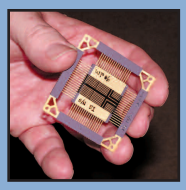
Summer 2008

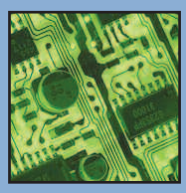
Missile Defense Agency

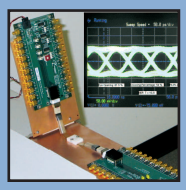
TechUpdate

A Quarterly Newsletter for MDA Technology Transfer

INSIDE







▲ Big energy users, especially in large cities, increasingly are monitoring their utilities consumption. And new offerings from Embedded Research Solutions are allowing these consumers to curtail their usage and participate in energy incentives programs.

Plugging In to Energy Savings

MDA-funded information technology lets users get savvy about power consumption.

by L. Scott Tillett/stillett@nttc.edu

Buildings and factories are a lot like living creatures. Their mechanical systems, from elevators to manufacturing equipment, are like muscles. Specialized fluids and life-giving utilities—such as water, natural gas, steam, and electricity—course through their structure. And they respond to their environment. They get hot and cold, and they can feel the effects of humidity.

Increasingly, monitoring the physiology of buildings, factories, and aircraft has relied on networks of sensors that serve as a nervous system—collecting data on conditions and problems and then feeding information to an automated brain center such as a building management system (BMS). Such systems allow human users or rules-based software to monitor conditions and make decisions—whether shutting down a machine that has reached a certain temperature or closing off a gas line that has developed a leak.

But a nervous system for a building or another structure needs computing power not just at the brain center; it also needs computing power at the nodes—at the sensors and data-collection points. Computing

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Fuel for Thought

MDA-funded technologies promise efficiency for energy users and food producers.

by L. Scott Tillett/stillett@nttc.edu

As food and energy prices continue to rise, the focus of daily life falls evermore on efficiency. Am I wasting food? Am I wasting gas? Am I an inefficient consumer?

For many of us, the answer to those questions is, "Probably." But new MDA-funded technology offers hope for a more efficient future. And this issue of *MDA TechUpdate* highlights several technologies that address the notion of improving the energy picture.

One exciting prospect involves technology developed by MDA-funded HelioVolt Corporation (Austin, TX), whose leaders envision a future in which buildings would be covered in materials to soak up solar energy, effectively turning their exteriors into onsite power plants. The company's process allows copper-indium-gallium-selenide (CIGS) films for solar cells to be applied onto glass, metal, or polymer platforms to create solar-energy-enabled construction materials such as spandrels, sunshades, awnings, or roofing panels. HelioVolt's process can produce photovoltaic films 10 to 100 times as fast as current methods, and can absorb the same energy in a film 100 times as thin as silicon, which has been widely used in solar technology.

This issue's cover story features another energy-smart technology. Embedded Research Solutions, LLC (Annapolis, MD), has found a solid commercial market for its MDA-funded miniature software in the monitoring and control of utilities—such as steam heat in huge office buildings and electricity in factories. The approach not only helps a large energy consumer reduce unnecessary consumption of energy, it also allows those big users to take advantage of income-generating energy-incentives programs that seek to keep energy demand and capacity in check. The technology also is being deployed in military applications.

And then there's food—fuel for the body and, in the case of corn-based ethanol, fuel for our cars. But there's another fuel facet to food: Producing food more efficiently means using fuel more efficiently. So smart farming factors in to the energy picture, and MDA-funded Spectral Sciences, Inc. (Burlington, MA), is working on a tool that could prove helpful to food producers. The company has developed an imager that would allow farmers to determine the health of crops, including soil conditions and identification of unwanted growth of vegetation. The imaging system could be deployed easily on satellites, giving farmers a quick aerial view for use in maximizing crop yield.

MDA funded all of these technologies for their potential in missile defense. But the companies developing the technologies are wisely seeking commercial opportunities beyond missile defense. Commercialization not only offers additional revenue streams for improving emerging technologies, the approach also allows the American public at large to share in the benefits of those MDA-funded technologies. To discover other MDA-funded energy-saving technologies, please visit our Web site, www.mdatechnology.net.

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The MDA Technology Applications program sponsors publication of *MDA TechUpdate* to encourage the transfer of missile defense technology to American businesses and other government agencies. *MDA TechUpdate* is produced for MDA by the National Technology Transfer Center-Washington Operations (NTTC). Readers are encouraged to reprint *MDA TechUpdate* articles, provided context is preserved and the Missile Defense Agency is credited. Please send NTTC a copy of any publication that includes information from *MDA TechUpdate*, whether it does so in whole or in part.

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[*MDA TechUpdate* Summer 2008: Approved for PUBLIC RELEASE, 08-MDA-3546 (30 JUNE 08)]

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Chip Immunization

Process offers radiation protection for aerospace, medical, and consumer electronics.

by Keith Costa/techapps@nttc.edu

As the microelectronics industry continues to make computer chips smaller and faster, there will be an increasing need to keep them safe from natural, and possibly manmade, radiation. One MDA-funded company believes it has developed a process that can offer such protection to aerospace, medical, and consumer electronics without enormous costs, because it can be inserted into existing assembly lines by adding only a handful of production steps.

Silicon Space Technology Corporation (Austin, TX) created the patented process, called Buried Guard Ring (BGR), specifically for complementary metal-oxide semiconductor (CMOS) integrated circuits, which are widely used in military and commercial microprocessors and memory devices, as well as in image sensors and data converters.

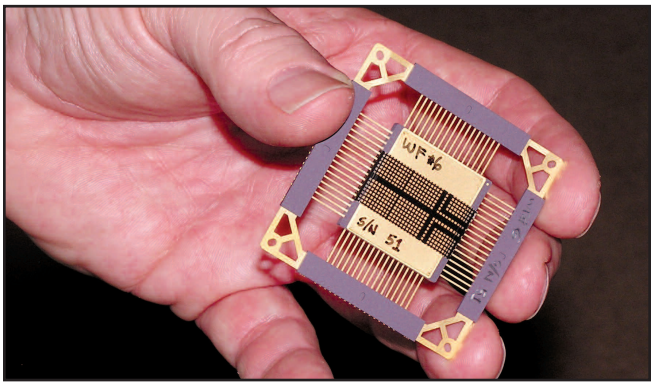
The company already has demonstrated BGR can change the properties of CMOS chips in ways that dramatically improve their ability to function in radiation-laden environments. Later this year, a number of products built with BGR will be on the market, including chips from Texas Instruments that enable high-speed communications and data transfer using a FireWire interface, the same kind used to connect many camcorders to personal computers for downloading video.

The military employs FireWire data-interface capabilities in its most advanced fighter aircraft and aerospace applications, which is why Silicon Space Technology and Texas Instruments are bullish on the sales prospects for BGR-enhanced CMOS products. In the future, BGR radiation-hardened chips could find their way onto space vehicles, commercial aircraft, medical devices, and deep-drilling tools.

