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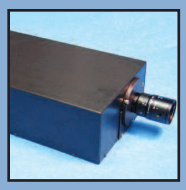
Missile Defense Agency

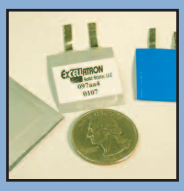
TechUpdate

A Quarterly Newsletter for MDA Technology Transfer

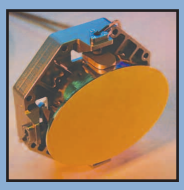
INSIDE



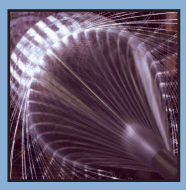














▲ Touchstone's metal-matrix-composite manufacturing process was used to make the rocket-motor case shown in this static firing test. Tanks developed with the company's process also could be used to store commercial gases.

# On the Lighter Side

## New material adds strength, lessens weight of pressure vessels.

by Michele Rejonis/mrejonis@nttc.edu

A new fiber-reinforced material could replace aluminum in pressure vessels such as motor cases and commercial gas-storage tanks, leading to lighter products with three times the strength of their predecessors.

Touchstone Research Laboratory (Triadelphia, WV) has developed a unique material and manufacturing process for metal-matrix composites with military, aerospace, and commercial applications. While metal-matrix composites are not new, Touchstone has an advantage because its process is faster and less expensive than typical fabrication of metal-matrix composites. The company's prepreg material is impregnated with molten metal as it is being wound onto a mandrel, unlike the conventional metal-matrix-composite process, which infuses the metal matrix after the filament is wound on a mandrel. This requires know-how that company representatives feel would be hard for competitors to achieve. To protect intellectual property, the company has applied for patents.

Touchstone developed the material process with help from MDA, which awarded the company an SBIR Phase II contract in 2003 to develop a linerless storage tank for the Space Based Laser satellite. In exploring other applications and commercial possibilities, Touchstone has focused on metal-matrix composites for

continued on page 9

# Finding the Right Path

The road to success is not always the obvious route.

by L. Scott Tillett/stillett@nttc.edu

A wise person once said that a career path only makes sense in hindsight. For many researchers, that axiom is a true one. And a similar axiom applies for commercial applications of the technologies those researchers are developing: Sometimes, the path of product development only makes sense in hindsight.

We see it a lot here at the MDA Technology Applications program: A technology developed for one application—be it a role in missile defense or a specific commercial use—often ends up seeing great success in an application for which the technology was not originally intended.

Flip through any issue of the *MDA TechUpdate*, and you're likely to run across several technologies that deviated from anticipated paths. You might find an article on a laser that, while promising for missile defense, has shown more immediate success as a medical tool. Or you might find an article on a material that, while appropriate for space and aviation applications, has tapped in to ground-based applications as a stronger market.

The challenge for an MDA-funded inventor often is knowing when to guide a technology down a preplanned route and when to let other factors (such as market demand and interest from investors) pull that technology along a different course, toward possibly unanticipated applications. The direction that makes the most sense commercially often is not the same path that an inventor envisions at the beginning of technology development. However, it's a path that, when viewed in hindsight, can seem as if it were brilliantly planned from Day One.

But—and this is the important thing to remember when dealing with technology transfer—MDA does not lose out when technologies zip off down these brilliant commercial paths that seem to have little to do with missile defense. As companies trek toward successful applications that are more commercially oriented, improvements and innovations along the way help create mature products that can be inserted into missile defense applications. Commercial customers of MDA-funded innovations such as software or imaging technology, for example, might suggest improvements or features that will prove helpful to MDA users, as well. Ultimately, MDA can and does benefit from commercial enhancements to the technologies.

Promising technologies that follow a commercial path do not simply come to a happy dead end at commercial success. Along the way, innovations serve as loop-backs and bridges that deliver strong, mature technologies for the MDA mission. It's a path that does not seem obvious during the beginning stages of product development. But it's a path that makes sense in hindsight—because it benefits both commercial users of technology as well as MDA.

**Editor** L. Scott Tillett
**Production Manager** Lisa Hylton
**Contributing Writers** Leslie Aitcheson, Paul Carroll, Michael Felton, Michele Rejonis, Alan Sherwin, L. Scott Tillett, Joan Zimmermann
**Advisors** Paul Carroll, Jeff Reynolds, Alan Sherwin, Duane Zieg
**Layout** Lan Crickman

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Please address inquiries and mailing list corrections to:
National Technology Transfer Center-Washington Operations
2121 Eisenhower Avenue, Suite 400
Alexandria, Virginia 22314
Attn: Editor, *MDA TechUpdate*
Tel: (703) 518-8800 x500, Fax: (703) 518-8986
E-mail: stillett@nttc.edu
Web sites: www.mdatechnology.net, www.mda.mil/mdalink/html/mdalink.html

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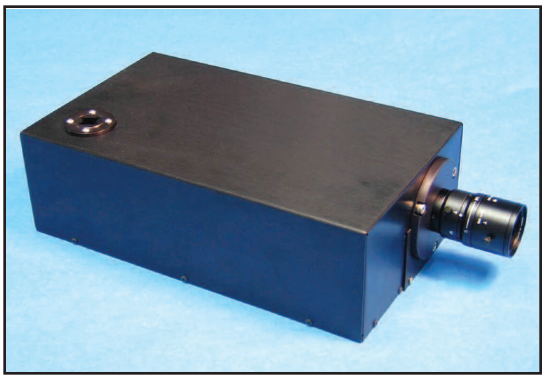
CONTENTS

# Spectrum in the Blink of an Eye

New imager design yields a clear and rapid picture of chemical composition.

by Joan Zimmermann/jzimmermann@nttc.edu

Bodkin Design and Engineering, LLC (Wellesley, MA), is developing an imager methodology with the ability to rapidly acquire hyperspectral images at a high frame rate, allowing the viewer to identify the chemical composition of imaged targets. This innovative design has commercial applications in the petrochemical industry, medical imaging, food inspection, agricultural imaging, and drug enforcement.



