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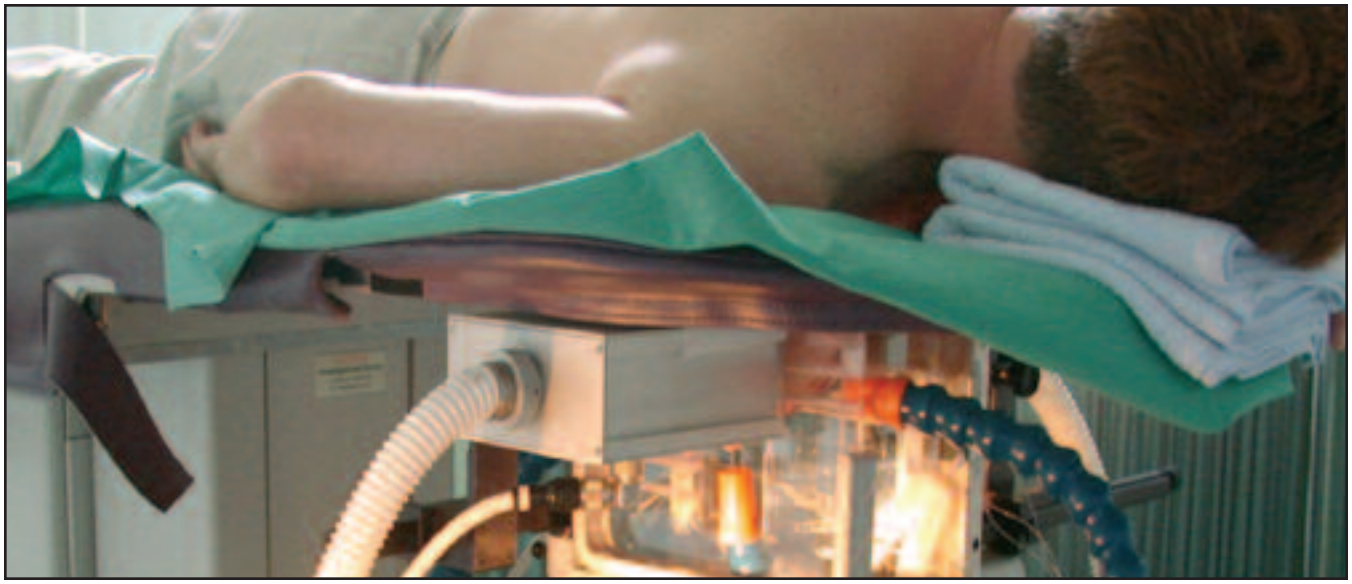
Missile Defense Agency

TechUpdate

A Quarterly Newsletter for MDA Technology Transfer



▲ A man demonstrates Celsion's cancer-treatment technology, based on adaptive phased-array techniques. Treatment involves directing heat at deep-seated tumors and "hot spots" in surrounding healthy tissue.

INSIDE

Phasing Out Breast Cancer

Emerging microwave technology targets tumors deep within the body.

by Joan Zimmermann/jzimmermann@nttc.edu

A radar anti-jamming technique once directed toward missile detection is now poised to shoot down cancer cells.

By simultaneously nullifying and amplifying electromagnetic waves, phased-array techniques improve many types of radar and communications systems. With a focused heating regimen based on an adaptive phased array (APA) technique, the founder of Celsion Corporation (Columbia, MD) has established Celsion Canada, Ltd., which is now testing a targeted microwave therapy in the fight against breast cancer.

While improvements in technology and awareness have reduced average tumor size at diagnosis, breast cancer remains the third leading cause of death in women in the United States. New classes of drugs and biotherapeutic agents have brought the five-year survival rate to 85 percent, but problems remain with specifically targeting tumors. Mastectomies still must be performed in about half of all U.S. breast cancer diagnoses (the rate was 56 percent in 2004), leaving women with physical and emotional scars, and side effects such as swelling and pain that may persist for years.

In addition to accepted standards, other approaches to tumor destruction have been studied, including focused ultrasound, cryoablation (freezing), and laser photocoagulation. Heat applied in the form of radio waves and microwaves has also

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Shining On

by L. Scott Tillett/stillett@nttc.edu

Editor's Note: After working for more than 12 years with the MDA Technology Applications program—six of these as editor—Patrick Hartary has accepted a job elsewhere. We wish him well in his new adventure.

There's a saying about clichés. It goes something like this: A cliché is just something that was well-said in the first place. So even though clichés often induce groans, they also in many cases evince truth.

As I take over the job executed so well by Pat Hartary over the past six years, a couple of cliché proverbs and sayings come to mind. One of those proverbs is: "Don't hide your light under a bushel." This advice is roughly the same as guidance on tooting your own horn, and it's advice that inventors often fail to heed. Though they might achieve technical success in the laboratory, they might be less successful at getting the word out about their success.

That problem probably reminds you of another cliché proverb: "If a tree falls in the forest and no one is around to hear it, does it make a sound?" Frankly, we at the MDA Technology Applications program are not concerned with the answer to that question. We know darn well that the tree makes a sound, and our job is to make sure that plenty of others hear it, too.

The *MDA TechUpdate* is the vehicle we use to do that job. The newsletter draws readers who will hear that tree make a sound when it falls in the forest. The publication makes its way into the hands of 9,000 readers, and articles that appear in the publication also are made available on www.mdatechnology.net, ready to be read by millions more.

MDA TechUpdate in effect helps MDA-funded inventors remove the bushels from their lights—so that they might brighten the paths of many others. Put another way, *MDA TechUpdate* holds a microphone to the horn being tooted by the inventor and broadcasts the sound to the world. Through *MDA TechUpdate*, the tooting is being heard by the investment community, government agencies, other technology researchers, systems integrators, and the media. And folks are listening: Solid commercial connections between companies are being established because someone read about a technology in *MDA TechUpdate* and took action to find out more.

The *MDA TechUpdate* serves as a bridge—yes, that's another cliché—that connects inventors with users who have technical challenges or business problems to address. Keeping that bridge strong requires two things: It requires MDA-funded researchers—and there are hundreds of them out there—to let us know that they want free help tooting their horns. And it requires the continued interest of curious readers. If you are an MDA-funded researcher, drop us a line and let us know what's going on with your MDA-funded technology. (Your innovation might very well end up being featured in *TechUpdate*.) And if you are a reader, tell your friends and colleagues about *MDA TechUpdate*. It's one of the greatest free sources of news on emerging technology that you'll find anywhere. That might sound cliché, but it's true.