Aircraft manufacturers, for example, worry about radiation at altitudes above 30,000 feet because the complex circuits in avionics systems are susceptible to damage from cosmic particles. Closer to the ground, BGR-CMOS chips can run hotter and more reliably than today's commercial versions. Below the ground, these qualities have led Texas Instruments to consider BGR technology for electronics that control drill bits and augers used in drilling for oil. Medical devices also could be a target market for BGR, according to Silicon Space Technology President and CEO Wes Morris. Advances in such technology—electronic implants, in particular—come with the concern that they could be more sensitive to radiation.

Filling a need

Morris founded Silicon Space Technology in 2004, after accumulating more than 20 years of experience working on rad-hard technology for semiconductors. He started with RCA Laboratories in Princeton, NJ, in 1981, followed by stints at the Harris Corporation and SEMATECH before becoming a consultant. During his consulting days, he came up with the idea of BGR for CMOS integrated circuits, initially attracting interest from MDA and the Air Force Research Laboratory.



▲ This 16-megabit, static random-access-memory (SRAM) chip was manufactured using Silicon Space Technologies' patented Buried Guard Ring process for radiation hardening.

MDA provided SBIR funding to Silicon Space Technology to demonstrate its BGR technique and implement it in a commercial chip line—in this case, at a Texas Instruments plant in Dallas, TX. The resulting communications chips were blasted with radiation but still worked perfectly. For the Air Force Research Laboratory, the company leveraged SBIR funding and teamed once again with Texas Instruments to produce 16-megabit static random-access-memory (SRAM) chips, which are undergoing radiation testing today.

The benefits of CMOS technology include relatively low power consumption and reduced waste heat—because CMOS transistors draw electricity only when needed—and the ability to pack lots of logic functions onto a single chip. These attributes led to its widespread adoption for computer applications.

The problem is standard CMOS chips, made from bulk silicon wafers, can fail in radiation environments, something the U.S. military cannot afford to have happen in its satellites and interceptors when trying to track and destroy enemy missiles. Failure can come in the form of a "latchup," which means a chip, inundated with radiation—e.g., gamma radiation, protons, neutrons—experiences something like a short circuit and locks up. The chip then needs to be powered down before it can work again. In some cases, the event is so damaging that resuscitation is impossible. Radiation-related problems also can

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More Power in a Lighter Package

Lithium-air battery research is drawing interest from aerospace giants.

by Keith Costa/kcosta@nttc.edu

An MDA-funded company is in the final stages of developing a rechargeable battery that already is drawing interest from the aerospace community because it promises to pack more power in a lighter package than a lithium-ion battery.

US Nanocorp (Farmington, CT) started work on the prototype, a lithium-air, high-energy battery, for MDA in 2005 after receiving a Phase II SBIR contract. At the time, MDA wanted to find out if lithium-air batteries could satisfy energy storage requirements for the High Altitude Airship, a dirigible that could serve as a sensor platform for providing persistent surveillance and communications capabilities over a wide area.

Lithium-air batteries can take in oxygen from the atmosphere or can come with a built-in container of oxygen.

Perhaps the most important feature that could make lithium-air batteries attractive to aerospace and portable electronics consumers is the potential for energy densities that far outmatch what today's ubiquitous lithium-ion rechargeables bring to the table. Energy density is a measure of stored energy for a certain amount of mass; batteries with higher energy densities are more efficient at delivering their stored energy to a load.

▲ US Nanocorp has built a prototype lithium-air battery as part of a Phase II SBIR project.

Today's lithium-ion batteries have energy densities that can reach a maximum 200 watt-hours per kilogram. But lithium-air batteries are expected to reach 1,000 watt-hours per kilogram. US Nanocorp already has achieved 800 watt-hours per kilogram.

What does this mean to end users? In the same application, lithium-air batteries would last longer between charging cycles than lithium-ion batteries. Further, high energy densities translate into lower-weight products, which is a main reason why aerospace industry giant Boeing has expressed interest in US Nanocorp's technology for satellite use, according to Jinxiang Dai, research and development vice president for US Nanocorp. Boeing and other companies in the space business are always looking for ways to lower the weight of items going into orbit.

Dialogue with Lockheed Martin, the prime contractor for the High Altitude Airship, has continued throughout the Phase II project for MDA, Dai added.

At the heart of US Nanocorp's patent-pending innovation is what it calls the oxygen-selective-membrane (OSM) air cathode. The jelly-like membrane keeps oxygen away from the lithium-based anode that is made with thin-film technology; if the lithium came in contact with oxygen, a reaction would produce heat instead of electricity.

For a battery that draws oxygen from the atmosphere, the oxygen dissolves into the OSM, which also keeps moisture out of the cathode. Indeed, the inspiration for the membrane came from artificial-blood research that produced a material that can carry oxygen.

For the Phase II project, the company decided the prototype would have a self-contained oxygen supply, instead of taking it in from outside the device.

US Nanocorp's biggest challenge on the lithium-air battery project has been achieving a longer cycle life. Battery cycle life refers to how many times the device can be recharged before it dies.

Typical lithium-ion batteries found in most cell phones, for example, have a possible cycle life of 1,000 charges. US Nanocorp's cycle-life target for its lithium-air technology is 350, but right now the prototype can achieve only 50 charges.

In practice, the difference between a cycle life of 1,000 and 350 may not be so great, once one factors in the greater energy density for lithium-air batteries. If a lithium-ion cell phone battery that is charged at least once a day lasts three years, a lithium-air battery like the one US Nanocorp is developing should last just as long because it would be charged only once a week.

If produced in mass quantities, lithium-air batteries should be comparable in price to lithium-ion devices, Dai said.

US Nanocorp has a commercialization partner for its Phase II project in Ultralife Batteries, Inc., a major battery manufacturer that pledged $150,000 to help defray some development costs. US Nanocorp is considering having a role in lithium-air battery manufacturing, possibly producing components for a larger company.

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Skyscrapers Wrapped in Sunlight

Rugged solar generators may someday be embedded in shutters, roofing, and other building materials.

by Joan Zimmermann/jzimmermann@nttc.edu

HelioVolt Corporation (Austin, TX) has turned a small company into a big contender in the alternative energy boom, thanks to a new process for manufacturing photovoltaic thin films.

At a time when Americans are accepting that fossil fuel is becoming a relic, solar energy shines thanks to its free and practically eternal energy source. One of the keys to capturing the sun's energy is the use of photovoltaic materials, which turn sunlight directly into electricity, with no fuels, no emissions, and no moving parts.

In an increasingly competitive photovoltaic market, HelioVolt has secured more than $100 million in capital to begin manufacture of photovoltaic films in a newly constructed plant in Austin, TX.

In part due to the properties of the photovoltaic material, copper indium gallium selenide (CIGS), and in part due to its patented FASST® manufacturing method, HelioVolt is well positioned to enter the PV industry at a time when solar energy has come to the forefront as a solution to the world's energy woes.