▲ Bodkin's imager could be used in law-enforcement cameras to help investigators detect evidence of drug labs.

Bodkin will produce a dual-band stand-off detector under an MDA Phase II SBIR contract for remote kill assessments in hit-to-kill engagements. The low-jitter, video-frame-rate detector was designed to rapidly characterize the products of combustion of a successful missile interception or an explosion, and the imager's infrared wavelength range allows the viewer to determine what type of payload (biowarfare, chemical) is being imaged.

Because the imager is staring, not scanning, the result is consistent across the pixel plane; each image can be quickly offloaded and another "snapshot" taken at a data-cube rate of 30 hertz, without the jitter and overlay problems of competing techniques. This approach translates to fast results without filters or moving parts. Each pixel contains spectral information that can be translated to chemical composition.

The detector operates in visible, short-wave, and mid-wave infrared (IR) wavelengths. The company has built hyperspectral imagers in the visible, SWIR, MWIR, and LWIR bands, but the current Phase II device is a dual-band system with an SWIR hyperspectral imaging channel and an MWIR video imaging channel, making it suitable for some nonmilitary applications. In areas such as drug interdiction, the imager could be incorporated into a surveillance camera to detect evidence of a "crystal meth" lab, often a crude shack in a weedy field that reeks with the byproducts of drug synthesis. The gaseous clouds (phosphine, sulfur) associated with such laboratories are frequently dense enough to be detected and identified by an infrared imager. In the petrochemical industry, the imager could be used to detect oil seeping from leaks at a drilling site, as well in the discovery process itself, by sensing upwelling hydrocarbons that float on the sea surface.

Pollution detection is another application of the Bodkin hyperspectral imager. Whether used as an online monitor or an investigative tool, the imager has the ability to quickly identify a wide range of chemical species, making it a valuable tool for both detection and clean-up. Thus, water treatment plants, industries that release byproducts into waterways and the atmosphere, and gas utilities are examples of enterprises that might benefit from hyperspectral imaging. In marine biology applications, the imager could be used to detect the chlorophyll signal that heralds the early signs of algal blooms, which can be devastating to fish and mollusks, or in agricultural applications such as determining soil condition, plant stress, and time-to-harvest. Detection of food contamination by such deadly bacteria as Salmonella species or pathogenic strains of E. coli is another potential use.

In medical use, hyperspectral imaging has been making inroads and has been the subject of intense academic and clinical interest. While cancer detection has largely been the province of the MRI and CAT scan, the maturing technology in both detector sensitivity and digital resolution is accelerating the promise of hyperspectral imaging in distinguishing malignant tissue from normal tissue, without ionizing radiation or the limitations of MRI. Furthermore, hyperspectral diagnosis might prove to be far more sensitive than current technology through detection of specific, cancer-associated molecules.

The company continues to develop its imaging capabilities with SBIRs from other agencies, and is eager to work with partners to validate and refine its technology. Among its current commercial products are an Ethernet-connected security camera with pan, tilt, and zoom capabilities, a miniature 3-D spectrometer, and the long range OmniSpotter™ dual-band camera for multiple applications.

**CONTACT INFO**

Timothy Shea
Bodkin Design and Engineering, LLC
Tel: (617) 795-1968, ext. 116
E-mail: tshea@bodkindesign.com
Web: www.bodkindesign.com

# New Battery Edges Theoretical Limits

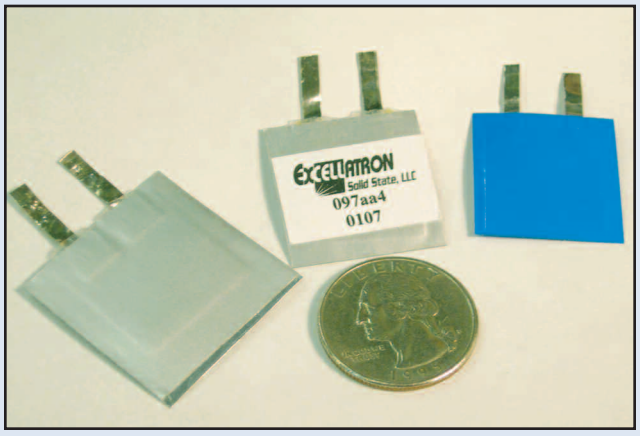
A lightweight battery with heavyweight potential.

by Joan Zimmermann/jzimmermann@nttc.edu

Question: What do an advanced lithium battery and a giant water pistol have in common? Answer: A versatile company, founded by the inventor of the Super Soaker®, Lonnie Johnson. Dr. Johnson founded his company, Johnson Research and Development Company (Atlanta, GA), on the strength of the proceeds from the Super Soaker water gun, a summer staple for the younger set. However, Johnson's real prowess is in thermodynamics, an ability that kept him busy for many years in the Air Force and at NASA's Jet Propulsion Laboratory, and that now is fueling some significant advances in energy technology.