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Business Valuations: More Realistic?

by Patrick Hartary

One of the key forces shaping the 1990s was the popularization of personal computers and the Internet, leading to the dot-com boom. Investments in high technology began to soar, and companies involved in fiber optics, photonics, and computer-related products were merging together or being acquired for millions, even billions, of dollars. In the Winter 2001/2002 issue (page 15), the article "Does It Count?" highlighted 18 cases where BMDO-funded companies had transitioned to this new level. The average estimated valuation of these transactions was about $2 billion. Since the article was published, 23 more MDA-funded companies have been acquired, although for a lot less money. The table below provides key data on these purchases, whose average estimated value (not including the seven undisclosed transactions) is roughly $63 million.

Purchased Company	Purchaser	Year of Transaction	Estimated Value of Transaction	MDA SBIR/STTR Contracts
Vixel Corporation	Emulex	2003	$310 million	7
Foster-Miller	QinetiQ	2004	$167.2 million	27
Genus	Aixitron AG	2004	$143 million	5
ALPHATECH	BAE Systems	2004	$88.4 million	12
Sensors Unlimited	BF Goodrich	2005	$60 million	6
SY Technology	L-3 Communications	2001	$48 million	8
Planning Systems	Foster-Miller	2005	$42 million	4
Sterling Semiconductor	Uniroyal Technology Corporation	2002	$40 million	8
Brashear LP	L-3 Communications	2004	$36 million	4
On-Line Technologies	MKS Instruments	2001	$22 million	14
Clarity[1]	CSR	2005	$17.1 million	N/A
Scientific Materials	Flir Systems	2006	$13 million	8
Genex Technologies	Markland Technologies	2005	$10 million	9
Sagebrush Technology[2]	NextPath	1999	$2.6 million	N/A
Celsion Limited[2]	Augustine Cheung	2005	$1.8 million	N/A
Summit Imaging	Photon Dynamics	2003	$1.5 million	2
Mississippi Polymer Technologies[3]	Solvay	2006	Undisclosed	N/A
Morgan Research	Stanley Associates	2006	Undisclosed	3
Bandgap Technologies	Intrinsic Semiconductor	2004	Undisclosed	11
CTI Lidar	Lockheed	2005	Undisclosed	21
Q-Peak	Physical Sciences	2002	Undisclosed	3
PowerStor[4]	Cooper Bussman	2001	Undisclosed	N/A
Advanced Ceramics Manufacturing	MP Technologies	2005	Undisclosed	6
Photon Research Associates, Inc.	Raytheon Company	2004	Undisclosed	17

[1]Clarity was spun off of IC Tech, which had 7 MDA SBIR contracts.
[2]Sagebrush Technology and Celsion have successfully commercialized non-SBIR-related research funded by the Strategic Defense Initiative Organization, one of MDA's predecessors.
[3]Mississippi Polymer Technologies was spun off of Maxdem, which had 11 MDA SBIR contracts.
[4]PowerStor was a subsidiary of PolyStor, which had 2 MDA SBIR contracts.

KaZaK Technology Pulls in Customers

'Hands-off' pultrusion process promises simplicity and savings.

by Joan Zimmermann/jzimmermann@nttc.edu

A simple low-tech pultrusion technique is now being adapted to lend its simplicity, efficiency, and cost savings to production of complex composite structures for high-performance military and commercial hardware.

With its automated composite-shaping technique, KaZaK Composites, Inc. (Woburn, MA), is able to manufacture net-shape structures to the specifications of the user—whether it is a cylindrical utility pole or flat panels for military shelters and containers. The pultrusion process is completely hands-off; it starts with dry spools of fiber and/or fabric reinforcement, adds wet resin, then moves the material through a heated tool. The result is a continuously produced stream of low-cost, constant cross-section composite hardware that can be cut automatically to length at the end of the processing line. Pultruded composites, which can be reinforced with many fibers such as Kevlar®, fiberglass, or carbon, can be less expensive and lighter than metal but just as strong, making them suitable for applications ranging from small stanchions on Navy ships, to enormous shipping containers and even the structure of ocean-going vessels.

▲ Among KaZaK's potential customers is the utility-pole industry. New collapsible designs may help reduce injuries in vehicle-pole collisions.

KaZaK developed and advanced its highly refined, versatile pultrusion technique with MDA Phase I and II SBIRs investigating strong, cost-effective carbon/epoxy missile canisters for the PAC-3 program, specifically to make very straight, large cross-section (up to 20 feet long) boxes. KaZaK has also built larger "superscale" pultrusion machines, including the world's widest pultrusion equipment, optimized for making composite sandwich panels greater than 10 feet wide and of unlimited length, used for military shelters, ship superstructures, and shipping containers.

The company has worked with the Army to develop a pultrusion-optimized modular shelter system that ships a rapidly deployable 19 × 90-foot building in a 20 × 8 × 8-foot standard ISO container. The KaZaK shelter is capable of cost-effectively competing with tents for troop housing and buildings for field operations. There is also growing interest in such structures as temporary habitats for nonmilitary purposes.

KaZaK also has an answer to the humble wooden utility pole. The rigidity of the wooden pole that makes it so valuable for its purpose also means that fatal automobile impacts are not uncommon. KaZaK has demonstrated a pultruded composite utility pole with unique energy-absorbing features, as well as a way to reduce replacement time and cost for poles downed by impact, weather, or age. The designed-in collapse mechanism promises to be superior to the current wooden breakaway designs. Because of the composite pole's unique arrangement of fiber reinforcement, it can absorb some of the automobile's energy as it bends in a controlled collapse, thus transferring less energy (better known as trauma) to the driver and passengers. Fewer fatalities and injuries should result when widely implemented by utilities.

In addition, KaZaK's composite utility pole is designed to break cleanly away from the overhead wires that it carries, reducing the damage to the lines and allowing repair work to be achieved more quickly. KaZaK also offers a butt-pole replacement system, which leaves the upper wooden half of the utility pole intact and allows the damaged lower portion to be replaced with the composite base. At four million pole replacements per year, KaZaK's partial replacement base can offer a savings of $5,000 per unit, a number that adds up quickly. The installment of the base can also be performed without disruption to service. Another interesting application is a self-recovering post, initially developed to replace steel for use around aircraft carrier elevators, but now being marketed as a maintenance-free post for the thousands of roadside signs that are replaced each year. These posts can be bent flat by an impact and can then be restored to vertical after the load is removed.

KaZaK is interested in pursuing nonmilitary applications for its pultrusion technology and is actively seeking licensing, partnership, and teaming opportunities.

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Compact Chip Takes Flight

Unique chip architecture provides high-speed image processing for Earth and sky.

by Joan Zimmermann/jzimmermann@nttc.edu

To distinguish friend from foe in short order, or make sense of any visual scene, nothing beats a keen set of eyes and a quick-thinking brain. In fact, no machine can beat a human at this task—at least not yet. Computational Sensors Corporation (CSC; Santa Barbara, CA), however, has built a better silicon eye with a series of MDA SBIR contracts for the development of a chip with a new architecture specifically for high-speed image processing.