▲ In coming years, the surfaces of many buildings—from windows to metal exteriors—could be covered in solar-enabled materials based on technology from MDA-funded HelioVolt.

HelioVolt received a Phase I SBIR in 2004 to help develop flexible photovoltaics as a lightweight power supply for MDA's High Altitude Airship. The company brought its business case to reviewers at a 2004 MDA Business Focus Workshop. The review panel heartily endorsed the company's case, and HelioVolt took off.

HelioVolt developed a way to produce photovoltaic thin films quickly and under vacuum or nonvacuum conditions with a platform manufacturing process. Called FASST, the technology has been likened to a printing press. Instead of expensive silicon, HelioVolt uses CIGS. FASST can apply CIGS films onto glass, metal, or polymer platforms to create products ranging from conventional solar modules for retrofit on existing buildings to solar-enabled construction materials such as spandrels, sunshades, awnings, or roofing panels. Furthermore, FASST can produce those CIGS-based photovoltaic films 10 to 100 times as fast as current methods, and can absorb the same power in a film 100 times as thin as silicon.

The Department of Energy believes that solar power has the potential to provide 50 percent of the electricity needed by developed countries, and the global market is expected to be in the tens of billions by the end of the decade. Historically, however, many otherwise green individuals often have objected to the unsightliness of solar panels perched on rooftops like big, bulky afterthoughts.

CIGS solves these aesthetic issues with a much more uniform appearance compared to polycrystalline silicon modules, making feasible solar-enabled building materials such as exterior facings, roof panels, doors, and windows, leading HelioVolt to envision high-rises enrobed in solar-generating surfaces. Experts in the industry concur with this assessment, projecting that building-integrated photovoltaic systems will be the fastest-growing portion of the photovoltaic market over the next 10 years. CIGS-based photovoltaics can last more than 25 years, are proven to be rugged, and have the highest potential efficiencies (19.9 percent in the laboratory) of any other thin-film material.

HelioVolt's FASST manufacturing technology was developed by company founder and CEO Billy J. Stanbery to solve cost problems in the thin-film photovoltaic market but may also find uses beyond PV. HelioVolt's intellectual property is "potentially applicable to any semiconductor and for numerous processes and fabrication methods—printed electronics, electrodes for fuel cells and batteries, and even high-temperature superconductors," according to the company.

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Improving Infrared Detection

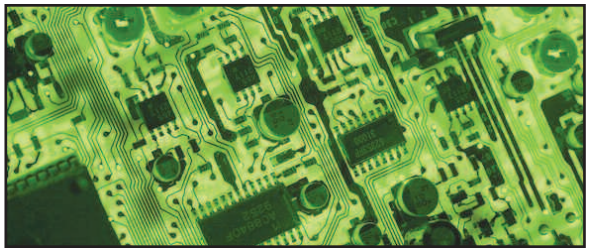
An old material becomes new again for imaging and sensing.

by Joan Zimmermann/jzimmermann@nttc.edu

A long-sought alternative material for use in infrared imaging is reaching maturity, offering the promise of higher resolution and a longer-life product.

Nanolight, Inc. (Norman, OK), is pursuing a revolutionary advance in the ability to grow low-defect lead-salt materials on silicon substrates, yielding a structure that promises comparable or better performance with lower-cost infrared detection for sensor applications compared to the best competitor in its class—mercury cadmium telluride (MCT). Lead-salt materials were of great interest until the late 1970s, but their pursuit was relinquished in favor of MCT when it proved more suitable for the applications at that time.

Working with MDA Phase I and Phase II SBIRs, Nanolight researchers expect their novel fabrication technique to provide key effective means of identifying unique target signatures, such as missile emissions. Lead-salt materials can enable the construction of high-quantum-efficiency sensor systems, based on mid-wavelength infrared (MWIR) detectors. Such systems would provide effective early warning and interceptor guidance against missile threats for a wide range of ground vehicles and aircraft.



▲ Nanolight's fabrication methods are producing new materials that can enhance components for sensors used in applications such as pollution detection and medical diagnosis.

In addition to missile defense applications, there are also many applications for nanolight diodes in laser absorption spectroscopy applications, as many molecules of interest reside in the MWIR and long-wavelength infrared (LWIR) regions. In particular, mid-wavelength lasers are good at sensing ozone, carbon monoxide, carbon dioxide, methane, and sulfur dioxide at parts-per-billon sensitivity, essential for detecting greenhouse gases, and automobile and industrial plant emissions. The nitride-related molecules such as nitrous oxide (NO) and ammonia (NH_3) are also detectable in this range, making it useful for noninvasive medical diagnosis. Other applications include night vision and explosives detection.

The company is now striving to improve the fabrication methods, collaborating with the Opto-electronics Group at the University of Oklahoma (OU) and others to develop lead-tin-selenide (PbSnSe) focal plane arrays (FPAs) for use in infrared cameras. A complete prototype is to be developed within two to three years. Nanolight President Zhisheng Shi and his group at OU have been working on the experimental and theoretical aspects of depositing PbSnSe directly onto silicon via a p-n junction motif. That approach would allow integration of the detector onto the readout circuitry. Such an architecture promises dramatically improved device performances for MWIR and LWIR detectors. In addition, the material itself has a large dielectric constant, which helps to screen and localize any defect-related effects.

Nanolight's new method will help PbSnSe become a viable alternative for the lower-performance MCT materials on silicon substrate, and will also benefit the effort to carry out the large-size integration that is needed for high-resolution imaging.

Apart from their utility as highly sensitive detectors in the infrared, IV-VI materials are also seen as a viable medium for high-temperature, continuous-wave laser operation. Ease of tunability is another reason this material family is being touted for laser diodes.

Furthermore, Shi sees the "far long-term" potential to integrate both lasers and detectors on the same substrate, but this will require further work in overcoming the optical-path challenge. In the meantime, Nanolight, a small company that recently spun out of OU, is making its way forward in part by offering epitaxial and wafer-polishing services for other technologists on the cutting edge of research and manufacturing.

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Positive Identification

Imager could distinguish real warheads from countermeasures and monitor crop health.

by Joe Singleton/jsingleton@nttc.edu

Farmers, firefighters, and pathology investigators may see their work in a different light with the help of a spectral-imaging system designed to track nuclear warheads.

