SBIR Success Stories | 2019

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SBIR Success Stories
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NETWORKED CARRIERS

Wireless networking propels Navy maintenance system

Imagine dozens of sensors posted all over a human body, monitoring various vital signs, from pulse and blood oxygenation to the stress on certain joints and tendons. The sensors feed data back to a system, creating a status snapshot of the body and its component parts that medical professionals can evaluate in order to determine what needs to be fixed.

This type of monitoring system is exactly what founder Steven Chen and his team set out to build in 1997. Except instead of humans, Chen worked with 10,000-ton ships.

When Chen founded his company, 3e Technologies International (now Ultra Electronics 3eTI), the U.S. Navy was still using a time-based approach to maintenance. This meant that, in general, ships were taken for repairs based on how long they had been in operation rather than being fixed piecemeal as problems arose. Chen, though, had other ideas.

Initially, after opening its doors in 1995, his Maryland-based company focused mainly on building sensors for hard drives. But as that market became flooded, the company, Chen said, "had to find a new direction."

That direction came in the form of an SBIR solicitation topic issued by the Navy to update the monitoring and maintenance systems on its ships. Using its sensor-building background, 3e developed what it called a "base-monitoring" system—a series of sensors attached to various parts of the vessel, from the propulsion system to the generators, all communicating with one another over a local area network. The system would allow the Navy to transition to a condition-based maintenance approach, where it could detect faults and make repairs on an ad hoc basis, saving it time and money. The novel approach won 3eTI the company's

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first SBIR contract.

"We were trying to take risks rather than be comfortable. We wanted to build products, and that was the difference between us and a lot of other companies," Chen said.

A Phase II contract followed, then it went to Phase III, an important achievement for any SBIR. Eventually, 3eTI's monitoring technology was employed on six different classes of ships and in every Naval base around the globe. But the company still had more steps to take.

Around 2004, Chen and his team attended a presentation hosted by tech giant Intel. The company was pitching the idea of wireless internet on laptop computers, technology that, at the time, was slow and costly. But where others saw a far-fetched idea, Chen saw opportunity. Following the presentation and an introduction with Chen, Intel enlisted 3eTI to rewrite important security software stack for its software, which later became the secured Wi-Fi offered in the computers using the Intel Wi-Fi technology.

This meant, Chen said, that "the 3eTI technology, funded by DoD SBIR, scaled with chips from Intel."

While the partnership proved a financial boon, 3e again resisted resting on its laurels. Instead, the company took its newfound experience in the wireless sector and applied it to its existing technology. The wired ship-monitoring system was effective, but installing so many sensors added unnecessary weight to the vessels. With the Intel deal in the rearview, the next step was a logical one: cut the cords.

"The Navy looked at the wireless system and said, 'Wow, this really improved the efficiency,'" Chen said. "What we were doing became the industry standard. We saw that was the future."

In addition to untethering the sensors, transitioning to wireless also allowed 3eTI to easily add upgrades such as security cameras and smart meters to the system.

"Once you have wireless, you can hook up cameras and everything. Then you're doing control and security at the same time. It's all related," Chen said.

The move toward cybersecurity marked a larger shift in the company, which now offers security solutions for municipalities and large-scale utility providers, among others.

"At the end of the day, it's great that the government is doing a wonderful job helping companies commercialize."

Chen sold the company in 2006 as an Intel Capital portfolio company. It was bought again in 2011 by Greenford-based defense company Ultra Electronics.

Chen is now a principal with Blu Venture Investors in Virginia, a firm focused on startup funding, where he initiated a cybersecurity investment program. The venture capital company has made investments in approximately 50 businesses, with 25 in cybersecurity, several of which have received SBIR contracts or other government funding.

Chen said his experience working for a company with more than 40 SBIR contracts to date has given him an appreciation not only for the companies themselves, but also for the U.S. government SBIR program as a whole.

"I love government-funded technologies, because I understand winning an SBIR Phase I is not easy," Chen said. "If I have 10 companies that are asking for me to invest in them, if they have SBIR awards, that is a big deal because of the rigid selection processes they have to go through.

"At the end of the day, it's great that the government is doing a wonderful job helping companies commercialize."

Steven Chen

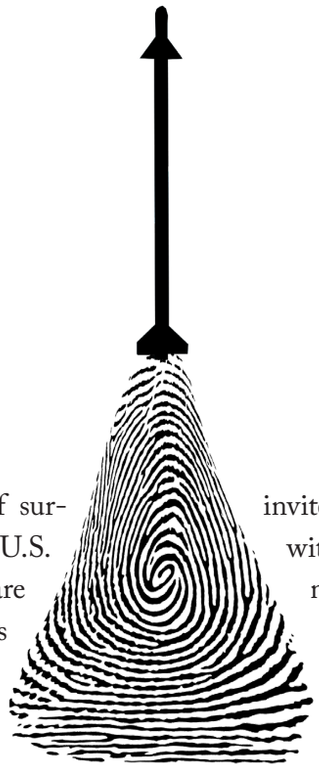
Courtesy Steven Chen

3e Technologies International, Inc. (Ultra Electronics 3eTI)

Rockville, MD • SBIR contract: N00178-99-C-3026 • Agency: Navy • Topic: N98-114, Context Dependent Prognostics and Health Assessment: A New Paradigm for Condition-Based Maintenance

Plume Straight

Missile plume simulation for defense testing



With the ever-present threat of surface-to-air missiles, many U.S. military jets and helicopters are equipped with infrared or ultraviolet sensors that alert pilots to hostile fire. But these sensor systems are not perfect. American warfighters, and taxpayer investment in the aircraft, are often still at risk.

The complication lies in a long-standing conundrum: Anti-missile defense systems must be tested and proven in realistic environments before being deployed in the field, but testing them against actual missiles is not an option. Instead, testing is done with simulated missiles that emit mimic plumes generated by a pyrophoric fluid, which ignites on contact with air. The flow of the pyrophoric fluid is controlled by valves that control the fluid flow to imitate the behavior of real missile plumes. However, the actuators that usually control those valves have limited control bandwidth and begin to overheat and lose power after a few seconds. To improve the effectiveness of simulated missile plume testing, the military needed a completely new kind of fuel valve and actuator system.

In 2003, the Air Force's Arnold Engineering Development Complex (AEDC)—which houses the most advanced flight simulation test facilities in the world—invited the private sector to help find a solution, with support from the Air Force's Small Business Innovation Research (SBIR) program. Maryland-based Active Signal Technologies, Inc. (AST or Active Signal) became aware of and accepted the challenge in 2012.

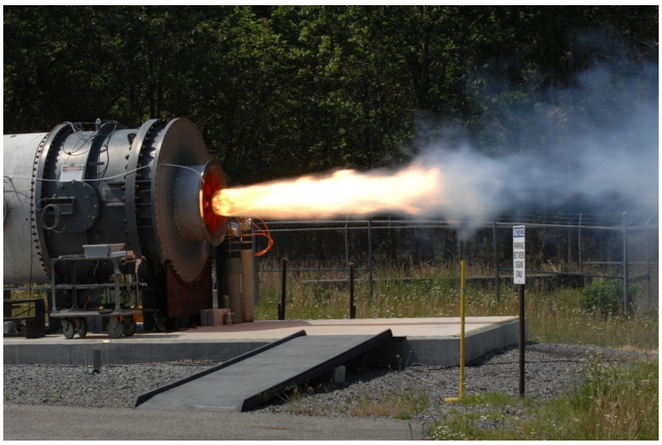
The first piece of the puzzle was the actuator. "I'd actually been playing with the concept for some time at Active Signal, and we had built a proof-of-principle model," said AST Chief Engineer Dennis Kohlhafer. "AEDC needed something with high force and higher frequency response, in a relatively small size, with a reasonably good operational life span. We thought this new actuator we'd been experimenting with might just work."

The OFact, as Kohlhafer called his new opposing field actuator, not only produced the needed force, it was able to sustain that for over three minutes, compared to the 20-second run time of the old system. This OFact also offered the advantage of a wide dynamic range coupled with high frequency response. Unlike traditional actuators, the OFact could quickly and precisely control and change flow. With that, plume profiles could be tailored from high- to precisely controlled low-flow rates, delivering more realistic and accurate conditions

for anti-missile defense exercises.

"Dennis had a really neat solution for the actuator," said Keith Bridger, co-founder and AST President. "Then we were faced with the nitty-gritty work of designing a valve based on that new actuator, which proved very challenging given the wide dynamic range required." Challenging, but not impossible. With support from the AEDC SBIR, Kohlhafer and Bridger designed a new plume simulator valve to work with the actuator.

While AST already had the critical technology and concept for the project in place, they credit much of their success in implementing the technology to their collaboration with AEDC and other stakeholders, including NASA's Glenn Research Center (GRC). "This was a great team effort. We got a lot of support from the AEDC staff," Bridger said, "and we consulted quite a bit with the jet fuel people at NASA GRC, who gave us a lot of free advice."



A fully-assembled pyrophoric fluid flow valve prepares for a ground test.

According to Taylor Swanson, an aerospace engineer in the AEDC Analysis and Technology Branch, AST's technology was just what they needed for their Towed Airborne Plume Simulator (TAPS). Developed in conjunction with the Center for Countermeasures, TAPS was designed to test aircraft missile warning systems in operational environments. Swanson considers it a prime example of technology transition through the SBIR program to achieve the Air Force's needs.

"The improved valve/actuator system developed by AST relieved some important limitations of the current system," Swanson said, noting the improved frequency response and run duration. Those advances will allow TAPS to simulate a wider range of missile types and threat engagement scenarios. AEDC intends to incorporate the new valve into operations, and is currently using two versions of the new valve-and-actuator technology in its missile plume simulations.

Moving forward, AST envisions a series of valves with practical applications beyond missile plume simulation. One strong possibility is aircraft controls, said Bridger. "The advantage there," he noted, "is that this type of actuator is very fault-tolerant, which means that if the power fails, the actuator will swing freely instead of jamming in one adverse position."

The technology could also be adapted to metering fuel into jet engines, an application NASA is interested in. "If you can modulate that flow at a certain frequency," Bridger explained, "you can make engines run leaner, with a higher air-to-fuel ratio, which means reduced emissions and increased fuel efficiency." Such a system could be hugely advantageous in commercial aviation. Pushing the benefits even further, the valves could be used to make jet engines quieter, a concern in both military and civilian spheres. The actuator technology also has promising application outside aviation, such as in motion control for robotics. The same quick reaction times that enable the actuator to power fuel valves so precisely can be useful in robotics, which demands quick, precise motions and responses to physical cues.

AST's Bridger credits much of the company's success to SBIR support. "The SBIR/STTR programs are important to the US commercial market because they give small businesses the chance to actually put new technologies to the test," he said, noting that otherwise, potential solutions are just sitting on a piece of paper as somebody's brainchild. "Every young entrepreneurial type—we were young once—has new ideas they want to try, but might not have the opportunity without SBIR funding."

EAR TO THE WATER

A MARINE MAMMAL SONAR DETECTION SYSTEM BENEFITS THE NAVY

Marine-environment researchers have been listening to the ocean.

Specifically, they've been homing in on marine mammals' responses to Navy sonar.

In March of 2000, there was a marine mammal-stranding event in the Bahamas. According to a 2001 joint interium report by the National Oceanic and Atmospheric Administration (NOAA) and the US Navy, it was concluded that Navy sonar was the cause of this stranding, and that the Navy should "put into place mitigation measures that will protect animals to the maximum extent practical."

During "war game" exercises, the Navy uses active sonar to detect submarines and underwater hazards. Unfortunately, cetaceans, an order that includes some 70 species of whales, dolphins, and porpoises, are far more sensitive to active sonar than was previously believed. And because marine mammals rely on echolocation, or innate bio-sonar, as their primary means of communicating, migrating, breeding, and finding food, any disruption to their ability is of primary concern.

When exercises take place in waters native to cetacean pods, research has revealed a correlation between anti-submarine acoustic pulses and marine mammal stranding or "beaching," eardrum ruptures, and premature ascension (which can cause decompression illness). Among the *Cetacea*, whales are particularly vulnerable to the sonar used in anti-submarine warfare exercises.

Under a US Federal Court ruling to prioritize marine mammal health and safety, and in compliance with environmental requests, the Navy has become increasingly proactive in monitoring for whale activity

and presence in "shared" waters. After initial modifications to their training exercises, naval anti-submarine operations sought alternative technology that would allow for conducting underwater tactical training without disturbing marine mammals. When this specialized need emerged, Jacksonville, Florida-based Analysis, Design & Diagnostics, Inc. (AD&D) saw a prime opportunity to diversify their sonar business.

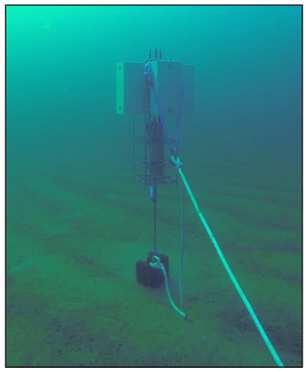
"Those assessments required the Navy to do more to protect whales and dolphins in the training grounds," said Gary Donoher, AD&D president. "We have responded to several SBIRs [and STTRs] regarding marine mammal mitigation, but the first phase was in 2001."

AD&D has been in the sound analysis business for twenty years. "One of AD&D's core competencies is understanding sounds in the world's oceans," Donoher said. "We've supported the United States Navy in detecting and classifying submarines and surface ships." Today, the company provides the Navy passive technology that captures and analyzes marine mammal activity via sonobuoys and technology fitted onboard naval vessels. Sonobuoys use a passive receiver and a radio transmitter to record and transmit underwater sounds. Together, the data received provides a location on marine mammals (or any objects in the water).

"In the years after we were awarded our first STTR contract, we have continued to improve our technology," Donoher said.

But AD&D wasn't always interested in listening for marine mammals. According to Donoher, before federal court cases ruling that the Navy should continue "monitoring and mitigation measures" to prevent harm to marine mammals, "AD&D considered marine mammals' sounds to be unwanted clutter. At that time, our detection and classification algorithms were tuned to ignore these sounds." But that perspective quickly changed.

"Once we realized that the Navy wanted to know if marine mammals were in the vicinity, we decided to exploit the marine mammal vocalizations and began optimizing our algorithms to automatically detect and classify these sounds," Donoher explained. But because their sensor product line was previously geared toward non-mammal frequencies, AD&D reached out to cetacean experts for direction.



An underwater Marine Mammal Detection and Mitigation sensor

"The first step in developing our Marine Mammal Detection and Mitigation (MMD&M) technology was to ensure that we fully understood the types of sounds marine mammals make," said Donoher. AD&D teamed up with Dr. William Watkins at Woods Hole Oceanographic Institution (WHOI) for his world-renowned expertise in marine mammal vocalizations.

Working with Dr. Watkins, AD&D learned that *Cetacea* produced a variety of sounds. Quoted in an article for *OceanUs* Magazine, Watkins classified them as "Whistles, clicks, click trains, and burst pulse transmissions." The ability to distinguish these sound frequencies helped tune AD&D's development efforts to create a mitigation system alerting Navy vessels to avoid potentially harmful activities.

According to Donoher, Whistles are vocalizations that have characteristics of a continuous wave (CW), Linear Frequency Modulation (LFM), Non-Linear FM or Hyperbolic transmission modes. This marine mammal vocalization category consists of low-frequency calls from blue whales and the North Atlantic right whale; as well as higher frequencies observed from melon-headed whales and the common dolphin. When these sounds fall in the lower-frequency spectrum, Donoher called them "moans and groans."

"Clicks, click trains, and burst-pulse transmissions are temporally short, broadband sounds produced by sperm whales, Cuvier's beaked whale, and bottlenose dolphins," said Donoher, "We use our click

Photos courtesy AD&D

Gary Donoher,
President, AD&D

detector for these sounds." Regardless of where sound frequencies fall in the spectrum, he said, "They all have similar characteristics, and we use our whistle and click detectors to locate them."

To ensure accuracy, Donoher and his team tested their detection and classification algorithms against the direction Dr. Watkins provided. "We also obtained acoustic data that was recorded from Navy surface ship sensors and from sonobuoys deployed by Navy aircraft," Donoher said. All of the data enabled AD&D to place their buoys in the water, and relay mammal vocalizations and locations to MMD&M components aboard the ships.

"We were onboard the Navy ships' Improved Performance Sonar (IPS) platforms," said Donoher, "and we are currently working to back fit this technology onto all Navy Surface ships and submarines." The automated system uses passive acoustics to detect mammal vocalizations, then alerts ships to move out of shared waters. The technology has been developed to use onboard sensors and operates on commercial-off-the-shelf hardware that has been approved for shipboard use.

Regardless of weather or operational conditions, the MMD&M system provides the Navy nonstop, reliable marine mammal detection support. The detection system also allows commercial industry an effective and low-cost method to monitor marine mammal activity when conducting offshore activities that may be harmful to marine life.

"In the years after we were awarded our first STTR contract, we have continued to improve our technology, Donoher said. "We have developed high frequency sensors that can detect the highest frequency vocalizations produced by marine mammals." AD&D has continued to improve the detection and classification technology, so much so that they are able to classify some species to a taxon level.

In the near future, AD&D predicts that all DDG 1000 (newest destroyer class ships) and CG (Ticonderoga class) warships will employ MMD&M technology to protect marine mammals from the adverse effects of active sonar, while still allowing the Navy to maintain anti-submarine warfare readiness.

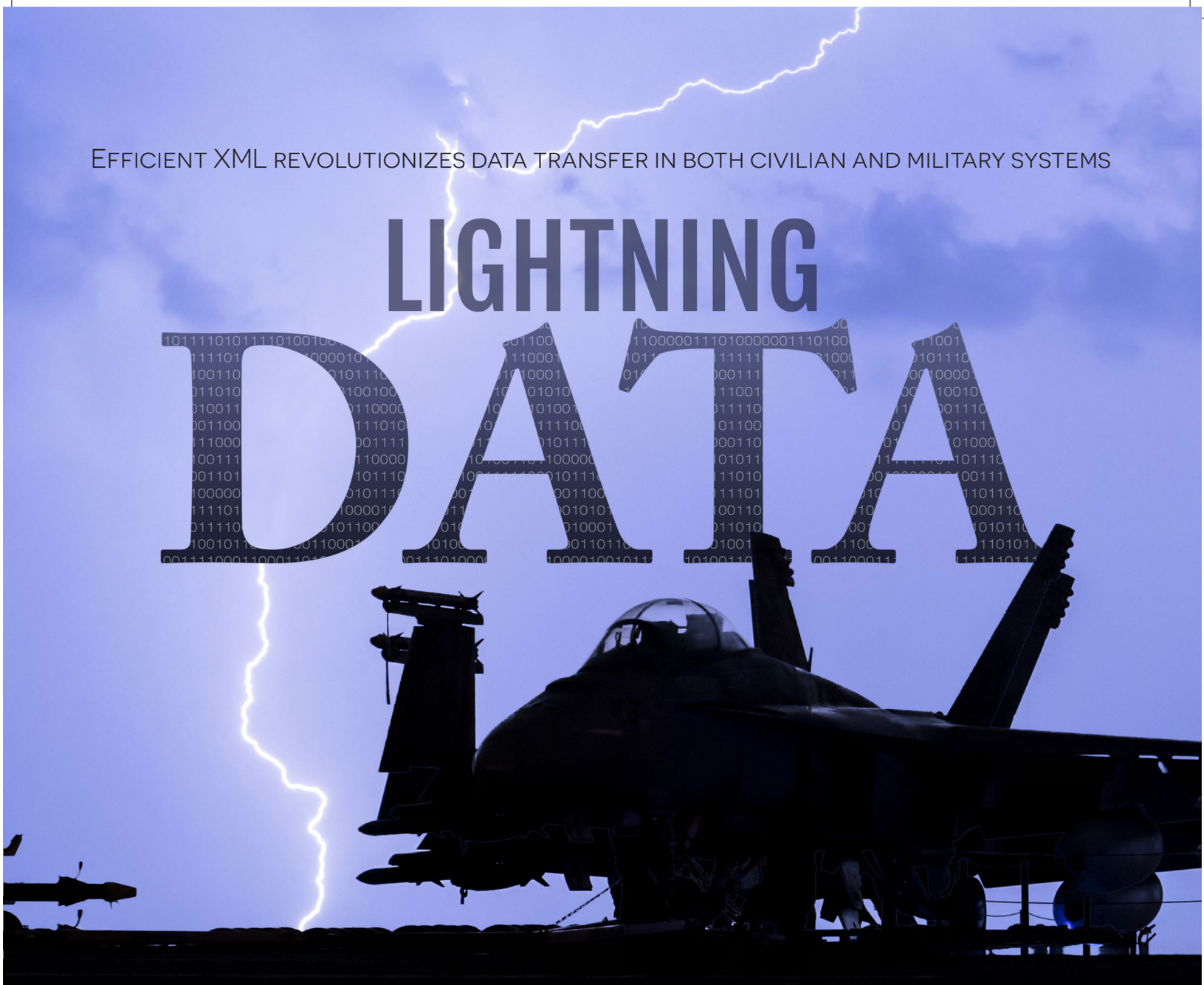
Teamed with Dr. Watkins at Woods Hole Oceanographic Institution (WHOI), Duke University Marine Laboratory, and Advanced Acoustic Concepts, Inc., and thanks in no small part to the DoD's SBIR/STTR program, AD&D has successfully addressed the Navy's marine mammal detection need.