With the help of some MDA Phase I and II SBIRs and similar contracts with DARPA, CSC developed novel architectures and interconnects for massively parallel computing in a compact integrated circuit. Conventional image processors typically yield data output in the megahertz range, rapidly creating a backlog of information to be sorted and analyzed. To address this backlog and to prepare for high-speed operations, both of which are needed for missile threat discrimination, CSC stacked integrated circuits beneath a two-dimensional detector array. This very-large-scale integration approach enables the chip to perform the image processing onboard the circuitry, and to avoid the customary bottleneck at the tail end of the processing stream. The result is a fast, low-power imaging device that boasts a small footprint and a light weight. CSC's superior 3-D stacked sensors offer lightweight, highly sensitive image-processing ability with high resolution and very high frame rates.

CSC's small chip is ideal for applications that require high performance in small spaces, and its featherweight characteristics are attractive to aircraft manufacturers who hate weight. On the military side, the company is now working to outfit micro-unmanned aerial vehicles (micro-UAVs) with a thermal eye.

The weight savings also make the chips suitable for other applications, including more conventional UAVs, multiple kill vehicles, mobile military units, and medical imaging. For commercial aircraft, CSC sensors have applicability in threat discrimination. One outstanding risk to commercial airliners is the threat of a surface-to-air missile attack, an issue that arose in the years following September 11. To combat such a threat, small imaging sensors, placed on the fuselage of a jet and coupled with relevant software, could give warning of an incoming object in time for a pilot to take evasive action.

A more earthbound application is in border security, where infrared cameras are already used to detect movements in the vast and scrubby areas that constitute much of the U.S. border with Mexico. CSC's image-processing chip, when outfitted with infrared capabilities, could offer better performance to the Border Patrol.

On the medical side, CSC is currently testing its technology in collaboration with researchers at Lawrence Berkeley National Laboratory and the University of California, San Francisco, Medical School for iterative reconstruction of CAT scan and MRI images. Particularly relevant for CAT scans, faster digital image processing can lower the total radiation dosage for patients. In addition, curtailing the dwell time in MRI machines can reduce the anxiety that some people experience while inside the noisy and closely confining units.

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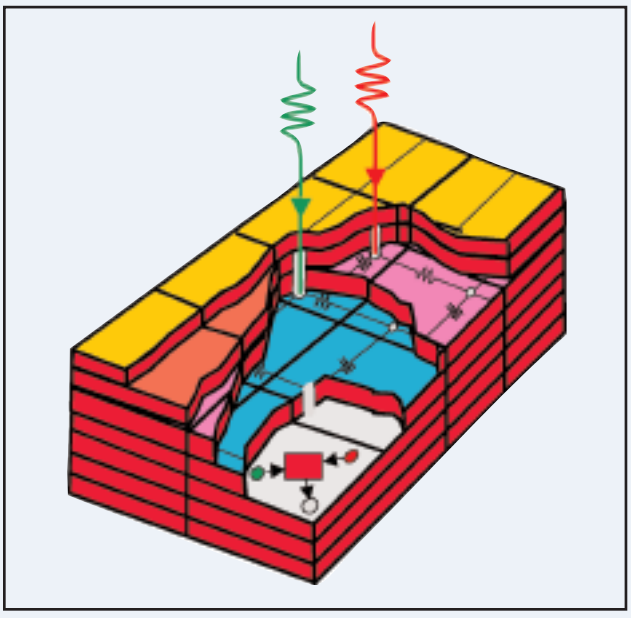


▲ Computational Sensors' compact lightweight chip.

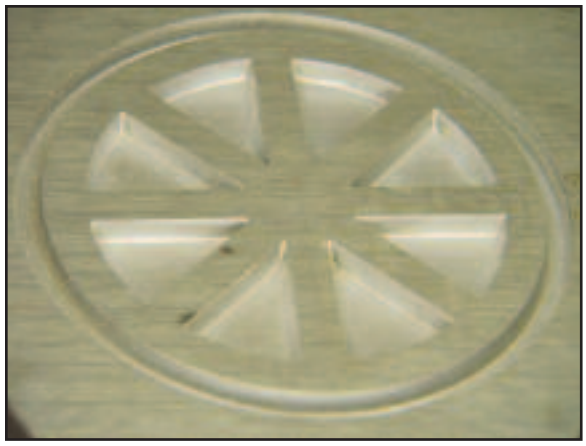
Making the Cut

Lasers are being used to machine one of the toughest compounds known into mirrors.

by Michael Felton

Silicon carbide (SiC) is tough. It keeps drill bits from dulling, withstands the high heat of power circuitry, and forms beautiful, super-hard gemstones. MDA wants to use SiC to make mirrors because the material expands and contracts very little during temperature changes. But toughness is a double-edged sword in this case, making SiC hard to machine.

Mound Laser & Photonics Center, Inc. (MLPC; Miamisburg, OH), is attempting to form a mirror out of SiC. Instead of using typical polishing equipment, the company is using a laser. But no ordinary laser will do.



▲ This image shows silicon carbide that has been laser-micromachined. MLPC can micromachine surfaces as large as 12 inches by 12 inches while producing features as small as a few microns in diameter.

MLPC is one of the few laser micromachining shops in the country that uses a picosecond laser. This type of laser fires extremely short pulses—approximately 10 picoseconds—thousands of times per second. The precise control of the laser allows it to be used like a drill—with a drill bit as small as 5 microns in diameter that does not dull and does not break. Using this laser tool, MLPC has created a system to micromachine surfaces as large as 12 inches by 12 inches, producing features as small as a few microns.

For MDA, MLPC will use the laser to cut into the surface, removing material until the mirror is curved correctly. "The idea is to take a mirror blank, stick it under the laser, measure it, determine where the high spots are, where it needs to be machined and then machine it into final figure," said Dr. Larry Dosser, president and CEO of MLPC. To reduce cost and time, the process will run iteratively with no operator intervention.

Having completed a Phase I SBIR, MLPC is now in the midst of a Phase II to determine how long it will take to surface a mirror. "We are measuring material removal rates right now under various types of laser conditions and utilizing the unique qualities of this picosecond laser," Dosser said. In June, MLPC upgraded from a 2-watt picosecond laser to an 8-watt version, possibly enabling faster machining.

While there are few nongovernment customers for SiC mirrors, MLPC generates half its revenue from commercial sources and is eager to apply lessons learned from micromachining for MDA to its other customers. "Right during the Phase I program we were already talking to commercial customers that we feel can utilize the technology," Dosser said. "We find that this is a very good way to introduce technology into the marketplace."