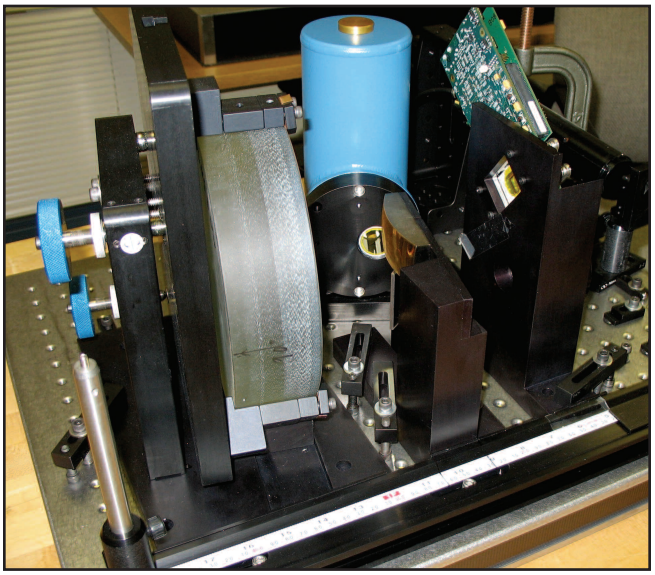
The system uses multispectral infrared imaging to determine the temperature and material of objects—whether flying projectiles, burning buildings, or even the earth's soil.

Spectral Sciences, Inc. (Burlington, MA), developed the system with help from MDA funding. The agency originally funded the company through a 2005 SBIR Phase II contract to develop a new sensor for a proposed space-based missile defense platform capable of discriminating between real nuclear warheads and countermeasures, not just detecting targets. Such discrimination is made possible by gauging the temperature and material composition of incoming objects through the detection of patterns or signatures found in the various infrared wavelengths emitted or reflected by the target.

While Spectral Sciences' project focused on benefits for missile defense, the project leader, Dr. Pajo Vujkovic-Cvijin, said the technology's thermal analyzing capabilities could provide benefits to nondefense-related applications as diverse as agriculture, biomedicine, and firefighting. For agriculture, the imaging system could be deployed on satellites that could help farmers determine the health of crops, including soil conditions and identification of unwanted growth of vegetation. These imagers could also prove useful to firefighters in determining the actual heat and intensity of a blaze that needs extinguishing. Medical applications would be primarily in pathology, where infrared imaging could improve and hasten diagnoses by avoiding the need to stain and dye biologic samples before inspecting them under a microscope.

In addressing space and cost considerations for the new system, Spectral Sciences had to develop and integrate an imaging system capable of advanced data analysis while using the existing infrared camera, as used on interceptor vehicles. This requirement posed two engineering challenges for the company. First, new hardware comprising an imaging system had to be inserted between the lens and the light-sensitive "retina" of the camera (focal plane array; FPA), without disrupting the operation of the tracker-imaging system. Second, the imager had to be immune to vibrations inherent in a space launch. (The commonly used approach to spectral imaging systems—one based on an interferometer—is not suitable for high-vibration environments.)

To solve the first problem, the company devised a method to "slice and dice" the light from the object to different wavelengths or "colors" for analysis purposes, and then reconstitute the image components before sending them along to the FPA. This "slice and dice" process begins with the sensor processing infrared light from the object with a light-dispersing element known as a polychromator.



▲ Spectral Sciences' multispectral imaging system can determine the temperature and composition of objects as diverse as warheads, buildings, and farmland.

From this polychromator, the dispersed light array of infrared goes through a device known as a spatial-light modulator, which selects the desired wavelengths. Use of a reflective-array device solves the second problem, vibration, as its components are so small and stable that they are not affected by gyrations of the platform. Based on the imager's programming, it selects wavelengths rapidly at a rate of more than 10,000 frames per second. By comparison, a DVD movie has a rate of 30 frames per second. After being selected by the spatial-light modulator, these infrared wavelengths are sorted into a data cube, or a three-dimensional image. Each "slice" of the data cube represents the thermal signature of the target at a different wavelength.

The system then analyzes the data to determine thermal signature patterns that might indicate an active target. In the case of missile defense, the data analysis results in a go/no-go decision to destroy or ignore the target in question.

In parallel with the spectral analysis of the incoming image, the same FPA is used for target-tracking purposes.

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Building a Genome in a Minute

A promising technique for rapidly sequencing DNA is ready to compete.

by Joan Zimmermann/jzimmermann@nttc.edu

Leveraging some experience from a decade of research with various aspects of missile defense technology, Reveo, Inc. (Elmsford, NY), is developing DNA sequencing techniques that can produce an entire genome in less than a minute, on the cheap, and at a 99.9 percent accuracy rate.

If successful, Reveo's innovation would be welcome among forensics labs, police investigators, doctors, medical researchers, and purveyors of the burgeoning "personal genomics" industry—all of whom seek fast, affordable, and accurate tools to sequence DNA—be it for drug development, criminal evidence, diagnosis, or tracing your ancestry back to the Medici family.

▲ This image shows human chromosomes, which consist of DNA containing many genes. Reveo's methods offer researchers a tool for quickly producing genetic blueprints (genomes) encoded in DNA.

Reveo's proposed device is called the Omni Molecular Recognizer Application (OmniMoRA). The device relies on physical contact with individual DNA bases, or molecules called nucleotides, on a stretched-out single DNA strand to read the sequence directly, and uses a series of sensors to relay the results into data.

Reveo's founder, Sadeg Faris, is a ground-breaking engineer with more than 200 patents, and he invented the fastest-known superconducting oscilloscope. He has made a habit of spinning companies out of his technological prowess. For some of the principles that support the new sequencing method, Faris gives partial credit to his extensive work with BMDO, MDA's predecessor, in next-generation optoelectronics and photonics. In the early 1990s through 2000, BMDO funded Reveo through SBIRs to develop nonlinear optical materials and optoelectronic modulators for space applications, signal processing, and communications.

Reveo's technique relies on physical methods rather than the indirect chemical methods that are associated with other DNA sequencing techniques. OmniMoRA uses electrically conductive probes called "nano-edges" to identify each DNA base by contact and by both exciting and measuring the vibrational patterns associated with each base. An array of nano-edges looks somewhat like the teeth of a comb. The process is analogous to counting beads with one's fingers, with nano-edges acting as fingers. Reveo developed the nano-edge technology with help from DARPA funding.

Reveo scientists believe the company's technology holds such promise that they have submitted it for competition in the $10 million Archon X PRIZE for Genomics contest, which will reward the first private effort to map 100 human genomes in 10 days.

Reveo aims to meet the goal at a recurring cost of no more than $10,000. That means 3 billion bases, times 100, in 10 days or less. By contrast, the Human Genome Project cost $3 billion by the time it was completed in 2003—exclusive of the many years of preparation and instrument development that preceded the actual piecing together of one representative human genome, consisting of 3 billion base pairs. Put another way, if you had to write down all the base pairs of your own genome, it would take you 60 years, working eight hours every single day. You would fill 500,000 pages of paper. And you'd probably get writer's cramp.

Reveo's device also will be able to determine the presence and placement of genomic methyl groups, tiny molecules that influence when (or if) a gene will actually be expressed. Current methods for decoding methyl group placement are chemical and not amenable to the high-throughput sequencing that is now available for DNA. Determining positions of these methyl groups is the basis for the new discipline of "epigenetics," a subdiscipline that has prompted the rewriting of genetics textbooks and is now forcing scientists to rethink the dogma on which they have relied for decades. Methylation patterns are thought to hold the key to cancer formation, to name just one example.

