the loss of 343 firefighters at the World Trade Center."

Much of New York City's landline and cell phone infrastructure was also damaged or destroyed during the attacks. Moreover, the disaster generated so much communications traffic in and around the city that the remaining intact landline, cellular, and two-way pager systems became too congested to be of use to first responders and emergency-management personnel.

The experiences of September 11 have driven many organizations and individuals to realize that new communications systems are needed to secure our country and improve our ability to respond to terrorist attacks. In addition, the ongoing conflicts in Afghanistan and Iraq have broadened the need to provide a mobile, interoperable, and secure communications system solution for the U.S. military and first responder personnel, such as U.S. Army National Guard, firefighters, police, and emergency medical services (EMS).

In 2004, the secure mobile router system co-developed by Western DataCom and NASA was successfully used by the Army for an aerostat (balloon)-based radar, called the Persistent Threat Detection System, in Operation Iraqi Freedom. The system permits military technical operations centers (TOCs) in Iraq to send secure, high-speed voice, video, and data communications to the field through tactically deployed mobile units. This was the first use, during war, of technology enabling TOCs and mobile units to send secure voice, video, and data communications, according to Western DataCom.

First responders from Cook County, Illinois; the New York Port Authority; and the New Jersey Port Authority are currently utilizing the company's secure system in preparation for natural or man-made disasters. Also, in 2004, Western DataCom developed a secure-communications modem to be utilized primarily by first responders for homeland defense operations. These products were successfully deployed during the Republican National Convention and the presidential inauguration.



Western DataCom Co., Inc.'s Executive Travel Case sets up connections automatically to the Internet, Secret Internet Protocol Router Networks (SIPRNETs), and Non-secure Internet Protocol Router Networks (NIPRNETs), for use by the U.S. Joint Forces Command.

Recently, Western DataCom received a $100,000 Glenn Alliance for Technology Exchange (GATE) award from Glenn and Battelle, an organization that helps bring NASA technology to companies outside the traditional aerospace industry. The award, in the form of $50,000 in cash and $50,000 in Glenn engineering time, will be used to design a small personal computer encryptor card for commercial markets. This card is anticipated to act as a shield outside of a computer, protecting its hard drive from outside "attacks," such as worms and viruses, as well as "middle-man" and "spoofing" threats. (A "middle-man" is someone who unwittingly spreads a virus by simply opening or forwarding an e-mail, while "spoofing" is a technique used to gain unauthorized access to computers. A user receives e-mail that appears to have originated from one source when it actually was sent from another source, in an attempt to trick the user into releasing sensitive information.)

The two NASA engineers assigned to this project have experience with Western DataCom, in that they were involved with the 2000-2001 "space router" project that culminated in the basic technology platform utilized in the company's current encryptor product line.

Once the commercial personal computer card is operational, Western DataCom plans to design a top-secret military version. The company intends to have the commercial card designed and operating, and to have work started on the military version, by the end of 2005. ❖

*Lund, Donald A., The Lessons of Non-Interoperability in Public Safety Communication Systems. University of New Hampshire, April 2002.

Cooking Dinner at Home—From the Office

Originating Technology/ NASA Contribution

It is well past quitting time, but you are still stuck in the office. Your spouse left work over an hour ago, but is caught in bumper-to-bumper traffic. As a result, neither of you were available to pick up your daughter on time from her soccer game. If your son hadn't gotten detention at school today—which also made him late for work—he could have picked her up.

The next thing you know, it is already 8:30 at night, and your family members are finally all together under the same roof. No one has had a bite to eat since lunch, and dinner certainly isn't going to cook itself…or is it?

For those who are all too familiar with this situation, it might be time to welcome the oven of the future into your homes: the *Connect*Io Intelligent Oven, brought to you by TMIO, LLC, of Cleveland. Applying the same remote command and control concepts that NASA uses to run experiments on the International Space Station (ISS), *Connect*Io allows its owners to cook dinner from the road, via a cell phone, personal digital assistant, or Internet connection.

By combining remote-access technology with the capability to both cook and refrigerate food, TMIO, LLC, has eliminated the "wait time" of cooking.

Partnership

In 1994, David Mansbery was at the helm of an active family whose schedule rarely allowed for home-cooked meals. Growing tired of frequent fast-food dinners, Mansbery set out to bring traditional, home-cooked dinners back into his home. At the time, Mansbery was president of a natural gas supply company, and NASA's Glenn Research Center was one of his biggest clients.

When Mansbery pitched his idea of a hot-and-cold, remotely operated oven to Glenn, the NASA center lined him up with a group of its engineers that had worked on the ISS Electric Power System, the Solar and Heliospheric Observatory (SOHO) that studied the Sun, the Cassini spacecraft that is currently visiting Saturn, and several experiments that flew on the Space Shuttle. These engineers supplied Mansbery with "Embedded Web Technology" software that was developed at Glenn in 1996. According to its inventors, Embedded Web Technology marries embedded systems (hardware or software that forms a component of a larger system and is expected to operate without human intervention) and the World Wide Web, to let a user monitor and/or control a remote device with an embedded system over the Internet, using a convenient, graphical user interface. In contrast to general purpose desktop computers, embedded systems contain processors, software, input sensors and output actuators—all of which are dedicated to the control of a specific device.

NASA counts on Embedded Web Technology to allow astronauts to operate experiments from anywhere on the ISS, using any laptop computer available to them. This way, NASA can operate its experiments without having to install user-interface software on all of the laptop computers for every space-bound instrument. To date, an estimated $150 million has been saved by use of this software to control Space Station payloads.

With authorization to use the Embedded Web Technology, Mansbery formed the TMIO company to execute his idea. The NASA software enabled low-cost, real-time remote control and monitoring of the resulting intelligent oven product.

Product Outcome

With combined cooling and heating capabilities, TMIO's *Connect*Io stainless-steel professional series oven provides convenience and healthy living for today's active lifestyles. Before leaving for work, consumers can place fresh food in *Connect*Io, where it will remain properly refrigerated until a programmable cooking cycle begins; the oven is preprogrammed with a universal cooking menu, which can be customized to the user's preferences. The menu allows the user to simply enter in the dinner time, and the oven automatically switches from refrigeration to the cooking cycle, so that the meal will be ready as the family arrives home for dinner.

Should plans change, the embedded software enables the user to conveniently and instantaneously adjust and control the oven settings while away from home, via a cell phone, personal digital assistant, or the Internet. This includes re-refrigeration, warming for a completed meal, and any temperature or time modifications that need to be made on the fly.

*Connect*Io's unique two-cavity design offers independent cooling and cooking of two separate dishes. For instance, chicken can be placed in the top compartment and potatoes in the bottom. Each dish cools and cooks according to its own instructions.

Built-in Ethernet capabilities allow for a seamless connection of *Connect*Io to the outside world, so additional wiring is not required. The oven also features touch screen controls that integrate into flat panels around the house, allowing for a sophisticated and practical way to see if dinner is ready without having to leave a room, or perhaps miss a part of a favorite television show, to check on the oven. Furthermore, TMIO asserts that *Connect*Io's advanced structural design leads to safer and more energy-efficient cooking and self-cleaning cycles.

The technology was recognized as one of TIME magazine's "Coolest Inventions" for 2003, as Reader's Digest's "Best of America" for 2004, and honored with the 2004 "Best of Innovations" award by the Consumer Electronics Association. It has made numerous television appearances on programs like CNBC's "Power Lunch," "Good Morning America," "The View," and ESPN's "Cold Pizza," as well as A&E Television Network's "At Home with the Brave," a show that offers home-renovation remedies to soldiers returning from Iraq and Afghanistan; TMIO contributed a *Connect*Io oven to a deserving soldier and his family, who were featured on the program. TMIO has also announced its engagement of a Beverly Hills-based product placement firm to help bring *Connect*Io to prime time television and Hollywood movie sets.

Built from NASA technology, one-too-many nights of fast food, and some forward-thinking inspired by the cartoon, "The Jetsons" (TMIO openly admits to this influence), *Connect*Io has revolutionized the cooking industry and brought the family back together for dinner. ❖

Astronaut Daniel Burbank, mission specialist for STS-106, uses a laptop computer to keep up with busy chores onboard the Space Shuttle Atlantis. Embedded Web Technology, developed at Glenn Research Center, allows astronauts to monitor and operate International Space Station experiments from remote positions, just as it lets owners of the *Connect*Io Intelligent Oven cook meals—away from home.

From a remote location, the *Connect*Io Intelligent Oven can be programmed to automatically switch from refrigeration to the cooking cycle, so that the meal will be ready as the family arrives home for dinner.

Cost-Cutting Powdered Lubricant

Originating Technology/ NASA Contribution

Scientists at NASA's Glenn Research Center developed a high-temperature, solid lubricant coating material that is saving the manufacturing industry millions of dollars. The material came out of 3 decades of tribological research, work studying high-temperature friction, lubrication, and the wearing of interacting surfaces that are in relative motion. It was developed as a shaft coating deposited by thermal spraying to protect foil air bearings used in oil-free turbomachinery, like gas turbines, and is meant to be part of a larger project: an oil-free aircraft engine capable of operating at high temperatures with increased reliability, lowered weight, reduced maintenance requirements, and increased power.