Dr. Johnson spun off Excellatron Solid State, LLC (Atlanta, GA), to help commercialize one of these advances, a lithium-air rechargeable battery that has the potential to last up to eight times as long as current lithium-polymer batteries. Through an MDA SBIR Phase II for the development of a solid-state, long-lasting, lightweight power source for the High Altitude Airship, Excellatron is developing a battery that in theory could reach an energy density of more than 10,000 watt-hours per kilogram. Thin-film batteries using the low-cost, efficient lithium-deposition technique sidestep the more environmentally problematic nature of battery disposal by forgoing the use of leaky acids or toxic heavy metals.

Lithium-air batteries use atmospheric oxygen as the cathode active material, and lithium (usually combined with another metal such as nickel) as an anode, with a novel electrolyte as a medium for the ions to cycle through. In most "air" batteries, the limiting component is the air cathode, which must be porous to allow enough oxygen into the cycle for efficient battery power. Building on the company's established thin-film lithium and lithium-ion battery technology, Excellatron has overcome corrosion and battery-capacity barriers, and has provided demonstration lithium-air batteries to a customer.




▲ Lithium-air rechargeable batteries from Excellatron have the potential to last up to eight times as long as current lithium-polymer batteries.

The initial target of the battery technology is the cell-phone industry, where major manufacturers could participate in the further development and adaptation of the batteries for all manner of portable electronics. Imagine having your laptop battery function for an entire day instead of having to scramble for a wall plug within hours, or how you might reach the theoretical limit of thumb strength during a Super Mario marathon. Eventually, a scale-up of the battery could lead to much more versatility and longevity in hybrid vehicle systems, perhaps freeing us from the tyranny of the gas pump some day not so far away. With 12 patents approved and eight additional patents pending, Excellatron is engaged in a stepwise plan to incrementally improve and increase battery size and efficiency, preferably through partnerships.

In a parallel effort, Excellatron's parent company, Johnson R&D, is developing a solid-state pump for cryocooler applications. With the help of a Phase I SBIR for MDA's next-generation infrared-sensing and spacecraft-cooling technologies, Johnson is in the early stages of refining a low-vibration refrigeration system that has several advantages over competing technologies, most notably lack of vibration. In addition, the device will not cause electromagnetic interference, and is expected to increase the reliability and lifetime of infrared (IR) sensors and spacecraft cooling systems, at a lower cost and with greater ease of production. Military applications include IR seekers for missiles and gun sights, and commercial and academic applications exist for MRI, telecommunications, and low-temperature physics.

Johnson R&D and Excellatron are seeking to license their technologies and foster strategic placement of their products.

**CONTACT INFO**

Anthony Pace
Excellatron
Tel : (404) 584-2475
Email: pace@excellatron.com
Web: www.excellatron.com

# A New Recipe for Batteries

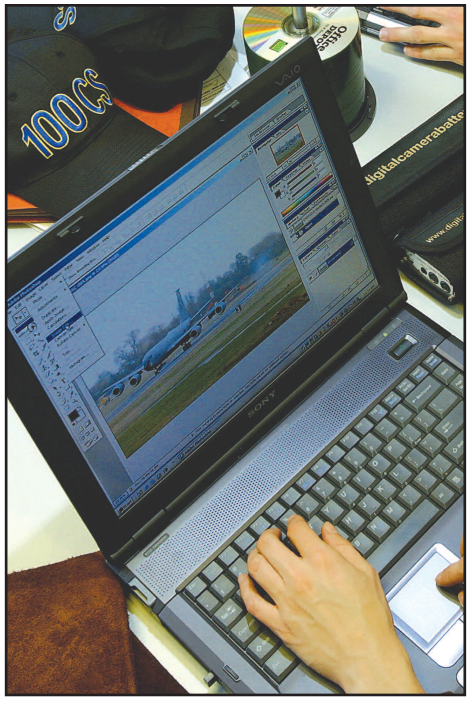
## Approach using modified vanadium oxide promises better capacity.

by Michael Felton

Researchers have developed a new "recipe" to make cathodes (the weak link in rechargeable lithium-ion battery performance) run far longer than they now do in conventional batteries.

Most laptop computers, portable music players, and cell phones run on lithium-ion batteries, and although improvements in battery design and engineering have increased their capacity, the amount of energy they store, and thus, provide, hasn't increased much over time.

Most state-of-the-art lithium batteries use cathodes made from lithium cobalt dioxide ($LiCoO_2$). Such cathodes store electrons and have reversible (rechargeable) capacity in the range of 150 milliampere hours per gram (mAh/g). By contrast, the anode material, graphite, has a reversible capacity that approaches 300 mAh/g. The capacity imbalance between the cathode and anode is one important factor that impedes progress toward more energetic lithium-ion batteries. As a result, recent research has sought to develop cathode materials that can improve the capacity imbalance between lithium-ion battery-electrode active materials.



▲ Research and development by Physical Sciences, Inc., is leading to new materials for batteries that could be used in devices such as laptop computers.

### Polymer-modified Vanadium Pentoxide

MDA-funded Physical Sciences, Inc., (PSI; Andover, MA), which had already been working in other areas of lithium-ion battery science, decided that it should look for more promising cathode materials and, after studying various potential alternatives that were already available, settled on vanadium oxide ($V_2O_5$).

"$V_2O_5$ has been in the literature for 50 or 60 years, but it never gained favor with the battery community because there are a few inherent drawbacks," said Kevin White of PSI. One important drawback was that while it could theoretically store four electrons per formula unit (approximately 600 mAh/g), only one electron could be used reversibly. "It was clear that the unmodified material was just not going to get to anywhere interesting," he said.

The researchers experimented by adding conductive polymers to the material, hoping it would make $V_2O_5$ more amorphous (fewer large crystals) and more conductive so charges could move more readily. Making $V_2O_5$ more amorphous was a known way to improve $V_2O_5$, but White stumbled upon an interesting phenomenon.