An instantly deciphered genome such as the one promised by Reveo—aside from catapulting genomics into the future—would someday help to "personalize" patients with their unique genetic makeup as it pertains to their treatment, especially in the pharmaceutical area. On the advantageous side, this information can help make a simple drug like heparin, which is monstrously difficult to dose and medically manage, much safer and more effective.

Reveo's ambition in the realm of DNA sequencing has led it to spin off a company called ReVase to support technology

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Ribbon of Merit

Fiber-optic technology could benefit computer and electronics test-equipment markets.

by Joe Singleton/jsingleton@nttc.edu

An innovative technology capable of moving data faster within high-end computers may soon benefit the multibillion dollar electronics test-equipment market.

Using a patented fiber-optic polymeric ribbon technology, circuit boards, central processors, and memory can be optically interconnected for faster data transfer within computer systems.

MDA funded New Span Opto-Technology, Inc. (Miami, FL), through a 2004 SBIR Phase II contract to develop a fiber-optics component for military computer systems that can relay high rates of data.

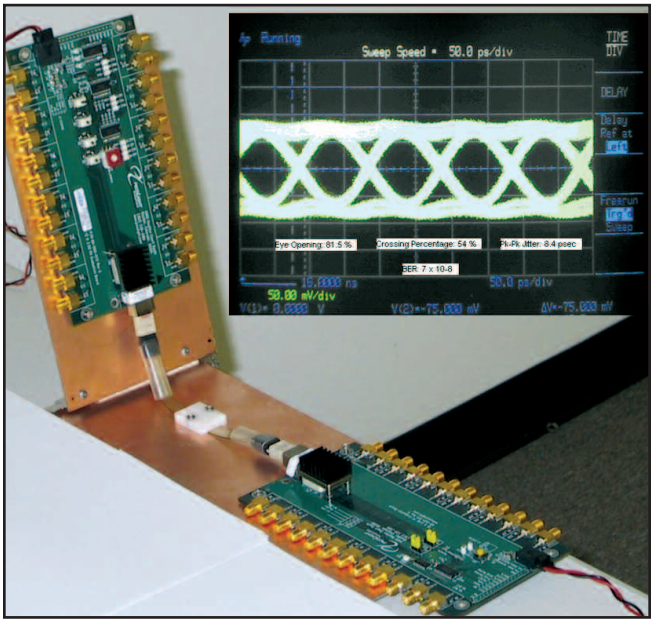
Sophisticated data acquisition and analysis systems often include a number of plug-in modules to perform dedicated tasks, such as signal processing or image processing. The central processor must synthesize the data from many such sources. As the capabilities of the electronics increase, a data bottleneck occurs unless the supporting components can communicate at sufficiently high rates.

Conventional interconnect systems, which use conductive cables or copper traces (the conductive paths etched into the copper cladding of a printed circuit board), have reached their inherent data-rate limit. Optical couplers, the optical equivalent of electrical connectors, can fill the need in high-end systems for military processing and commercial test equipment such as digital oscilloscopes—instruments commonly used to view and compare very high-speed electrical signals.

While there are many commercially available optical systems, New Span has come up with an innovative way to couple light into its multichannel ribbon waveguide using a bus architecture not feasible with other interconnect systems.

In a conventional system, light traveling in an optical waveguide on the main board is reflected into the plug-in module—a one-to-one connection from source to destination. A second module would require a second waveguide channel. New Span uses a different approach that is analogous to the electrical bus systems used in standard computer designs, reducing the complexity of the optical system. Using a phenomenon known as evanescent coupling, some portion of the light energy in the main waveguide is tapped off by the coupler and directed to the destination. The remainder of the energy can continue down the waveguide to where it can tap in to additional couplers. This analogous bus structure reduces the complexity of the optical system and allows designers to continue using a well-established and familiar computer architecture.

New Span estimates the use of the optical ribbon will improve the speed at which a computer's microprocessor can communicate with its peripheral devices from an average of 800 megabits per second to as high as 30 gigabits per second. The company's early testing of the technology with a 12-channel high-speed signal generator demonstrated that undistorted signals can be captured at speeds of up to 2.5 gigahertz per channel, or a 30 GHz aggregate rate. Michael Wang, New Span's research director, expects further improvements in the company's technology to provide as much as a fourfold increase in speed, corresponding to 10 GHz per channel.



▲ New Span's optical coupling technology may enable computers to operate with a fourfold increase in data transfer rates.

New Span's most likely market outside of defense is the electronics test-equipment industry. Specifically, digital oscilloscope manufacturers are prime commercial targets. Oscilloscope manufacturing is a huge industry, with its global market value expected to reach $1.7 billion by 2010, according to a recent analysis by the Frost & Sullivan consultancy firm.

The company's technology also might benefit personal computing by using fiber-optic ribbons to separate dual-core or multicore processors, which are closely stacked in today's systems. The tight stacking makes it difficult to remove heat from the devices. New Span's technology would allow the processors to be separated for better thermal management without sacrificing data transfer speed.

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power at the nodes controls timely collection, processing, and routing of data.

Software for these nervous-system endpoints must be fast and light, and MDA-funded Embedded Research Solutions, Inc. (ERS; Annapolis, MD), has developed just such a solution. Embedded refers to its technology as "miniature software," but the company's product goes well beyond simple software for nodes in a building management system. The company is building a business based on a hosted approach to data collection. Not only is ERS supplying miniature software (loaded on tiny processing devices that can be attached to sensors); it also sells a service that includes real-time collection of data, aggregation of the data, and then delivery of the data back to the customer.

The software for ERS's technology was funded through SBIR Phase I and Phase II contracts from MDA, for a concept known as pervasive computing—in which multiple sensors work together on a network. Company officials envision use of pervasive computing as being applicable throughout missile defense.

▲A cooling tower atop a Manhattan office building is just one piece of the power and utilities equation being monitored by Embedded's technology.

The incentives factor

The kind of pervasive data gathering, processing, and delivery that ERS's technology promises is growing in popularity as overseers of real estate realize there are savings to be had in managing their buildings more efficiently. In addition to the obvious savings from conserving energy, having better insight into how energy is being used in a building also allows the manager of the building to participate in government-endorsed energy initiatives.

Such programs can offer monetary incentives or energy credits to companies that curtail their energy usage to take pressure off of the power grid, usually during peak hours for consumption. Some programs allow companies to buy and sell the energy credits like commodities. Sellers curtail their energy and earn energy credits that they can sell into a market. Other big energy consumers then can buy the credits and boost consumption to meet their individual power needs. Ideally, the approach keeps capacity in balance and prevents utility companies from having to activate costly backup power plants to meet high peak demand.

The interest in managing power consumption has spawned companies such as ConsumerPowerline and Mosto Technologies Companies, two energy-asset-management firms that work with large users that want to tap in to the energy- incentives programs. To help those users, such companies have turned to ERS. Mosto is using the company's technology at sites such as Manhattan's Rockefeller Center. ERS President Drew Sweetak said his company's devices and node software are working to gather data on steam-heat usage at Rockefeller Center buildings.