This advanced coating, PS300, is a self-lubricating bearing material containing chromium oxide, with additions of a low-temperature start up lubricant (silver) and a high-temperature lubricant, making it remarkably stable at high temperatures, and better suited than previously available materials for high-stress conditions. It improves efficiency, lowers friction, reduces emissions, and has been used by NASA in advanced aeropropulsion engines, refrigeration compressors, turbochargers, and hybrid electrical turbogenerators.

PS300 is ideal in any application where lowered weight and reduced maintenance are desired, and high-temperature uses and heavy operating speeds are expected. It has notable uses for the Space Agency, but it has even further-reaching potential for the industrial realm.

Partnership

The Great Lakes Industrial Technology Center (GLITeC), a NASA technology incubator that helps small business take advantage of available NASA technologies, assisted ADMA Products, Inc., in obtaining a license for PS300.

Oil-free bushings coated in PS300 save companies thousands of dollars in repair costs. PS300 is a composite high-temperature, lubricating, chrome-oxide-based material that is embedded with compound particles that function as solid lubricants.

ADMA, based in Hudson, Ohio, specializes in powder metallurgy products from titanium, zirconium, niobium, and other advanced materials and alloys. It had been using PS200 for 8 years already when NASA developed the more advanced PS300. Vladimir Moxson, ADMA president, jumped at this new opportunity. GLITeC worked with company management to design a commercialization plan, and ADMA now holds the license for PS300.

Through GLITeC, NASA continued to support ADMA with the development and commercial application of PS300. Researchers worked closely to optimize the manufacturing process and maximize yield. The result was that, after the collaboration, ADMA was able to increase yields of the key starting material from 5 percent to 45 percent. This improvement reduced the price of the PS300 composite, cut delivery times of the product, and increased ADMA's profits.

ADMA is now supplying the advanced PS300 at a reduced cost to thankful customers, who, in turn, are saving hundreds of thousands of dollars from the use of this space-age product.

Product Outcome

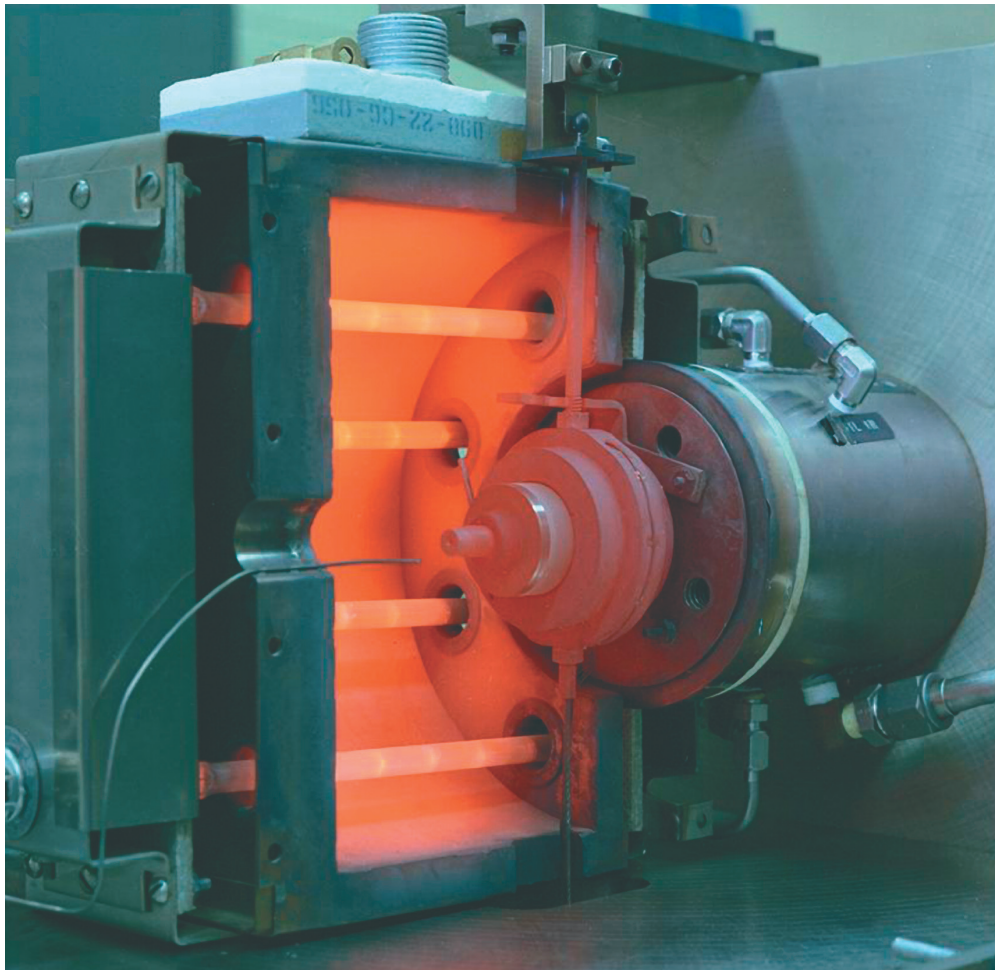
PS300 starts as a powder, which ADMA can either manufacture into a customized solution for a customer's specific needs or apply directly as a coating, via thermal spraying techniques or standard powder metal application methods, such as the press and sinter methods. In short, ADMA can work this material to fit any needs.

One of ADMA's customers, Elliott Turbomachinery Company, of Jeannette, Pennsylvania, has had resounding success with PS304, a derivative of PS300 which is used for coating by plasma spraying. Elliott is a designer and manufacturer of air and gas compressors, steam turbines, power recovery turbines, and power-generating equipment. The company has heavy, moving machinery, called lift rods, that withstand an amazing amount of wear and operate in temperatures up to 1,005 °F.

ADMA provided, through Hohman Plating and Manufacturing Corporation, of Dayton, Ohio, PS300 powdered lubricant-coated valve lift rods for Elliot's steam turbine compressors, with noteworthy economic benefits. Elliott had previously replaced the rods every 2 years, but projects that these new rods will last 8 years. It estimates that this will save at least $3 million in repair costs, not including the additional advantage of not having to leave the equipment idle for days upon days during the actual repairs.

ADMA has provided another company with this dry lubricant and had similarly remarkable cost-saving effects. The Lincoln Electric Company, of Cleveland, Ohio, designs, develops, and manufactures arc welding products, robotic welding systems, and plasma- and oxygen-cutting equipment. Lincoln had the need to replace a set of bronze bushings that were an integral part of a dryer oven used in a manufacturing line. The current bushings were causing system failures, which led to downtime and frequent, costly repairs. ADMA produced a set of PS300 bearings to address the problem.

Lincoln found that these bearings showed such high reliability that the company decided to retrofit all of its sintering furnaces with them. This expenditure, the company estimates, will save an average of $200,000 per furnace per year, over an estimated lifespan of 10 to 20 years. Like Elliot, Lincoln is finding additional economic return, since the furnaces do not have to be shut down as often for maintenance and repairs. It refurbished a number of its furnaces and even its subsidiaries abroad are working to replace their bronze bushings with the space-age material. ❖



This red-hot machine (pictured here with the door open) tests the PS300 bearing materials under very high temperatures.

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.

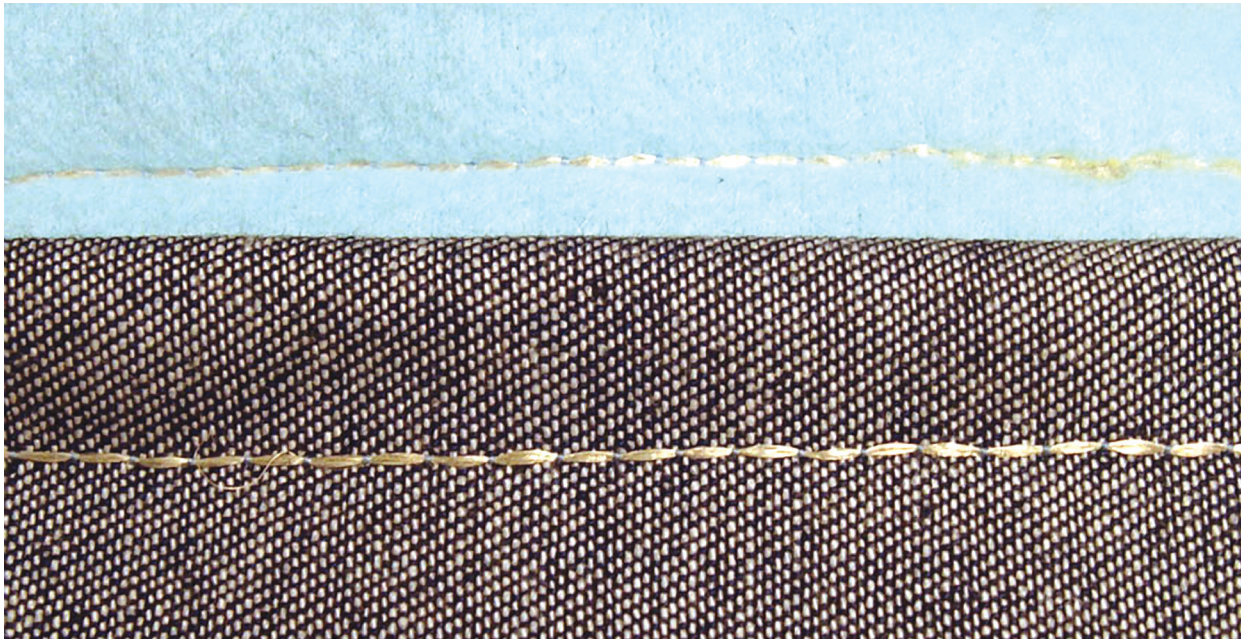
Electrotextiles will allow wearers a variety of functions, ranging from listening to MP3s to controlling temperature. Like so many electronic entertainment trends, when this catches on, it has the potential to change the electronics industry and make electrotextiles and electronically conductive fibers 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. ❖