MLPC's commercial micromachining customers are primarily medical device manufacturers that need very small modifications to important parts for medical devices. In addition, many companies turn to MLPC for creating prototypes because laser machining can operate directly from CAD drawings. For example, in work for a government lab, MLPC created a fully functional extremely small spring out of a sheet of aluminum.

With its 17 full- and part-time employees, MLPC makes most of its commercial revenue from laser marking and welding, but sees a growing role of laser micromachining in the near future. The company plans to continue to innovate for cutting-edge projects, like making mirrors for MDA, as well as to educate current and potential customers about the new capabilities in laser micromachining, to solve tomorrow's machining problems.

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Good Vibrations

Device 'harvests' a structure's natural energy to power sensors.

by L. Scott Tillett/stillett@nttc.edu

If it vibrates, it creates energy. So why not harvest that energy and use it to power sensors or other devices on whatever it is that's vibrating? One MDA-funded company, Midé Technology Corporation (Medford, MA), is doing just that. And the company's solution is smaller than a cassette tape.

Midé has developed an "energy-harvesting" device that can be used to power other devices such as low-power sensors. The energy harvester, known by the product name "Volture," can be attached to any structure that vibrates—be it a bridge, a moving car, or industrial machinery—and then converts the mechanical energy radiated by that structure to usable DC electrical energy. The key to the Volture's power-conversion abilities is Midé's proprietary packaged piezoelectric actuators. (Piezoelectric materials, or piezos, are materials that generate a voltage when a mechanical force is applied.) Through a proprietary process, the piezos are packaged in polyimides and epoxies, making them more robust and less brittle than raw, cantilevered piezos.

MDA originally funded Midé through an SBIR Phase II award to develop distributed power systems using energy harvesting. Such systems could be used throughout the Ballistic Missile Defense System to power remote sensors and other devices, as well as to charge batteries. Midé's MDA project also was co-funded by Halliburton Energy Services, which has tested Midé's energy harvesters.

Midé continues to run fatigue tests on its Volture, which company officials claim is the first product of its kind to reach the market. The company has been fatigue-testing the device at 10 G's, at a vibration of 120 hertz, for more than several million cycles. At that frequency, the Volture can produce close to 25 milliwatts of power—enough to run many types of sensors and other low-power devices. By comparison, a raw piezo in the same situation—even if protected by a medium such as spring steel—would probably fail at "significant vibrations," according to Midé project manager Chris Ludlow.

Midé's device also should be able to withstand corrosive environments, since it is packaged and sealed. In addition to the packaged piezo, the Volture includes a rectifier bridge, capacitors, and other electronics. The device measures about 3.5 inches by 1.5 inches by 0.25 inches.

Developers at Midé believe the product will be well-suited for applications that include an engine or some source of known, measurable vibration—so the Volture can be pre-tuned to harvest energy from a particular frequency. The company continues to work on developing a Volture that can harvest from a wide range of frequencies or that can dynamically tune itself. For now, the product works best if preset to harvest from a specific frequency of vibration.

Midé officials expect military users and users of wireless-sensor networks to be primary markets; the company's device could be used to power sensors on aerospace equipment, automobiles, and industrial machinery. And as industry develops more sensors and products that run on low power, the Volture could find plenty of additional applications.

In addition to the MDA SBIR work, Midé also is working on an SBIR Phase II with the Department of Transportation to investigate use of energy harvesters to power sensors that monitor train brakes. Ludlow said the Volture would be especially appropriate for such "set and forget" applications—in which it might be cumbersome or not cost-effective to electrically wire sensors or power them with batteries, which would have to be periodically replaced.

Company researchers would like to characterize frequencies and energy output for an array of different machinery—allowing Volture devices to be pre-tuned easily for particular applications. For example, Midé researchers know that the Volture, when attached to a standard microwave oven, experiences a vibration of 0.3 G's at 120 hertz and can produce about 10 microwatts—enough power for some types of sensors.

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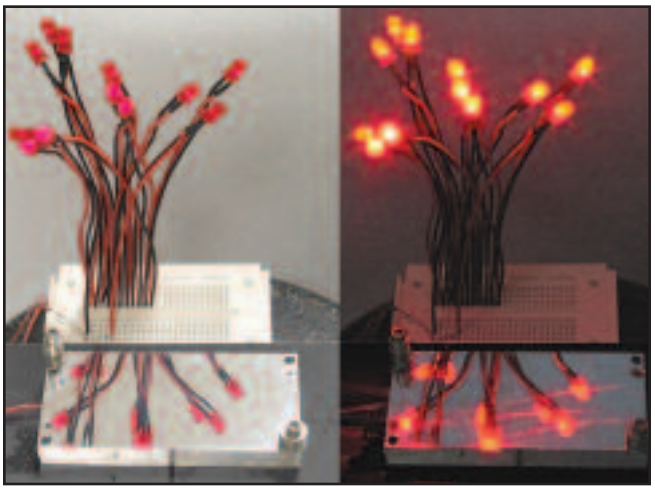

▲ Midé's Volture product can "harvest" vibrational energy to power devices such as light-emitting diodes. For this photo, the energy was generated by a shaker mechanism in the lab. The Volture requires no batteries or external power source.

Waste Not, Want Not

Regenerative fuel cell recycles water to produce hydrogen and oxygen.

by L. Scott Tillett/stillett@nttc.edu

Getting oxygen for use in a fuel cell is usually easy. You just pull it out of the air. But if the fuel cell is operating in the vacuum of space or at a high altitude, the oxygen has to come from somewhere else. And one MDA-funded company knows just the place to get it.

MDA-funded Giner Electrochemical Systems, LLC (Newton, MA), is developing a regenerative fuel-cell system that will replenish the oxygen in a fuel cell by capturing product water from the fuel cell and processing the water to transform it back into hydrogen and oxygen.

The process by which the water is broken down into hydrogen and oxygen is known as electrolysis, and Giner's project is requiring the company to develop a special solar-powered electrolyzer appropriate for high-altitude or even space-based applications.

MDA originally funded Giner through a Phase II SBIR award to develop an advanced regenerative fuel-cell system for possible use in the High Altitude Airship (HAA) program. The HAA project seeks to put in place unmanned, untethered, lighter-than-air high-altitude airships that can be used in ballistic missile defense.

Giner's work could lead to more wide-ranging improvements in fuel-cell and electrolyzer technologies. The emerging technology also should draw interest from designers of space vehicles or space stations, as well as the automobile and energy industries. Giner officials have suggested that some innovations being pursued under the MDA project could eventually prove useful for fuel-cell-powered cars.

▲ Giner's electrolyzer will be part of a closed-loop system that promises extremely minimal loss of hydrogen, oxygen, and water.