"What is happening in New York is they are now going to charge usage fees for steam, versus in the past it was simply a flat rate," Sweetak said. "So they need to understand their energy consumption. They need to understand when their peaks are." Sweetak said that, using the technology, customers can avoid peak charges by becoming more aware of their energy usage and making adjustments—such as turning off lower-priority equipment at certain times.

At Rockefeller Center, ERS's devices pass along data wirelessly to an onsite system that transmits the data via the Internet to the company's server farm, where it is then aggregated, processed, validated, and passed back as actionable information that Mosto can use to manage the incentives for Rockefeller Center.

ERS also is seeing significant business through its relationship with ConsumerPowerline. In early 2008, ERS's technology already was deployed at seven ConsumerPowerline customer sites, and Sweetak said ConsumerPowerline would be using ERS's technology or services for 300 customer sites by the end of this summer. While an energy customer could pay a few thousand dollars per month for this type of granular data monitoring, the return in incentives could amount to hundreds of thousands of dollars annually, according to ERS officials.

Sweetak said nodes at a customer site could be set up to pass along data in several ways. A node could transmit the data wirelessly. It could transmit the data via cellular or analog modem. Or it could transmit the data via a hardwired network connection. The last method is useful for environments such as aircraft, another application area where ERS's technology is taking off. Sweetak said the company is working with aircraft companies Lockheed Martin, BAE, and Gulfstream to deploy ERS software and hardware for sensors used on

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military and surveillance aircraft—for applications such as monitoring the performance of cooling systems.

The Lockheed-BAE work involves a project known as CATB, which is a Boeing 737-300 modified to perform mission systems testing for the F-35 Joint Strike Fighter program. The Gulfstream work involves systems on electronic-warfare aircraft for foreign forces. Specifically, Gulfstream has provided Israel with aircraft for its Conformal Airborne Early Warning program and its Special Electronic Mission Aircraft program.

ERS's tiny technology—about the size of a matchbook—is perfect for aircraft, where space is at a premium. "It's cheaper. It's smaller," Sweetak said. "We can do it with off-the-shelf components."

Commercial transformation

ERS's success at commercializing its MDA-funded technology is somewhat surprising, given the company's direction five years ago. (See *MDA TechUpdate*, Winter 2003, "Tiny Wireless Computers Create Sprawling Networks.") At that time, ERS was positioning its technology largely as a tool for the R&D community. "What we found ourselves doing was becoming a research organization," Sweetak said. "You know, 'Hey look, here's a platform piece of code. Come, masses, to us and we will adapt it to your needs.' That really didn't have a lot of legs."

So Embedded repackaged its technology—from a simple plug-and-play wireless device, suited to researchers who wanted to collect data such as river temperature or rainfall levels at various points in the field, to a product optimized for commercial and industrial users.

The improved device—which ERS has branded a Monitoring & Control Server (MCS)—still acts as the gateway for data from field sensors and actuators. But the connectivity is more versatile these days. MCS can work on a wired or wireless network, and stored data within the MCS can be retrieved via a network connection (Ethernet or cellular), via dial-up, or by simply plugging in a USB memory device. Inside the repackaged device, the core miniature software remains essentially the same, however.

▲ The Monitoring & Control Server manages the collection and flow of data gathered from sensors in a building's utilities infrastructure.

After enhancing its device, ERS went out and found distributors, including Optima Energy, LLC, in Pennsylvania. "So with that kind of impetus, that's when it started to catch fire. People started to notice," Sweetak said. "Certainly there was a market force at play here, and that's energy." Through Optima, ERS is working with New York-based textile maker Louis Hornick Company. The work with Hornick involves eight ERS devices collecting data at about 40 points, gathering information on use of steam, natural gas, and electricity. In addition to its business with ConsumerPowerline, Mosto, and Optima, ERS also works with Energy Curtailment Specialists, a New York company that helps clients manage utilities consumption.

"People started to notice. Certainly there was a market force at play here, and that's energy."

–Drew Sweetak, President of ERS

"Our R&D five years ago probably accounted for 95 percent of our income," Sweetak said. "That would be grants and research projects. Today, that has flipped to 95 percent commercial contracts. And that was hard."

In addition to MDA funding, the company has received financial help from partners that include the State of Maryland's Technology Development Corporation (TEDCO) and the Maryland-based LaMotte Company, which makes testing equipment for several industries. The involvement of TEDCO and LaMotte helped ERS get matching MDA SBIR funds through the FastTrack program. Several years ago, wireless giant Nokia also funded ERS with a convertible note that allowed the Annapolis company to conduct essential market research.

Sweetak said his company would continue to seek partnerships that allow the company to boost its commercial exposure. "It's important for us to tie up with larger companies at this point—whether that's an investment vehicle or a product strategy," he said. "So I would be very much interested in trying to solicit collaborative requests."

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Talking Technology Transfer

Cynthia Gonsalves wants the nation to reap the benefits of DOD-funded research.

by Keith Costa/techapps@nttc.edu

▲ Gonsalves.

The Department of Defense has played a key role in technology transfer for decades—indeed, well before legislation in 1980 codified such activity as a crucial mission area. For DOD, technology transfer includes making new advanced materials, equipment, and software created by its laboratories, or developed elsewhere with military funding, available to the general public through commercialization. In time, commercialization may ensure the availability of these technologies for transfer back into DOD systems, a step sometimes referred to as technology transition.

Technology transfer is happening at military and civilian facilities across the country. Keeping tabs and providing oversight is DOD's Office of Technology Transition (OTT), led by Acting Director Cynthia Gonsalves. In the Office of the Secretary of Defense (OSD), Gonsalves reports to John Kubricky, the deputy under secretary of defense for advance systems and concepts in the Director of Defense Research and Engineering (DDR&E) organization.

Gonsalves has been working with the Office of Technology Transition since it began operations at DDR&E in 1994. Before then, she and the group of people who would move on to DDR&E worked on industrial base issues for another OSD organization. At the Office of Technology Transition, Gonsalves chairs the Defense Technology Transfer Working Group and oversees the Technology Transfer Integrated Planning Team; MDA participates in both. Among other programs, she also manages the Technology Transition Initiative, which provides funding to help fledgling technologies survive the proverbial "Valley of Death" so they can be inserted into DOD systems.

MDA TechUpdate sat down with Gonsalves at her office in Arlington, VA, in April to talk about technology transfer, including MDA's role in this mission area. In the discussion that ensued, she covered topics ranging from technology transfer initiatives spearheaded by her office to challenges facing technology transfer professionals in this new century.

TechUpdate: Let's start with some background. What is the Office of Technology Transition's particular role in technology transfer?