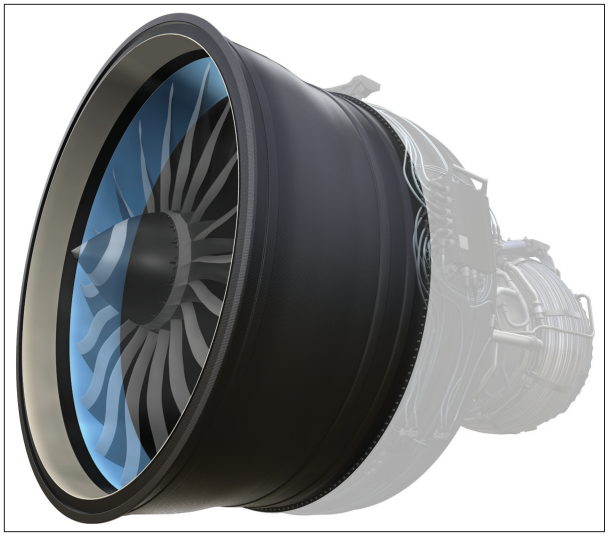
AmberStrand™ is a trademark of Syscom Technology, Inc.

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.

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.

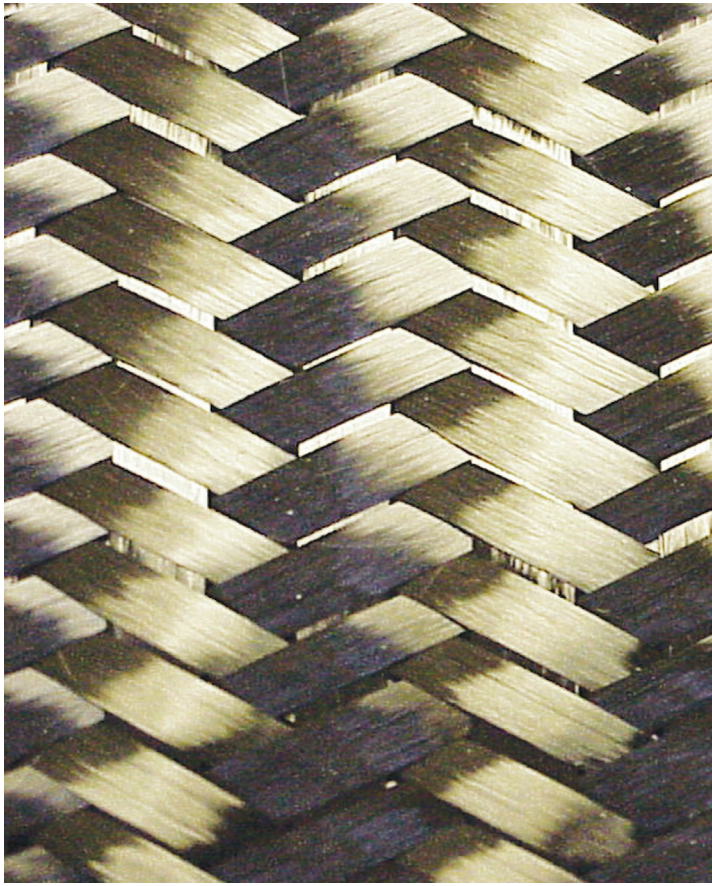
The prototypes proved feasible. A&P, a seventh-generation, family-owned company is partnered with two major manufacturers of jet aircraft engines—Williams International and Honeywell International Inc.—and is sponsored by General Electric Corporation's Aviation division, GE Aviation, in the development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

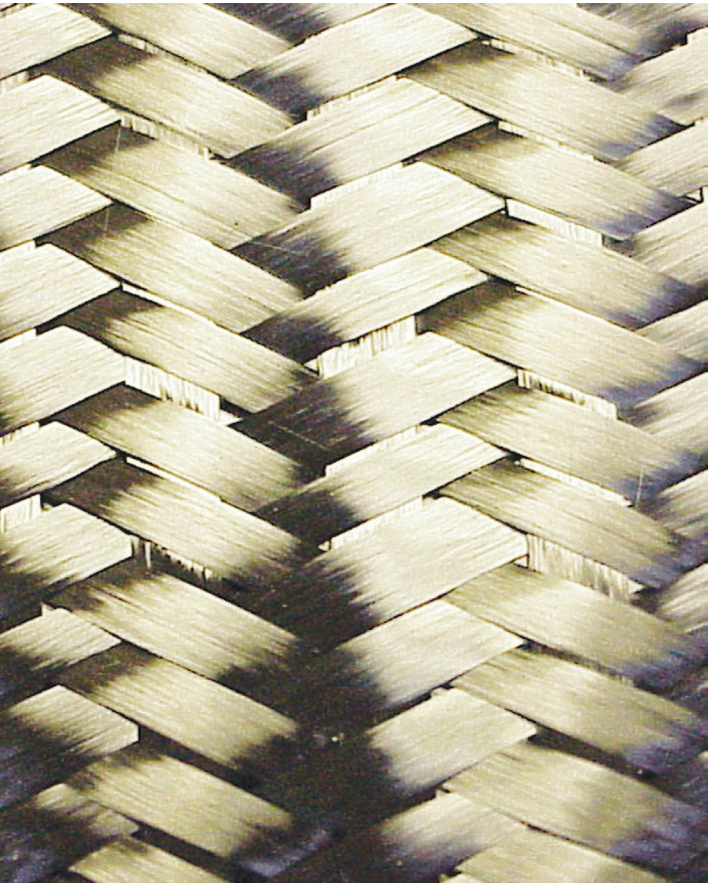
A&P uses triaxial carbon braid as an alternative to aluminum or other solid metal in the manufacture of braided fan containment cases for jet engines. The braided fan case has a toughness superior to aluminum and enables significant reductions in weight and fuel consumption.

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.

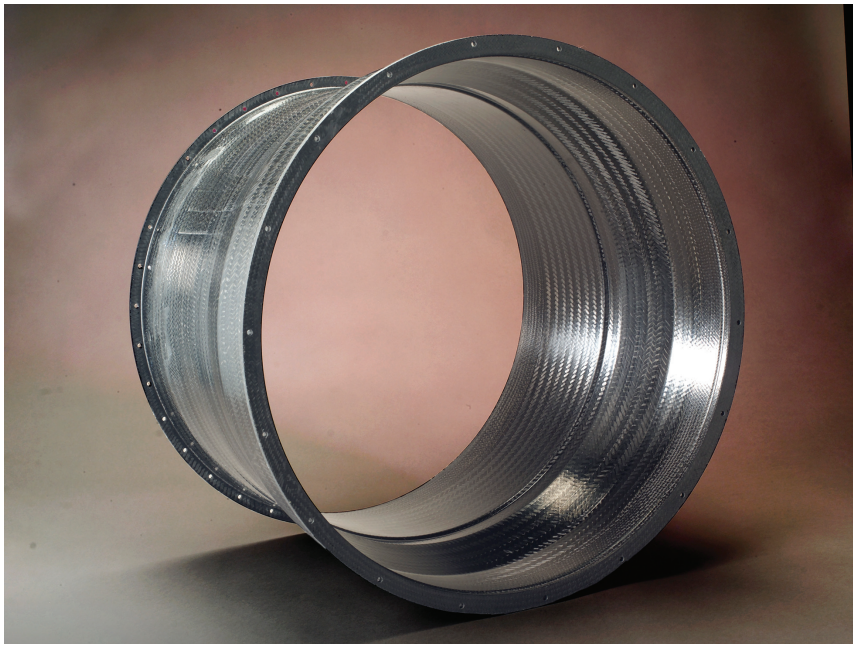
Not only can the efficiency of the manufacturing process increase noticeably with the braid, but the performance of the braided case exceeds the performance of conventional fan cases. Impact testing has shown that braided laminates perform better, because the failure mode is much more controlled. In 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. ❖

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.