Analysis, Design & Diagnostics, Inc.

Jacksonville, FL • STTR contract: N00014-02-C-0234 • Agency: Navy • Topic: Marine Mammal Detection and Mitigation

EFFICIENT XML REVOLUTIONIZES DATA TRANSFER IN BOTH CIVILIAN AND MILITARY SYSTEMS

LIGHTNING DATA



A special ops team hunkers behind a wall, checking maps and intelligence on their handheld devices. Just a few years ago, the wait for updated information would have been frustrating and dangerous, but not today. Today the information loads swiftly, without draining critical battery life, and the team is soon on the move.

Photo by 1st Lt. Mark Vetere

Warfighters from the front lines to the back offices—as well as the entire, interconnected, civilian world—now have an efficient and economical way to send and receive data, thanks in large part to AgileDelta, Inc., and the Air Force Small Business Innovation Research (SBIR) Program.

In the late 1990s, the Department of Defense was using Extensible Markup Language (XML) coding language for internet communications and data exchange. XML was everywhere, having been adopted as the default protocol for linking a connected world.

But while XML was useful and universally accepted, it wasn't very efficient, especially for the military's tactical users. XML data could require up to one hundred times more bandwidth than the formats used by aircraft, ships, vehicles, sensors, satellites, and support personnel. Information took a long time to download, gobbling power, memory, and processing capacity. The military needed a far more efficient and flexible approach to encoding and transmitting data—but one that wouldn't sidetrack it into technological isolation.

Aside from the significant military accomplishments, AgileDelta's widely applicable flagship technology has been a tremendous private-sector success.

Beyond the military, the revolution in mobile devices was also driving a new demand for ready access to increasingly larger amounts of data.

"I had faith that commercial industry would address the problem," said John Schneider, founder and CEO of AgileDelta. At the time, Schneider was working at a Federally Funded Research and Development Center (FFRDC) investigating ways to improve data sharing across the DoD and with NATO and other allies. Industry did develop a few technologies, but nothing that came close to what the DoD needed.

In 2001, Schneider teamed up with a group of scientists and engineers from some of the world's most successful software companies to form AgileDelta and tackle the XML challenge. In the beginning, they funded their internal research and development by providing high-value services to large technology companies.

"When people asked what percentage of time we spent providing services versus developing products, I'd joke that we spent 100 percent of our time providing services for our customers and the other 100 percent of our time developing products."

Schneider was only half-joking, given the brutal hours he and his partners were putting in. Some welcome relief and a big boost came in 2003, with an Air Force SBIR contract. AgileDelta had previously applied for a SBIR from a different branch of the military, but their proposal wasn't selected.

"We said we were going to build a far more efficient way to exchange data and get it accepted as a global industry standard, so I can understand their skepticism," Schneider allows. "They didn't think a small company could pull it off."

But pull it off they did. Support from the Air Force SBIR Program allowed the company to accelerate development of what they were calling "Efficient XML," to solve the cumbersome nature of XML data flow.

By the end of the SBIR in 2007, Efficient XML was already changing the world of data transfer, within and outside the military. The innovative system was able to optimize XML to levels that met or exceeded the DoD's most demanding tactical needs, while still enabling broad interoperability across user groups. Independent tests by the Air Force, Navy, and Army measured greater than 100-fold improvements in bandwidth utilization and transfer speeds, resulting in significant cost savings in bandwidth-use fees.

The Air Force Life Cycle Management Center (AFLCMC) projected that Efficient XML will save $18 million per year in fleet-wide INMARSAT bandwidth costs for one of their mobility

aircraft. AFLCMC has also flight-tested Efficient XML in the C-130 aircraft, accomplishing a reach-back to Air Mobility Command enterprise services for the first time without expensive satellite or radio upgrades.

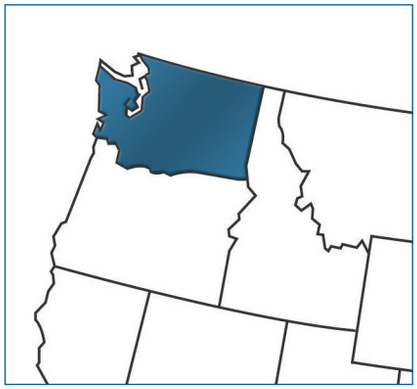
The DoD now mandates Efficient XML be used in the development and acquisition of all defense systems. Efficient XML has also been designated as a standard by the U.S. Intelligence Community and is being integrated by the Department of Homeland Security.

Looking ahead, Lockheed Martin has flight tested Efficient XML on advanced aircraft, such as the F-22 Raptor and F-35 Lightning II, showing interoperability between these aircraft for the first time. Lockheed intends to include Efficient XML in its Enterprise Open Systems Architecture across its aircraft portfolio.

Efficient XML has improved communications in everything from fighter jets to cellphones.

Aside from the significant military accomplishments, AgileDelta's widely applicable flagship technology has been a tremendous private-sector success. Efficient XML has been commercialized into a set of broad-based, off-the-shelf products that can be smoothly integrated into existing systems to optimize the secure transfer of XML data in everything from giant networks to handheld devices.

The venerable World Wide Web Consortium (W3C) adopted Efficient XML Interchange (EXI) in 2011 as the new global standard for super-efficient data transmission, fulfilling AgileDelta's ambitious, original SBIR goal of developing a new global standard. Technology writers called W3C's action "an event of historic importance," akin to the announcement of a new transcontinental railroad. Indeed, if the fastest U.S. trains experienced the same improvement, they would travel at 15,000 miles per hour and make the trip from Boston, Massachusetts, to Washington, DC, in just over four minutes.



Lining up with the W3C, the Zigbee Alliance and Internet Engineering Task Force have also adopted the technology—both are key players in laying the foundation for the "Smart Grid" and "Internet of Things," nothing less than the future network of internet-connected devices.

The Telecommunications Industry Association adopted EXI as a standard for digital radios, the Gaming Standards Association adopted it for gaming systems, the Open Network Video Interface Forum adopted EXI as a global standard for IP-based security systems, and the XMPP Standards Foundation is adopting it as a standard for chat.

Efficient XML has also been integrated as a key technology in the automotive industry, enabling the next generation of smart cars. The technology supports communication with vehicles via smartphone—locking and unlocking a car or setting speed and boundary alerts, for instance—and allows real-time updates on traffic, weather, and road conditions crowdsourced using vehicle sensors. Not surprisingly, the International Organization for Standardization (ISO) has adopted EXI as the standard for communication between electric vehicles and the electric grid. Over 700,000 automobiles are now on the road using AgileDelta's Efficient XML, with hundreds more being added daily.

"The SBIR was crucial to accelerating development of the technology at a critical time when industry was looking to develop a standard for efficient data exchange," said Schneider. "If we had missed this window, industry would have likely developed a standard based on older, less efficient technologies that weren't going to meet DoD needs."

TechLink

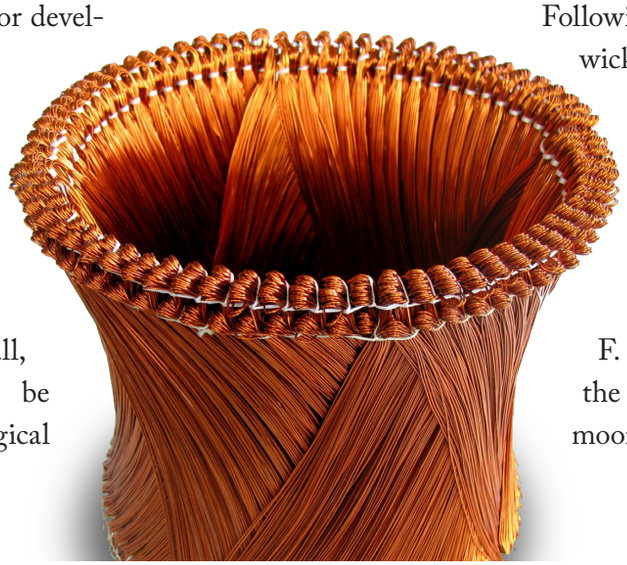
STRIKING COPPER

A New Hampshire family business designs magnetic components critical to multiple technologies, from motorized surgical equipment to long-range missiles

Behind some of the world's most powerful missiles is a tiny, precision-wound component that ensures the payload reaches its target. And behind these components is a New Hampshire-based company, Airex, that, with help from several Small Business Innovation Research contracts, has risen to the forefront of commercial and military motor development and manufacture.

Founded more than a half-century ago by plastics pioneer Richard Sedgewick, the company found its feet creating epoxy molds into which it fixed copper coils, creating small, precise motors that could be used in everything from surgical instruments to wafer repair, molecular IR absorption spectrometry to nuclear missiles.

"These things, in some cases, go around and around, and in some cases they go back and forth, but they always have copper wire," said Jim Sedgewick, Richard's son and current Airex president.



Following the first-generation Sedgewick's lead and starting in the 1960 and 1970s, the company found a home in aircraft, implementing its mechanical gyroscopes into commercial planes and short-range missiles. Around the same time as President John F. Kennedy famously announced the United States would land on the moon within the decade, Airex was

All photos courtesy of Airex

hard at work at Raytheon and in the Charles Stark Draper Laboratory (formerly a research lab based out of MIT) developing the electromagnetic components that would power the guidance systems for nuclear missiles.

With a range of more than 7,000 miles, the famous Peacekeeper and Trident missile systems developed by the U.S. military require state-of-the-art guidance programs. These high-precision programs necessitated the development of custom magnetic components, a void that Airex eagerly stepped in to fill. Their efficient design featured automated manufacturing, insuring precise unit-to-unit repeatability. Later, the company applied this evolving technology to highly efficient actuators that could help guide aircraft missiles while using less energy than traditional components.

"The military help to develop the technology in the 1990s gave us the commercial applications, which in turn has given us enough ongoing business to serve the military needs," Sedgewick said.

Growing up, Jim Sedgewick had watched his father mold the company into a versatile design powerhouse, pivoting from plastics to electromagnetic actuators. In 1988, the senior Sedgewick handed the reins to his son who, by that time, had established himself as an adroit businessman.

Under Jim Sedgewick's guidance, the company further refined its technology, deploying the automated winding of the copper coils to a manufacturing floor that featured the highest quality levels to insure repeatability and consistency for its motors. The company was also able to upgrade the density of the copper itself, making for components that were both more powerful and more versatile.

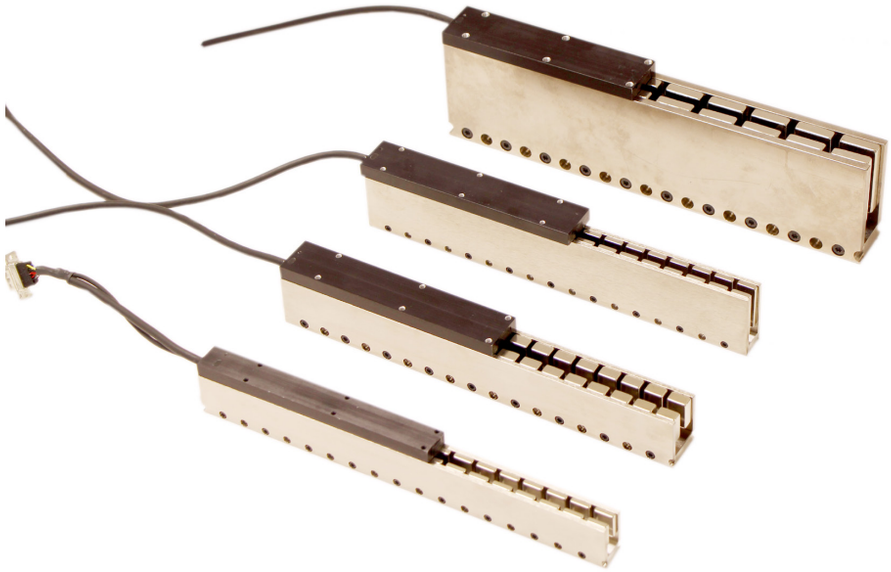
In the mid-1990s, Airex went through its first SBIR contract process. The company saw an opportunity to commercialize the same technology it had long used for the military. The SBIR funding, Sedgewick said, was crucial — particularly at a time when defense budgets were tightening. The company struck gold with one of its first commercialization efforts, contracting with medical equipment giant Stryker Instruments to help build miniature motors for operating room tools such as bone drills, bone saws and pin inserters. With their uniform, consistent torque, Airex's lightweight motors proved perfect for surgical applications. The automated manufacturing systems — developed with the help of the SBIR program — made commercial deployment possible.

The company has since worked with Northrop, Lockheed, Honeywell, Raytheon and General Dynamics to deploy this technology across multiple defense platforms.

"There's been huge commercial interest in the motors," Sedgewick said. "It's basically one of the best performing parts of our business."

The dual-use relationship between the military and commercial sides of the business has been a reciprocal one, he noted, where each side benefits from the other.

Jim Sedgewick with daughter Lindsay Badger

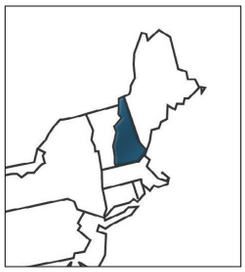


The "Ironless Linear Motors" created by Airex are meant for actuators, precision stages, photonics platforms, semiconductor equipment, pick-and-place systems, and inspection systems requiring responsive control at high bandwidths.

"The military help to develop the technology in the 1990s gave us the commercial applications, which in turn has given us enough ongoing business to serve the military needs," Sedgewick said. "The high-performance designs required on the military side are attractive for high-end commercial markets, while the cost reductions required on the commercial side to stay competitive work to the advantage of the military."

Airex continued to obtain SBIR funding into the early 2000s, including two large Phase II contracts to develop more technology for the U.S. Air Force. Some of this included preliminary work on a magnetic bearing-style motor that Sedgewick believes could one day replace more traditional copper counterparts.

"There are other technologies, but regardless we believe there is a place for this tech going forward," he said. "We think there really is a demand for high-end components, whether that be magnetic bearing-type components or motor components."



In keeping with Airex's history as a family company, Sedgewick's daughter, Lindsay Badger, recently took over as general manager. With her extensive experience, Badger hopes to move Airex into a future beyond mechanical-style gyroscopes while remaining grounded in the high-quality tech and diversity of applications that has served the company well.

The SBIR program provided foundational financial and networking support that Sedgewick called "absolutely fundamental" to companies, no matter their size or ambitions. Having access to resources that can help develop new technologies is critical to small business, and drives increased performance for both military and commercial application.

"(The SBIR program) sustained us through those couple years which were very tough on the commercial side," he said. "There's still a fundamental need for development in this country that will bridge to the next technology. The diversity provided by the SBIR, in the same way you diversify your stock portfolios, can really be helpful for a company."

Airex Corp.

Dover, NH • SBIR contract: F04701-96-C-0045 • Agency: Air Force • Topic: AF93-104, Manufacture of Stator and Rotor Assemblies for Missile SFIR Assembly

LASER-GUIDED EFFICIENCY

Innovations in 3-D laser projection aid in the manufacture, assembly, and inspection of composite materials

As the world's leading industrial laser-projection company, Aligned Vision has spent decades helping fabricators streamline their manufacturing processes even while increasing accuracy and cutting costs. An important early linchpin in the success of the company—which today contracts with Boeing, Lockheed Martin, Northrop Grumman, and many others—was a 1990s contract from the Air Force's Small Business Innovation Research (SBIR) program.

In the early 1980s, Scott Blake, now president of Aligned Vision, worked for a company that produced laser media as part of "big laser light shows" for corporate special events and spectacles such as the Olympics, Super Bowls, and the Statue of Liberty rededication ceremony. In a major twist of fate, the technology attracted the interest of the Sikorsky Aircraft Corporation, a division of Lockheed, which wanted to use it to project the dimensions and locations on blueprints for aircraft builds to assist in the manufacturing process.

In response, Blake formed Assembly Guidance (now Aligned Vision), and pioneered 3-D laser projection technology to guide the hand layup of composite materials in the manufacture of advanced aircraft. The business supplied laser-based assembly guidance systems to companies that included Sikorsky and Learjet. But then the aerospace industry saw a recession in the 1990s.

That, Blake said, is where the SBIR came in. "One of the key things that kept us in business in the lean times and kept our business moving forward was that SBIR."

The Assembly Guidance team had a vision for a new kind of projection system, one that would not only create laser projectors to facilitate the assembly of composite components but would also instruct workers in how to actually fabricate the composite materials, and automatically inspect the materials afterward.

With its detailed proposal, the company received a Phase I SBIR contract from the Air Force to design and build a concept.

Their initial concept, Blake said, "was really ugly, but it worked."

In fact, the concept was so successful, and received enough outside interest from the aerospace sector, that Aligned Vision was able to commercialize its Laserguide technology even before the company received the second phase of its SBIR award. During the Phase II work, the team focused on helping manufacturers get composite materials set precisely in place during builds. Out of this "composite manufacturing process control system" came a new generation of automated inspection systems, Laservision.

"Without LASERVISION, inspection is done by people, and while people have good mobility and visual and tactile senses, they are not accurate or rigorous," Blake said. "[Our systems] cost a lot less than human inspectors, do a much better job of inspecting, and create documentation from the process that you can't get from a human inspector."

Manufacturers want to know what's going into all their various parts, he said, explaining that the SBIR-funded inspection system has evolved into a way to verify and document the integrity of each part during every step of its production.

The company has firmly established itself as the go-to solution for aerospace manufacturers, and just about everything that flies uses at least one of Aligned Visions' systems in its manufacture, Blake said, including the F-22, F-35, 787 and the H-60 family of military helicopters. Aligned Vision also works with ship builders, and has pegged the automotive industry as its next frontier. In 2000, the company, grown to include roughly 30 employees, received the coveted Tibbetts Award for its SBIR work on automated manufacturing processes.

Blake credits the SBIR program for giving his company a shot in the arm when it needed it most, propelling it to the successful position it's in today.

Over the years, other companies have imitated and adopted laser systems similar to those developed by Aligned Vision. It's no wonder. As Blake said, the systems have been so effective at reducing errors, improving speed, and saving money that they've become industry standard among many aerospace companies.

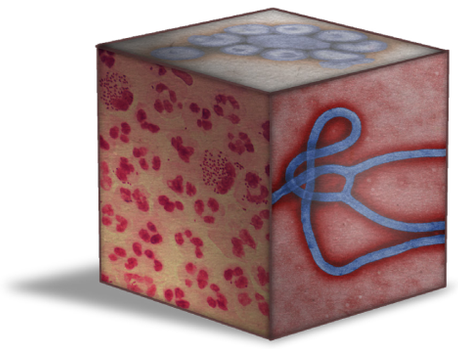
Blake credits the SBIR program for giving his company a shot in the arm when it needed it most, propelling it to the successful position it's in today. "To me, it's an ideal way to drive new technologies," he said. "All new technology has risks, and if the envelope is really being pushed there will be failures. SBIR funding enables the ability to work through failures to achieve new levels of performance that benefit everyone."