Gonsalves: We deal with technology transfer policy and oversight from an OSD perspective. And we're facilitators. For example, we're an interface with the private sector to help interested parties work with the Department of Defense. We're also projecting a vision for what tech transfer should be for the department, and laying that out for implementation.

TechUpdate: What changes resulted from the creation of the Office of Technology Transition in 1994?

Gonsalves: The military services and defense agencies did some form of tech transfer before this office existed. There was an OSD component, but the services were supposedly out in front. Once we were stood up, they now had a place where they could collaborate with us and each other. You now have the Defense Technology Transfer Working Group and the Technology Transfer Integrated Planning Team for training and sharing best practices across the department. We bring people into an environment where tech transfer is the focus, and they feel as if they can call upon others in DOD to accomplish their missions.

TechUpdate: The Law requires DOD to conduct a robust technology transfer program. An important goal is introducing advanced technology into the marketplace to boost the U.S. economy. Our readers are familiar with the myriad benefits of commercializing government-funded technology. Why else is technology transfer so important to DOD?

Gonsalves: It is important because DOD spends a lot of money in research and development, and we need to know where that technology goes with certainty. Technology transfer tools give us the visibility to track a technology all the way through from the point of invention at a laboratory, to a contractor, then to a military system. Those tools include cooperative research and development agreements (CRADAs) and patent license agreements, which gives us a stake in what happens when a technology leaves a lab, and puts us in a position to provide assistance, if needed.

If we did not have such a focus, the technology we develop in our labs in some cases could wind up on the shelf. This happens now. When we selectively pursue marketing of our technologies, we have a better chance to get them into use. Remember, we're not in the business of building our own systems; we rely on contractors for that. So we need to get the technology to them and help it mature so it can be inserted, which is technology transition.

A lot of the technology DOD funds in and outside the labs has military and commercial use, and, in fact, without both there might not be a big enough market for a technology, or the company developing it, to survive. What happens when the military makes a product line, say, once every four years, and the company makes all you need in a year? What does the

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company do for the other three years? Just wait around? I don't think so. You often need both a commercial and a military market to be viable. Otherwise, the next time we need to make a buy, the company is gone. All this investment in research and development and then it's gone. That's not very efficient.

TechUpdate: Does that mean technology transfer and transition complement each other?

Gonsalves: They do complement each other. Transition is something that many years ago we called transition-to-production because DOD had significant oversight and interface with the manufacturing world with our weapon system and program managers. Today, we're calling it transition-into-a-weapon-system-from-R&D, and that's what we're trying to accomplish. They are complementary in that we're transferring technologies from a DOD laboratory to a company, so we can have a production capability for our systems. With our Technology Transition Initiative, we're trying to provide a nexus where the developers and the acquirers both agree on what the exit criteria will be to insert a capability into our systems.

"We all claim to be looking for innovation these days, but I think MDA truly is seeking the most innovative ways to accomplish its missions and stay ahead of enemy threats."

–OTT Acting Director Cynthia Gonsalves

TechUpdate: MDA doesn't have any laboratories. Its technology transfer activities through the Technology Applications (TA) program are largely focused on helping small businesses, universities, and others commercialize their MDA-funded advanced technologies, which could lead to eventual insertion into missile defense systems. What is your assessment of the TA program?

Gonsalves: MDA looks for innovation. That's a key thing. We all claim to be looking for innovation these days, but I think MDA truly is seeking the most innovative ways to accomplish its missions and stay ahead of enemy threats. MDA is an organization that looks at the private sector, academia, and government labs on the same playing field in terms of opportunities for research, but it doesn't stop there. It shepherds out those technologies that need to make the transition.

I'm impressed with the tools MDA employs in this regard—specifically, the Business Focus Workshops and Technology Applications Reviews. The unique way MDA brings in private-sector experts to mentor workshop and review participants is outstanding. I think the way MDA manages its R&D programs and its supporting tech transfer and SBIR programs is an excellent approach producing good results.

When I read *TechUpdate*, there are many times when I find connections between the technologies in them and the programs in my office. We find connections to other services, other department programs, and the commercial sector. It's very good.

TechUpdate: Your office has developed a new technology transfer information management tool called the Intellectual Property Management Information System (IPMIS), which is now operational. How will it be used?

Gonsalves: IPMIS is a DOD-wide database of the invention disclosures, patents, patent license agreements, and, eventually, a means of tracking of royalties, so that the department has an overall picture of its intellectual property holdings. This is intended to be a resource for our technology transfer decision makers and intellectual property attorneys so they can quickly have access to anything that's out there in our portfolio of DOD-owned technologies.

For example, if an Army lab wants to find information about patents held elsewhere in DOD, it can turn to IPMIS to find out who the stakeholders are for those patents and where they can be found. The U.S. Patent and Trademark Office only tells you who the inventor is, not where he or she works. The Army lab may want to license those patents along with a technology of its own, using IPMIS to make sure all stakeholders can offer input for the negotiations. IPMIS also will help identify which patents and copyrights assigned to our contractors and grantees come with government-purpose rights to the underlying technology.

TechUpdate: What was the state of affairs before IPMIS?

Gonsalves: Some organizations had the latest, greatest intellectual property management systems, but they were few and far between, and we had some organizations still relying on paper records. We've been working on IPMIS since 2002. I want to stress that it was not developed so this office can oversee what deals the services or labs are making. It's to be able to say we know this patent came from this lab, and we tell someone who is interested in licensing it who to talk to. If we think multiple labs might have an interest in the patent, we can find out who needs to be involved.

TechUpdate: What are some of the biggest technology transfer challenges still facing DOD?

Gonsalves: There is the continuing challenge of explaining why DOD, or any Federal department for that matter, should fund technology development for commercial application. We're encouraged to market, but is that a proper DOD mission? Marketing to the commercial sector puts new technology into the economy. Looking at it as a means to an end, it's justified, because we have to go to the commercial sector to buy a product—but that production capability has to be there in order to make the purchase.

We've talked many times about having to justify your own job here periodically, and I think that's something we always struggle with for tech transfer. What's the value back to the customer for investing in tech transfer? The investment may not be

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money. It may be personnel time. I think that over time we can show that it's been worthwhile, a cumulative effect in that we're getting technologies out there that are incorporated into products, and the private sector is finding avenues back into DOD.

TechUpdate: Is there a challenge that comes with DOD no longer being the biggest player pushing advances in some technology areas?

Gonsalves: There is the challenge resulting from a changed investment landscape for technology. In the 1950s and 1960s, there were whole market sectors, like communications and information technology, in which DOD created the market base or was the dominant player. Now the commercial use of communications and IT outpaces what we do in the Federal government. We haven't lost interest in them; we still have a need for them; we still develop. But how do you interface with those technology sectors when you're just one car in a 100-car train? I think tech transfer tools give us a means to work with companies in those sectors where we are a small piece of the market. These companies can work with us because we're not a competitor, and they can get access to unique facilities paid for by the government that they couldn't pay for themselves. So there is still an important role for us, and this is why industry continues to seek us out, as we seek help from the private sector.