Corrosive Gas Restores Artwork, Promises Myriad Applications

Originating Technology/NASA Contribution

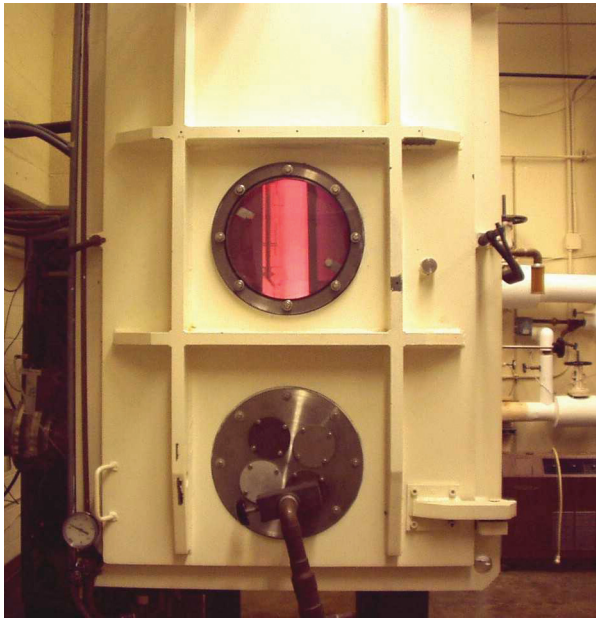
Short wavelength solar radiation in the space environment just outside of the Earth's atmosphere produces atomic oxygen. This gas reacts with spacecraft polymers, causing gradual oxidative thinning of the protective layers of orbiting objects, like satellites and the International Space Station, which maintain low-Earth orbit directly in the area where the corrosive gas is most present.

To combat this destructive gas, NASA engineers developed long-duration coatings that are resistant to the effects of its problematic presence. To validate the effectiveness of the coatings, NASA had two options: Either send the materials into orbit for testing, which would involve the cost of launches and severely limit access to the experiments, or recreate the atmospheric conditions here on Earth. NASA chose the latter, and the Electro-Physics Branch at Glenn Research Center constructed ground facilities to test the durability of different materials by introducing them to a recreated form of the corrosive space gas.

The experiments were successful, and the coatings are currently used on the International Space Station. In the experimentation, though, the scientists discovered several additional interesting applications for their test facilities and beneficial uses for atomic oxygen here on Earth.

Partnership

Led by Glenn's Bruce Banks and Sharon Rutledge, the Electro-Physics researchers became familiar with atomic oxygen's unique characteristic of oxidizing hydrogen, carbon, and hydrocarbon polymers at surface levels. While destructive to spacecraft polymers constructed with those materials, atomic oxygen's selectivity could, they realized, also be applied in instances where someone wanted just those elements removed. Over the past few years since they made this realization, Banks and his team have partnered with several churches and museums to restore fire-damaged or vandalized artworks, and with an international forensics organization to develop new methods for detecting forged documents, as well as having developed a method for using atomic oxygen to remove bacterial contaminants from surgical implants.



The Atomic Oxygen Exposure Facility in operation at Glenn Research Center has been used for the removal of smoke damage and aged varnish from the surface of paintings and for cleaning organic contaminants from surfaces of materials.

Product Outcome

Atomic oxygen is able to remove organic compounds high in carbon (mostly soot) from fire-damaged artworks without causing a shift in the paint color. It was first tested on oil paintings. In 1989, an arson fire at St. Alban Episcopal Church, in Cleveland, nearly destroyed a painting of Mary Magdalene. Although the paint was blistered and charred, after 230 hours of atomic oxygen treatment and a reapplication of varnish, it was once again recognizable as a work of art. In 2002, a fire at St. Stanislaus Church, again in Cleveland, left two paintings with soot damage that the atomic oxygen process was able to remove.

Buoyed by the successes with oil paints, the team also applied the restoration technique to acrylics, watercolors, and ink. As long as the paints were primarily synthetic, the results were promising. They discovered though, that some organic acrylics and ink, in particular, required less exposure so that the atomic oxygen would not begin to wear away at the medium itself. This potential liability has been used advantageously, however, in instances of graffiti removal. Experiments showed that, by using a pencil-thin beam of atomic oxygen, the team was able to remove most inks except black permanent marker.

At Pittsburgh's Carnegie Museum of Art, where an Andy Warhol painting, "Bathtub," was kissed by a lipstick-wearing vandal, the technique successfully removed the offending pink mark with a portable atomic oxygen gun. The process lightened a spot of paint, but a conservator was easily able to match the spot, thus restoring the painting.

The successes with the art restoration process were well-publicized, and Lynda Taylor-Hartwick of the Independent Association of Questioned Document Examiners Inc. (IAQDE), a multinational, nonprofit professional organization dedicated to the art of forensic analysis of documents, read about the effects of atomic oxygen on ink and became curious about possible applications for this process in the field of forgery detection. She found that it can assist document analyzers in determining if, for example, checks or wills have been altered.

Atomic oxygen oxidation of ink may cause altered pen marks to look differently than the original marks. It can help examiners discriminate between two different inks, because different inks may oxidize at different rates, showing document examiners any signs of tampering. Usefulness, however, is not limited to instances where the

inks are of different manufacture. Atomic oxygen, which oxidizes and removes organic materials by converting them into gasses, works gradually. Thus, thick layers of carbon or organic materials take longer to remove than thin layers. The ends of pen strokes tend to have much thicker ink deposits than the rest of the line, enabling the use of atomic oxygen exposure to determine which lines were drawn first, which strokes were made as one fluid movement, and which overlapped strokes have been added at a later date, a clear indication that a document has been altered.

The most telling sign, though, is the layering of ink that occurs when someone writes over a letter or number to alter it. Take, for example, the classic case of modifying a report card to turn an F into a B before showing the parents. To complete this feat, the belatedly concerned student would connect the lines at the top of the F with a curved stroke, making it more similar to the letter P, and then finish the job by looping in the base, thus raising the grade to a B. In order to make the job look good, though, the strokes must connect to the original letter, even overlap a little to make it look uniform. It is the overlapping, a miniscule amount of layering, that atomic oxygen can erode in order to expose the alteration.

While most parents may not go the extent of acquiring a portable atomic oxygen gun to check a report card, the application becomes more relevant for applications like determining check fraud or altered wills. Just as an F can become a B, a 1 can become a 9 or a 3 can become an 8, which could have potentially significant financial implications in instances of fraud.

Parishioners at St. Alban Church, in Cleveland, thought this painting of Mary Magdalene was ruined after an arson fire destroyed much of the property. The same corrosive attributes of atomic oxygen that eat away at spacecraft were able to remove the layers of soot and smoke that covered the painting.

It is not just paint and ink that the Glenn team is experimenting on, though. The gas has biomedical applications as well. Atomic oxygen technology can be used to decontaminate orthopedic surgical hip and knee implants prior to surgery. As a result of handling, fabrication, and exposure to air, the surfaces of these implants are often contaminated with endotoxins (naturally occurring compounds found within bacteria) and other biologically active contaminants. Such contaminants contribute to inflammation, which can lead to joint loosening, pain, and even the necessity to remove the implant. Previously, there was no known chemical process which fully removed these inflammatory endotoxins without damaging the implants. Atomic oxygen, however, can oxidize endotoxins and any other organic contaminants to convert them into harmless gasses, leaving a contaminant-free surface.

The inventors have patented this application for atomic oxygen and believe it could lead to significant reduction in health care costs for the more than 2.8 million people who receive orthopedic implants annually. They also believe that it promises increased functional life of implants, as well as a reduction of inflammation and the associated joint pain that patients experience.

Additional collaborative research between the Cleveland Clinic Foundation and the Glenn team into the terrestrial uses of atomic oxygen shows that this gas's roughening of surfaces even improves cell adhesion, which is important for the development of new drugs.

While this application is still in its testing stages, the others are available for use. The patent for atomic oxygen art restoration is now in the public domain. Use of the technology for document alteration detection was never patented, and it, too, is available in the public domain. A patent was licensed for the removal of biologically active components from surgical implants, and Glenn is currently in talks with a company that sells plasma treating equipment. ❖

Food Supplement Reduces Fat, Improves Flavor

Originating Technology/NASA Contribution

During the Mercury missions, astronauts ate terrible food: freeze-dried powders and semi-liquids in aluminum tubes. Decades later, though, astronauts now have meals prepared by celebrity chefs and access to everyday items like shrimp cocktail, stir-fried chicken, and fettuccine alfredo. While the culinary selection has improved, the developers of these gourmet delights are still faced with a number of challenges.

Space foods, which can be available in rehydratable, thermostabilized, irradiated, and natural forms, are tested for their nutritional value, appeal to the senses, storability, and packaging. The foods are also tested to ensure that they are low in weight and mass, require little energy to prepare for eating, have a minimum of 9 months shelf life for shuttle missions and 1 year for use on the International Space Station (ISS), and are stored at room temperature.

Additional challenges include the need to develop foods and equipment that take up very little space, are easy to operate and clean, and require minimal water use, while also creating minimal air pollution and odors, which can be hazardous to the health and well-being of astronauts. The foods must be crumb-free to eliminate excess floating particles. Space foods must also be free of pathogenic microbes and create minimum waste and mess.

Finally, space foods have to taste good, while still managing to be healthy. Toward this effort, NASA testing helped in the development of a revolutionary new fat substitute that cuts calories and extends shelf life.