Aligned Vision

Chelmsford, MA • SBIR contract: F33615-96-C-5627 • Agency: Air Force • Topic: AF95-193, Composite Manufacturing Process Control System

An Air Force SBIR contract helps create a safe, portable, fully automated bio-detection system

LABORATORY in a BOX



In late 2013, a mysterious disease began spreading through a small village in the West African nation of Guinea. First an 18-month-old boy, seen playing by a hollow tree where bats were roosting, suddenly fell ill with fever and vomiting. He died two days later, followed in the next few weeks by several members of his immediate and extended family. It was the beginning of the largest Ebola outbreak in history. By late 2014, the virus-borne disease had sickened more than 20,000 people, claiming thousands of lives in West Africa. American troops were deployed to help battle the outbreak, carrying with them crucial medical supplies and materials to build treatment units.

In the midst of the outbreak, an Emergency Use Authorization from the FDA gave American medical workers access to an important new testing tool—an innovative "lab in a box," called FilmArray, developed by the BioFire Defense Company with support from the

Air Force Small Business Innovation Research (SBIR) program. For the first time, medical workers could safely, efficiently, and accurately test for the Ebola virus out in the field.

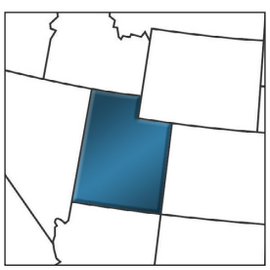
"This is the kind of test that a reference laboratory would do, except it's packaged in a way that you can do it all in a little box," said Kirk Ririe, co-founder and Chief Executive Officer of BioFire Defense. "It's like an entire reference lab packed into a cubic foot of instrumentation."

Whether it's a global outbreak like Ebola or a superbug raging within the confines of a community clinic, the first step in disease containment is biosurveillance—the gathering, analysis, and communication of information related to disease activity. But detecting pathogens in the field can be difficult, if not impossible. Without a laboratory, fragile chemicals might not be stored properly and equipment can be easily damaged. The FilmArray resolves all of those concerns in one closed-system device about the size of a small desktop printer. In true plug-and-play fashion, the FilmArray system is simple for anyone to use, takes only two minutes of prep time, and minimizes contact with potential contagions. A patient sample (blood, saliva, or other bodily fluid) is injected along with a little water into small plastic packet and inserted into the FilmArray device, which is connected to a laptop computer. FilmArray performs all the diagnostic operations and returns accurate results in about an hour, reporting which pathogens have been detected, as well as which can be ruled out. Using the same sample in a single test packet, the system can analyze, identify, and report on multiple pathogens at once, including the Ebola virus, Marburg virus, and anthrax. To do the same work in a conventional reference lab, a technician would have to physically split up a sample among different tests—a time-consuming procedure that could cost thousands of dollars. In comparison, a single FilmArray packet costs under $150.

Kirk Ririe is working to make FilmArray available to a more global market, putting easy-to-use disease diagnostics into the hands of as many people as possible.

To discover whether a specific bacterium or virus exists within a patient sample, FilmArray utilizes the polymerase chain reaction (PCR), a process used in molecular biology to amplify single copies of DNA. If there's any trace of the target DNA, PCR multiplies it by millions of times making it easier to detect—like replicating many needles from the single one hidden in a haystack. Ordinarily, PCR requires several different chemical reagents, all kept at specific temperatures, to be carefully measured and mixed together by a trained lab technician.

"When you're using the PCR technology, you're typically in a laboratory with refrigerators and freezers, and almost all of the regents are in liquid form," explained Deepika de Silva, the Executive Vice President of Chemistry at BioFire. "This makes it really hard to deploy the tests into any remote area." BioFire, however, developed freeze-dried reagents—revolutionizing bio-detection by making portable testing feasible. The FilmArray's ease of use, small size, and reliability enables bedside monitoring of patients in isolation, and significantly reduces the time to get diagnostic results. In fact, the medical team at Emory University Hospital used FilmArray to diagnose the first two Ebola patients infected in the U.S. Three hundred hospitals and counting have adopted FilmArray, and other users include the Department of Health and Human Services, Department of Defense, and state and local law enforcement.



BioFire began as Idaho Technology in 1990, co-founded by three friends working in the corner of a potato equipment facility. They met at Utah State University, where Ririe and Randy Rasmussen were undergraduate students under the guidance

Loading a test packet into the FilmArray device.

of then-PhD candidate Carl Wittwer. Their goal was nothing less than the elimination of disease through smart thinking and innovation.

"The three of us became good friends and essentially worked together for our entire careers," Ririe said. "We've had moving meetings every week where we climb a mountain in Research Park [near University of Utah] and talk."

Early SBIR funds awarded to Idaho Technology in 2001 enabled the group to develop the freeze-dried reagents, and additional Air Force SBIR contracts allowed the company to create the rapid PCR machine and further develop the technology for military biothreat testing. Over the next two decades, the Salt Lake City-based company hammered away to perfect the device throughout multiple product stages, making it more compact and durable while still maintaining a high level of accuracy.

The name was changed from Idaho Technology to BioFire Diagnostics in 2012. In January 2014, the company was acquired by the multinational biotechnology company BioMérieux. The original company was split into two groups, BioFire Defense and BioFire Diagnostics, which developed more products reflecting their military and medical specializations. BioFire Defense's FilmArray BioSurveillance System can recognize 16 different biothreat pathogens at once (this was the technology the FDA approved for emergency use in Ebola detection). BioFire Diagnostics currently has four FDA-cleared medical panels—respiratory, blood culture, gastrointestinal, and meningitis—that test for viruses, bacteria, parasites, yeast, and antimicrobial resistance genes.

"With FilmArray, you can run a pouch that tests for all the common causes of respiratory infection in one hour, and in the next hour, run a bio-threat test," Ririe said.

Ririe is working to make FilmArray available to a more global market, putting easy-to-use disease diagnostics into the hands of as many people as possible. Most of the company's sales are still in the U.S., but international sales are ramping up quickly.

"We have one of the world's only FDA-approved Ebola tests, and the safest Ebola test, period," Ririe said.

From its humble beginnings in a potato equipment warehouse, BioFire is setting the standard for molecular diagnostics, and is on its way to fulfilling the co-founders' original quest of making the world a healthier and safer place.

DEPTH CHARGES

Photos Courtesy General Dynamics Mission Systems

Navy SBIR leads to Resilient, rechargeable batteries powering autonomous undersea applications

On March 8, 2014, Malaysia Airlines Flight 370 disappeared over the Andaman Sea. After an erratic flight path, it slipped off the radar and under the waves, carrying 239 passengers and crew members. The disappearance triggered one of largest, most extensive, and expensive multinational aviation search efforts in history.

A few weeks later, Phoenix International, a marine service contractor that provides worldwide manned and unmanned underwater services, deployed a Bluefin-21 autonomous underwater vehicle (AUV)—powered by Bluefin's 1.5kWh subsea battery—to conduct underwater sensor sweeps, aiding in the search.

The Bluefin-21 AUV was developed by Bluefin Robotics—a small business founded in 1997 by a group of engineers from Massachusetts Institute of Technology's AUV lab. In February 2016, Bluefin Robotics was acquired by General Dynamics Mission Systems, a business unit of General Dynamics. Since the acquisition, General Dynamics has continued to invest in, and advance, the Bluefin Robotics AUV products and related subsea power solutions. They are now fielded worldwide, across both defense and commercial industries.

Regarding the Malaysian Air search, Chris Moore,

Director of Commercial Operations, Phoenix International, said, "We had a lot of great support from Bluefin Robotics, and we successfully dove 15 times down to 5,000-plus meters, doing side-scan sonar surveys looking for a debris field from the airplane crash. On one of our dives, we achieved 27 hours of endurance off one of the Bluefin battery banks." The endurance and depth both earned world records for the Bluefin-21 AUV, which was powered by technology developed with the help of a Navy SBIR award.

Certainly, undersea search and rescue is a vital activity. But the applications for the Bluefin battery to power AUVs, or autonomous robots for underwater applications, extend beyond search and rescue.

The Bluefin-21 is a torpedo-shaped AUV that can be used to conduct both military and civilian oceanic operations. Within the Bluefin-21 (and other untethered robots) the Bluefin 1.5kWh subsea battery is the operational foundation for use in deep water, keeping sailors out of harm's way. The AUV can be used for mine countermeasures, anti-submarine warfare, and mapping of the sea floor. It also has applications in oil and gas exploration, archaeological investigations, and for assessing infrastructure safety.

Bluefin Robotics' subsea batteries leverage a rigorously tested, fully submersible, modular design that eliminates a need for the battery to be packaged in a heavy, sealed vessel. The rechargeable lithium-polymer cells provide high energy-density and the modularity of the batteries enable rapid battery swapping and speedy redeployment of subsea devices or AUVs.

"Instead of a heavy vessel that can withstand pressure, the unique battery design saves on weight and space, and that increases the energy density," said Adam Mara, Director of Power Systems for the Bluefin Robotics product line of the Maritime and Strategic Systems business unit within General Dynamics Mission Systems.

The 30-pound battery can not only be placed directly into the water, the battery electronics include built-in protection, monitoring, power control, and battery conditioning. Its functional design allows a user to simply replace a discharged battery with a charged one, enabling battery "swappability" and the rapid turnaround of submersible equipment.

"You can change out the equipment very fast. Instead of having to open up a pressure vessel, which takes a lot of time, you just get the AUV out of the water, swap out the batteries, and it is ready to re-use—all in half an hour," said Mara.

Mara said, "This SBIR funding, as well as internal investment, helped us develop and test our new battery capability down to 6,000 meters."

Finally, the Bluefin 1.5-kWh subsea battery has a fully automated charging system. Full battery recharge can be accomplished in six hours or less. And it can operate for up to 16 consecutive hours.

"Power is the driving technology behind all autonomous robots. Our original goal was to develop a battery to withstand pressure at underwater depths. This pressure-tolerant battery technology allows our AUVS to operate efficiently at deep depths for long durations," Mara said.

Creating a reliable underwater electric power source is a challenging engineering task. With a Small Business Innovation Research (SBIR) contract from the Navy's Office of Naval Research in 2001, Bluefin Robotics was able to achieve this feat, and emerge as a world leader in AUV products designed for defense, commercial, and scientific applications.

Mara said, "This SBIR funding, as well as internal investment, helped us develop and test our new battery capability down to 6,000 meters. That spun off into a new power line that is now available to everyone. If Bluefin Robotics didn't have the SBIR, we would not

Working in Boston harbor, a specialist installs a Bluefin battery into an autonomous underwater vehicle.

have been able to go to deep depths."

Its UN-certified, stainless-steel shipping container allows AUV deliveries by ground, sea, or air, making it highly desirable for subsea emergency-response operations, both in military and civilian theaters. "One of the most important features concerning developing a battery that is not housed in a vessel," Mara said, "is the ability to respond rapidly. Our batteries can be shipped anywhere, ready for use."

The Bluefin battery can power multiple types of payloads, including geophysical payloads that collect bathymetry data and backscatter data; high resolution cameras; and mineral survey payloads. The battery also powers electric field sensors, magnetometers, conductivity temperature and depth sensors, and navigation, telemetry, and propulsion systems.

The Bluefin battery is now a critical part of the General Dynamics Mission Systems product family of AUVs. These batteries have also been used to power remotely operated vehicles (ROVs), profilers, buoys, and submersible systems.

Mara added, "The AUV industry is expanding rapidly. Demand for a reliable power system is increasing. The number of sensors that people use, and the number of applications for subsea power, are expanding. This unique power solution gives users surface access to the deepest depths of our oceans in order to carry out thousands of different kinds of activities."

Bluefin Robotics Corp. (General Dynamics)

Cambridge, MA (Fairfax, VA) • SBIR contract: N00014-01-C-0205 • Agency: Navy • Topic: N99-215, Pressure-Tolerant Batteries for Autonomous Undersea Applications

Pure Innovation

Photos courtesy Cascade Designs

An outdoor recreation company in Washington state creates water-purification solutions

What do expedition hikers on the Pacific Crest Trail have in common with U.S. warfighters on the ground in Afghanistan? Among other things, they all need to tend to their bodies' most basic requirements: food, shelter, clothing, and, perhaps most of all…water.

Like the 2,650-mile trail with its dry, 30-mile stretches, soldiers in harsh climates are often faced with limited access to clean water, a limitation that poses a serious threat not only to the success of a given operation but to the very survival of the warfighters.

In a conflict zone, when treating local water isn't an option, the standard operating procedure has been to airdrop water bottle packages from planes or helicopters. But in locations such as Iraq and Afghanistan, wherein a few minutes of exposure might be lethal, that bottled water comes at a huge cost. And at other times, soldiers might be wading through what

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seems to be clean water, wondering why they can't just bend down and take a drink. But endemic contamination, invisible and often tasteless, poses its own risks.

In order for warfighters to drink from indigenous water sources, the Army needed an affordable, fast, single-pass solution that would address viruses, be resistant to freezing and thawing, and be simple to use by anyone, anywhere, anytime.

The same ultrafiltration hollow-fiber membrane technology developed for the military came to be featured in the commercial MSR Guardian hand-pump purifier.

In 2008, the U.S. Army issued a Request for Information to the domestic water purification market. The Army was interested in commercially available, off-the-shelf, water treatment devices that troops in the field could use easily and efficiently. Finding nothing suitable for the harsh conditions faced by the warfighter, a Small Business Innovation Research (SBIR) solicitation was issued to encourage small businesses to compete for the research and development of an innovative water purification device robust enough to meet warfighters' needs.

"The SBIR program allows us to reach out and build partnerships that may not otherwise exist," said Jeffrey Pacuska, team leader for the soldier clothing and configuration management team at the Natick Soldier Research Development and Engineering Center (NSRDEC or Natick Labs). "We utilize the SBIR program to facilitate the incorporation of novel technologies that come out of small businesses and parts of the American industrial base that we don't always have the opportunity to work with. We take those technologies and put them into soldier platforms where we can have a defined impact on soldier survivability and lethality."

Doug Sanders said, "We couldn't be prouder of our work and the trust the US military has ultimately placed in our gear."

Seattle-based Mountain Safety Research (MSR) and its parent company, Cascade Designs, were well-positioned to address the Army's needs. With a world-class research and development laboratory, this nearly 50-year-old, family-owned small business successfully researches, engineers, tests, manufactures, and markets gear for outdoor enthusiasts worldwide. MSR had been manufacturing conventional water micro-filters for decades—but only to treat bacteria and protozoa. Water purification that addresses viruses had previously been a time consuming, costly, two-step process, requiring chlorine or iodine to be added to filtered water.

Responding to the SBIR solicitation topic, MSR worked with the Army team at the Natick Labs in Massachusetts to develop and propose the holy grail of water filters—an "ultra-filtration" individual water treatment device (IWTD).

Utilizing best-in-class hollow fiber technology, their IWTD came to be part of an integrated drinking system. Water taken directly from local sources is placed in a bladder with an attached drinking tube. The IWTD is then spliced into the tube so the user can drink directly from the bladder, pulling water through the purifier.

A military focus group was established so user feedback could be incorporated into the development pro-

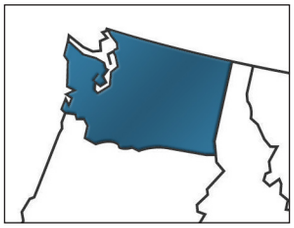
cess. "By working with MSR from the outset on the technology development," Pacuska said, "we were able to make sure that all of the requirements, those needs that soldiers have, were captured within that program, so that the final product has a high level of survivability and soldier acceptability."

Pacuska added that "we can test things in the mountains, we can test things in airplanes. We can go wherever we need to ensure that the item is going to meet those soldier-capability needs." Field testing for the MSR IWTD was extensive, and lasted for several iterations over many years. Full scale evaluations were ultimately performed at the Army's Jungle Operations Training program in Hawaii, resulting in high-profile field trials. The relationship enabled Natick Labs to push MSR to achieve mil-spec requirements for ultra-filtration. This had never been accomplished before.

"Working in tandem with Natick Labs has undoubtedly made MSR a better product-design company," said Doug Sanders, Vice President, MSR. "The development of core technology that meets the stringent needs of the U.S. military has informed and furthered our ability to provide clean water to MSR's outdoor customers. We could not be prouder of our work and the trust the U.S. military has ultimately placed in our gear for our nation's troops around the world."

In the end, two different products were designed—one for the military and another for the outdoor market. The same ultrafiltration hollow-fiber membrane technology developed for the military came to be featured in the commercial MSR Guardian hand-pump purifier. Launched in 2015, the Guardian received numerous prestigious design awards and enabled MSR to lead the outdoor market (in sales dollars) for water treatment products in 2016.

As of 2018, all U.S. Army foot soldiers (forward deployed infantry) will now be outfitted with the IWTD. The device provides soldiers with the safety and security of knowing that they can meet their own water requirements, greatly increasing their chances of success and survival in challenging and worst-case scenarios. According to Army Captain Kristopher Hartwell, the new IWTD also offers new flexibility for mission commanders. Now, Hartwell said, mission commanders "can consider using indigenous water supplies of unknown qualities, to filter and drink water where they weren't capable of doing that before. The IWTD creates much-needed flexibility in a commander's logistical support planning."



The Individual Water Treatment Device has been declared a unilateral success, both for the U.S. Army and for MSR. As a result, a warfighter on the battlefield in Afghanistan and a hiker on the Pacific Crest Trail can now both quickly and easily access safe, clean, potable water.

Innovations created by MSR benefit the Department of Defense as well as commercial markets.

Cascade Designs

Seattle, WA • SBIR contract: W911QY-11-C-0004 • Agency: Army • Topic: A09-161, Modular In-Line Water Purifier for MOLLE Hydration Systems

beating the HEAT

Jefunme / Shutterstock.com

Cryogenic machining technology for titanium alloys

Titanium has the highest strength-to-density ratio of any metallic element—making titanium alloys as strong as steel at only about half the weight. The alloys are also highly resistant to corrosion and have very low thermal conductivity. For all those excellent reasons, engineers are integrating titanium materials into the airframes of advanced military aircraft, including the state-of-the-art F-35 Lightning II Joint Strike Fighter.

Before titanium could be fully integrated into the production of advanced aircraft, however, certain machining challenges had to be overcome. Some of the very properties that make titanium so attractive for aircraft construction (like its toughness and heat resistence) also make the material exceedingly difficult to machine. When cutting or drilling titanium, heat quickly builds up on the cutting tool. Heat makes the tool softer, leading to increased friction, dulling, and rapid deterioration. This slows machining speed, which translates into higher production costs. One common way to dissipate machinging heat is through flood cooling, the flooding (or liberal dousing) of the cutting tool with a liquid coolant during the machining process. But flood cooling is inefficient, and because of the nature of the liquids used, can be unsafe for workers and the environment.

In the 1980s, companies began experimenting with cryogenic (very low temperature) coolants such as liquid nitrogen. Although the coolant was innovative, the method of delivery was the same old thing: spraying a jet of liquid into the machining zone.

One of the big problems in using liquid nitrogen as a flood coolant, according to Jay Rozzi, Principal Engineer and Partner at the engineering services company Creare, "is the nitrogen turns to vapor, which is a suffocation hazard, so you need a

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complex venting system." And for all that, he said, the result was only a ten percent to twenty percent increase in processing speed. "It wasn't worth it."

In 2002, Creare received a Small Business Innovation Research (SBIR) contract from the Enviromental Protection Agency (EPA) to investigate alternatives that would reduce the use of environmentally harmful chemicals and improve worker health and safety.

Instead of using the "brute force" approach of flood cooling, Rozzi and his colleagues ran a small flow of liquid nitrogen through the machine spindle and tool itself to absorb heat internally, rather than externally cooling the entire machining area. Their strategy required less than two-tenths of a liter per minute, far less than the amount required for flooding.

"You're only cooling the tool and nothing else," said Rozzi, "so it's possible to absorb the heat of machining very effectively and enhance the processing speed in titanium by two or three times, while improving your tool life by a factor of ten or more. These are order-of-magnitude improvements."