When enough conductive polymer was added to improve electrical conduction, the modified $V_2O_5$ cathode material capacity became dismal. Yet when less conductive polymer was added, battery performance improved, including the ability to be recharged and discharged many times.

When PSI examined the material's structure more closely, the reason for this improvement became clear. "Think of $V_2O_5$ as a bowl of fettuccini noodles. They're flat, like ribbons, and tangle together, so, from a bird's-eye view, there is very little order. That's why we call the material amorphous," White said. Unmodified $V_2O_5$ contains short-range order at the "noodle" level, but White's team found that the conductive polymer additive disrupted this micro-scale order.

### Building better batteries

The PSI team's work yielded a battery based on traditional graphite anode material and the modified $V_2O_5$ cathode material that stored more energy than traditional lithium-ion batteries, but, unlike previous $V_2O_5$-based systems, could also be recharged many times. Batteries could be charged and discharged completely more than 25 times, and, if cycled to lesser depths of discharge, could achieve more than 100 cycles without a significant decrease in capacity. "Improving battery cycle life further hinges on overcoming engineering challenges associated with adhesion of the cathode material to the underlying current collector and particle-to-particle cohesion within the modified $V_2O_5$ cathode," White said.

PSI conducted its research on 3- to 6-amp-hour cells, roughly the size of a deck of playing cards, and targeted use

continued on page 9

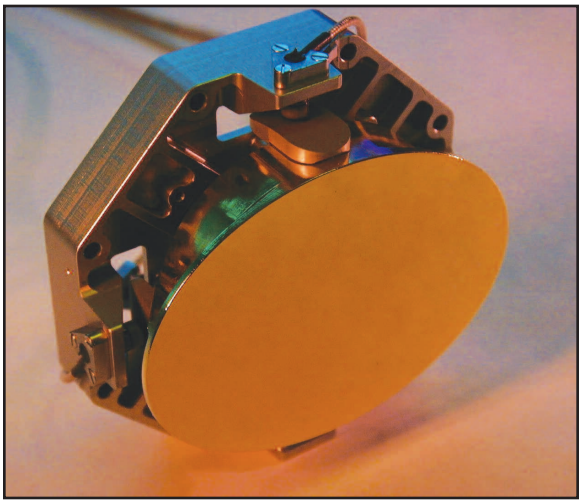
# Shake, Rattle, and Roll

## Innovative mirror-steering system gives precision optics a smoother ride.

by Alan Sherwin/asherwin@nttc.edu

Imagine filming a video on a roller coaster: The result would be a blurry mess as you and your camera were jostled about. The same challenge applies to optical systems used in communications and instrumentation applications in space and on the ground. But one MDA-funded company has developed a suite of optical steering devices designed to improve the vibration immunity of optical systems, allowing them to track moving targets with greater accuracy.

The company, Left Hand Design Corporation (LHDC; Boulder County, CO), was funded by MDA through a 2002 SBIR Phase II award to develop an enhanced fine-steering mirror or fast-steering mirror (FSM). Missile interceptor seekers must rapidly point their optical systems at different targets in a dense cluster, a sufficient challenge without the added problem of vibration caused by other moving components on the vehicle. This task requires a mirror that can be positioned rapidly and precisely. The design improvements LHDC successfully developed for this project can provide benefits for these and a wide variety of commercial and aerospace applications, including image motion compensation for orbiting Earth observation, ground- and space-based astronomy, video cameras, industrial inspection, laser communications, laser surgery, and photolithography.



▲ LHDC's system for steering optics such as mirrors could be used in aerospace applications, laser communications, and industrial inspection.

Consider an orbiting telescope. The optics can be pointed using a two-axis gimbal (like the adjustable head on your dentist's x-ray machine) and by adjusting the satellite's attitude (its orientation in space). These methods are sufficient for coarse and low-speed positioning, but they cannot provide continuous high-speed compensation in the presence of spacecraft platform vibrations. Such vibrations introduce disabling jitter in the optical signal, but FSMs come to the rescue with their capability of rapidly and accurately stabilizing the line of sight.

The mirror "payload" of the FSM system is typically 15 to 300 millimeters in diameter. An optical-tracking detector and/or inertial sensor senses instantaneous deviations from the ideal pointing angle and provides feedback to motors that rapidly adjust the position of the mirror, bringing the optical path back into precise alignment. The system design is critical, requiring materials with the necessary stiffness, lightness and thermal-expansion properties, further complicated by stresses introduced when the mirror is attached to its mount. For this reason, LHDC offers mirrors fabricated from a variety of materials chosen for the mission. LHDC's innovations in motor design have led to optimized weight and power consumption, a big hit with space mission engineers. The company's FSMs are currently flying in a number of military aircraft as well.

For more down-to-earth applications of FSMs, LHDC is receiving attention from customers in the field of line-of-sight optical communications, which use a modulated laser beam to carry the information from transmitter to receiver. Disturbances in the air (thermal, wind, and precipitation) and vibrations in the support structure can cause data dropouts, reducing the transmission bandwidth.

Bandwidth is an important parameter of FSM systems; in this case, the unit hertz (Hz) refers to the highest vibration frequency that the system can compensate for. In orbiting applications, gimbals can achieve bandwidths up to 10 Hz. Typical fine-steering mirrors provide bandwidths up to 1,000 Hz, but LHDC has extended that range to 2.8 kHz, and LHDC President Larry Germann has set his sights on 5-10 kHz.

Another key parameter is acceleration, which permits the FSM to compensate for high-amplitude vibrations. LHDC has achieved accelerations greater than 10,000 radians/second$^2$, more than 10 times higher than typical competing FSMs.