The science behind Giner's regenerative system is simple. When hydrogen and oxygen molecules come together to create power in a fuel cell, they also create a byproduct that is two parts hydrogen and one part oxygen—also known as H_2O, or water. Typically, fuel-cell users don't need that water. But at high altitudes, where oxygen is scarce and sunlight plentiful, that water could be used to produce oxygen and hydrogen, which in turn could be used again in the fuel cell to create power.

Giner researchers claim that their system will differ from other fuel-cell systems by being a truly closed-loop system, with extremely minimal loss of reactants (hydrogen, oxygen, water). Giner researcher Cecelia Cropley said that the system's only losses should occur through the natural permeability of valves and materials.

Compared with lithium-ion batteries—a potential competitor to fuel cells in high-altitude applications—Giner's system will offer greater energy density. (Energy density is the amount of energy per unit of weight.) Lithium-ion batteries have an energy density of about 200 watt-hours per gram. But Giner's regenerative fuel-cell system should have energy density greater than 600 watt-hours per gram. For high-altitude airships to be practical, they will need to be capable of long-duration flights—more than just a few days, according to Cropley. And such long-duration flights will require power systems capable of at least 600 watt-hours per gram, she said.

Another discriminating feature of Giner's technology is weight. The electrolyzer that the company is developing should weigh in at about half the weight of current state-of-the-art electrolyzers.

Creating the new fuel-cell system has required Giner to address issues such as a lack of readily available sensing technologies—a lack of hydrogen-in-oxygen sensors and oxygen-in-hydrogen sensors, for example. Cropley said the company has performed engineering "workarounds" to meet the challenges.

The next challenge for the company is putting the system all together. Cropley said Giner researchers want to ensure that when the final device operates, it switches smoothly between fuel-cell operations and electrolyzer operations.

Giner continues system development and seeks new materials that will help decrease the weight of the system and ancillary components—such as lighter valves and pumps, as well as higher-pressure pumps. Getting near-zero loss of reactants also will remain a focus.

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Power Plants with Wings

Megawatt generator addresses space and electricity needs for next generation of commercial and military aircraft.

by Michael Felton

Boeing Company's proposed 787 Dreamliner passenger airplane is expected to generate about 1 megawatt of electricity by using four onboard generators to power flight systems as well as in-flight entertainment. Although meeting current onboard power demands has led to improvements in generator technology, carrying four generators consumes an airplane's valuable space and load-carrying capacity. Innovative Power Solutions, LLC (IPS; Eatontown, NJ), is addressing this problem and taking onboard generators to the next level by developing a single, small, lightweight megawatt-class generator.

To date megawatt generators are large, low-speed machines that are used for electric utilities and back-up power. The generators are about the size of a workbench and weigh thousands of pounds. And this does not include the diesel or turbine power source producing the mechanical energy that the generator converts into electricity.

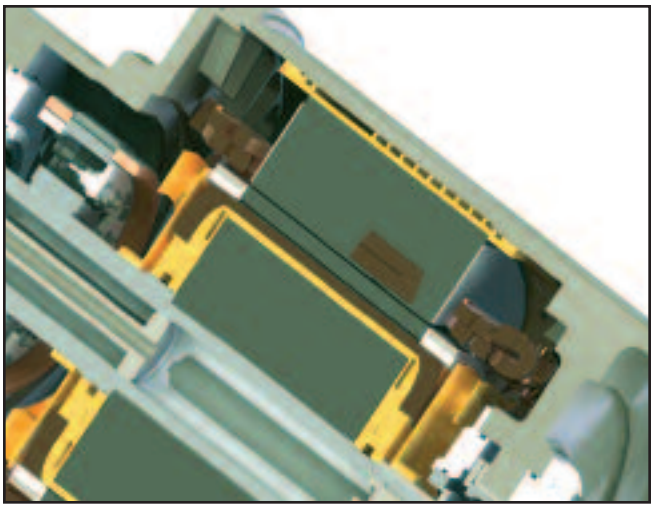
In order to reduce the generator's size, IPS has improved the method for removing heat produced by the generator. "Cooling is always the limiting factor," said Scott Jacobs of IPS. "If you can keep the copper cool and the insulation cool, then you can run a lot of power through the wires." Therefore, if the wires could be cooled more effectively, more electricity could be generated by a given-sized generator.

"Cooling is always the limiting factor."

—Scott Jacobs, IPS

IPS has developed and patented a new method of cooling the rotor to create more intimate contact with the heat source. The patented cooling technique allows every wire to come in contact with the cooling media along the entire perimeter of the coil. MDA originally funded IPS through a 2003 Phase II SBIR for innovative onboard power and cooling solutions. "A lot of companies use round wires for the rotors. The round wire technique does not allow every coil to be directly cooled," said Jacobs. IPS uses flat wire in an edge-winding fashion, similar to how a slinky toy looks. "With edge winding and flat wire, it's much easier to do a better job of cooling."

Now that the rotors have been cooled, heat in the stator has become the limiting factor. To address this, IPS has added radial fans to the rotor and designed fins into the internal housing to help remove heat from the air within the generator. "By transferring heat into the aluminum housing," said Jacobs, "the heat can be efficiently conducted to the cooling oil passages."



▲ The gold portions shown in this cross-sectional image depict cooling locations in IPS's megawatt generator. The device employs a patented cooling technique that lends itself to a more compact generator design.

As a result, IPS's generator weighs about 463 pounds—roughly 10 times lighter than typical 1-megawatt generators. Instead of being as large as a workbench, the generators are now only 22 inches long and 16 inches in diameter.

In addition to airborne uses, there are possible terrestrial applications for these generators. They could provide power in remote locations or disaster sites, and be transported easier because they weigh less and take up less space. Back-up power systems are also a potential market, especially units located on roofs or in basements where size or weight are critical issues.

IPS is finalizing the design of the generator and seeking customers in the defense, airframe, and jet engine manufacturing industries to gauge interest for such a generator.

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Missile Defense Meets Video-Game Tech

Fuzzy-logic software may help warfighters make better decisions in less time.

by Michael Felton

After pinning you down with a barrage of fire from his plasma rifle, the alien monster, now slightly low on ammunition, decides to hide behind a boulder and fires rapidly when he sees you.

The scenario above could be from any number of video games, but the next generation of missile defense command-and-control software may help soldiers make decisions by using the same techniques that make video-game monsters appear intelligent. The technique is called fuzzy logic, which is a mathematical way of handling gray areas. It provides an excellent tool for translating such difficult human words as, "almost," "nearly," "slightly," or "reasonably" into computer language.

▲ Schafer Corporation's fuzzy-logic software can examine and prioritize information for personnel in command centers.