In 2007 Creare won an Air Force Small Business Innovation Research (SBIR) contract sponsored by the Joint Strike Fighter program, which was critical in helping the company devise a way to deliver cryogens through the spindle of an existing machine tool rather than having to start from scratch by using a vacuum-insulated tube called a cryogenic lance. This technology development was key to enabling retrofits on existing machines.

"For multi-dimensional, complex technologies like this," said Rozzi, "SBIR funding is absolutely critical to take something from a nice science project, if you will, to a technology that can be integrated into real machines."

In 2009, the international manufacturing technology group MAG Industrial Automation Systems licensed the technology from Creare. MAG started a new enterprise 5ME, which has taken over the license. 5ME is now selling retrofit systems for milling, boring, and turning purposes, and is working with several machine and tooling manufacturers to market the technology broadly.

Lockheed Martin acquired equipment utilizing the cryogenic technology for cutting titanium F-35 components in 2015. Test cuts showed a 52-percent increase in cutting speeds as well as improved surface integrity and part quality. According to Lockheed, cryogenic technology will help lower the cost of large titanium parts by an estimated 30 percent.

For its part, Creare continues to work on solutions for engineering problems in such diverse fields as cryogenics, robotics, advanced materials, and biomedical engineering.

"This has a significant impact on cost savings for initiatives like the F-35 program," said Pete Tecos of 5ME, "not only in increased cutting speeds, but also through lower energy consumption, improved worker safety, and the elimination of the infrastructure and disposal required with flood coolants."

For its part, Creare continues to work on solutions for engineering problems in such diverse fields as cryogenics, robotics, advanced materials, and biomedical engineering. Projects have included a cryogenic refrigerator for NASA that is currently on the Hubble Space Telescope, signal processing software for cardiac electrophysiology, and two miniature vacuum pumps used onboard the Curiosity Rover on Mars.

"We have been fairly active participants in the SBIR program ever since it was founded in 1983," said Bob Kline-Schoder, President and Principal Engineer at Creare. "Our main goals have been and continue to be to do really cutting-edge research and development work."

That's a good thing. Who knows what new advanced material—with what new confounding challenge—is just around the corner.

Straight, Flush

U.S. Air Force photo by Master Sgt. Donald R. Allen

The Creare fastener measurement tool uses lasers to save time and money

The composite panels that make up the skin of the F-35 Lightning II are attached to its frame with tens of thousands of fasteners. To ensure that the aircraft meets operational specifications, every one of these fasteners needs to sit flush relative to the skin's surface. Even a single high fastener, if not caught until the later stages of the manufacturing process, would require the aircraft to be put back on the assembly line.

For full-rate production of the F-35, operators must install and fill 30,000 fasteners per day. Historically, the methods used for inspecting fastener features

lacked accuracy, speed, and repeatability. Traditional handheld gauges were time-consuming and prone to operator-induced errors, while previous generation laser-line scanners could only probe a single cross-section of the part, which failed to capture the complex surface curvature.

"The aircraft has many, many holes to keep the skin in place on the sub-structure," said James Poindexter, Program Manager at the Air Force Research Laboratory, "and there's a tight requirement to measure them before they're filled, and then again after they are filled, to make sure all the holes meet their tolerance specification. The operators were using handheld gauges, like a tire pressure gauge, which would take about eight seconds to manually record a measurement for each hole."

The F-35 team at Lockheed Martin and Northrop Grumman needed a better, quicker solution for fastener inspection. As a result, engineering research and development firm Creare, under multiple Small Business Innovation Research (SBIR) contracts from the Air Force and Navy, with support from the Air Force Manufacturing Technology (ManTech) program, developed the handheld fastener measurement tool.

Fast, easy to use, and highly accurate, the fastener measurement tool works by projecting multiple laser lines onto the surface of the aircraft and imaging the resulting pattern with a camera. This technique, called structured lighting, can rapidly provide 3-D measurements of fastener profiles.

"The tool allows for measurement of the depth of a fastener once it has been put in an aircraft panel, which is not quite as simple as it sounds," said Dave Kynor, principal engineer at Creare. "You can imagine an aircraft panel is inevitably curved, and it might be curved in two directions. Then you put this fastener in, and you want to know how far it lies below the surface panel."

Initial SBIR funding to build the fastener measurement tool began in 2013. Creare spent the next four years performing technology development, testing, and demonstration in close collaboration with partners at Lockheed Martin. Toward the end of the Phase II contracts, the technology was transitioned to Creare's affiliate company, Edare, for production, sales, and subsequent technical support. Last year, Lockheed Martin placed the first order of 18 systems with the expectations that additional sales will follow.

"Creare was obviously the best company for the job, since they had done previous work for the Navy in this area," said Poindexter. "In addition, Lockheed afforded Creare the time to bring the prototypes that were being developed to the shop floor to gather real-world data and feedback."

Creare's system has been identified as one of the key technologies needed to meet the F-35 production rate goals for the U.S. Department of Defense.

Based in Hanover, New Hampshire, Creare was founded in 1961. Their focus was on technology commercialization. The company has a long-running history with the SBIR program since it began in 1982. Their contracts include success stories like a cryocooler for the Hubble Space Telescope, a spin-off dedicated to micromachining, licensing of Envelop® protective coverings, and delivery of specialized equipment for aircraft carrier catapults.

Kynor joined the company over twenty years ago, bringing with him an expertise in biomedical engineering, and began work on an intraoperative imaging system that employed structured lighting. The device incorporated laser scanning capability into a surgical laparoscope to provide highly detailed, real-time 3-D measurements of organ shape and position.

Eventually, Creare found other applications for structured lighting, including underwater imaging for the Navy and aircraft inspection for the Air Force. The technique projects a known pattern of light from a laser source onto a surface. The pattern then gets captured by a camera positioned at an oblique angle. A laser line

Photo courtesy Creare

Under multiple Small Business Innovation Research (SBIR) contracts from the Air Force and Navy, with support from the Air Force Manufacturing Technology (ManTech) program, Creare developed the handheld fastener measurement tool.

projected onto a flat surface would appear straight, but any uneven topography distorts the shape of the line. Thus, the deformed pattern captured by the camera is able to give detailed depth and surface information.

For the fastener management tool, Creare's engineers faced the challenge of packing the structured lighting system into a handheld device that needed to calculate results very quickly. Because operators are always moving around the production floor, the system—including its processor—had to be contained in a portable device. Kynor and his colleagues eventually went with a high-speed, battery-operated processor tethered to a belt pack, and managed to whittle the acquisition time down to two seconds for a go/no-go indication.

"When we scan the fastener, we get well in excess of 50,000 3-D points, and there is a lot of fitting and image processing involved to provide the inspector with a go/no-go answer," said Kynor. "Getting the processing time down to an acceptable value was really complicated, and took a significant effort."

Another challenge was making the fastener measurements highly accurate and repeatable in a portable, handheld device. They decided to add rubber feet on the tool so it would sit on the aircraft's surface at a known distance. The final device has repeatability that is better than 1/1000th of an inch.

Creare's system has been identified as one of the key technologies needed to meet the F-35 production rate goals for the U.S. Department of Defense. Since receiving the first units in September, 2017, Lockheed Martin has trained more than 100 people in how to use the tool. The main impact will likely be a reduction of labor costs and manufacturing cycle time. Lockheed Martin anticipates that the application of the technology on unfilled fasteners alone will lead to significant savings in time, with further savings expected when the device is expanded to measure filled fastener flushness.

"The SBIR funding itself was very important, but the Air Force involvement also facilitated a process where we got connected to key stakeholders at both Lockheed and the Air Force," said Kynor. "We went through a formal research and development methodology with design reviews, and that process was incredibly valuable."

Creare, Inc.

Hanover, NH • SBIR contracts: FA8650-14-C-5020, N00014-13-C-0384, FA8650-13-C-5185 • Agencies: Air Force / Navy
Topics: AF131-120, AF112-122, Fastener Measurement Tool

TechLink

Flight Upgrades

CTSi's Mudbucket technology enables faster, safer avionics updates

LCPL. John McGarity

As anyone who's experienced a major computer update can attest, a change to one system or program can easily render it incompatible with other programs. But what is typically a minor annoyance for consumers is a critical safety and operational problem for military vehicles such as fighter jets: With today's complex digital flight systems, any change to a system brings a new need to ensure all of a plane's systems communicate with each other as expected.

And the increasingly rapid proliferation of new advancements in flight systems (as well as in onboard systems on other military vehicles) means more frequent demands to integrate upgrades into existing systems—a process that formerly required years of time as well as costly and potentially dangerous flight testing.

Thanks to SBIR-funded technology developed by Maryland-based Coherent Technical Services, Inc. (CTSi), upgrades to vehicle systems can now be added quickly and inexpensively—and tested on the ground without the risk and expense of flight testing. CTSi's Mudbucket technology (for Multiplex Data Bus Controller/Translator Transmitter) streamlines the upgrade process by modifying data from new systems to enable it to communicate seamlessly with existing systems.

"What it does is it allows you to change the data on the bus [the apparatus that connects different systems] without the other systems on that bus realizing you've made a change," explained Tom Sanders, managing director of CTSi. "So if you have a system you want to replace or upgrade with a more modern system, then instead of making changes to the software that's already on the platform, you're able to make changes to the data going across the data bus. To the rest of the aircraft, it looks like the old system, while in fact it's a new system."

An example of Mudbucket's functionality is updating the radar on a fighter jet. "If you want to put new radar on an aircraft like the F-18 or F-16, and you want to avoid the time and cost of making the changes to

the software inside the mission computer, by using the Mudbucket, you can do the integration much, much faster and much more cheaply," Sanders said.

Mudbucket also allows more ambitious integration of new components into existing systems.

"We've got a project right now where we're going to put a new data link, a new helmet, new radar, a new display, and a new data recorder on an old platform, and we're going to do it without having to make changes to all the legacy systems on the platform," Sanders said. "So we're going to do all that stuff in less than a year and for less than $10 million dollars."

Previously, Sanders explained, implementing such upgrades would have taken several years and significantly greater cost, and would have required reprogramming the plane's mission computer software. Furthermore, updates could only be done during the plane's regular upgrade cycle, which could require waiting for years, Sanders said.

"For example, the F-18 is already locked down for the next several years, and so you would have to wait until you could get into the upgrade cycle to do something like this. And it would take a lot more money, there would be a lot more testing involved. So with our approach, you can have something like this done in less than a year. And you can do it when you need to, when it's convenient."

Mudbucket also provides a safe, inexpensive way to test flight systems. "If you've got a new avionics box, a new data link or something like that, you can make the Mudbucket represent the rest of the aircraft if you want to test out just that one box and see what it would be like to integrate it with the full aircraft," Sanders said. "So we're able to do a full integration test for that box before ever getting onto an aircraft. Anytime you can avoid having to touch an airplane or a weapons system or something like that and do your testing early in the development environment, it saves a lot of time and money."

The Army, Navy, and Air Force are all using Mudbucket, Sanders said. "They're still finding new uses for it. So for example, our Air Force customer is now using Mudbucket as a cybertest tool, and we're seeing more and more new applications like that—they're not even ideas that CTSi comes up with, they're coming from our customers. Once our customers understand the technology, they're able to bring applications that will have a very significant impact on their operations."

CTSi has also been exploring potential civilian applications for their technology, Sanders added. "We actually did some work for FedEx as they were looking to reduce the crew requirement for one of their aircraft. We think we may have other opportunities for work like that on the civilian side in the future."

Sanders said, "The SBIR program is what allowed us to get our start, and this would have never happened without the funding and the opportunities that they provided."

Because Mudbucket allows systems upgrades to be integrated quickly and inexpensively, it has also opened the door to other opportunities for innovation. "Now, instead of having to go to the original manufacturer that built the platform [to make upgrades], third-party vendors can come in and make changes to an aircraft that was previously locked up by proprietary data from the manufacturers. So it truly is an open-architecture solution that opens legacy platforms to third-party applications."

The SBIR program was a critical part of CTSi's growth, Sanders said. "The SBIR program is what allowed us to get our start, and this would have never happened without the funding and the opportunities that they provided. It's led to a lot of new opportunities and capabilities for CTSi. It's opened up doors for us with all the Services and NASA to use Mudbucket as a tool to bring new capabilities to their aircraft or tanks or ships or whatever, which has led to other opportunities for developing our capabilities."

Coherent Technical Services, Inc.

Lexington Park, MD • SBIR contract: N68335-11-C-0135 • Agency: Navy • Topic: A06-086, Navy Mudbucket Surrogate Aircraft Controller/Monitor

TechLink

PERSISTENCE on a LEASH

Photos courtesy CyPhy Works

A GROUNDBREAKING PERSISTENT UAV SAVES WARFIGHTER LIVES AND SHOWS ENORMOUS POTENTIAL IN THE MARKETPLACE

The police chief who handled the Columbine School shooting said that if he had been able to see what was happening inside the building, he would have sent officers in sooner. For an engineer at CyPhy Works, hearing that statement was a powerful "aha" moment. Would it be possible to create a small drone that could enter a structure and stay up for hours, even while providing secure communications?

Founded by Helen Greiner in 2008, CyPhy Works has become a leader in unmanned aerial vehicle (UAV) technology. This is the same Helen Greiner who co-founded iRobot, of Roomba vacuum fame. iRobot also developed the less well known PackBot, a military robot designed to carry out dangerous missions in high-threat scenarios. Since its creation, PackBot has saved the lives of countless warfighters. The new mission of CyPhy Works, located in Danvers, Massachusetts, was to target specific problems using robotic design.

A "persistent" drone, able to stay up for extended periods of time, might have helped at Columbine, and could be a life-saving tool for warfighters, too. In order to make the idea a reality, CyPhy Works turned to the Small Business Innovation Research (SBIR) program for development funding. An initial SBIR Phase I award from the National Science Foundation in 2009 was later "adopted" as a Phase II by the Defense Advanced Research Projects Agency (DARPA) in 2010, leading to a Rapid Innovation Funding award (RIF) from the U.S. Air Force. The result? A prototype of a pocket-sized tethered drone. This concept demonstrator was powered through a microfilament tether that allowed operators to remain at a safe distance during dangerous entry operations.

CyPhy Works delivered a few of the miniature tethered drones to the Air Force for use in confined spaces such as buildings, caves, and tunnels. But somewhere along the way to deployment and commercialization, demand emerged for a larger persistent UAV that could provide surveillance, reconnaissance, and communications.

"We had customers tell us, 'That tether thing is amazing. If we could just have [a larger UAV] that goes up and stays there, that would be really useful for us,'" Greiner said. "So we raised investment capital and built the PARC system, further evolving the tether and communications concepts developed under the initial SBIR."

CyPhy's Persistent Aerial Reconnaissance and Communications (PARC) system is a three-foot-wide flying hexacopter attached to a Kevlar-strengthened microfilament tether. The tether provides power as well as a closed communications link between copter and operator. PARC weighs 15 pounds, is able to carry its payload up to about 400 feet, and can stay aloft for more than 200 continuous hours of autonomous flight. A variety of payloads can be supported, including cameras, environmental sensors, and communications equipment.

Greiner cited SBIR funding as being vital to the development of the engineering concepts underlying both the pocket-sized drone as well as PARC.

According to Greiner, researching and developing the tether system was key to making PARC work. Problems such as wind and spooling of the tether (about the weight of a cell phone charge cord) had to be addressed, and the electronics and tether technologies that provide power and communications needed to be developed. "The spooler is a whole new invention," Greiner said.

CyPhy Works' Data Platform provides secure connectivity through the cloud, and allows personnel in the field and elsewhere to see in real-time what PARC is seeing. The technology is also protected from jamming, spoofing, and interception. Industry has been quick to see the value of a rugged UAV that provides stable, secure, and extended autonomous flight. There has been an influx of venture capital from interested companies, including General Catalyst, Lux, Motorola, and UPS.

Currently, CyPhy is marketing the PARC system for

Helen Greiner, founder of CyPhy Works, has spearheaded any number of innovations within the robotics and aerial vehicle sectors, generating value within the marketplace as well as saving the lives of American warfighters.

use in public safety venues and for monitoring operations in mining, construction, and the energy-industry. Two PARC systems were used for surveillance during the Boston Marathon, providing real-time video to the Massachusetts Emergency Management Agency's (MEMA) operation centers, which gave the system high marks.

Greiner cited SBIR funding as being vital to the development of the engineering concepts underlying both the pocket-sized drone as well as PARC. She explained that, as a small company, CyPhy Works had to choose one of the two projects to prioritize. The demand for PARC made it the obvious choice for commercialization. But that didn't preclude eventually commercializing the miniature drone or making it available for military uses.

"The Pocket Flyer has a lot of great military applications—tunnels, culverts, buildings," Greiner said. "The [military] could really use the Pocket Flyer so they don't have to put a guy into the building first. You could fly a robot in."

In the meantime, PARC is providing a persistent presence as an "eye in the sky" for American troops, companies, and citizens. The U.S. Army and Marine Corps have deployed PARC systems through both Special Operations and the U.S. Army's Rapid Equipping Force. The technology is in high demand.

According to Greiner, a representative from Special Forces told her that PARCs were saving lives. "That's a great feeling," Greiner said. "What's better than having your equipment come from the SBIR program and be out there at the tip of the spear helping with current operations and keeping our guys safe?"

CyPhy Works, Inc.

Framingham, MA • SBIR contract: W91CRB-10-C-0071 • Agency: DARPA • Topic: NSF-08-548, Extreme Access System for Entry (EASE)

THE REAL DEAL

New technologies transform the simulation industry

Before it moved its cutting-edge interfaces from the simulator to the real world, Distributed Simulation Technology, Inc. (DiSTI) jumpstarted business by helping get Air Force pilots off the ground.

As simulator technology matured in the 1990s, it became possible to network different flight simulators so pilots could wargame together. Such networking allowed pilots to climb into flight simulators in groups of four to dogfight. Without access to what those pilots were seeing, however, their instructors were flying blind.

In the late 1990s, the Air Force Research Lab sought a solution that would allow instructors to see, in real-time, the dizzying array of gauges and instruments in each simulated cockpit. At the time, dogfight

simulators ran on powerful graphic workstations, often while real instruments below the simulator displayed speed, altitude, and other vital information. The simulator technology was proprietary, but each workstation in a room shared information with the others using the relatively new Distributed Interactive Simulation (DIS) protocol.

In 1998, DiSTI won an Air Force Small Business Innovation Research (SBIR) contract to find a way to read DIS data from simulation networks and display them for instructors. Swinski and the company's other founders knew that a new graphics application programming interface called OpenGL could make the design of simulator displays much easier. Instead of attacking the problem by changing the instructor workstations, "We made a tool to make graphics," said Joe Swinski, DiSTI's president and CEO.

That tool, first used to simulate the cockpit of the A-10 "Warthog" fighter, allowed Air Force engineers to simulate instruments, which in turn allowed instructor workstations to share what the pilots were seeing. Manual gauges and instruments were replaced with flat-panel displays—graphical representations of the simulators' gauges and instruments.

Distributed Simulation

The graphic user interface on a cockpit tutorial.

"Using real instruments was expensive—tens of thousands of dollars in each cockpit," Swinski said. "So instead of using real instruments, they'd put in virtual instruments developed using GL Studio."

The technology became the core of DiSTI's flagship product, GL Studio, which transformed the simulation industry. GL Studio was the first simulation development tool to use OpenGL and C++, a commonly used programming language.

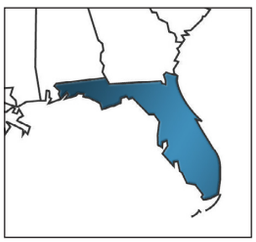
Even as it was transforming the industry, GL Studio was also opening the door for additional business. The Navy gave DiSTI its next major contract—to use GL Studio to create the first fully interactive 3-D trainer to help maintenance personnel learn how to service the F/A 18-C warplane. As its offerings grew in both the aviation and virtual-maintenance training spaces, DiSTI won business from commercial companies as well, including Boeing, Lockheed Martin, Honeywell, Raytheon, Thales Group, and BAE Systems, among others.

When they first started out with their handful of employees, DiSTI was focused more on training other companies to use the DIS protocol than on product development. But GL Studio and other technologies developed with SBIR support have helped DiSTI expand to an 80-employee company.