In developing its FSM products, LHDC must address the somewhat conflicting goals of fine-positioning precision, high acceleration, and high bandwidth while maintaining mirror flatness. Extending the bandwidth (while respecting customers' cost constraints) presents an enormous technical challenge, requiring expertise in motion-control electronics, mechanical design, sensors, and materials and process (M&P) science.

continued on page 10

# Defending Against the Elements

## Material for radar domes offers durability and savings.

by Leslie Aitcheson

Mentis Sciences, Inc. (Manchester, NH), has developed and is testing a low-cost composite radome for the Patriot Advanced Capability (PAC-3) missile program.

A radome—a combination of the words radar and dome—covers an antenna or other electronics, protecting equipment from sun, wind, and precipitation. Radomes often come in the form of geodesic bubble-like structures that cover large radar systems for military operations; however, smaller cone-shaped radomes are also used to cover missile seekers on interceptors and other systems.

Mentis' progress on a composite radome represents a major feat for a 20-employee small business, since it is competing with large defense contractors. If Mentis parts are used for PAC-3 and other defense systems, it is estimated that the government will save as much as $250 million due to low-cost production using innovative techniques for processing. This technology, nearing fruition, emerged largely with help from the MDA SBIR program, which provided Phase II contracts for Mentis' work.

"We received SBIR funding in the 2001-2002 timeframe and focused this process on a deliverable, teaming with Lockheed Martin," explained John Dignam, principal investigator on this project for Mentis Sciences. "Now this SBIR project is coming to fruition."

Radomes for missile seekers have special challenges. "If your material changes state or phase at any time during the mission, then the seeker cannot acquire its target," Dignam said. "In a sense, it's like driving down a highway without wipers during a rainstorm. … Everything coming toward you would be distorted, refracted and reflected. You wouldn't be able to see your destination. That's the same functional equivalent of a radome."

He explained that the challenge has been to identify low-cost materials that can withstand these high-temperature environments between 600°F and 1,200°F in flight. And while not in use, they must also endure weather-related exposure over long periods of time.

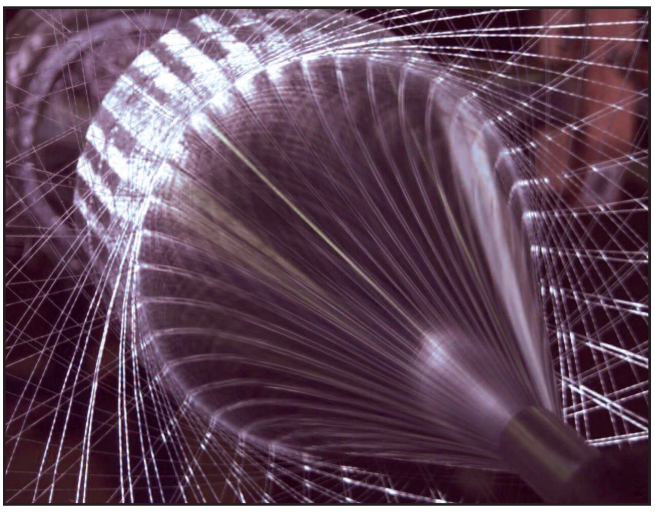
In addition, a radome must have inherent electronics capabilities. It must have a low thermal conductivity/low dielectric while also being electrically translucent, or stable, at elevated temperatures. Weight and strength are also major concerns.

While still in testing, Mentis' radomes show promise over other solutions. The general solution in the defense community has been to use ceramic materials, which can withstand high temperatures and which can be fabricated using materials that have electronically beneficial properties. But high-value-added ceramic processes translate to waste, time, and ultimately cost. They are typically capital-intensive and time-consuming to fabricate—and require secondary machining to be brought to final form. Challenges in output rate are significant, and the molds cannot be easily tailored based on changing needs. The other alternatives, composite materials, are faster and less expensive to fabricate but typically cannot withstand environments above 600°F. They also require secondary machining.

Mentis has developed a low-cost composite-materials process that combines braiding and weaving to fabricate net-shape parts that can withstand high temperatures of 1,200°C. Significantly less capital-intensive, it also addresses other manufacturing concerns presented by the alternatives, and Mentis is able to make as many as two parts per day, with minimal waste. The final material made using the process is lightweight, electrically and thermally stable, and aerodynamic. Moreover, it has a low dielectric and is able to withstand necessary G-loads and elevations.

The company uses commercial off-the-shelf woven goods developed in conjunction with JPS Glass Fabrics, which makes the quartz fiber in specified configurations. "We make a net-shaped pre-form. It is formed on a tool and pressed in a mold to cure," Dignam said. "There's no secondary machining

continued on page 10



▲ Quartz fibers are braided onto a mold in a semi-automated process to make one of Mentis' radomes.

# A Good Prognosis

System provides instant info on a vehicle's readiness and lifespan.

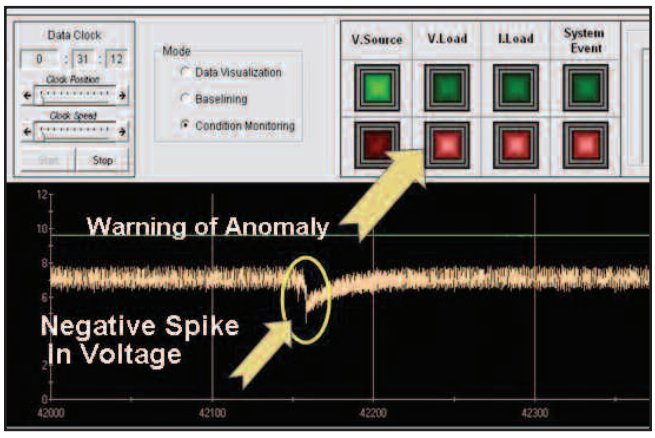
by L. Scott Tillett/stillett@nttc.edu

An MDA-funded company is developing a system that can collect data from sensors and instruments on a car, aircraft, or other vehicle and then provide the operator with a simple message about the readiness of the vehicle—describing its overall condition and its expected short-term operating capability.