Partnership

The NASA Glenn Garrett Morgan Commercialization Initiative (GMCI) is a program for small, minority-owned, and woman-owned businesses that can benefit from access to NASA resources. GMCI provides services that enable companies to grow and strengthen their business by leveraging NASA technology, expertise, and programs.

Diversified Services Corporation, a minority-owned business based out of Cleveland, Ohio, was able to take advantage of this NASA program for technology acquisition and development, and for introductions to potential customers and strategic partners, such as the NASA Food Technology Commercial Space Center, at Iowa State University (the center closed December 31, 2005), for taste tests and performance studies. Fresh ground beef (90-percent lean) was used to prepare hamburger patties formulated with or without 10-percent fat substitute. Hamburger patties without the added fat substitute served as the control in each experiment. Patties were weighed for evaluation of cooking yield, and then cooked to an internal temperature of 72 °C. The cooked product with or without fat substitute was rapidly cooled, and then subjected to freeze drying or irradiation in retort pouches to NASA specifications. Changes in volatile profile during storage, and sensory properties were determined. Addition of 10-percent fat substitute did not influence the sensory characteristics of the ready-to-eat hamburger beef patties or dramatically change its volatile profile after 30-day storage.

With the GMCI assistance, the company developed and commercialized a new nutritional fat replacement and flavor enhancement product it had licensed from the U.S. Department of Agriculture and is now marketing it through its subsidiary, H.F. Food Technologies Inc.

Diversified Services Corporation developed and commercialized a new nutritional fat replacement and flavor enhancement product with assistance from NASA.

Product Outcome

The Nutrigras fat substitute is available for commercial applications and helps to satisfy the body's desire for the taste and mouth feel of fatty foods, even though the body does not actually need these foods—in fact, many people need fewer high-fat foods in their diets. With obesity on the verge of outweighing smoking as the number one cause of preventable death, the Centers for Disease Control and Prevention are showing rapid rises in the prevalence of

The Nutrigras food supplement creates food that is more moist, more tender, and more flavorful than its full-fat counterpart, and 1 pound of the supplement replaces 1 pound of animal fat.

children at severe weight levels; and while the American diet continues to be reliant on large quantities of high-fat foods, nutritionists are searching for solutions.

Nutrigras is one such solution. It is a stable emulsion of 9-percent vegetable oil and 62-percent water that has been formed by turbid excess steam jet cooking and made stable with microencapsulation in a starch solution that holds the emulsion steady. It is available in liquid, gel, or dry form and can be easily customized to the specific needs of the food manufacturer. When constituted, it looks and tastes just like real fat, but it is significantly healthier.

It is primarily intended for use as a partial replacement for animal fat in beef patties and other normally high-fat meat products, but can also be used in soups, sauces, bakery items, and desserts.

Nutrigras is intended to be used as a direct, pound-for-pound replacement of fat, and since it is only 9-percent fat, it is possible to produce products that have 90-percent less fat than their full-fat counterparts. It contains 80-percent fewer calories per gram than fat.

In addition to the nutritional benefits, the fat replacement has added industrial benefits. First, it costs less than the food it replaces and can help manufacturers reduce material costs. Secondly, in precooked products, Nutrigras can increase moisture content, which increases product yield. For example, in research on cooked beef, the Nutrigras-enhanced product shrank 10-percent less than the beef that had not received the additive.

It is healthy, has wide-spread applicability, and is more cost effective than using full-fat products; but really, how does it taste? That is the big breakthrough. With Nutrigras, the finished product is more moist and tender. Quantitative consumer testing conducted by the company indicated that a beef patty made with Nutrigras was actually preferred to the full-fat beef patty. The unique structure of Nutrigras allows for improved flavor delivery. The construction of Nutrigras is receptive to the addition of flavors that can be carried and then released in a "burst" when consumed. This can be positioned as a point of difference for food manufacturers.

The company has been working on a number of specific applications, with the primary focus on beef, pork, chicken, and turkey. Work has also been done to enhance the performance of various baked goods, ice creams, ice cream novelties, soups, sauces, and salad dressings.

Development work and testing has been completed on beef patties. In beef, optimal results have been obtained when converting 80/20 ground beef (80-percent lean meat/20-percent fat) to 80/15/5 (80-percent lean meat/15-percent Nutrigras/5-percent fat.) Product testing is currently underway on pork sausage and chicken, and one customer is currently working on a turkey enhancement.

Nutrigras can be used to add flavors to a variety of baked goods, resulting in reduced fat and calories while enhancing flavor. Moreover, preliminary research has indicated the potential for product stability benefits from Nutrigras. Baked goods are left moister, better tasting, and the resultant product contains less fat and fewer calories.

Ice cream can be made with less heavy cream by replacing a portion of the cream with Nutrigras. Overall costs are reduced (cream is more costly than Nutrigras), and the flavor profile is enhanced and improved. In addition, unique flavors can be obtained through customized formulations. Nutrigras can act as a stabilizer and reduce the use of extraneous gums and emulsifiers that are expensive and clutter product labels. Nutrigras has also demonstrated the ability to reduce the negative freeze/thaw characteristics of conventional ice cream.

Additionally, soups can be flavor enhanced, better tasting, and have improved mouth feel. Low-fat sauces and salad dressings can be improved in similar fashions.

The company has been able to repay the help provided by NASA by contributing to the Space Agency's astronaut diet. The Nutrigras fat substitute can be used as a flavor enhancer and shelf-life extender for use on the ISS. ❖

Nutrigras™ is a trademark of H.F. Food Technologies Inc.

Deicing System Protects General Aviation Aircraft

Originating Technology/NASA Contribution

Ice accumulation is a serious safety hazard for aircraft. The presence of ice on airplane surfaces prevents the even flow of air, which increases drag and reduces lift. Ice on wings is especially dangerous during takeoff, when a sheet of ice the thickness of a compact disc can reduce lift by 25 percent or more. Ice accumulated on the tail of an aircraft (a spot often out of the pilot's sight) can throw off a plane's balance and force the craft to pitch downward, a phenomenon known as a tail stall.

The Icing Branch at NASA's Glenn Research Center works using the Center's Icing Research Tunnel and Icing Research Aircraft, a DeHavilland Twin Otter twin-engine turboprop aircraft, to research methods for evaluating and simulating the growth of ice on aircraft, the effects that ice may have on aircraft in flight, and the development and effectiveness of various ice protection and detection systems.

Typically, ice is removed from general aviation craft with either "weeping wing" liquid deicing systems or inflatable rubber bladders, called pneumatic boots, installed along the wings. Both of these methods have drawbacks, including the finite, limited effectiveness of the liquid deicers and the added weight and power usage of the boots. Collaborative research at Glenn focused on using expanded graphite foil heating element technology to effectively replace these standard methods with a method that was usually limited to use on jets with heated wings and leading edge surfaces. The super-thin graphite, which covers a large surface area without significant weight penalties and heats quickly to melt ice, proved a viable solution, and this new safety equipment has now been made available to the aerospace community.

Partnership

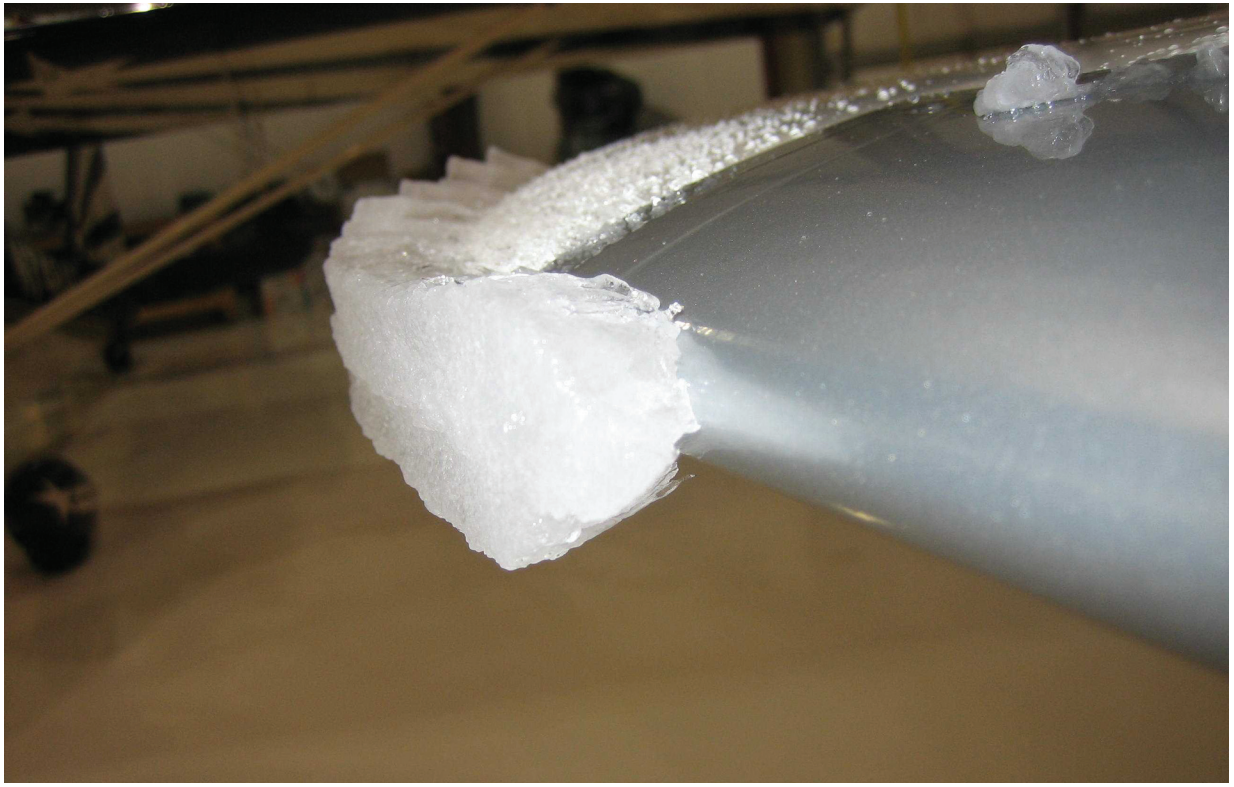
Kelly Aerospace Thermal Systems LLC, of Willoughby, Ohio, is a division of Montgomery, Alabama-based Kelly Aerospace Inc., a leading subsystem supplier to general aviation equipment manufacturers and aftermarket customers. The Ohio-based design and development branch worked with researchers at Glenn on the deicing technology with assistance from the **Small Business Innovation Research (SBIR)** program.