"Today, we're growing in the automotive space and the embedded world," Swinski said. "We've leveraged the technology that we built years ago as the business has migrated."

DiSTI's commercial success understates the overall impact the company's technology has had in the marketplace. DiSTI's technology was never patented, and has been adopted by dozens of additional companies in the simulation space and beyond. DiSTI-designed technology now powers a broad range of human-machine interfaces—interactive displays that control everything from smart phones to high-end medical equipment, cockpit instrumentation, automotive trainers, smart thermostats, and infotainment systems in cars.

As hardware has become smaller and cheaper, opportunities have expanded. Among other applications, DiSTI's technology has been used to develop displays for NASA's next-generation Orion and Virgin Galactic's commercial spacecraft. For this Florida company, the sky's no longer the limit.



FINDING FAULT

EVISIVE LEVERAGES MICROWAVES FOR A NOVEL, NONDESTRUCTIVE EVALUATION TECHNOLOGY

In the 1980s, Jack Little, President of Evisive, LLC, working in the nuclear power industry, encountered a vexing problem. "There is a flexible joint component made of reinforced rubber that joins the power-producing steam turbine and its condenser, while accommodating movement and expansion. When the part needs to be tested to assess its condition, the entire plant has to be shut down, the part removed, tested, and then reinstalled. It is a time-consuming and very costly process," he said.

Jack knew there had to be a better way. He wanted to be able to perform an in-place inspection of the component using a nondestructive evaluation (NDE) technique. But no technology existed to accomplish this. The dielectric, reinforced rubber was not amenable to ultrasonic or eddy current inspection, and the configuration prohibited radiography or other traditional condition assessment techniques. Undeterred, Jack looked for a new method.

Microwave radiation propagates in the expansion joint material and is reflected at every change in dielectric property, including defects, moisture, foreign matter, and physical geometry. Jack discovered that the radiation could be monitored as an interference pattern, dramatically reducing the complexity of microwave imaging systems (which are otherwise very similar

to radar), and thus making possible a portable, field-deployable tool. This phenomenon is what led Jack to conceive of, and ultimately patent, his disruptive technology in the early 1990s.

In short, the part being tested is immersed in microwave energy. These radiated microwaves interact with the detectors as they leave the transducer—and again as the reflected energy is returned. The energy reflected from the specimen, including response from the material and features within the material, is combined with the radiated energy to generate an interference pattern. A response is returned at each interface where the dielectric constant changes; or where there are defects or material property variations. Depending on the application, the transducer is positioned manually, using a hand-held wireless battery-powered probe; or mechanized positioning systems; or using fully automated robotic operation.

Detecting anomalies and defects in materials such as high-density polyethylene (HDPE), fiberglass, ceramic matrix composites (CMCs), fiber reinforced plastic, and reinforced rubber—used in a wide array of pipes, pumps, cooling towers, military combat vehicles, nuclear power plants, windmill turbines and advanced aerospace applications—requires nondestructive testing to assure integrity. Disassembling these critical components to examine them for defects and anomalies is often not an option.

Evisive's microwave NDE technology is now recognized by engineers around the world as the preferred method for inspecting a wide range of dielectric materials. This came as the result of research and development supported by contracts with the Small Business Innovation Research (SBIR) program. Of these, a U.S. Army project, NDE of Ceramic Armor, was critical. The U.S. Air Force project entitled Effective Nondestructive Detection and Quantification of Defects and Damage in Ceramic Matrix Composites (CMCs), dramatically advanced the technology. Additional SBIRs further refined Evisive's groundbreaking work.

The Air Force sought to develop a quality-control technology for manufacturing and condition assessment of advanced CMC materials for a wide range of applications. Unlike typical composites, where the matrix between reinforcing fibers is an organic resin, in CMC materials both the fiber and the matrix are ceramic. The complex reinforcing fiber structure makes these materials extremely challenging to inspect. Conventional testing methods capable of imaging the parts are time consuming and costly, and often not able to test the part in place.

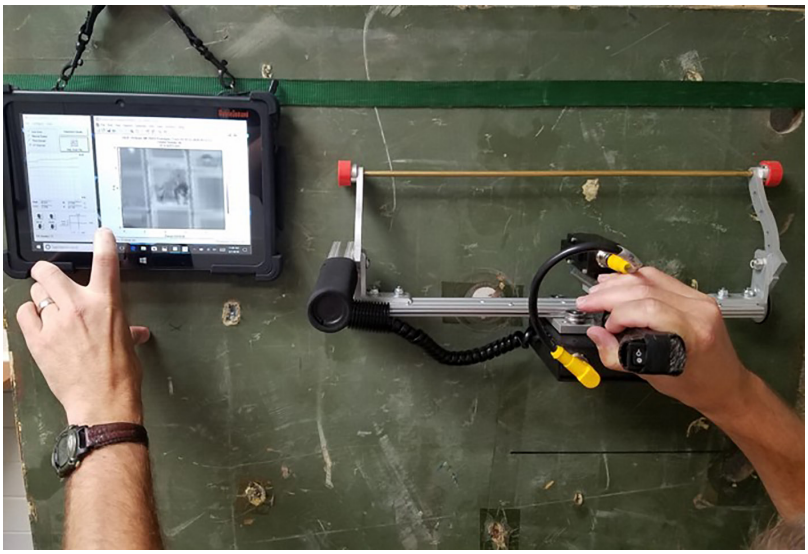
"During the Air Force project under Dr. George Jefferson, we developed and validated a method for efficiently creating a volume image of the material. This involved substantial equipment and methodology development," said Karl Schmidt, Evisive's Defense Applications Program Manager. The effort included development of the system to simultaneously image many layers of the material and present a 3D image.

> **"SBIR is an amazing asset to U.S. small business firms...In addition to providing a path to commercialization, it allows inventors to invent!"**

The Air Force SBIR enabled the testing of the technology for in-process measurement of material density, a critical attribute in the manufacturing process. The SBIR advanced the manufacturing process to enable efficient, in-process identification of defects in the material, improving quality in the manufacturing of advanced materials and reducing inspection costs.

Schmidt said, "The objective for the Army was to find a method for condition assessment of ceramic armor for vehicles, which is often made of a monolithic ceramic encased in a complex overwrap panel configuration. These complex structures do not lend themselves well to conventional NDE." The Army uses the technology daily for armor condition assessment in rebuild programs and related development applications.

William Green, materials engineer at the U.S. Army Research Laboratory, said, "We were looking for an NDE method that wasn't out there yet, that would make it possible to easily inspect an armored vehicle in



Evisive's groundbreaking work finds weaknesses in a variety of materials using a new microwave nondestructive evaluation.

the field by just walking up to it." The Army now benefits from reduced costs and improved safety with on-site field inspections.

Lisa Prokurat Franks, U.S. Army, Stryker Fleet System Engineering Branch, said, "I've been working with Evisive since 2006 when the senior scientist for nondestructive evaluation at Argonne National Lab identified Evisive to us. They provide the only technology capable of finding damage in the thick non-metals that we need for armor."

"Equipment delivered in the Army project is being used by the Stryker Exchange Program," said Jack Little. "They are reporting substantial cost savings thanks to real-time condition assessment which enables re-use of previously suspect armor panels. We are offering, and the Army is pursuing, a much-simplified version of the tool for deployment to Stryker teams and forward-operating bases."

Evisive's technological breakthrough has been well received by standard issuing entities. The American Society for Mechanical Engineering (ASME) identified the method for certain critical HDPE inspection applications. The American Society for Nondestructive Testing (ASNT) accepted Microwave Testing as a Method; the first new method recognized in a decade.

"To appreciate the significance of this achievement, understand the ANST only considers a technology as a 'method,' versus a 'technique,' if there is an overwhelming technical basis. Initially, the ASNT considered microwave NDE to be added as a technique; however, after many technical presentations, the guiding committee and ASNT membership voted to create a new Method Committee for microwave NDE," said Little.

The American Society for Testing Methods International (ASTM) is finalizing the HDPE inspection technique as a Standard, and this application is proceeding as an ASTM Method. The Electric Power Research Institute (EPRI) has identified the technology as an inspection requirement for HDPE.

Recognition by standards associations not only validates the technology but also stimulates its commercial potential. Recognizing the impact of the SBIR program on his company's achievements, Little said, "SBIR is an amazing asset to U.S. small business firms…In addition to providing a path to commercialization, it allows inventors to invent!"

Evisive, Inc.

Baton Rouge, LA

SBIR contract: W911QX-08-C-0052 • Agency: Army • Topic: A07-186, Non-Destructive Evaluation (NDE) and Testing of Ceramic Armor
SBIR contract: W56HZV-11-C-0077 • Agency: Army • Topic: A08-144, Non-Destructive Evaluation (NDE) for Ground Vehicles
SBIR contract: FA8650-12-C-5109 • Agency: Air Force • Topic: AF103-153, Effective Nondestructive Detection and Quantification of Defects and Damage in Ceramic Matrix Composites (CMCs)

CRYSTAL CLEAR SUCCESS

Innovations in crystal manufacturing benefit medical ultrasounds and other technologies

Ultrasound, or sound waves with frequencies above the limits of human hearing, has been used by bats for millions of years to navigate and find prey in the dark. While echolocation comes naturally to these creatures, humans only discovered the existence of non-audible sound in the late 1700s. Since then, rapid advances in our understanding of ultrasound have led to key developments in medical imaging and sonar systems.

Modern ultrasound technology relies on transducers to create ultrasonic waves. Commonly made from what are called piezoelectric materials, these transducers convert electrical energy into sound by stretching and compressing. When an alternating current is applied, they vibrate at high frequencies.

Traditionally, lead zirconate titanate (PZT) ceramics, given their affordability and ease of manufacture, have been used to produce ultrasounds. In 1997, however, researchers reported the discovery of a far superior piezoelectric crystal called lead magnesium niobate/lead titanate (PMN-PT). This new material allowed for more efficient energy conversion and higher signal-to-noise ratios. The manufacturing process for PMN-PT, however, proved to be challenging and expensive.

But then crystal-growth specialist H.C. Materials Corporation found a solution.

The Bolingbrook, Illinois-based company developed a cost-effective method of growing PMN-PT crystals, and went on to create the largest PMN-PT crystal fabrication line in the world. The improved manufacturing process enabled a new generation of ultrasound-based medical imaging devices with higher bandwidth, leading to better image resolution. It wasn't long before medical technology giants Siemens, GE, and Philips were all using H.C. Materials' piezoelectric crystals in their high-end imaging products.

H.C. Materials has provided high-energy density acoustic transducers for Navy sonar systems, such as super high-sensibility acoustic sensors

"We developed this technique for crystal growth that ended up being a practical and commercial success," said Pengdi Han, former CEO of H.C. Materials. "Today, we support a worldwide revenue market for high-end and high-quality ultrasound imaging for medicine. Our success is a story that was very unique."

Han developed the novel crystal growth process — which took almost a decade to perfect — under multiple Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) contracts from the Navy. The SBIR/STTR funding aimed to upgrade the quality of piezoelectric crystals for use in sonar, hydrophones, adaptive optics, and acoustic guidance and countermeasure systems.

In 2016, CTS Corporation, a leading designer and manufacturer of sensors, actuators, and electronic components, acquired H.C. Materials.

"H.C. Materials eventually merged into CTS Corporation, which is the number one manufacturer of PZT ceramics, and I think it is a good home for my company. The Navy was also happy to have this deal," Han said. "Last year we sold $80 million worth of crystal elements — half for the medical market and half for Navy-related projects — so the deal has overall been very successful."

Back in his home country of China, Han began his career with university degrees in electrical engineering and crystal chemistry. He spent several years working as an academic researcher with a focus on crystal growth techniques before shifting to the field of superconductivity. But after immigrating to the U.S. in 1988, Han found himself being drawn back to the world of crystals.

In 1997, researchers at Pennsylvania State University reported on the PMN-PT crystal, which exhibited a piezoelectric response five to ten times higher than other materials of its kind. The results stunned the field, but manufacturing challenges prevented these crystals from being grown in large sizes suitable for practical applications.

"This crystal contains lead oxide, about 70 percent by weight. At the high temperatures needed for crystal growth — up to 1,400 degrees Celsius — the only available material to use as a container is platinum," he said. "But the platinum is attacked by melting lead, so the container always leaks. Also, the evaporation of lead oxide is very toxic and dangerous."

The harmful conditions to workers and the environ-

U.S. Air Force photo/Airman 1st Class Ryan Conroy

The SBIR-supported innovations by H.C. Materials have benefited both the military and commercial sectors.

ment, as well as the costs of losing material through leakage, led many researchers to simply give up on growing PMN-PT crystals despite their attractive properties. But given his extensive background in crystal-growth techniques, Han believed he had the knowledge to overcome these issues. He founded H.C. Materials in 1998 with a focus on crystal growth and fabrication.

Supported by the Office of Naval Research, who had interest in creating a better sonar transducer with PMN-PT, Han began work on the leaky-container problem. He first thought impurities in the platinum might be causing the lead oxide to attack the crucible, but later found out that tiny microbubbles were to blame. Once he was able to fabricate an interstitial-free platinum crucible without microbubbles, the leakage stopped.

Another challenge came from growing the crystal in larger sizes even while maintaining compositional homogeneity. PMN-PT consists of two separate compounds: lead magnesium niobate and lead titanate. If one compound grows faster than the other, the ratio of the two compounds will change, along with the crystal's physical properties. By modifying the crystal growth direction, however, Han realized the overall composition would stay the same. This method, called the modified Bridgman growth system, allowed the company to grow spheres and cylinders 3 to 4 inches in diameter.

Although the research and development process took several years, Han's hard work eventually paid off. H.C. Materials has provided high-energy density acoustic transducers for Navy sonar systems, such as super high-sensitivity acoustic sensors for accelerometers and deformable mirror control for missile guiding. In the medical field, the company sells crystals to major manufacturers of high-end ultrasound imaging devices. Overall, Han's modified Bridgman growth system and related commercial fabrication line has been critical to the achievement of a new generation of acoustic transduction devices.

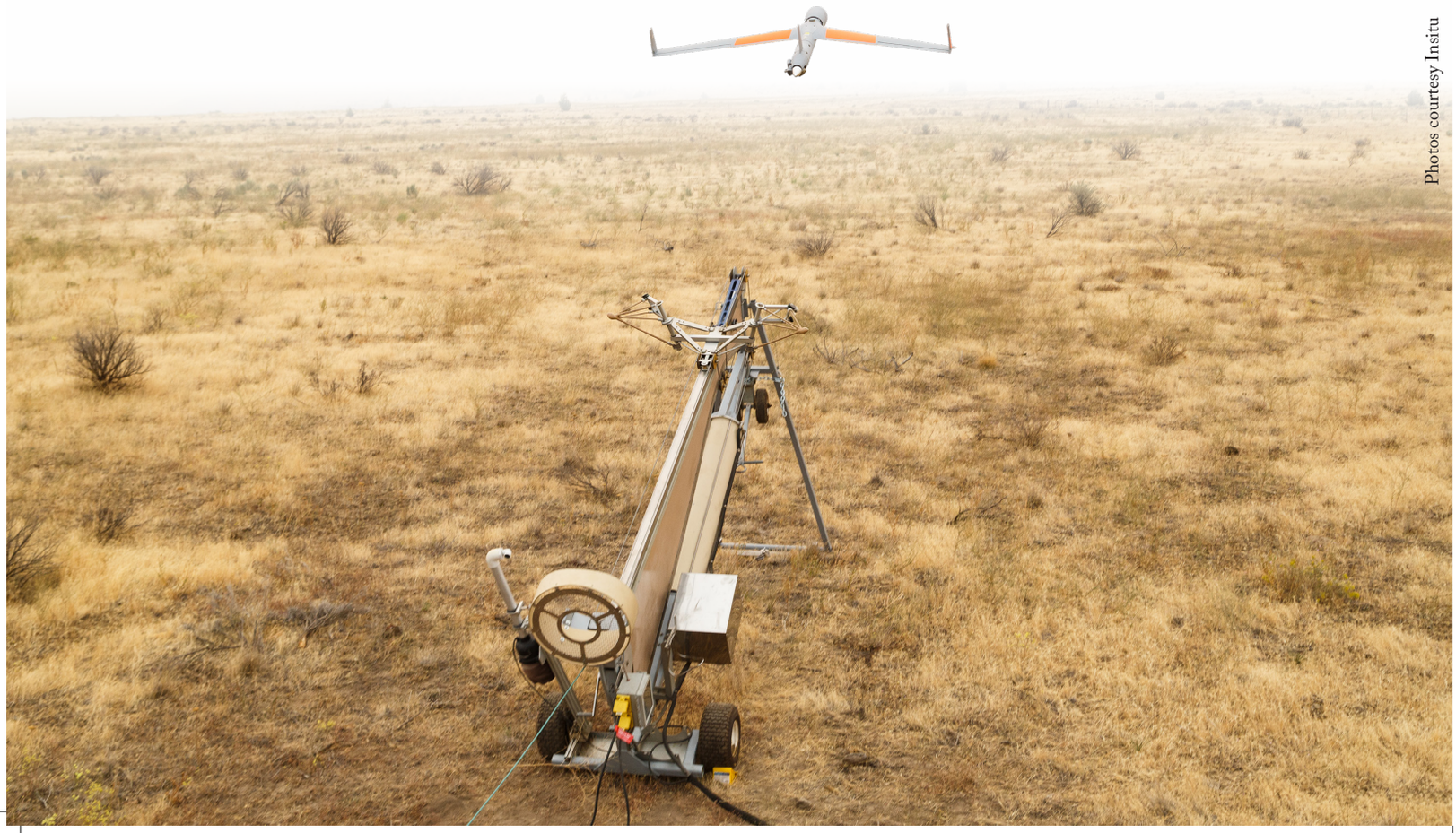
H.C. Materials, Corp. (CTS Corporation)

Bolingbrook, IL (Lisle, IL) • SBIR contract: N00014-04-C-0153 • Agency: Navy • Topic: SB031-005, Cost-Effective Production of Piezoelectric Single Crystals

The VIEW from ABOVE

Insitu creates milestones in UAS technology

In 1998, the creators of an unmanned aerial vehicle (UAV) launched their drone from the roof of a car off Newfoundland, Canada, sending it across the Atlantic Ocean. Less than 27 hours later, it landed in a meadow in Scotland. They knew they were making history. Their device, the Aerosonde, was the first UAV to cross the Atlantic—and it did it on less than two gallons of gas.



Photos courtesy Insitu

The result of a collaboration between scientists and engineers from the Insitu Group in Washington State, the University of Washington, and Environmental Systems and Services of Melbourne, Australia, the Aerosonde was considerably more nimble and innovative than other UAVs being developed at the time. It was equipped with a global positioning system (GPS) and weighed only about 50 pounds.

Steve Sliwa, Insitu's CEO from 2001 to 2008, cites the Atlantic crossing as an event that captured media attention and—along with company ingenuity and Small Business Innovation Research (SBIR) funding—moved Insitu from a garage-shop operation in Bingen, Washington, to a leader in unmanned aerial systems (UAS).

In 1996, the company received an SBIR contract to help develop a simulator that allowed for rapid testing and evolution of the technology Insitu was pursuing. At the time, the SBIR was focused on developing a UAV for environmental monitoring and weather sensing, but the simulator also proved to be very valuable in future projects.

"One of the key aspects of our technology was that we would design, build, test, and then redesign, build, test—a rapid iteration loop—and that was really important," Sliwa said.

That process was used to develop Seascan, Insitu's next venture, which was an entirely new approach to UAVs. "We'd have failures—some crashes and things like that," Sliwa said. "We'd go back and analyze all the data and test out ideas on the simulator, and then design, build, test, again. We did that as fast as we could."

Sliwa went on to add that the company wouldn't have survived without the SBIRs. "And the technology that we delivered during that time was the foundation for growing the company," he said.

Seascan was developed primarily with the fishing industry in mind. But September 11, 2001, changed the focus of the country and the company. Insitu pivoted to military applications, securing a joint-technology development contract with the nearby Boeing Company. Venture capital followed, and in 2004 the company deployed its ScanEagle (a direct descendant of Seascan) with the U.S. Marine Corps. According to Sliwa, the head of operations at the Second Battle of Fallujah in Iraq told him that he would have had 30 percent more casualties if they hadn't deployed ScanEagle.