The company, Management Sciences, Inc. (Albuquerque, NM), refers to its system as a "collaborative environment for data-driven condition-based maintenance." "It's the here and now of 'Are we ready to go?'" said Kenneth Blemel, vice president of the company.

The system actually consists of several technologies: a power-PC-based operating system, known as the D3 Information Recorder, that collects and records data in real time; a lightweight wiring system and 20-micron optical fiber sensors for gathering information; a postage-stamp-size electronics module known as the Sentient Guardian, which manages sensors and data collection; and a probabilistic-inference calculus that serves as the mathematical brain for making sense of all the data and delivers messages to a vehicle's operator. Blemel said the company has several patents pending for its technology.

MDA originally funded Management Sciences with an SBIR Phase II contract to work on the condition-based-maintenance system. Such a system has shown potential for use in missile defense programs such as the Airborne Laser, an aircraft that includes a very-high-power laser that could be used to destroy missiles.




▲ A user interface for Management Sciences' condition-monitoring system shows a "red light" indicator warning of an anomaly in equipment operation.

The integrated system that Management Sciences is developing could be applied to many types of vehicles and machinery, automatically collecting data on vibration, temperature, stress, strain, fluid levels, power levels, and other conditions—and then analyzing the data to deliver a final "readiness message" to the operator. In producing that final message, the system also could incorporate data that has been provided directly by the operator—not just from sensors.

The approach is one in which diagnostic information leads to a prognosis, according to Blemel, who explained that the Management Sciences system can deal with a vehicle the same way a doctor deals with a patient—but taking it one step further. Blemel said the system puts a diagnosis into context. It will not only supply information that confirms a vehicle (a "patient") is healthy; it also will indicate how much life the vehicle has left.

For example, the system might determine that tire pressure or fluid levels are slowly decreasing, but it might determine that the projected levels are sufficient for three days of regular use before maintenance is required. "I know each time when I go to get my annual physical, my doctor will say, 'You are doing great for somebody your age," said Blemel, comparing the system's capabilities with a health check. "But it is nice to know what that means for the next 10 years? And so this prognostic area was the next step forward."

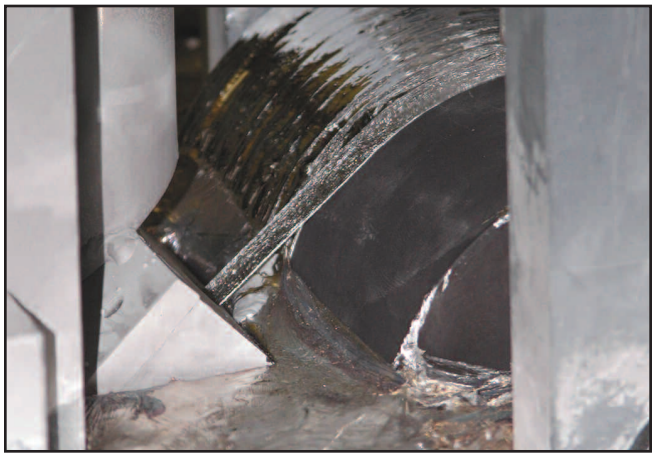
To produce prognostics for machinery, Management Science's calculus involves something known as a stochastic model, which takes into consideration random elements to produce a more real-world result. "It's a time-sequenced model, and so as you work forward, you learn how long things last—the same way you learn how many miles per gallon you get in your car," Blemel said. "And in doing that, you cast forward—very much the way you think when you say, 'I have enough gas to make it to Richmond.'"

Blemel said two key features set the company's system apart from other prognostic methods that involve sensors. First, the prognosis is delivered in real time. Blemel said the system can deliver a real-time prognostic result—such as indicating that a military tank is ready for a training mission but not for full-fledged field mission—because its calculus involves techniques to quickly approximate results. Other methods might seek an "absolute" answer, which would require lengthier analysis of data.

The second discriminator is weight. Blemel said Management Sciences has produced a product called "Smart Wiring," which weighs 40 percent less than conventional wiring used for such applications. "With that, we are able to put sensors on and not

continued on page 10

On the Lighter Side from page 1



▲ Touchstone's filament-winding process is used to manufacture a metal-matrix-composite cylinder.

missile motor cases. Structures that are produced with the fiber-reinforced material have several advantages over structures produced with conventional materials. The material, which the company calls MetPreg™, has the strength and stiffness of steel with the weight of aluminum. The material will maintain its strength up to 1,000°F, compared with 300°F for aluminum and 350°F for polymer-matrix composites. And the material will not outgas, unlike a polymer composite material, which does so when in a vacuum. This is a significant advantage for space-based applications since a material that outgases may cause problems if released particles interfere with sensitive optics.

For pressure vessels, the material provides a 38-percent weight improvement over steel, aluminum, and polymer-matrix composites while maintaining comparable strength. The weight and strength benefits should offer increased range and velocity for items such as rocket-motor casings. And, in some cases, fittings can be incorporated more easily than in metal tanks, which can require additional machining to attach various components.