Kelly Aerospace acquired Northcoast Technologies Ltd., a Cleveland-based firm that had similarly done graphite foil heating element work with NASA under an SBIR contract. Through its research, Northcoast had developed the Thermawing system, a lightweight, easy-to-install, reliable wing and tail deicing system. Kelly Aerospace engineers combined their experiences with those of the Northcoast engineers, and now continue to advance this work.

Product Outcome

The NASA-funded research has resulted in a handful of new products and applications, including the certification and integration of a thermoelectric deicing system, DC-powered air conditioning for single-engine aircraft, and high-output alternators to run them both.

Marketed as Thermawing, the aircraft deicing system employs a flexible, electrically conductive graphite foil



With NASA assistance, Kelly Aerospace has developed lightweight heating elements capable of keeping ice from forming on airplane wings.

that heats quickly for instantaneous rises in temperature when needed. It has an ultra-thin laminate construction that allows for low weight penalties. With this system, users are able to retrofit an aircraft with between 100- and 150-amp alternators producing 50 to 80 volts with negligible weight addition. This reliable anti-icing and deicing system allows pilots to safely fly through ice encounters and provides pilots of single-engine aircraft the heated wing technology usually reserved for larger, jet-powered craft.

It is simple to apply and requires far less wattage than standard electrical metal heating systems. The thin laminate system is applied like a tape, and it will bond to any surface of an aircraft where icing might become a problem. The laminate contains the flexible, expanded graphite foil that serves as an electrical and heat conducting layer, that works as effectively as multiple heat conducting layers and layers of electrical insulation. Energy can be controlled across the system, so that certain zones can be heated according to need, an energy-saving measure.

The Thermawing system is currently certified for use as airfoil protection on Columbia 350 and 400 single-engine aircraft, as well as the Beechcraft Baron B55. Kelly Aerospace is continuing to develop systems for other aircraft.

The company has also developed Thermacool, an innovative electric air conditioning system also for use on single-engine, general aviation aircraft. The typical method for cooling these aircraft uses a standard automobile air conditioner compressor, typically running off of a combination of belts hooked to the engine and electric motors, which drew too much energy for their use to be practical while on the ground or idling. Air conditioning in the cabin was available, then, only when the aircraft was airborne. Kelly Aerospace addressed this with a new compressor, whose rotary pump design runs off an energy-efficient, brushless DC motor. This now allows pilots to begin cooling the plane before the engine even starts.

Ice forming on an aircraft can pose serious risks. The Icing Branch at Glenn Research Center seeks to minimize these hazards by creating technologies that detect and prevent icing.

Weighing less than 14 pounds, the total system draws only 50 amps. The small compressor can be attached just about anywhere within the aircraft, and it is virtually maintenance free. Kelly Aerospace has been granted Supplemental Type Certificates (STCs) from the Federal Aviation Administration for use of the revolutionary air compressor on Cessna 182 models P, Q, and R, and Cessna 172 models R and S single-engine aircraft. It is currently developing a customized kit for the Piper PA-32 Cherokee Six, and more STCs are in the works.

To assist in running both the Thermawing deicing system and the Thermacool air conditioning system, Kelly Aerospace has designed an alternator capable of creating ample electricity, as well as the other complex electronics on the craft, whether the plane is airborne or idling on the ground.

Recently, Kelly Aerospace Thermal Systems entered into an agreement with Redmond, Oregon-based RDD Enterprises LLC, a developer of safety and performance systems for the experimental aircraft market. The partnership will allow Kelly Aerospace's thermal deicing systems to be widely available in this market. ❖

Thermawing™ and Thermacool™ are trademarks of Kelly Aerospace Inc.

Infrared Imaging Sharpens View in Critical Situations

Originating Technology/NASA Contribution

The Microgravity Combustion Science group at NASA's Glenn Research Center studies how fire and combustible liquids and gasses behave in low-gravity conditions. This group, currently working as part of the Life Support and Habitation Branch under the Exploration Systems Mission Directorate, conducts this research with a careful eye toward fire prevention, detection, and suppression, in order to establish the highest possible safety margins for space-bound materials.

Over the years, the group has established that many materials burn very differently in microgravity than they do on Earth. For example, attempting to stomp out a flame in microgravity could possibly accelerate combustion, at least temporarily (because an airflow is being created that did not exist before). Other interesting findings indicate that microgravity fires can spread faster upstream than downstream, opposite of the behavior of fire spreading on Earth, and that fire is actually weaker in microgravity. As a matter of fact, the weakest flames ever generated were done so in space. During the "Structure of Flame Balls at Low Lewis-number" (SOFBALL) experimental trials conducted during missions STS-83 (April 1997), STS-94 (July 1997), and STS-107 (January 2003), flames were generated in space with power as low as 1 watt—about 50 times weaker than a candle flame.

This is not to say that fire is safer in space, though. Fire outbreak on a spacecraft is just as dangerous as any fire situation on Earth, or arguably even more dangerous, given the inability of astronauts to evacuate. For this reason, the ability to detect subtle variations in temperature in a complex and varied thermal background could prove invaluable in a spacecraft.

Partnership

Innovative Engineering and Consulting (IEC) Infrared Systems is a leading developer of thermal imaging systems and night vision equipment. The Cleveland-based company was founded in 1999 by two microgravity combustion science researchers from the National Center for Space Exploration Research, an academic research organization located onsite at Glenn. In spinning off their new business venture, the two researchers utilized the engineering know-how they developed in measuring high-temperature flames for NASA space flight experiments.

Several years after opening for business, IEC Infrared Systems received a Glenn Alliance for Technology Exchange (GATE) award worth $100,000, half of which was in the form of additional NASA assistance for new product development. The GATE award was established by Glenn, the Ohio Aerospace Institute, and the Battelle Memorial Institute to assist small Ohio-based companies interested in collaborating with NASA to advance their products and processes.

IEC Infrared Systems used the funds earmarked for NASA assistance to work with electrical and optical engineers from Glenn's Diagnostics and Data Systems Branch on the development of a commercial infrared imaging system that could differentiate the intensity of heat sources better than other commercial systems. Firefighters, for example, could use the proposed technology to make clearer distinctions between the intense heat of a fire and the lower-level thermal signatures of human bodies in fire-based search and rescue situations where darkness, smoke, or fog can obscure their vision.

Product Outcome

The firsthand NASA knowledge and the follow-up funding and technical support from the GATE award were the catalysts for IEC Infrared Systems to evolve from a start-up venture to a multimillion dollar business with a staff of more than 30 scientists, engineers, and technicians spanning a wide range of engineering fields. Today, the company offers two major thermal imaging solutions that stem directly from its vast NASA experience: NightStalkIR and IntrudIR Alert ("IR" for infrared). These two imaging systems have found widespread use in emergency first-responder, facility security, and military applications.

IEC Infrared Systems' Thermal/Visual Imaging Systems product line features a suite of thermal imaging devices that are used in a wide range of applications.

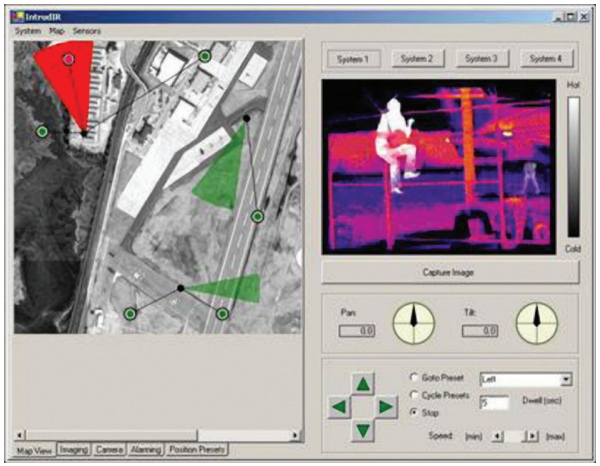
With advanced imaging capabilities, proprietary signal processing and electronics, and a tough, rugged exterior, NightStalkIR offers optimal daytime/nighttime surveillance in all weather conditions. Features include a low-light camera with lens options ranging from 50 to 180 millimeters (without the "halo" effect commonly seen in some imagers), full 360-degree rotation with pan and tilt, hand controller and PC software control, fixed or mobile (vehicle) mounting, and onscreen positional display of imaging direction and other tactical data. Optional features include fiber optic and wireless capabilities, an image-intensified camera that further enhances nighttime imaging in the visual spectrum, and Global Positioning System/compass/laser range systems that provide the precise location of observed targets for increased tactical awareness.