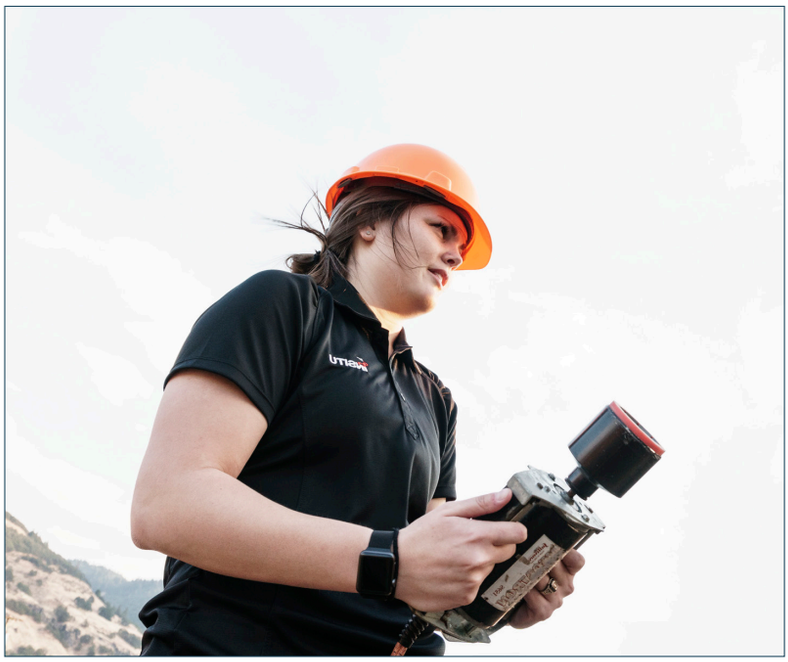
The talent of the Insitu team did not go unnoticed. After a few years of working jointly on contracts, The Boeing Company acquired Insitu in 2008, and it became an independent subsidiary.

> "The technology that we delivered during that time was the foundation for growing the company," Sliwa said.

Insitu now provides the ScanEagle or UAV flight hours to most branches of the military and 20 foreign countries, as well as to the commercial sector. From five employees in 2001 to more than 1,400 today, Insitu grew with surprising speed, it continues to make history. In 2009, its ScanEagle was used in the rescue of Captain Richard Phillips, who was captured by pirates off the Somalia coast; in 2013, ScanEagle became the first unmanned aircraft to conduct an FAA-approved commercial, beyond visual line of sight flight in the national airspace; and in 2017 Insitu celebrated one million hours of flight. Today it has locations in the U.S., Australia, and the United Kingdom.

Current CEO Ryan Hartman attributes Insitu's impressive military sales to the company's technological advances in payload, imagery enhancement, and dissemination techniques that "enable our customers to make even more informed decisions that protect and save lives."

The RQ-21A Blackjack and Integrator UAS were added to the company's offerings in the last few years, providing more payload capacity and flexibility in capturing information. "A typical Insitu UAS today includes four air vehicles or



Among the many beneficial applications for the UAV technology developed by Insitu, wildland firefighting is one of the most conspicuous, as seen in this photo from Oregon's 2017 Eagle Creek Fire.

AVs, a ground control station, remote video terminal, Insitu's patented launch system, and its unique, patented SkyHook recovery system," Hartman explained. "Systems can vary and are uniquely designed to meet a customer's needs."

Today, Insitu is experiencing growing demand for the surveillance capabilities of its UAS in the commercial sector. A large part of Insitu's commercial footprint is in providing ScanEagle flight hours. It is helping customers detect and monitor oil spills, ensure safe railways, fight wildfires, monitor marine mammal populations, pinpoint seafaring drug smuggling operations, and provide search and rescue.

Hartman described the commercial potential as a "tremendous opportunity," adding, "several years ago, I would have predicted that the explosion of new UAS companies was already behind us, but history has proven me wrong. The growing emergence of the commercial market and consumer markets has been the catalyst for another massive expansion in the number of companies offering some sort of commercial product."

Hartman noted that with growth there also was momentum for the industry to "put in place the regulations and laws that will enable the expansion and use of unmanned systems within the United States."

Insitu still has its main headquarters in Bingen. From experiencing high unemployment, the area is now a regional economic hub. And the original garage that harbored its first creation has morphed into an eight-building campus. The company currently has operations on three continents. They also place an emphasis on community, Hartman said, encouraging employees to engage as volunteers in civic organizations, support Science, Technology, Engineering, and Mathematics (STEM) educational opportunities, and act as good stewards of the land.

Hartman attributed Insitu's one-million-flight-hours milestone, reached in late July 2017, to "the professionalism and dedication of every single employee at Insitu." He then added, "Every employee from every corner of the company contributed to Insitu reaching this milestone. I am tremendously proud of where we have come, and look forward to all that we will do together in providing world-class service to our customers."

Insitu Group, Inc. (Boeing Defense, Space & Security)

Bingen, WA (St. Louis, MO) • SBIR contract: N00014-96-C-0115 • Agency: Navy
Topic: N94-130, Development of a Prototype Research Facility for Aerossondes within CIRPAS

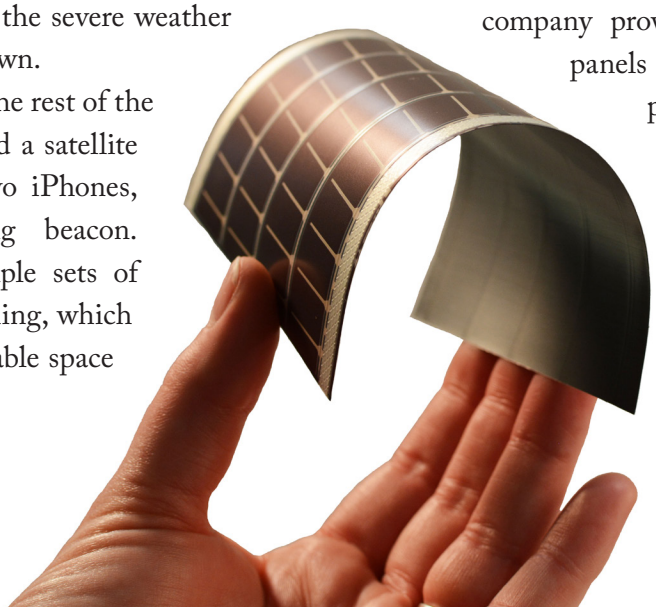
TechLink

It pays to be... FLEXIBLE

Flexible solar panels create an off-the-grid power source for both civilians and warfighters

When he's not in court or spending time with his family, attorney Douglas Tumminello of Denver, Colorado, nurtures a fascinating side gig as an extreme adventurer. In his illustrious second career, his accomplishments range from summiting Mt. Everest to setting a world record for rowing 3,600 miles across the Indian Ocean in 58 days. For one of his most ambitions expeditions—a solo ski trip from the coast of Antarctica to the South Pole—he needed gear that could withstand the severe weather but also not weigh him down.

To stay in touch with the rest of the world, Tumminello packed a satellite phone, a base station, two iPhones, and a satellite tracking beacon. Instead of packing multiple sets of batteries to charge everything, which would have taken up valuable space and mass, he found a lightweight, compact, and durable device that met all his needs: a rollable solar panel. Tumminello affixed the solar panel to his tent in camp and on his sled while traveling, and it provided a charge even in the harshest conditions, including during dense whiteouts.



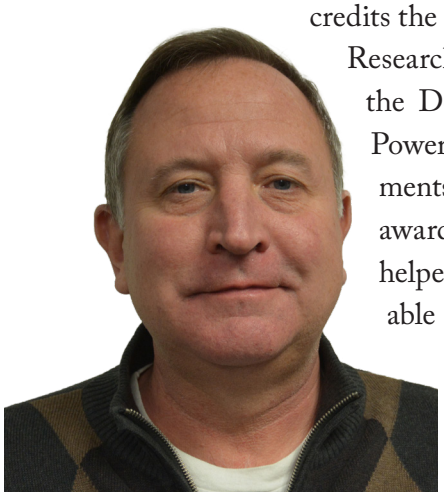
Tumminello represents one of many customers worldwide who have depended on PowerFilm's solar panels for off-the-grid survival. The Ames, Iowa, based company provides rollable and foldable solar panels for outdoors and recreation purposes, consumer electronics needs, and key military applications. It also works closely with clients to build custom solar solutions for special cases. For instance, PowerFilm has created a small, curved solar panel for a smart

bike lock that notifies owners of a theft, as well as a thin, all-weather solar panel to power an asset tracking system for semi-trailers, cargo containers, or rail cars.

PowerFilm started out, in 1988, as Iowa Thin Film Technologies. The co-founders, Frank Jeffrey and Derrick Grimmer, were research physicists at 3M working on applying amorphous silicon to a roll of flexible plastic. Amorphous silicon, a non-crystalline semiconductor material, can be deposited in thin films onto substrates like plastic to create solar panels. By creating a proprietary roll-to-roll manufacturing process, Jeffrey and Grimmer enabled lower-cost manufacturing and enhanced product functionality through ease of customization.

"Roll-to-roll fabricated amorphous silicon is extremely durable, flexible, and lightweight. You can roll it around a pencil, and it won't sustain any damage," said Daniel Stieler, President of PowerFilm. "It's also very durable, so you can drop stuff on it or drop it. Even if it were to get a hole in it, the solar panel is still going to be functioning at near 100 percent."

The properties of roll-to-roll amorphous silicon—the key technology behind PowerFilm's products—made it ideal for military applications. While the company got initial funding from the Department of Energy, Stieler credits the Small Business Innovation Research (SBIR) contracts from the Department of Defense for PowerFilm's later accomplishments. One of the key SBIR awards from the Army in 2002 helped PowerFilm develop foldable solar panels which could be incorporated into the fabric of military tents.



Wes White

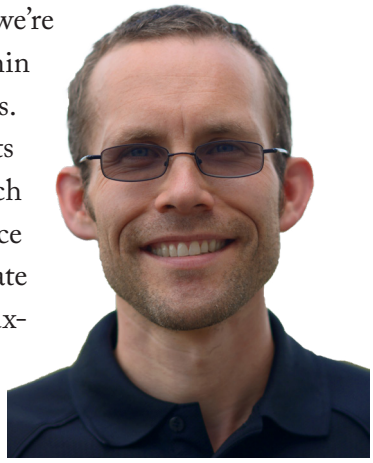
"The SBIR awards were really critical to PowerFilm's success and making it to the 30-year mark. Early funding focused on building up manufacturing, but didn't bring us to an end product or help us with market development," said Stieler. "The Army SBIR helped us cross the valley of death, and we came out the other side with products that we could sell to both civilian and military customers."

In addition, the foldable solar panels developed under the SBIR program remain a major commercial revenue stream, helping customers achieve their off-the-grid dreams.

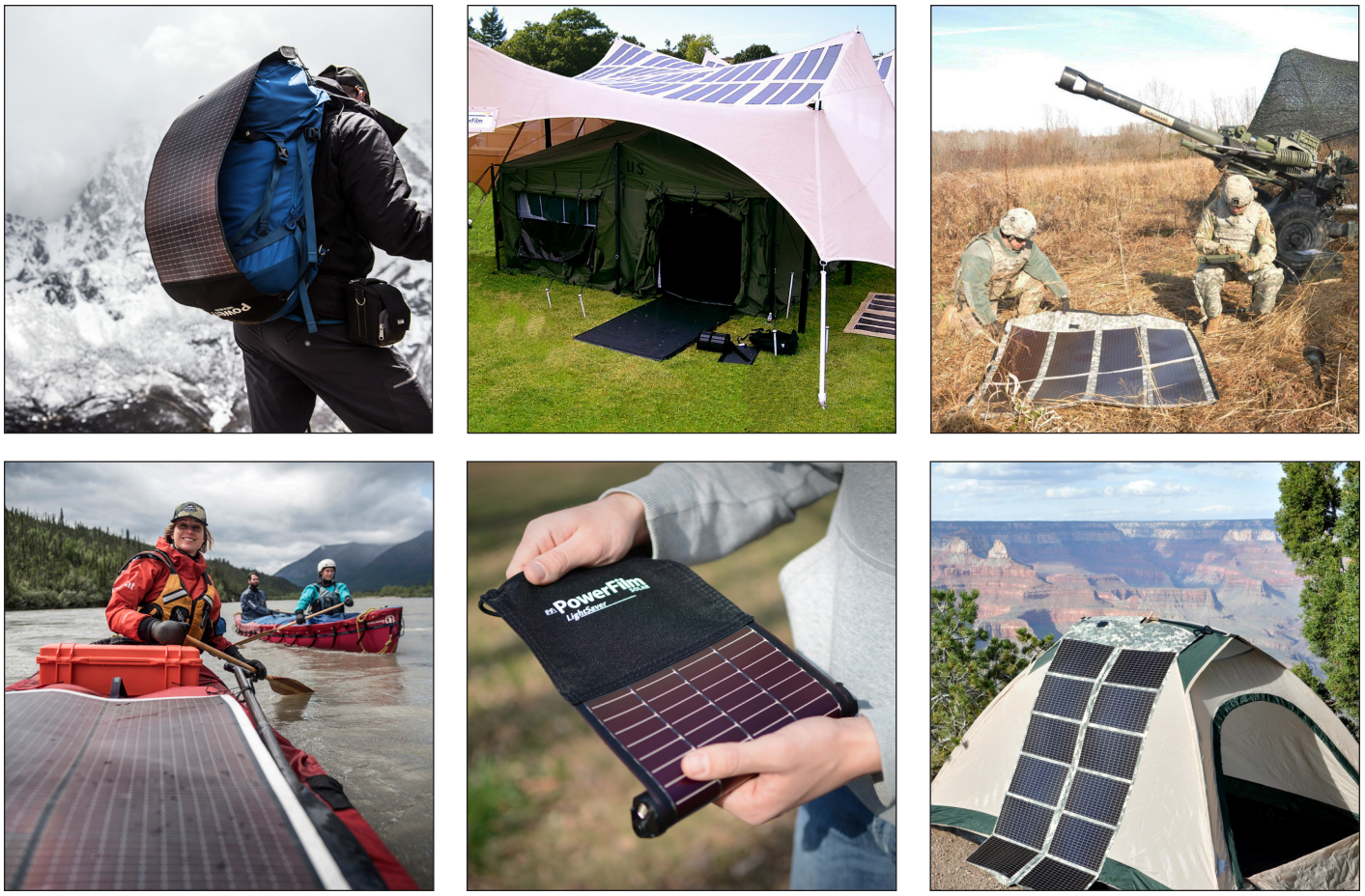
The Army SBIR-funded work resulted in the PowerShade, a shade structure that comes in three sizes with integrated solar panels capable of both generating electricity and reducing air conditioning load by up to 30 percent. Since 70 percent of convoys involve the delivery of fuel and water, use of the PowerShade at forward operating bases (FOBs) can dramatically reduce costs and even save lives, as these convoys have long been prime targets for militant attacks. In one test, it reduced FOB fuel use from 20 gallons per day to 2 gallons per day.

But the military applications don't end there. Wes White, Director of Military Business Development at PowerFilm, leverages his background as a retired Army officer with 20 years active duty to anticipate military needs that might be fulfilled by the company's products. He specializes in solutions for basing power (like PowerShade), solar panels for vehicles to cut fuel costs on the battlefield, and man-portable products that fit easily in a rucksack.

"In terms of basing power, we're putting lightweight, flexible, thin film solar panels on structures. They come in very handy on tents that can't take a lot of weight, such as a first-aid station or maintenance bay," said White. "We also integrate solar power on vehicles to give auxiliary power, such as unmanned aerial vehicles. And with an amorphous silicon panel that



Dan Stieler



The flexible solar panels created by PowerFilm have led to any number of astonishing applications, allowing both civilians and warfighters to take their power sources with them.

folds up nicely in the soldier's pack, he can charge just about every battery that he carries: radios, night vision devices, range finders, etc."

After a fundraising campaign, Iowa Thin Film Technologies went public in 2007, and changed its name to PowerFilm. A few years later, the company pivoted to more unique niche markets to give itself an edge over cheaper competitors from Southeast Asia.

More recently, PowerFilm has been making a name for itself as an original equipment manufacturer for custom solar solutions. PowerFilm is taking advantage of the growing internet of things (IoT) market by seeing how solar energy fits into sensors and tracking—to power thermometers in refrigeration trucks, for example, or level sensors in liquid nitrogen tanks.

In addition, the foldable solar panels developed under the SBIR program remain a major commercial revenue stream, helping customers like Tumminello achieve their off-the-grid dreams.

"Other than the funding, which helps any small company, the SBIR program helps with efficiency," said White. "We can sit here all day and try to guess what products we need to make in the future, but if the military comes out with an SBIR solicitation, it gives us that much-needed direction regarding what we need to focus on."

Iowa Thin Film Technologies, Inc. (PowerFilm, Inc.)

Boone, IA • SBIR contract: DAAD18-02-C-0009 • Agency: Army • Topic: A00-162, Flexible Photovoltaics for Fabric Structures

LASER SHARP

With help from an SBIR contract, a New Jersey company creates essential laser innovations

Thanks to a series of U.S. Air Force SBIR contracts, laser technology from the turn of the century, originally designed to monitor the upper atmosphere for nuclear detonations, is now being used for everything from astrophysics research to computer chip manufacture to tattoo removal.

The story of the solid state laser technology refined by Light Age, Inc. spans three decades, with stops in outer space and the inner workings of the human mind. And government funding through the SBIR program and other initiatives was a key to unlocking the technology, said Dr. Donald F. Heller, CEO of the privately held New Jersey company.

"This is why the SBIR and other government funding programs for research are so important," he said. "This work will keep paying dividends into the indefinite future."

Light Age's founders, who started the company in 1986 after leaving what is today Honeywell, licensed new laser technology developed during their time at the company. The basic concept: a more broadly tunable, solid-state laser system which could be used across a wide range of wavelengths even while consuming less power.

What made that ability to shift wavelengths possible was alexandrite, a rare but naturally occurring mineral first discovered in the Ural Mountains of Russia in the 1830s. As a gemstone, alexandrite is famed for its color-changing abilities under different kinds of light, and as a result its crystals provide greater tunability than the rubies used in many lasers.

Light Age's initial focus was on scientific and academic uses, including spectroscopy, which measures the interaction of light to determine the composition of different materials and how molecules interact with each other. The technology was also adopted for use in LIDAR, a laser-based remote sensing method similar to radar which uses light waves instead of sound to measure the upper atmosphere.

In 1991, Light Age was part of the first cohort of Advanced Technology Program (ATP) contracts, created in 1991 by the Bush Administration and administered by the National Institute of Standards and Technology (NIST) in order to encourage research and development with the potential to boost American competitiveness.

While the ATP contracts focused broadly on technology development, Light Age also received attention from the U.S. Air Force's Missile Defense Agency (MDA), which saw the smaller, lower-power laser systems as providing a way of monitoring the atmosphere for nuclear detonations.

"Throughout our history, Light Age has never marketed to government directly," Heller said. "The

government has come to us."

In 1997, Light Age won the first of several Small Business Innovation Research (SBIR) contracts from MDA to continue refining its laser technology. Funding from the SBIR program helped the company improve a system capable of generating laser light in both the deep ultraviolet and middle-infrared ranges—the invisible wavelengths at the opposite ends of the visible light spectrum.

SBIR funding "enabled improvements in all of the fundamental laser technology for developing tunable means for generating light at all wavelengths," Heller said. "We can make lasers capable of doing anything light can do—any wavelength, any temporal spatial energy distribution at almost any power."

Following the completion of Light Age's SBIR contracts in 2001, IBM approached the company to see if its technology could be used to develop a deep ultraviolet laser system that could essentially etch circuits onto silicon, allowing for smaller, denser, and more powerful chips. According to Heller, IBM had just ended an unsuccessful venture with a company that had failed to create a viable laser for the process.