TechUpdate: What are some of the ways you build a case for technology transfer accomplishments at DOD?

Gonsalves: We use specific success stories, which we highlight in our biennial report to Congress. For instance, we can say this came from a DOD lab, and now it's in the commercial market and you can buy it at Wal-Mart. We also keep track of the number of CRADAs, license agreements, and educational partnership agreements without necessarily talking about a particular outcome. In some cases, the impact of a CRADA is not known at the present time – it's hard to quantify when requesting budget dollars. It costs money to receive patents, but they set the ground rules for what intellectual property we own in order to license it to companies.

As an example, the Air Force has developed conventional and synthetic fuels for aircraft use. The effort was supported by several CRADAs and patent licenses. Additional technology was developed and transitioned for a low-temperature fuel additive. These products are being tested and certified for use in various military aircraft engines, and future plans call for transition to the civilian aircraft market. This is a win-win for both DOD and commercial aircraft users.

It's not a bad thing if people are still asking the value of tech transfer. When this happens, we're being given an opportunity to let them know what the program does.

TechUpdate: In what areas has technology transfer been the most successful?

Gonsalves: Probably the place where tech transfer happens most consistently is in the medical R&D community because oftentimes it's very hard to draw much of a distinction there between a military need and a civilian need. Efforts to treat warfighters have led to a whole range of technologies that would not have been developed without military R&D. I think we'll find that civilians will want to have some of the same state-of-the-art treatments we're developing and deploying for the warfighters.

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development. Other SBIR/BMDO-funded technologies at Reveo—including high-efficiency polarizing filters and chiral films for many subdisciplines of missile applications—have led to other Reveo spinoff companies. One example is VRex, which sells a variety of products relating to 3-D vision, including projectors, conversion films for laptop screens, and shuttered glasses.

Another spinoff company is Chelix, which sells solar-selective and privacy windows based on cholesteric liquid crystals and electro-optic control, also subjects of BMDO SBIRs. For the more insouciant seeker of optical entertainment, Chelix markets color-shifting pigments, for finishes that change hue based on the orientation of the viewer.

Based on the unique vision and entrepreneurial spirit of Faris, Reveo is a company clearly focused on the future.

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Chip Immunization from page 3

occur when particles change the bits containing important information in a chip. The radiation effect can range from a type of catastrophic failure called "single-event latchup" to a type of nondestructive failure called "multiple-bit upset." Depending on how critical it is to the functioning of electronics in a missile, jet fighter, satellite, or other platform, the failure of a single chip could cause a breakdown of the system's electronics at the most critical time. Silicon Space Technology recommends an "all rad-hard approach" for electronics to protect against systemwide, radiation-related failure resulting from the incorporation of just a single unhardened integrated circuit component.

The most common approach to protecting CMOS chips from radiation is a combination of shielding, sometimes called the aluminum-box approach, and adding redundant circuits. This approach, however, makes computer systems heavier and more expensive.

An early alternative going back to the 1960s was to build CMOS circuits on silicon that itself was grown on sapphire, a dielectric material whose properties can help isolate and control voltage swings upon exposure to radiation. The silicon-on-sapphire solution worked well, as did silicon-on-insulator technology pushed by the Department of Defense in the 1980s, but the majority of companies in the semiconductor industry has continued to make CMOS devices by putting circuits on bulk silicon.

Silicon Space has heated its BGR circuits to 125ºC without experiencing latchup. Most commercial circuits shut down above 85ºC.

Process improvements

The capabilities of bulk-silicon CMOS devices have continued to advance, and, despite being radiation-soft, they are widely used by the military. Accelerating the adoption of radiation-hardened vintage integrated circuits requires production processes that neither cost too much nor adversely affect procurement schedules, and it depends on having on-shore supply with a wide selection of hardened components, Morris said. The BGR approach can achieve those goals in any CMOS generation far more cheaply and effectively than any previous method, he added.

BGR gives bulk silicon CMOS rad-hard qualities akin to what was achieved with silicon-on-sapphire, while offering customers the benefits of vast technology advancements in bulk CMOS over the past 30 years, according to Morris. BGR-enhanced bulk silicon can be rated with the same "latchup-immune" label, he said.

A key metric for radiation hardening is dose-rate performance, measured in rads per second. For instance, in tests conducted by Silicon Space Technology, a commercial SRAM chip fails at a dose rate of 100 million rads per second, whereas a BGR-enhanced SRAM can function beyond 7 billion rads per second, making the technology more attractive for aircraft and space systems. The company also heated BGR circuits to 125ºC without experiencing latchup. Most commercial circuits shut down above 85ºC. Silicon Space Technology also has shown that BGR minimizes the possibility of multiple-bit upsets.

Silicon Space Technology can work with a manufacturer that wants to include BGR modules in a brand-new assembly line, but insertion into an already-functioning product line can be more cost-effective. BGR enhancements cost in the neighborhood of $5 million.

Inserting BGR capability into smaller, and denser, CMOS chips has been a challenge, but not an overwhelming one, according to Morris. In fact, the company has developed "non-invasive" processes that can survey an existing chip and automatically add the BGR structure ports to it without changing the device's size, power, or performance, he said. The company has successfully demonstrated its ability to integrate BGR into several CMOS process generations at the 250-nanometer (nm) scale, as well as at 180 nm and 130 nm. Now, it is researching ways to work at the 90-nm scale, which is close to the cutting edge of CMOS technology. Morris believes BGR, when combined with voltage scaling, will perform even better at smaller scales.

Meanwhile, Silicon Space Technology and Texas Instruments are readying a number of BGR-enhanced products for release. Soon there will be two rad-hard FireWire-related chips, as well as three digital-signal-processing offerings, all from Texas Instruments. Silicon Space Technology also has demonstrated high yield in manufacturing its first 16-megabit SRAM chips at 180 nm, which are due out to the market later this year.

The company has the flexibility to work with other integrated circuit manufacturers, as well as directly with systems suppliers. For instance, it has consulted with Rockwell Collins about radiation hardening for circuits in military radios. Texas Instruments, though, has the only chip-fabrication line with BGR process modules, and Morris wants to keep it this way for now so his company can devote all of its resources to launching its process model and making the Texas Instruments rad-hard product line successful.

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To reconstitute a visual of the target from its dispersed components, a second polychromator within the imager system is used.

Spectral Sciences' imagers, although still being developed, are expected to provide substantial cost savings to users. Dr. Vujkovic-Cvijin says the initial price of his company's imagers would provide twofold to fourfold savings over existing spectral-imaging and tracking (combined) imaging systems.

The company is continuing work to move its technology from the prototype stage to the commercial stage. Spectral Sciences now desires to form partnerships with established instrumentation companies. The company also seeks additional capital investment.

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Wang said his company is working hard to find the appropriate market for its technology. New Span is hoping soon to locate companies—namely prime computer manufacturers—that would be interested in partnering and perhaps even licensing its technology.

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