The vessels made with Touchstone's technology could play a role in a future "hydrogen economy," in which hydrogen fuel will be stored on vehicles and in distribution centers. Strong, light, linerless pressure vessels also could find commercial use in air tanks used by first responders or in tanks to hold medical gases.

Apart from in-flight advantages, metal-matrix-composite rocket-motor cases also may have advantages in the "insensitive-munitions" arena. The objective of insensitive-munitions requirements is to prevent rocket motors from inadvertently becoming bombs due to accidental or deliberate impact during transport or storage. In addition to the makeup of the rocket fuel, the performance of the casing material under impact has a significant effect on whether the fuel will ignite, burn uncontrollably, or explode violently. Touchstone currently is conducting further testing in this area to determine how metal-matrix-composite materials made with its process can be a benefit.

Another application for Touchstone's prepreg tape is "selective reinforcement." The tape can be used to give additional strength to aluminum or steel structures. And although it might not be cost-effective to make a whole structure using the metal-matrix composite, high-stress locations can be reinforced with the material.

As Touchstone moves forward, the company is working to scale-up the size of cylinders made with the metal-matrix composite. Company officials are on the verge of having a scaled-up cylinder prototype. From there, further testing will be necessary. Touchstone is hoping to attract additional funding sources to help support more R&D efforts.

**CONTACT INFO**

Brian Gordon
Touchstone Research Laboratory
Tel: (304) 547-5800
E-mail: blg@trl.com
Web: www.trl.com

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A New Recipe for Batteries from page 5

in moderate- to low-current-drain applications. The prototype PSI cells performed 30-percent better and, with improvements in manufacturing, could achieve 50-percent better capacity than state-of-the-art lithium ion batteries. "So in applications that don't involve high discharge rates—for something like running electronics, such as a laptop computer—this battery would be spectacular," White said.

Although the work has advanced from Phase I through Phase II SBIR funding from MDA, several steps remain before the technology can be commercialized. The battery must be built and tested in realistic conditions and applications, and White is seeking additional funding from government and potentially other sources to pass that milestone. PSI has arranged for a small advanced lithium-ion-battery manufacturer to conduct a trial production run, using $V_2O_5$ in the same processing equipment now used to produce batteries containing lithium cobalt dioxide.

**CONTACT INFO**

Dr. Kevin White
Physical Sciences, Inc.
Tel: (978) 689-0003
E-mail: kwhite@psicorp.com
Web: www.psicorp.com

Shake, Rattle, and Roll from page 6

The company offers two product lines: "High-Performance" (for space and other demanding applications) and "Cost-Effective" (for applications in which cost is more critical than low mass). As of late 2006, LHDC had delivered more than 80 of these systems. These products may be configured for the application from a large catalog of FSM and other motion-control components. In addition to complete systems, LHDC also offers as standalone products a line of linear actuators and two-to-six-axis motion-control components.

LHDC continues to refine its motion-control systems, with innovations in areas such as magnet configuration, to improve the efficiency of motors and actuators. With a mature and proven product line, the company is pursuing new applications and markets.

**CONTACT INFO**

Larry Germann
Left Hand Design Corporation
Tel: (303) 652-2786
E-mail: lgermann@lefthand.com
Web: www.lefthand.com

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Defending Against the Elements from page 7

or surface roughness. This translates to minimal waste as compared to different processes."

Mentis has also been challenged to determine the right formulation of resin in the fiber. "We looked at many different fiber finishes and surface chemistries to get the resins to bond to the fiber, with low void content and high mechanical strength." Mentis sought low-cost, nonablative, inorganic compounds that could perform at elevated temperatures with high shear strength between the fiber and the matrix. "Finding the right formulation took us 30 months," he said.

The biggest challenge, however, has been material loss from rain erosion. Under 1-inch-per-hour rainstorms, a typical composite will lose upward of 65 mils of thickness (i.e., 65 one-thousands of an inch) due to rain erosion. The most recent tests, conducted in October 2006, showed improvement and significantly reduced the material loss during the event.

PAC-3 is not the only system that could benefit from such a system. Mentis also has ongoing work with Raytheon Missile System Company for standard missile applications and MDA's Kinetic Energy Interceptor. Additionally, the company is looking into alternate applications that would benefit from this high-temperature, nonablative material solution. So although the technology does not have significant commercial applications in the traditional sense, it offers a wide range of cost-saving opportunities for DOD since it is scalable to different architectures and applications. Mentis, however, remains interested in dialog with other potential customers who are interested in its materials process.

**CONTACT INFO**

John Dignam
Mentis Sciences, Inc.
Tel: (603) 624-9197
E-mail: dignam@mentissciences.com
Web: www.mentissciences.com

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A Good Prognosis from page 8

increase weight of the vehicle with which we are working," he said. "Being lighter gives you the ability to take a few hundred pounds off the vehicle and then put back a little bit of that with some sensors that are attached to this wiring." The company has worked with partners to produce lighter-gauge wiring designed more for electrical service than for structural strength. For example, the wiring eliminates some of the weight from heavy steel overbraid by using shielding only where necessary.

Management Sciences offers its technology as commercially available products today, but the company continues to refine its offerings. Lately, the company has been working with the U.S. Army TACOM Life Cycle Management Command, whose work involves maintenance policies for Army vehicles. The Management Sciences' technology is part of a demonstration project in support of the Army's goal to ensure that all vehicles assigned to soldiers will operate properly for a specified period of time.

Ultimately, Management Sciences might license its technology to other companies that can service what is potentially a huge market—covering condition and maintenance diagnostics/prognostics on vehicles ranging from cars to tanks to yachts to airplanes. Blemel said Management Sciences might also develop its own call centers or response centers to assist with monitoring vehicles that use the technology—similar to General Motors' OnStar program.