Traditional programming excels at making binary decisions—male or female, over 35 or under 35, or whether ammunition levels are greater than or less than 50 percent. However, there is a big difference between having 51 percent ammunition and 99 percent ammunition, and it becomes difficult when using traditional programming to account for these differences. With fuzzy logic, a computer can weigh how close a variable may be to a tipping point and respond according to prescribed rules.

In the real world of today's command-and-control centers, humans are inundated with data and often have to make quick, life or death decisions. Computers have been helping with simple binary decisions for some time, but with the amount of information growing, humans may not be able to make the most informed decisions in time. And that is where Schafer Corporation (Chelmsford, MA) thinks fuzzy logic can help.

When Schafer programmers were working on command-and-control systems for the Ground-based Midcourse Defense system, they realized that fuzzy logic might help warfighters make quicker, more accurate decisions using the information being presented to them. The system will follow rules that the humans would follow if there were plenty of time to make decisions. The feasibility of fuzzy-logic assistance was tested in an MDA Phase I SBIR and Schafer is now prototyping a system in a Phase II SBIR as a proof of concept.

Schafer's intelligent-agent program employs fuzzy logic to "bring the operator's attention to the data that helps them understand those situations that need applied discretion," said Carol Daniel, director of system development at Schafer. The agent examines the data being presented to the command-and-control software, and if data fits certain rules it alerts the operator by highlighting the important information. "It does not rely on things like pop-up windows," said Ruth Wright, senior system engineer at Schafer. Because it is unobtrusive and does not alter the underlying command and control, the system can be more easily incorporated into other control software.

Fuzzy-logic systems are built on rules, but in missile defense—unlike video games—rules can change. Therefore, Schafer is forging new ground by designing this system to be flexible. "The rule set has to be expandable because not only may there be situations that you might not have anticipated, but you could have a change in military doctrine due to changes in leadership or the political environment," said Daniel. This flexibility will also enable the intelligent agent to be commercialized and used on other control systems.

In testing, Schafer found the system could reduce operator reaction time by an average of 43 percent, while also improving accuracy by an average of 58 percent for situations in which human discretion should be applied. The users also responded positively to the system, saying, "The agent helps you see things you don't have time to examine otherwise. It focuses your attention."

A flexible fuzzy-logic system like the intelligent agent could be useful to commercial industries that use command-and-control systems, such as chemical plants and other

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The Best Offense

Defense-planning tool could be used to manage assets and scenarios in many fields.

by L. Scott Tillett/stillett@nttc.edu

New software used for planning missile defense also shows promise for managing medical diagnoses and processes, as well as for commercial logistics, air-traffic management, and resource planning.

The software, developed by MDA-funded TechFinity, Inc. (Calabasas, CA), evaluates a missile threat and helps users decide which defense assets, in which locations and configurations, would be best for deflecting a missile attack or minimizing damage. MDA originally funded the technology through a Phase II SBIR contract in 2003.

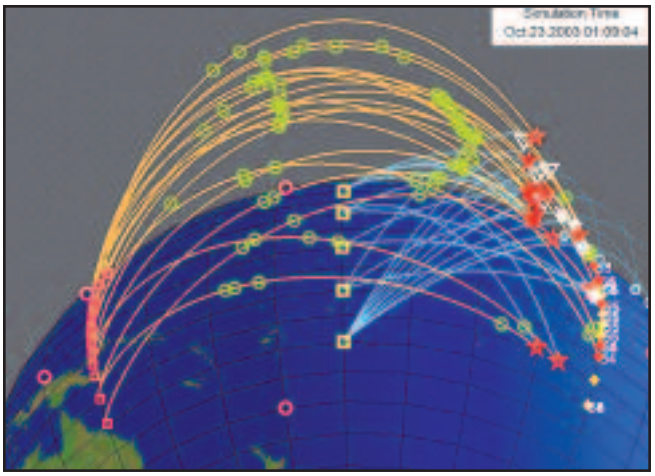
TechFinity calls the software "Defense Planner." The product is part of a larger suite of defense-related applications that the company is developing—with the eventual goals of integrating all the applications, enhancing their real-time information capabilities, and further automating their functions.

The company's current vision is for Defense Planner to be used for organizing, planning, and optimizing the location of missile-defense assets such as ships, ground-based shooters, sensors, and related equipment—given the potential of incoming threats. The tool can run scenarios based on enemy missile inventories and possible trajectories and then generate likely outcomes and optimal placement of missile-defense assets, displaying results in an interface that includes a map.

But the algorithms and features at the heart of Defense Planner also could be applied to other fields in which users need to plan, schedule, and understand lots of resources and assets—managing them to solve problems with optimal and efficient solutions. For example, TechFinity researchers expect federal funding soon for a project investigating use of their technology in a medical application. Such an application might involve an automated system that could take data from different input sources (medical sensors, for example) and then evaluate information and perform preliminary diagnoses. Company officials said that additional applications are not limited to the medical realm. Information users in the fields of logistics, transportation, and aviation also might find TechFinity's central technology useful.

TechFinity is not alone in developing such "decision-support" tools. But the company's innovation lies in its algorithmic approach, its focus on distributed computing, a flexible and modular architecture, and integration with a real-time sister application.

Defense Planner relies on numerical methods for its algorithms, while other defense-planning applications use techniques known as Monte Carlo methods. The numerical-



▲ TechFinity's Defense Planner software can evaluate a missile threat and help users decide which defense assets to use.

method-based algorithms—which have been challenging to develop, according to the company—allow Defense Planner to produce results in a matter of minutes. Algorithms that rely on Monte Carlo methods could take hours to produce a result—since they can rely on several thousand samples of scenarios to generate a solution or to recommend an action. TechFinity's numerical method uses only a handful of sample scenarios, chosen in a certain way, and then generates a weighted average to produce an accurate result quickly. Company researchers said speed and accuracy—not just accuracy alone—are important for military applications in which minutes and seconds matter.

Existing defense-planning tools may use a single "probability of kill" metric as a measure of the quality of the weapon-target assignment. TechFinity's innovative algorithms perform a probabilistic analysis of the battlespace to generate a probability distribution of the "probability of kill," which can extend the window of opportunity for engaging and destroying threats. This feature is currently being tested in Battle Manager (another TechFinity product) and eventually will be available to the Defense Planner.

A distributed-computing approach for Defense Planner means that each key process of the application can run on its own machine. Instead of all processes running on a single computer, they can all run individually on separate machines on a network—with the machines working concurrently to

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The Technology Applications program creates detailed profiles of MDA-sponsored research with commercial applications. New profiles are added quarterly to our Web site, www.mdatechnology.net. Summaries for some recent additions can be found below.