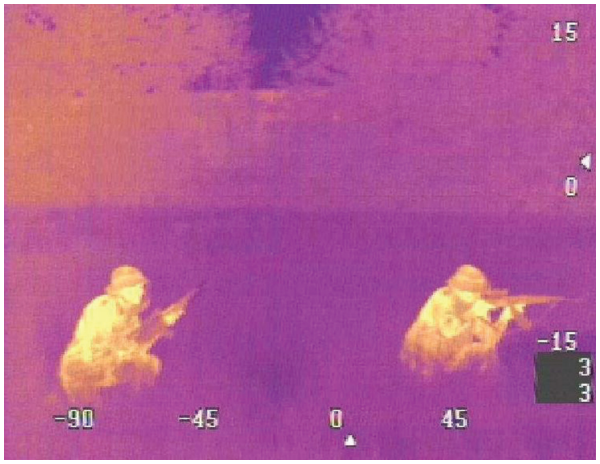
IntrudIR Alert is an intrusion-detection system designed to operate with multiple NightStalkIR thermal imagers. This software-based system allows a single operator to command and control these imagers over a

broad area, for maximum tactical and situational awareness and early warning of intrusions. Features include target tracking, based on either thermal signatures or motion detection (or a combination of both), continuous automatic tracking of these targets, and digital capturing of still images or short video clips, either on command or in response to alarms. In addition to being compatible with NightStalkIR, IntrudIR Alert can be integrated into larger security networks.

According to IEC Infrared Systems, NightStalkIR and IntrudIR Alert are being used in the United States and abroad to help locate personnel stranded in emergency situations, defend soldiers on the battlefield abroad, and protect high-value facilities and operations. The company is also applying its advanced thermal imaging techniques to medical and pharmaceutical product development with a Cleveland-based pharmaceutical company. This cooperative effort was enabled by a NASA Space Act Agreement, as Glenn continues to encourage IEC Infrared Systems' founding partners to explore new product ideas based on the techniques developed during their tenure at NASA. For the founders, their work with NASA and their related commercial endeavors have given a whole new meaning to "playing with fire." ❖

NightStalkIR™ and IntrudIR Alert™ are trademarks of Innovative Engineering and Consulting Infrared Systems.





This software-based system allows a single operator to command and control these devices over a broad area, for maximum tactical and situational awareness and early warning of intrusions.

Modern infrared imaging devices allow users to see through smoke and fog, as well as in total darkness. They have widespread use in military, facility security, and emergency first-responder applications.

Engineering Software Suite Validates System Design

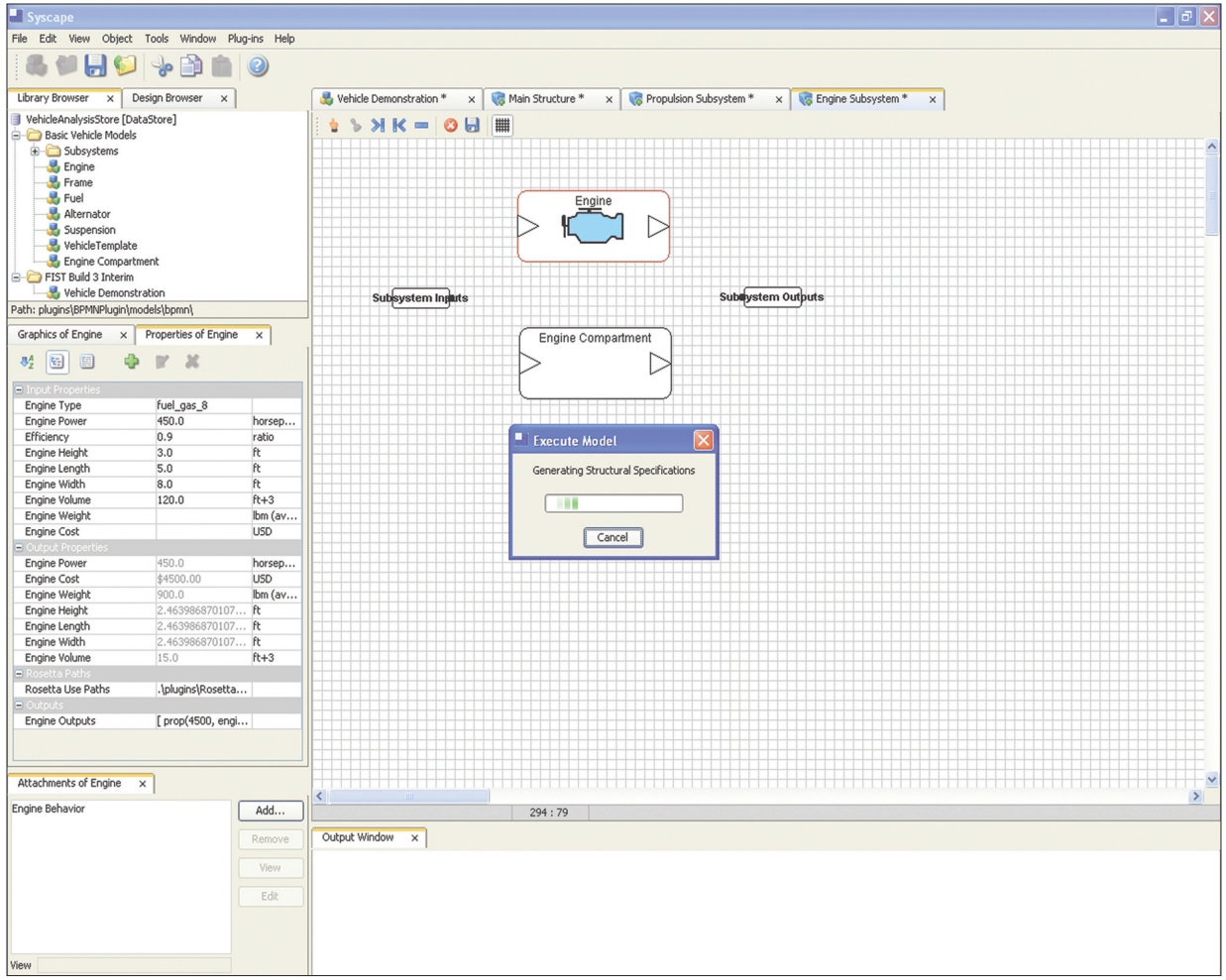
Originating Technology/NASA Contribution

Design errors are costly. When it comes to creating complex systems for aerospace design and testing system readiness, engineering system requirements must be clearly defined, and these systems need to be tested to ensure accuracy, consistency, and safety. Testing a system, however, can require as much as 50 to 70 percent of the total design cycle time. The ability to identify potential problems early in the design cycle saves time and expense, while still ensuring safe and reliable systems. This type of research is of interest not only to the NASA Ames Research Center's Robust Software Engineering group, but to government agencies and industry, any sectors which build critical, expensive systems, such as control software for an aircraft or the U.S. Ballistic Missile Defense System's command and control system.

Partnership

To date, more than $6.5 million of government funding has been dedicated to the development of EDAptive Computing Inc.'s (ECI) EDAstar engineering software tool suite. NASA's Ames Research Center provided a significant share of this funding, through a total of five **Small Business Innovation Research (SBIR)** contracts (three Phase I contracts and two Phase II contracts). This backing from Ames allowed the Centerville, Ohio-based company to generate critical components of the software tool suite, namely Syscape and VectorGen.

Syscape is a platform-portable, customizable system design editor that utilizes a hierarchical block diagram structure, multiple design views, and user-defined plug-ins to capture executable specifications of multidisciplinary systems. These executable specifications can be used to analyze concepts and requirements; balance risk and performance trade-offs among the various subsystems; develop system and subsystem specifications; and apply formal, mathematically rigorous techniques to ensure safety, accuracy, and consistency. Once created, executable specifications can be used in conjunction with VectorGen to automatically generate tests to ensure system implementations meet specifications. According to the company, the VectorGen tests considerably reduce the time and effort required to validate implementation of components, thereby ensuring their safe and reliable operation.



With graphical editing tools, EDAstar-based solutions can be used to rapidly create high-level, high-confidence design concepts.

The multiagency SBIR support has further allowed the company to expand operations from 5 core employees in 2000 to 15 employees in 2007. Additionally, in 2004,

EDAptive Computing received a $45,000 commercialization assistance award from the NASA Glenn Garrett Morgan Commercialization Initiative to support marketing, planning, and awareness efforts in the defense and aerospace industries.