Five years later, IBM unveiled a high-resolution photolithography system based in part on Light Age's technology. Called NEMO, the system demonstrated that it was technically possible to etch features smaller than 30 nanometers onto silicon chips—3,000 times smaller than a human hair and three times smaller than what was typical at the time.

The breakthrough gave chipmakers "seven years of breathing room before any radical changes in chip-making techniques would be needed," an IBM scientist said at the time. True to IBM's word, newer chip-creation technologies have since supplanted NEMO, but virtually every embedded processor used in today's cellphones, laptops, and other systems is based on integrated circuit chips—some with features now approaching 10 nanometers or smaller—that draw from the immersion photolithography techniques pioneered by Light Age's laser technology. One estimate has put the overall economic impact of the manufacturing breakthrough at more than $1 trillion.

Dr. Donald F. Heller

Over the past decade, Light Age has primarily focused on refining its laser technology in the middle-infrared part of the spectrum, where it has the greatest potential for scientific and medical applications.

Today, most of the company's revenues come from medical systems, including its own dermatology products used in hair and tattoo removal. At the same time, Light Age also makes advanced spectroscopy systems used for basic science in universities and national labs around the world. In 2003, the company moved to a 40,000 square-foot research and manufacturing facility in Somerset, New Jersey. It has a customer base of several thousand organizations, ranging from large manufacturers and startups to universities and international research organizations.

Light Age is also collaborating with university, corporate, and government partners on next-generation medical systems, including work with Vanderbilt University on developing tools for precision neurosurgery, a laser solution for certain types of vision loss now being commercialized, and research funded from the National Institutes of Health (NIH) and Department of Defense (DoD) to develop next-generation, advanced imaging systems for soft tissue.

"We have enormous capabilities here—there are only a few things we can't pursue," Heller said. Like most small businesses, Light Age is undercapitalized, according to Heller, and government programs like SBIR have helped the company "support research and development" over the past three decades.

"Getting something off the ground always requires time and money," Heller said. "That is what happens when new basic capabilities are developed, and this work needs to be supported."

Light Age, Inc.

Somerset, NJ

SBIR contract: DASG60-00-C-0003 • Agency: MDA • Topic: All Solid-State Laser for Generating Deep Ultraviolet and Middle Infrared Coherent Light
STTR contract: W91XWH-08-C-0109 • Agency: Army • Topic: A08-T038, Dual-Functionality Laser System for High-Contrast Diagnostic Imaging and Precision Surgery

Enabling micromachining for today's electronics

Smartphones have finally become the all-in-one device that techies long dreamed of. Most of us now carry around a phone, music player, camera, GPS system, and a computer, all in one tidy package. Still dreaming, ambitious developers and manufacturers continue to pack more memory and higher graphics display resolution into ever-smaller, more advanced units.

Micromachining, the use of special laser-based equipment to cut tiny features into circuit boards, is a key technique for manufacturing compact devices. Much of this micromachining is performed by instruments called "Q-switched diode-pumped solid-state lasers," which emit energetic short pulses of light in the ultraviolet (UV) range. These powerful lasers can drill holes a fraction of a millimeter across, cut printed circuit boards, and dice silicon wafers with utmost precision. Such processes were once done by mechanical drills and other cutting tools, but as the size of consumer electronics shrank, it became increasingly difficult to use mechanical tools.

Based in California, Lightwave Electronics Corporation spearheaded the development of the Q-switched UV laser technology in the late 1990s, and in the process, helped facilitate the miniaturization of electronics for devices like smartphones. Founded in 1984, the company invented and manufactured a number of different types of both infrared and visible output lasers. Q-switched UV lasers are solid state, and operate by turning infrared-spectrum light into UV with special crystals. Today, UV lasers have become one of the cornerstones of industry.

Early Small Business Innovation Research (SBIR) awards from the Air Force, as well as support from other government agencies, helped Lightwave Electronics—one of the first diode-pumped solid-state laser manufacturers—push laser technology forward into wide commercial application. But it didn't happen overnight.

"In my first year with the company in 1998, a team developed a very early version of the Q-series. It ran great but there were issues with contamination and degradation mechanisms," recalls Mark Arbore, a former project leader at Lightwave Electronics. "It might take a few years to make something work on the lab bench, but it takes many more years to have a commercial product."

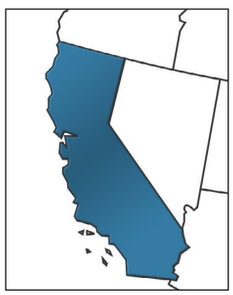
The relatively long pulse width of the Q-series was pivotal, proving superior to shorter pulse widths used by Lightwave's competitors. Long pulses gave heat from the laser slightly more time to spread, which meant it could melt a deeper layer rather than just vaporize a thin surface layer.

"Back then I wasn't at all sure whether long or short pulse widths would be better. Now, with almost 20 years of hindsight, it looks like long pulses have a good range of applications," said Will Grossman, the former Vice President of Engineering at Lightwave. "From an economic standpoint, the long pulses have worked out well and dominated a large segment of the market. I would be surprised if it's not used in some way for most of the electronics consumers use today."

"One of the reasons today's microelectronics work as well as they do, and are as cheap as they are, is thanks to semiconductor manufacturing technology that relies on lasers."

Optical technology giant JDS Uniphase (JDSU) bought Lightwave in 2005, largely because of the Q-switched UV laser technology. Improved versions of this same Q-Series line are sold today by Lumenum, a spin-off company of JDS Uniphase, a market-leading manufacturer of innovative optical and photonic products.

"The future was with the Q-series. Ten or fifteen years ago, anybody who had memory chips in their computer benefitted from a Lightwave laser," said Arbore. "One of the reasons today's microelectronics work as well as they do, and are as cheap as they are, is thanks to semiconductor manufacturing technology that relies on lasers."



And thanks as well to the SBIR program and the small businesses that seize their opportunity and run with it.

Just CHILLING

Easy to maintain environmental control units help keep military operations running cool

Imagine you're a warfighter in Afghanistan back in the early 2000s, trying to get some rest after an exhausting mission. But it's 95 degrees inside your tent barracks. As unlikely as it sounds, the air conditioning function on your environmental control unit has been icing up. A mechanic is outside, working in a raging dust storm, turning on the heat to melt the ice.

Icing was a recurring, serious problem in the military's Field Deployed Environmental Control Units (FDECU), says Bob Scaringe, founder and president

of Mainstream Engineering Corporation. "They had poor air flow design," he explained. When the units were used for cooling, moisture removed from the air would freeze on the evaporator coil. "Then the air wouldn't flow through it, creating even more ice. The only solution was to turn on the heat to melt the ice. You were going the wrong way."

Environmental control units (ECUs) are vital to military operations. Having a dependable, easily maintained unit that also met tightening 21st-century environmental standards was a key objective for the Department of Defense. In 2005, Scaringe's Florida-based company won an Air Force Small Business Innovation Research (SBIR) contract to develop a reliable, modular ECU that used a non-hydrochlorofluorocarbon (HCFC) refrigerant. The once common HCFC refrigerant R-22 had been linked to depletion of the earth's ozone layer, and was in the process of being replaced by a new generation of hydrofluorocarbon (HFC) refrigerants. Scaringe saw a catch, however. While the new refrigerants had zero ozone depletion potential, they did have a high potential to contribute to global warming, which was gaining notice around that time as an issue of concern. Scaringe realized that refrigerants would likely change as advances were made, so flexibility would have to be built into whatever system he engineered.

The units also had to be easy to work on. During development, Mainstream engineers spent a lot of time talking to soldiers, airmen, and marines responsible for maintaining the legacy FDECUs, which were notoriously difficult to repair.

"They really had skin in the game," Scaringe said. "We would send them some of our hardware, letting them take it apart. They'd tell us, 'We like this.' Or, 'This is terrible. How do you expect us to do this while we're sitting on the ground in the desert?'"

Scaringe said that virtually all of the innovation on ECUs began with Mainstream's first SBIR contracts, and he credited that early support with helping to significantly advance the technology.

The company further made sure that any repairs or work could be done with a standard toolkit. "That's just as important as some of the technology," Scaringe said. "If the guy can't repair it, it doesn't matter how slick it is. Everything is going to break at some point, especially in the harsh climate of the desert."

Mainstream's first HECU prototype was 33 percent lighter than the traditional FDECU and consumed 25 percent less power. For the refrigerant, it used propane, which has an ozone depletion potential of zero and a remarkably low global warming potential. That first prototype also demonstrated a nearly six percent reduction in power consumption compared to units using the HFC refrigerant R-410A, which was becoming the go-to replacement for R-22 in the United States. But here was another catch—at that time, propane wasn't approved for use in this country as a refrigerant. Propane, a naturally occurring hydrocarbon gas, was being used as a refrigerant in Europe but not in the U.S., because of concerns about potential flammability. So Mainstream developed a

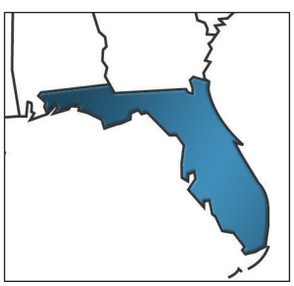
Mainstream Engineering has received both city and state awards for job creation and economic development.

Photo courtesy of Mainstream Engineering Corp

In a desert theater, warfighters can be substantially hampered by the simple absence of air conditioning.

prototype HECU that used R-410A, which had zero ozone depletion potential even though it also came with a relatively high global warming potential.

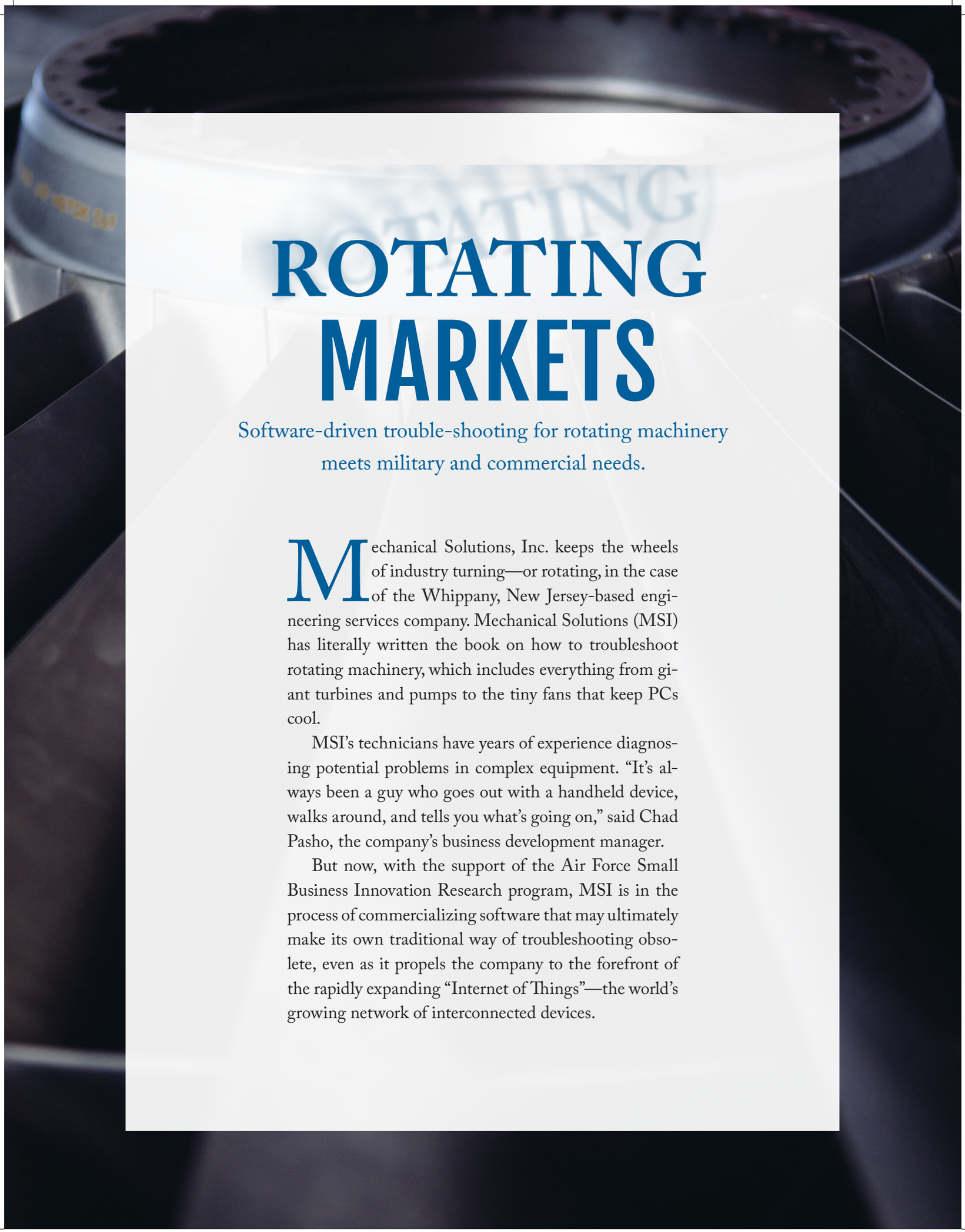
By 2007, Mainstream was manufacturing and selling its lightweight Modular Environmental Control Unit (MECU), with R-410A refrigerant and a "plug and play" design that allowed electrical elements to be unplugged and plumbing lines to be disconnected without the need to braze or solder tubing. In the ensuing years, Mainstream Engineering continued to advance the technology, with developments that included an Enhanced Environmental Control Unit (E2CU) and an updated MECU, both compatible with either R-410A or propane (R-290)—which was approved in 2015 for use as a refrigerant in the United States. Today, Mainstream has manufactured and sold thousands of ECUs, including to every branch in the military.



Scaringe said that virtually all of the innovation on ECUs began with Mainstream's first SBIR contracts, and he credited that early support with helping to significantly advance the technology. He recalled the long process of learning how HFC refrigerants such as propane and new synthetic oils work within a system—but said all that trial and error gave the company an important leg up.

"A lot of what we were forced to do," Scaringe noted, "ended up giving us tremendous insight into how to make these things work better."

To which warfighters living in tent barracks in searing desert climes would say, "Thank you."



ROTATING MARKETS

Software-driven trouble-shooting for rotating machinery meets military and commercial needs.

Mechanical Solutions, Inc. keeps the wheels of industry turning—or rotating, in the case of the Whippany, New Jersey-based engineering services company. Mechanical Solutions (MSI) has literally written the book on how to troubleshoot rotating machinery, which includes everything from giant turbines and pumps to the tiny fans that keep PCs cool.

MSI's technicians have years of experience diagnosing potential problems in complex equipment. "It's always been a guy who goes out with a handheld device, walks around, and tells you what's going on," said Chad Pasho, the company's business development manager.

But now, with the support of the Air Force Small Business Innovation Research program, MSI is in the process of commercializing software that may ultimately make its own traditional way of troubleshooting obsolete, even as it propels the company to the forefront of the rapidly expanding "Internet of Things"—the world's growing network of interconnected devices.

"It's an interesting time for industry," said Pasho. "We're starting to get a lot more always-on sensor data monitoring, and as that shift happens, we're positioned to apply our monitoring technology and our diagnostic algorithms to those data streams."

Through several Air Force Small Business Innovation Research (SBIR) contracts, MSI worked with the Air Force's Arnold Engineering Development Complex (AEDC) to develop condition-monitoring software to track the health of the complex's equipment. As the most advanced and largest center of flight simulation test facilities in the world, AEDC is home to a host of rotating machinery—most notably the equipment that drives Arnold's five active wind tunnels. The tunnels, used for a wide variety of testing and evaluation procedures, are activated on an unpredictable schedule, increasing the need for solutions that automatically monitor system health on an ongoing basis. Beyond the wind tunnels, AEDC has 47 electric motors in the 90,000- to 600,000-horsepower range which drive up to 53 equally sized compressors/turbines.

"They have a lot of machinery that runs for infrequent, high-profile testing," Pasho said. "That was their pain point."

Mechanical Solutions worked with AEDC officials and its own engineers to break down how they troubleshoot different kinds of machinery trains throughout Arnold Air Force Base. That knowledge was then incorporated into software that can continuously monitor sensors on the machinery and identify potential problems before failures occur. For example, in the past, a skilled technician would use a handheld device to study the vibration signature of a piece of machinery to identify issues such as misalignment. Now the company's software can steadily scan sensor readings and compare them to an algorithm to automatically identify potential problems.

"Usually you sent a vibration specialist out to collect the data and determine if the issue was misalignment," Pasho said. "We've trained the software to look at the data and make the diagnosis automatically."

MSI's SBIR contracts formed the baseline for developing and commercializing the firm's Sentry™ software, which has two versions. Sentry Automated Diagnostics, a comprehensive online condition monitoring system, provides real-time, physics-based diagnostics. Sentry Operations Optimization provides custom analysis and solutions for optimizing machinery performance. The software includes an interface that allows engineers to tailor its use on specific machinery trains, using existing sensors or equipment added specifically for monitoring purposes.

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Mechanical Solutions uses the software on its own service calls, and is in the early stages of commercializing the product for DoD sites as well as for non-military customers considering it for ongoing monitoring and diagnostics. The ultimate goal for the system, said Pasho, is to "market it as general health monitoring diagnostic software for the overall marketplace."

The expanding Internet of Things has positioned Mechanical Solutions to take advantage of the growing numbers and sophistication of networked sensors and monitoring systems found on a range of industrial equipment. Pasho predicts significant demand for software that can analyze and manage these increasing data flows in power plants, processing plants, refineries and water treatment plants, among others.

"In one sense, we might be working ourselves out of a job," Pasho said. "But if that's where the market's going, we'd like to be on the leading edge."

GOOD VIBRATIONS

Microsensor arrays offer chemical monitoring solutions for public spaces

On March 20, 1995, five men boarded the Tokyo subway on separate lines, all headed toward Tsukiji Station in Central Tokyo. It was Monday morning rush hour, a time when it would have been easy to blend into the bustling crowds at one of the world's busiest commuter centers. The men carried bags with containers that would later be described as resembling lunch boxes or thermoses. Inside the containers was a colorless, odorless liquid that, when activated, would release a nerve gas called Sarin. At a coordinated moment, not long after stationing themselves in their selected cars, the five men dropped their bags and exited the subway while the fumes from the liquid began to leak out. In a panic, sick passengers exited at various stations, carrying traces of the fumes with them. When bystanders tried to help the victims, they were also exposed. In all, 13 people died and more than 5,500 people were injured by the attack, which was later connected to a doomsday cult called Aum Shinrikyo. The incident sparked renewed recognition that transportation infrastructures, especially where there are people in confined spaces, were particularly vulnerable to assault. And it also raised the question of how to handle the immediate aftermath of a chemical attack.

"The desire to monitor these locations for any trace releases was already a high priority," said Hank Wohltjen, founder of the Bowling Green, Kentucky-based Microsensor Systems, Inc. "But even in the Tokyo subway incident, the people who were injured were immediately transported to the hospital, and, at that point, no one knew what they were dealing with. Of course their clothes were contaminated, so lots of people associated with the incident were inadvertently exposed to low levels of these toxic chemicals."

For four decades, Wohltjen has been exploring the question of how technology can monitor low-level traces of toxic chemicals. In the late 1970s, as a graduate student at Virginia Tech, he invented the Surface Acoustic Wave (SAW) microsensor—a small chip of quartz with a microelectrode patterned onto the surface. He continued to develop the technology in the early 1980s as a researcher at the U.S. Naval Research Laboratory (NRL) in Washington D.C.

The SBIR program, through its support for growing businesses and nascent technologies, provides a launchpad for passionate innovators looking to develop their ideas.

"The quartz device mechanically resonates—like the string on a guitar—at very high frequencies," Wohltjen says. "We apply extremely thin coatings of a polymer to the devices to make the vibrations sensitive to chemical vapors. The coating acts as a 'sponge' for certain types of vapor. When the 'sponge' absorbs a particular vapor molecule, it gets heavier and causes the resonant frequency of the chip to decrease. Using this technique we can measure mass changes as small as a few picograms."