For more information on a particular technology, visit www.mdatechnology.net. Enter the search code (e.g., #661) for the technology profile in the "Quick Search" box and then click the "Go" button. Be sure to include the number sign when searching.

You can also browse through our archive of technology profiles. On the far right side of the home page, you'll find the "Featured Technologies" link. Click on the links there to browse all available technology profiles.

Cost-Breakthrough Titanium Production as a Commodity Metal

With funding from MDA, Vartech, Inc. (Idaho Falls, ID), has developed a process to produce titanium-aluminide alloy powders using a chemical vapor-phase process. The alloys are ideal for high-temperature environments in which weight is important, since the alloys have greater strength-to-weight ratio than aluminum alloys. The company seeks to produce high-value coated materials and other products that would demand a high dollar-per-pound value. Potential applications include aircraft/aerospace parts, missile components, and high-temperature valves such as those used in automotive equipment.

▲ Reactor for titanium production.

Search code for tech profile: #658

Compact RF Systems for UAV Payloads

ARC Technology, Inc. (Whitewater, KS), has built a series of plug-and-play antennas that can directly radiate the output of their compact, high-peak-power electrical pulse generators, using radio-frequency (RF) signals to disrupt electronics systems. MDA funded the company through a Phase II SBIR award to develop compact RF systems for unmanned aerial vehicle (UAV) payloads. ARC's technology disrupts or destroys communications systems, computer systems, sensors, or even remote triggering devices without being lethal to people around them. The technology also could be used to disrupt electronic systems in vehicles such as cars fleeing from law enforcement. Military applications could include disabling the electronics of enemy vehicles, weapons, or roadside bombs. Moreover, the technology is being studied for possible use in disrupting growth of cancer cells.

▲ Device to disrupt electronics systems.

Search code for tech profile: #663

▲ Materials for optical memory technology.

Improved Materials for Optical Memories

Through an SBIR Phase II award, the MDA funded a new optical memory technology being developed by Scientific Materials Corporation (Bozeman, MT). MDA's Advanced Systems Deputate has provided more than $7.48 million in Phase III funding for this project, as it is geared toward high-performance, real-time signal processing for radar applications. The optical materials allow radar systems to process complex radio-frequency (RF) waveforms at higher-bandwidths in real time, yielding more information about targets. The new optical materials are expected to enable processors to handle data bandwidths up to hundreds of gigahertz, and should prove useful in a variety of other applications, as well as in radars.

Search code for tech profile: #661

Phasing Out Breast Cancer from page 1

been used. A specialized application of microwave heat is now under consideration in an exciting new clinical trial scheduled to take place in 2006, thanks to a technology that MDA funded at Lincoln Laboratory nearly two decades ago. During the latter years of the Cold War, Dr. Alan Fenn of the Massachusetts Institute of Technology developed an adaptive phased-array antenna for nulling and focusing radar under the auspices of the Strategic Defense Initiative Organization (SDIO), for missile detection applications. It soon became apparent that this same technique could be useful in directing heat to deep-seated tumors, while reducing "hot spots" in surrounding healthy tissue.

Dr. Augustine Cheung, founder of the medical device company Celsion Corporation, had long been interested in using heat to treat disease. He acquired an exclusive license to Dr. Fenn's technology and incorporated it into an early device, the MicroFocus 1000™. Over the years Celsion has gone on to establish a line of related thermotherapy platforms for the treatment of benign prostatic hyperplasia (BPH), and most recently liver cancer, using radio-frequency (RF) waves to provide the heat. However, as Celsion moved more towards the development of RF-based thermal therapy with liposome-encapsulated chemotherapy drugs, the APA technique simmered on the back burner, but on a parallel course. In a series of studies conducted from 1999 to 2004, however, Dr. Fenn and a host of breast cancer specialists continued to test the APA-based Microfocus 1000 device in breast cancer patients as a neoadjuvant treatment prior to breast surgery.

Two advantages of APA focusing are its ability to deliver heat into tumor sites deep in the body, and the fact that microwave energy preferentially heats tumor cells, which have a comparatively higher water content than surrounding healthy tissue. In addition, the placement of the antenna is minimally invasive, allowing patients to leave the treatment with "a tiny bandage," according to Dr. Fenn. Eventually, it is hoped that APA can be applied remotely, without the need to insert any needle into the tumor. Remote application would also be helpful in focusing energy on chest wall tumors—such cancers are more difficult to treat than those that occur on the periphery of the breast.

▲ Celsion's tumor-fighting technology.

Celsion's work could help patients avoid mastectomies.

In two papers published in the Annals of Surgical Oncology (2002 and 2004), researchers were able to demonstrate in a total of 35 breast cancer patients the safety and utility of this method for killing tumors by the use of heat alone. In one study, 10 patients scheduled for mastectomy received the heat-alone APA focusing treatment prior to surgery and 8 of 10 patients had a tumor response. As part of this safety study, all of the patients were required to have a mastectomy regardless of any tumor response. In another study, 25 patients with early-stage breast cancer scheduled for lumpectomy received the heat-alone focusing treatment, and the heat dose for 100 percent tumor kill was established. All of these patients had lumpectomies and only one patient had any residual cancer cells after surgery. Two other studies of the APA focusing treatment in more than 40 additional patients with early-stage and advanced breast cancer have since been explored and the results are awaiting publication. The outcomes of these initial trials in more than 75 patients are encouraging, and clinicians have decided to add a new component to the APA treatment, again prior to surgery in a clinical trial for patients with advanced breast cancer.

To this end, in early 2006, Dr. Augustine Cheung resigned his executive positions at Celsion, while retaining his license to APA technology and related assets, and began to devote his full-time efforts to the development of APA technology as a thermotherapy platform for breast cancer treatment. Currently, he is preparing a round of clinical studies that combine APA-based tumor-heating with intravenous infusion of Adriamycin® (doxorubicin) and other drugs. The idea is that the drugs will be "enhanced" by heating, possibly speeding up reaction times, resulting in a higher response rate at the site of the tumor. Simultaneously, the ordinary systemic action of the drugs will target any circulating tumor cells or potential micrometastases elsewhere in the body. Celsion has already established a track record in clinical trials using RF heating and liposome-encapsulated doxorubicin, with a therapy called ThermoDox™, in the treatment of liver and prostate cancers.

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solve a problem fast. Additionally, the flexible, modular nature of Defense Planner means that users can swap databases in and out as needed to represent different elements of the Ballistic Missile Defense System (BMDS). In other words, the tool is not limited to use with just one element or component of the BMDS.