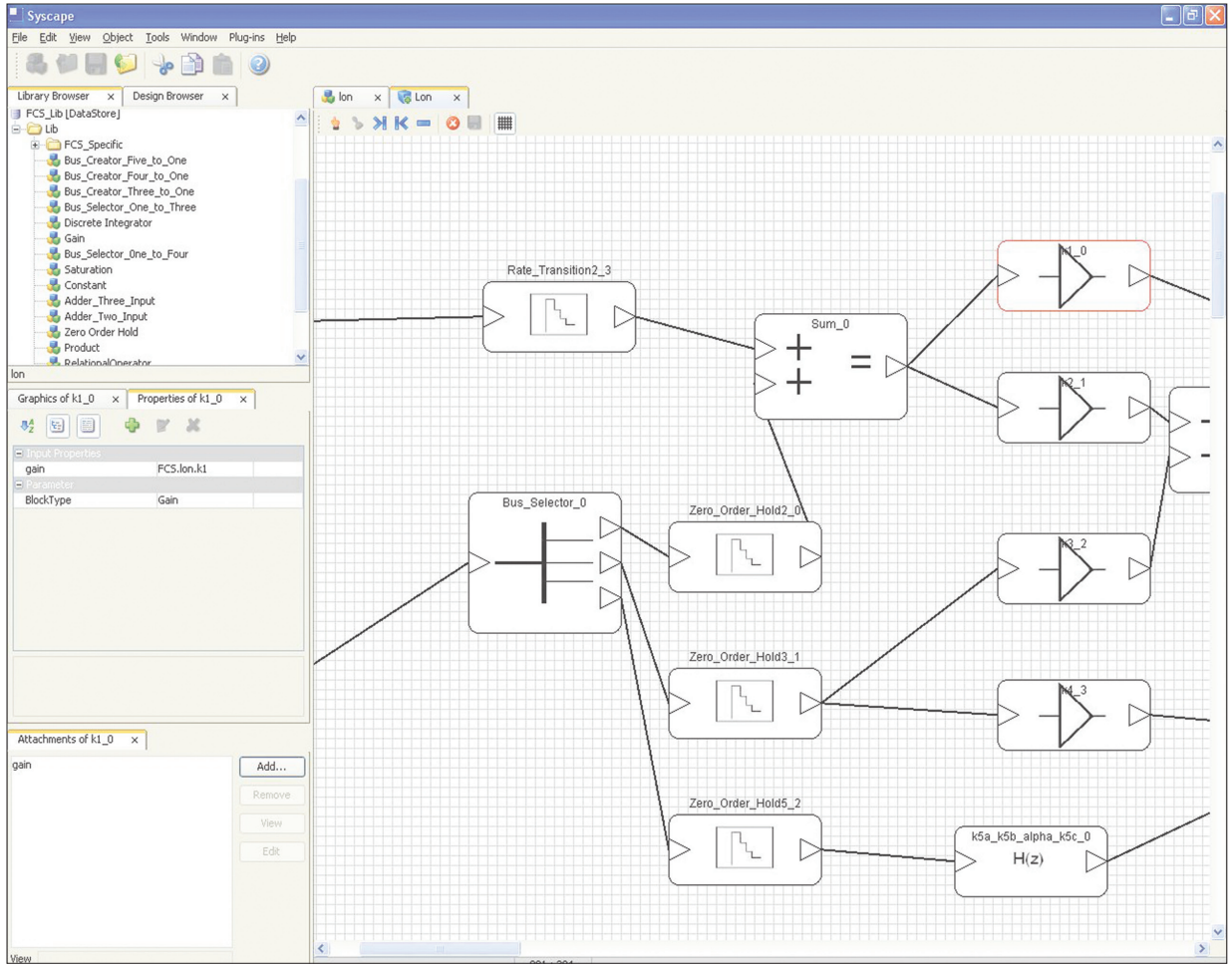
Product Outcome

EDAstar is ECI's unique solution to completely capture and validate system design requirements. With graphical editing tools, EDAstar-based solutions can be used to rapidly create high-level, high-confidence design concepts with automatically generated tests in a fraction of the time needed by current methods. Further, EDAstar can be used for simulating requirements, assessing risks, and checking their consistency and correctness before expensive mistakes are made in system design and development.

In addition, EDAstar-generated tests, monitoring, and assertions can be used to verify and validate a design or implementation against its specification. EDAstar complements and bridges gaps in existing commercial-off-the-shelf (COTS) tool-based design flows, fitting in the design flow between tools to capture requirements and tools to create detailed specifications and design. Furthermore, EDAstar tools and models can be used as the framework and semantic glue, respectively, for integrating multidisciplinary models, tools, and methods for modeling and simulating a multidisciplinary system of systems.

EDAshield, an additional product offering from ECI, can be used to diagnose, predict, and correct errors after a system has been deployed using EDAstar-created models. EDAshield is a collection of methods and reusable software and hardware assets for system security and can be used to assure trustworthiness, as well as generate anti-tamper logic to protect hardware and software against reverse engineering.

Initial commercialization for the EDAstar product included application by a large prime contractor in a military setting, plus the award of a 5-year U.S. Naval Air Systems Command delivery order contract with a ceiling of over $45 million, entitled "Competent/COTS Upgrade Recertification Environment." Customers include various branches within the U.S. Department of Defense, industry giants like the Lockheed Martin Corporation, Science Applications International Corporation, and Ball Aerospace and Technologies Corporation, as well as NASA's Langley and Glenn Research Centers. ❖



EDAstar can be used for simulating requirements, assessing risks, and checking their consistency and correctness before expensive mistakes are made in the system design and development.

EDAstar™, EDAshield™, and Syscape™ are trademarks of EDAptive Computing Inc.

Thin, Light, Flexible Heaters Save Time and Energy

Originating Technology/NASA Contribution

Ice accumulation is a serious safety hazard for aircraft. The presence of ice on airplane surfaces prevents the even flow of air, which increases drag and reduces lift. Ice on wings is especially dangerous during takeoff, when a sheet of ice the thickness of a compact disc can reduce lift by 25 percent or more. Ice accumulated on the tail of an aircraft (a spot often out of the pilot's sight) can throw off a plane's balance and force the craft to pitch downward, a phenomenon known as a tail stall.

The Icing Branch at NASA's Glenn Research Center uses the Center's Icing Research Tunnel (IRT) and Icing Research Aircraft, a DeHavilland Twin Otter twin-engine turboprop aircraft, to research methods for evaluating and simulating the growth of ice on aircraft, the effects that ice may have on aircraft in flight, and the development and effectiveness of various ice protection and detection systems.

Partnership

EGC Enterprises Inc. (EGC), of Chardon, Ohio, used the IRT to develop thermoelectric thin-film heater technology to address in-flight icing on aircraft wings. Working with researchers at Glenn and the original equipment manufacturers of aircraft parts, the company tested various thin, flexible, durable, lightweight, and efficient heaters and developed a thin-film heater technology that they discovered can be used in many applications, in addition to being an effective deicer for aircraft.

Product Outcome

The result of this research was the development of a new thermoelectric heater the company has dubbed the Q•Foil Rapid Response Thin-Film Heater, or Q•Foil, for short. The product meets all criteria for in-flight use and promises great advances in thin-film, rapid response heater technology for a broad range of industrial applications. Primary advantages include time savings, increased efficiency, and improved temperature uniformity.

EGC makes the heaters out of thin layers of varying materials that are bonded to form heater laminates. The inner layer, made of a flexible graphite foil (marketed separately by EGC as ThermaFoil), is electro-thermally conductive and typically laminated between a heat-conducting outer layer, and a protective insulating layer. The inner layer provides full electrical conductivity, eliminating the need for wire elements, metal etchings or heat-conductive fibers. In addition to being readily available and relatively inexpensive, the graphite foil is energy efficient.

Developed in conjunction with NASA for in-flight aircraft deicing, Q•Foil heaters are now available for a broad range of applications from as small as a single square inch to as large as several square feet, and provide extremely rapid thermal response and even heating for a wide array of temperature ranges.

Because Q•Foil conducts heat well and can cover a large area, little energy is needed for it to raise the surface temperature to the necessary degree, and it is capable of heat increases as rapid as 100 °F per second if needed, which can translate into savings in time or energy. Designers can configure it to heat an item more quickly or to heat an item to the same temperature as other heaters would, while expending less energy.

Not only does Q•Foil work quickly and efficiently, it is also precise, controllable to within 3 °F. If it is being used for an application that requires different temperature zones, Q•Foil can also be configured to accommodate this within the same heating coil.

While the product is available in a variety of sizes, ranging from 1 square inch to 100-foot lengths, the company notes that it is most efficient over large spaces, as this allows the user to get the most advantage of its unique cost- and energy-saving properties. Thin-film flexibility allows it to be mounted to a variety of objects, and it maintains flexibility through a full range of temperatures. The company has services to assist customers with determining the right dimensions and designs they will require for a specific job.

In addition to wing deicing, EGC has begun looking at the material's usefulness for applications including cooking griddles, small cabinet heaters, and several laboratory uses. ❖

Q•Foil™ is a trademark, and ThermaFoil® is a registered trademark of EGC Enterprises Inc.