Management Sciences continues to look for mid-tier capital—around $10 million. Blemel said the money could go toward helping brand the technology, setting up call centers, and outsourcing to manufacturers to make components.

**CONTACT INFO**

Kenneth Blemel
Management Sciences, Inc.
Tel: (505) 255-8611
E-mail: kenneth_blemel@mgtsciences.com
Web: www.mgtsciences.com

# On Closing Windows

Knowing when to refocus is a critical business skill.

by Paul Carroll/pcarroll@nttc.edu

I recently learned a lesson about the closing of windows, and I don't mean the software from Bill Gates and his people that sends you off with a pleasant descending arpeggio. Rather, this lesson concerned the closing of a window of opportunity, or maybe more correctly, a window of profitability.

I used to work for the U.S. division of a German company that designed and produced DC motor systems, primarily for the home-healthcare industry. The business was newly formed and growing rapidly, and the operation was lucky to have found an entire market niche that had been slumbering for decades and was poised to grow rapidly with the increase in age of the baby boomers.

The motor systems built by the company were clearly technologically superior, were more aesthetically pleasing, ran more quietly, and only cost about 20 percent more to produce than the slumbering competition's systems. Because the market was very cost-conscious, manufacturing the motor systems in Europe and shipping finished assemblies into the United States was not a feasible solution due to the high cost of labor in the European Union and unfavorable import duties. So the company set up a plant here in the United States to assemble the systems and started to source the components from all over the world.

To control costs, the U.S.-based division contracted with companies in China and the Far East to make the circuit boards and wiring harnesses; in Hungary for transformers and DC motors; in the Czech Republic for ball bearings; and in the United States for molded plastic parts, threaded rods, and fasteners. The division set up three assembly lines and learned a lot of painful lessons about what it really takes to run them, and run them well.

**"You always want to have the next product or service in the wings, ready to pull out to carry your company forward."**

## Up and Down

After getting its first few contracts in hand, the division took the market by storm, quickly capturing more than 50 percent of one market segment, 30 percent of another—and then the outfit was well on its way to selling more than a quarter-million motor systems a year.

The business grew to more than $3 million in sales inside of two years, and it looked likely that it would achieve more than $5 million in its third year. The company grew and moved into still larger facilities. Things seemed great when I left to pursue my MBA.

A few years later, the assembly lines had all disappeared, and the U.S. division had been reduced to a warehousing and shipping facility, selling fewer motor systems than it had during its second year of operations. The division had let go of most of its staff, and the lead salesman had recently departed for another opportunity. The president of the division told me that the German parent company had decided to centralize all of its manufacturing in Hungary, so it shut down the U.S. lines.

Given the cost-sensitive U.S. market and the high import duties, the action of the parent company doesn't seem to make much sense, until you poke around on the Internet a bit. There you discover that you can now cheaply buy identical, and nearly identical, motor systems from Taiwan and China. These systems are such complete knock-offs of the original system that two suppliers have faithfully reproduced the marks in a molded part that the German company used to ID production lots.

## Success and Competition

One could blithely chalk this case up to the perils of cheap foreign competition, but there are further subtleties to be learned from the fate of this German company. In many ways the company was a victim of its own success and lack of foresight. It had kept a close eye on its established competitors, and knew what "the other side" was planning. Yet the company had been producing systems in a large enough volume and at a sufficient profit to attract competitors to set up against it, and had failed to anticipate the inevitability of these new, outside players entering the market. More specifically, the company overlooked the reason why almost no large-volume, basic manufacturing is done in the United States: Asian manufacturers can simply make many parts for less than what it costs other companies to make them in the United States. But cheap foreign competition aside, the company had neglected to plan for the reduction in profit margin that direct competition would bring to the market segment.

Now, conventional business wisdom would dictate that the German company should have avoided entering the

continued on page 12

On Closing Windows from page 11

market in the first place, as it was one that didn't have sufficiently high barriers to entry to prevent such competition from stealing market share. Rather, I believe that the company was completely correct in entering the market, since it had a product that the market clearly wanted and since it could make a nice profit and return on its investment. What the company failed to understand was that the market had a window of time in which the company would be able to operate profitably. The company failed to have a suitable exit strategy—or a second product or market to focus on when the competition (which should have been anticipated) starting taking away business and reducing profit margins.

In my current incarnation as a technology/business expert for the MDA Technology Applications program (the agency's tech transfer program), I see this blindspot again and again. Companies frequently understand that there is a window of opportunity for entering a market, and they plan for the market entry and the rise in manufacturing and production. But they fail to account for how their competition will react, and for the inevitable reduction in unit profit that competition will create.

### Key Questions

How to avoid this trap is the question, and there are several questions you should ask yourself to determine the answer:

- How quickly will your existing competitors react to your new market entry? If existing competitors can "retool" to make a very similar product quickly and easily, then this may be a market to avoid.
- What are the barriers to entry in your market that will prevent other new entrants from joining the fray? If you are making something that is relatively easy to reverse-engineer and you are selling to a large enough market, then you will attract competitors.
- Are you a one-trick pony? You always want to have the next product or service in the wings, ready to pull out to carry your company forward, leaving the old, now unprofitable market to your competitors.

Leaving a market behind or abandoning a product that you have spent long years developing is a wrenching and difficult thing to do. Yet knowing when to walk away (and knowing that, in almost every case, you will *have* to walk away) from a given product or market is as important as knowing when to get into the market in the first place. You don't want to wake up one morning and discover that the window of opportunity, and profitability, has painfully closed on your company.

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