TechFinity has designed Defense Planner to work fast, but it remains essentially a planning tool. Another company product—Battle Manager, also developed with MDA SBIR funding—is being designed as more of a real-time management tool that military leaders would use for commanding a battle. TechFinity officials said Defense Planner and Battle Manager would eventually be integrated to allow real-time sharing of data between both systems. Using data from Battle Manager means that Defense Planner will not rely on generic models; instead, it will use actual real-time Battle Manager data to do planning.

Ongoing challenges for the company include enhancing real-time functionality and automating certain features of Defense Planner to require less user intervention. The company continues to seek new customers and also remains open to outside investors.

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Good Vibrations from page 7

Midé continues to address technical questions such as how to increase the power produced by the Volture and how to broaden the range of frequencies from which a device can harvest energy. Making the Volture smaller and lighter also will remain a focus.

Company officials continue to seek partners that can help Midé develop a self-tuning harvester. A partner that could provide an application for the harvester as well as funds for development would be ideal, according to Ludlow.

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factories. Schafer's development of flexible rules could allow this software to be added to next-generation software for controlling everything from the production of gasoline to the making of paper. But the development of new, application-specific rules will be needed because command-and-control decisions for launching missile interceptors are quite different from running a chemical plant.

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Phasing Out Breast Cancer from page 13

Encouraging results from the company's experience in this area have strengthened the evidence supporting this application, hopefully pointing to better outcomes for breast cancer. The ultimate goal of this effort, of course, is to destroy tumors, prevent recurrence, and help patients avoid mastectomy.

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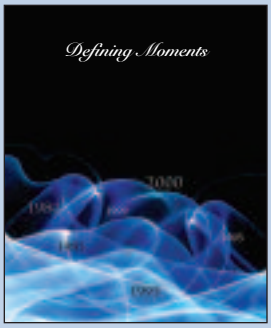
SPOTLIGHT



The latest special report from the MDA Technology Applications program is available online. The report, titled *Defining Moments: Selected Highlights from 25 Years of Missile Defense Technology Development & Transfer*, offers historical perspectives on U.S. missile defense and technology commercialization. You can find the publication in the *Special Reports* section of our Web site, www.mdatechnology.net.

20 Questions

Considerations for small companies attempting to build a business around technology

by Paul Carroll/pcarroll@nttc.edu

The following are some strategic questions to address when building a small company based on technology. If you are not already examining these aspects of commercialization, or do not understand them, then you may need to re-think your business proposition.

MARKET

1. What problem or need are you solving? Generally who needs it? What are the alternatives to your solution? Is the market driving your efforts (i.e., "technology pull") or are you trying to fit the technology into a market segment (i.e., "technology push")? Where is any market research to back up your claims that the customer wants your technology? Is it a unique solution to a common problem or a good solution to a unique problem?

2. Who are your competitors? How do you compare in cost, performance, schedule, and other measures to each of them?

3. How have you segmented your current or prospective customers into value segments? Which segments will you target first and why?

4. Who specifically is your customer? Do you have companies and specific names in the companies that you want to sell to?

5. What are the obstacles involved in your target customers adopting your solution? Can you meet business expectations as well as technical expectations? What is the ROI to your customer? Is it worth the risk they will take working with an unknown company?

TECHNOLOGY

6. What is the compelling advantage of your technology? What are the benefits, not features, of your solution? How does it compare to current solutions? What is the "value proposition" of your solution? In other words, can you provide a succinct "why buy" story?

7. What is the source of your technology? Do you own it? Is it protected as valuable intellectual property (patents and/or trade secrets)?

8. What is the development status of your technology? What is the Technology Readiness Level (TRL) level? When will a commercially viable product be ready for market?

9. If your technology is still in the development stage or early prototype stage, what is the probability of success for your technical approach? What is the probability that the resulting product can become cost-competitive and sustain a viable business? Does it make business sense?

10. Have you assessed the technical risk in bringing the technology to market and full production? (At which of the seven stages, from concept to scaled-up manufacturing, is the product or process at this time?) Are there any "inventions" or "still to be defined engineering accomplishments" required to complete the development of a marketable product and volume production? Have you estimated the cost in time and money to complete the needed development stages? Have these estimates been validated by manufacturing-knowledgeable people?

BUSINESS

11. What are your risks? How are you mitigating your risks?

- Execution risk (ability for management and staff to execute on a given plan)
- Technical risk (the technology fails to perform as expected)
- Market risk (customers are incorrectly identified or do not adopt the product as planned)
- Competitor risk (competitive response)
- Regulatory risk (if the product requires industry or government regulatory approval)
- Macroeconomic risk (everything outside of your control)

12. How are you structured as a business? What is your Business Readiness Level (BRL)? Do you have the various specialties such as finance and accounting, legal, business development, marketing, production, sales, etc.?

13. Who's on your team (including you)? What have they accomplished in previous lives? What skills do you need to add to grow the company to the desired level?

14. Who is running your company on a day-to-day basis? Or, put differently, do you have a chief operating officer (COO) with a strong business and marketing background? Can the founders relinquish authority to the COO so that he/she can do his/her job properly? Do you have a defined succession plan for when professional leadership will be brought in?

FINANCIAL

15. Do you have a board of advisors and/or directors (especially outside advisors /directors)? Do they offer insight or introductions not otherwise available to the company?

16. How will you get your product or service to market? What alliances or distribution channels do you have/need?

17. What valuation have you set for your technology/company? What method did you use to value it? (This should be a hard-nosed, quantitative analysis. If asking for outside funding, your potential funding source will value you and require (in most cases) part of that value in return for funding.)

18. How much funding do you still require to get to market? What are your funding sources beyond the government and how do you plan to tap in to them?

19. Where is your "cliff"? (At what point will your company run out of funds if you get no new contracts/sales?)

20. What is the exit strategy (both for you and any potential investors)?

Tech Trivia

After reading this newsletter, you've stored a lot of new information in your brain. Play our Tech Trivia game to test what you just learned.

1

Tech Trivia

Technology related to adaptive phased-array antennas, used in the 1980s for missile detection, has been developed by Celsion Corporation. Now, a Celsion spinoff company is testing the technology as a possible means for treating:

A. Osteoarthritis
B. Multiple Sclerosis
C. Leukemia
D. Breast cancer

2

Tech Trivia

An energy harvester created by Midé Technology Corporation is about the size of:

A. A match box
B. A cassette tape
C. A laptop computer
D. A refrigerator

3

Tech Trivia

Mound Laser & Photonics Center is using a picosecond laser to create mirrors out of:

A. Silicon carbide
B. Zinc telluride
C. Vanadium carbide
D. Titanium boride

4

Tech Trivia

Schafer Corporation's missile defense command-and-control software uses which mathematical technique to handle gray areas?

A. Binary direction
B. Applied discretion
C. Blurred inference
D. Fuzzy logic

Answers: 1. D, 2. B, 3. A, 4. D

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