In 1985, Wohltjen and some of his colleagues left the NRL and formed Microsensor Systems, Inc. where they worked on the commercial development of SAW microsensors. They created a pocket-sized chemical warfare detection system using the technology, and they also began manufacturing gas chromatographs for agencies such as the Occupational Safety and Health Administration (OSHA) who used the chromatographs for industrial safety and hygiene purposes.

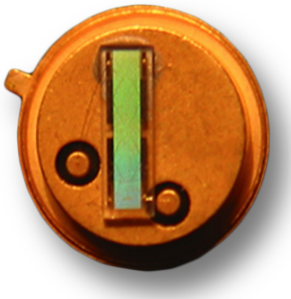
Hank Wohltjen

Then, in 1995, the Tokyo subway was attacked, and the desire for Microsensor Systems' technology spiked. Through the Small Business Innovation Research (SBIR) program, the U.S. Department of Defense (DoD) called upon Wohltjen's company to create a detection system that would help protect U.S. troops and American citizens from similar chemical attacks and their consequences. The company contracted with the Defense Advanced Research Projects Agency (DARPA) to develop a fully-automated, high-performance SAW microsensor array for mobile air sampling and chemical monitoring. The first phase of the technology was completed in 1998 and combined the SAW technology with the miniature gas chromatographs and pattern detection software. It's since been developed into a highly reliable, portable monitor that can be deployed anywhere in the world with the unique ability to detect low levels of chemical agents. The project, as it was originally developed with DARPA, has been focused on intelligence gathering. Those programs are classified but, according to Wohltjen, the technology has been used to help protect key facilities across the country, including major metropolitan mass transit systems.

"I can say that it was successfully deployed in the field and that it was in operation for several years monitoring for unexpected releases of toxic chemicals." Wohltjen said. "It has turned out to be a useful device in monitoring the presence of toxic materials in scenarios where it was necessary to protect people from potential exposure."

The detection system continues to be developed for commercial use. For instance, the company has built systems to

A surface acoustic wave chemical microsensor "chip" from Microsensor Systems is only 5 mm in diameter.



measure emissions so that refineries can meet environmental standards. Other commercial applications overlap with the goals of DoD and public health agencies. Monitors have been deployed at chemical weapons handling depots to detect leaks. And hospitals can use the monitors in the event of a chemical weapons attack, if something like that were to happen in the U.S. Wohltjen says the machine could be positioned in the emergency room where it would continuously analyze the air.

"As people came in, it would be able to detect toxic materials present and sound an alarm," he said. "Then people would know to take more careful action in handling these people who are coming in for triage."

Wohltjen has come a long way from when he first founded Microsensor Systems, Inc. In the early days, he said, he was simply fueled by the belief that the detection technology he and his colleagues were developing had the potential to make a contribution to society. Now Wohltjen serves on several boards for tech start-ups and has worked as the principal investigator on more than $10 million of U.S. government funded R&D projects.

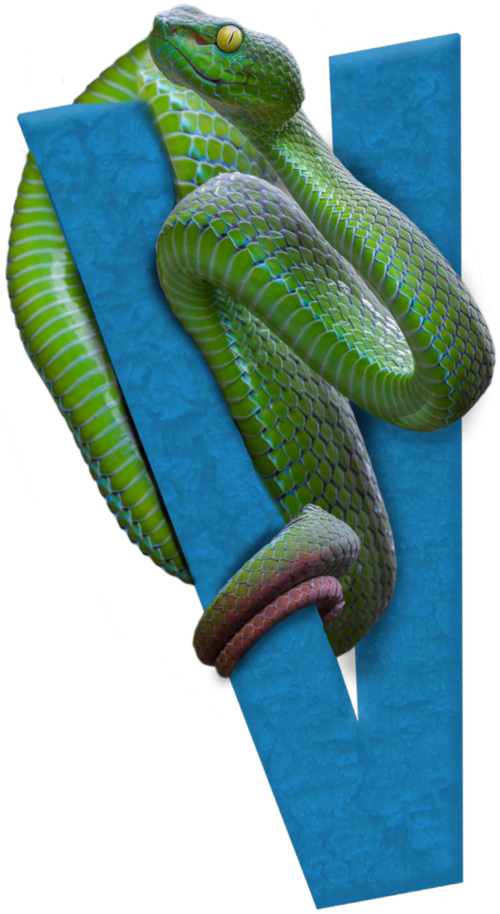
As for Microsensor Systems, Inc., it no longer exists by that name, having gone through several acquisitions, most recently by ENMET, LLC, in Ann Arbor, Michigan (for whom Wohltjen serves as the CTO). Still, Wohltjen says, a lot of the people who started with the SBIR contract in 1996 continue to work at their same desks in the Bowling Green office. And the detection technology? It has relied on niche applications in which it continues to be highly relevant and effective. For example, Wohltjen's company builds and maintains critical infrastructure detectors in Washington, D.C., New York, Boston, Los Angeles, and Chicago.

The SBIR program, through its support for growing businesses and nascent technologies, provides a launchpad for passionate innovators looking to develop their ideas. "You have some technical people who have an idea and want to commercialize it, but who know nothing about business or production—I'm speaking mainly about myself," he said. "But we believed the technology had utility. There's a relentless effort required to adapt technology as required to solve a specific problem for a specific customer. It's something that takes many, many years. But that has been our passion. And we've stayed with it."

Photos courtesy Hank Wohltjen

Microsensor Systems (ENMET, LLC)

Bowling Green, KY (Ann Arbor, MI) • SBIR contract: DAAH01-96-C-R115 • Agency: DARPA • Topic: SB941-067, Fully Automated, High Performance SAW Microsensor Array for Mobile Air Sampling and Chemical Monitoring



iPER

Monterey Technologies' Visual Planning, Execution and Review software lets military and commercial planners execute complex missions on the fly.

Imagine the following scenario: late one evening a United States Navy attack submarine, the USS City Fish, departs the Virginia Capes Operating Area in Virginia Beach, Virginia. The longplanned deployment, crossing the Atlantic Ocean, is first scheduled to stop in Faslane, Scotland, approximately 3,500 miles away. The operation includes multiple anti-submarine warfare (ASW) exercises, port visits, and special operations.

During a routine radio check later that night, the crew receives an urgent message. Current deployment plans are cancelled and the USS City Fish is ordered to make "best speed" to the Suez Canal for a different operation in the Arabian Gulf, more than 9,000 miles away. Retasked, key personnel gathered to create a new plan.

But there is a problem: the crew is not prepared for operations in that area of the world. Executing a major change of plan requires extensive and simultaneous re-planning of navigation, operations, weapons, engineering, and logistics. Navigation charts and environmental data, such as weather forecasts, need to be studied in detail. Complex operations, ship courses, and maneuvers must be developed using mission planning products, including Power Point charts and Excel spreadsheets (not integrated with each other), paper maps, decision briefings, Word documents, and

USMTF messages (United States Message Text Format are military standard messages).

The inordinate amount of time that it takes planning teams to create mission planning products is a fundamental challenge. Each Power Point and Excel spreadsheet requires many hours of effort. Every plan change is manually updated, possibly introducing human error, and reviewed. The process is iterative until a final plan is approved that allows the sub to reach its destination safely and on time.

Bryan Ramsey, Deputy Program Manager for Science and Technology Project Management Activity 281, Naval Air Systems Command (NAVAIR), said, "We were using grease boards, white boards, and other tools, such as Power Point. There was no single tool to plan and coordinate everything to get from point A to point B. If someone made a change, we had to go back to the whiteboard and redo everything. And if there was a mistake, there could be a disaster."

Enter Monterey Technologies, Inc. (MTI). Robert (Bob) Chamberlain, President, explained: "At issue was, and continues to be, how large planning teams go about planning for complex operations. In response to the Department of Defense's SBIR (Small Business Innovation Research) call, we proposed a digital software program to the Navy that automates those manual planning processes and automatically captures and presents the data in a familiar format. We automated the planning process so they could make a change and be sure there are no transcription errors, eliminating mistakes, and saving hours of time."

Visual Planning Execution and Review Mission Planning Application, ViPER MPA, is an elegant logistics planning application engineered by ex-Navy planners. Chamberlain said, "A handful of us had backgrounds as tactical navigators. One of them is Todd Cloutier." MTI's lead business director for mission planning systems, Cloutier is also a former submariner. Cloutier said, "My title was Plans Officer, on the USS Abraham Lincoln. I did that every day for four years. I absolutely understood the problem that ViPER solved."

"I believe in the SBIR program," said NAVAIR's Brian Ramsay. "If we had tried to do this through a regular acquisition process, it would have cost much more money."

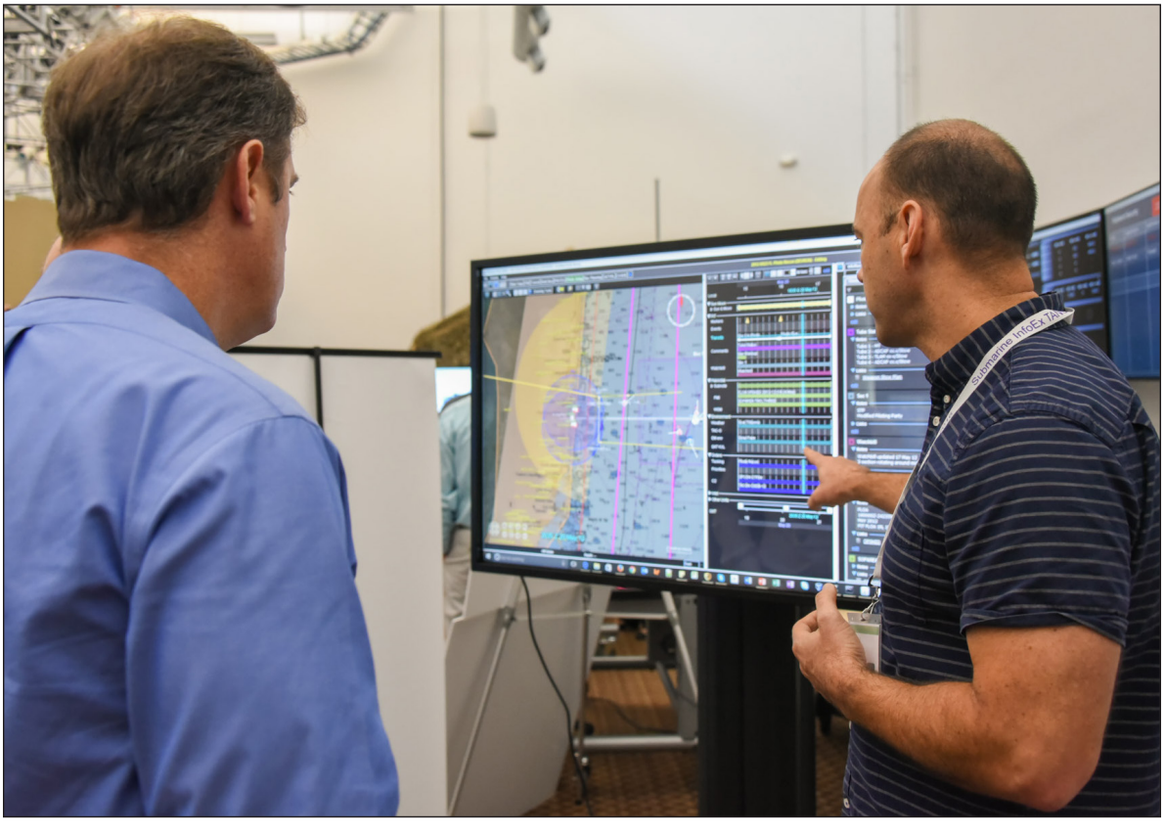
One of the tasks that Cloutier tackled, as Plans Officer, was to shuffle through seven types of charts in order to identify the shallowest points in the transit corridor. This was taking from seven to eight hours to accomplish. Using ViPER MPA, however, this same task can now be done in three to four minutes.

Cloutier said, "We wanted to ease the transition to execution. We want to say, 'Go!' and then start going. How do we do that in ViPER? The solution is all the data goes into one database."

ViPER can visualize all of the geographic and time-based constraints. It shares information digitally and automatically. It outputs flowcharts and messages, uses a plans database (routes, maps), helps define routes, performs calculations for tactical decisions, consults weather forecasts, and exports data, including screenshots and orders, and schedules of events in a small, readable file. It also prints the plan, significantly reducing the time between the Commander's order to execute a new plan and the executive order to follow it.

Bob Chamberlain

"I believe in the SBIR program," said NAVAIR's Brian Ramsay. "If we had tried to do this through a regular acquisition process, it would have cost much more money. Doing this with a small business initiative,



A Monterey Technologies team member demonstrates ViPER at a sales conference.

we saved money and taxpayer dollars. The SBIR gave us the ability to work with Bob, Todd, and Monterey Technologies. ViPER provided us with a single tool that enables electronic planning across multiple different platforms, does the coordination, and synchronizes data and messages in real time."

Based in Park City, Utah, with offices throughout the U.S., MTI is a human-centered analysis, design, and ergonomics firm that believes technology should be developed to serve the needs of the human user. Current clients include the military, defense contractors, and the commercial sector.

Chamberlain said, "There are significant non-military applications for the general ViPER product. For example, international relief efforts, like in Haiti, where a team must plan for multiple types of assets over time, determine who needs what, when they need it, where supplies are, where they need to be, how to get them there, and what the priority is for delivery. And wildfire response, like the 2017 and 2018 massive California wildfires. This is a situation where there needs to be a huge coordination effort. ViPER does exactly that."

Luckily, ViPER MPA is integrated on all Navy submarines. If the USS City Fish had been real, the crew would have simply entered the new deployment order into the system. The navigation, engineering, and operations plans would have been downloaded and safety checked against the latest chart and environmental data. The crew would have slept peacefully, and spent the next week in transit to the Arabian Gulf preparing for their new mission. And once on station, the crew would have been rested, trained, and ready to go.

Monterey Technologies, Inc.

Park City, UT / Monterey, CA • SBIR contract: W911W6-05-C-0006 • Agency: Army • Topic: A03-070, Merging Sensor and Stored Terrain Database Data for Rotorcraft Poor Visibility Weather Operations

a SLIVER of SILVER

Standardizing nanomaterials benefits occupational safety research

Humans have been aware of silver's antimicrobial properties for thousands of years. Persian kings refused to drink water not kept in silver containers, and Macedonians applied silver plates to wounds to facilitate healing. Some Western homesteaders dropped silver coins into milk to prevent spoilage.

These days, silver still serves as a simple, cost-effective way to control microbial growth in a variety of medical applications, including dental work, burn treatment, and catheters. The precious metal is often used in the form of nanomaterials—tiny particles, hundreds or thousands of times thinner than a human hair. And the use of nanomaterials isn't limited to silver. Some commercial pregnancy test strips utilize gold nanoparticles, and many everyday household products like cosmetics, cleaners, supplements, and clothing incorporate traces of different nanomaterials. As nanomaterials of silver, gold, platinum, and other compounds have become more readily available, scientists are researching their uses in many fields, including cancer therapeutics, medical diagnostics, water purification, and solar energy.

While the technologies are promising, the increasing use of nanomaterials also raises new questions about potential risks to consumers. To answer important safety questions, rigorous studies on toxicity and the occupational health effects of exposure to nanomaterials through inhalation, dermal contact, and ingestion need to be fully quantified.

San Diego-based nanoComposix, Inc. is paving the way for these essential studies. Scientist Steven Oldenburg founded the company in 2004, out of frustration over the difficulty of acquiring high-quality nanomaterials. He was also motivated to speed the pace of nanomaterials research and product commercialization.

"Every time I ordered a product from a nanomaterial or chemical company," Oldenburg said, "I would spend hours performing characterization only to realize that the shape, size distribution, agglomeration state, or chemical purity was not what I was expecting."

In 2008, the company won an Air Force Small Business Innovation research (SBIR) contract to investigate how nanoparticles affect occupational safety and health.

One of the biggest impediments to studying the effects of nanomaterials was variation in the materials themselves. The inconsistency of nanomaterial manufacturing, including product contamination by residual chemicals, led toxicology laboratories to come up with widely disparate results.

"There was really nobody making a material that was suitable for the toxicology community to adopt as a standard to do the tests," said Thomas Darling-

Bjoern Wylezich / Shutterstock.com

ton, Research Lead in Composites at nanoComposix. "One of our key roles was to provide well-controlled, well-characterized, and uniform nanoparticles that we could use to study the effects on the human body which relate to safety and health."

Take silver, for example. Many of the manufacturing processes for silver nanoparticles are not well-controlled, allowing contaminants to infiltrate the resulting product. So nanoComposix's scientists and engineers created highly purified silver nanoparticles using a specialized process to wash away any reactants from the material, ensuring that silver meant silver—that the label on the sample matched the actual product. That way, toxicologists could accurately determine the material's influence on occupational health apart from other chemicals in the mix.

Under the SBIR, the company developed more than 250 variants of nanoparticles. The idea was to tune a single characteristic at a time, in order to be able to investigate whether attributes such as size, shape, aspect ratio, or surface chemistry had a specific impact. Each material was characterized and sorted based on its properties, and a series of 20 reference panels were created that could be used to develop predictive risk models for occupational health and safety. The reference panels represented a set of standardized nanomaterials with well-defined physical and chemical characteristics—a feat that had not been attempted before.

In essence, nanoComposix was able to create a library of standardized nanomaterials for toxicologists. The availability of highly characterized, precisely engineered nanomaterials has already led to hundreds of studies that test the possible implications of using such components in the workplace.

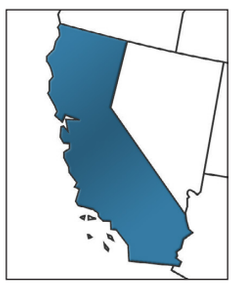
"As people are doing more things with these materials, now they have a resource where they can look up, say, silver nanoparticles: Are they dangerous? How can I work with them?" said Oldenburg. "One of the big impacts of our library is the emergence of a body of literature focused on a common set of materials. More than 300 publications have come from research based on the library, so there's this really rich, deep academic investigation that has gone on. "

"The SBIR," Oldenburg said, "allowed us to reach out to the nanotechnology and nanosafety communities, and massively accelerated our ability to help out."

Along with helping toxicologists better understand the potential health risks of these versatile and powerful materials, nanoComposix has also improved the quality of nanoparticles available to researchers around the world. Today, a wide range of laboratories in government, academic, and industrial sectors use the company's materials for both toxicology testing and nanomaterials research, including more than twenty labs within the Department of Defense.

"The company was founded on the principle that people making nanomaterials were making things that didn't necessarily correspond to what they said they were. You have to test them, characterize them—it's a complex process," said Darlington. "We go the extra mile, so if you get something from us, it's going to be what it says it is."

Emerging from work accomplished under the SBIR, two of nanoComposix's silver nanoparticles have been selected by the National Institute of Standards and Technology (NIST) and the Organization for Economic Co-Operation and Development (OECD) as reference standards—an immense opportunity as well as recognition of the company's years of hard work.



"The SBIR," Oldenburg said, "allowed us to reach out to the nanotechnology and nanosafety communities, and massively accelerated our ability to help out."

At the Speed of HOLLYWOOD

Rapid DNA identification system helps military and civilian law enforcement agencies track criminals and victims

DNA evidence is not only vital in criminal investigations and counter-terror operations, it's also endlessly fascinating for fans of television crime shows. Unfortunately, the DNA samples that might take an actor a few minutes to run on TV can take real-life forensic labs anywhere from 6 to 24 months to process. But thanks to ANDE Corporation's groundbreaking Rapid DNA identification system (also named ANDE), we're a step closer to convicting criminals at the speed of Hollywood.

Richard Selden, ANDE Founder and Chief Scientific Officer, said, "Rapid DNA is designed to overcome the primary limitation in conventional labs—the months required to generate a DNA ID. The labs are inundated with samples, and by enabling non-scientists to process DNA quickly, ANDE is bringing actionable results to the places that need them most: the police station, the battlefield, the border, and the disaster site."

In 2011, under the company's former name, NetBio, Selden won a Small Business Innovation Research (SBIR) contract from U.S. Special Operations Command to develop a mobile rapid DNA identification unit for non-technical users. The resulting ANDE system allows military or law enforcement personnel to work directly in the field. In approximately 90 minutes (or one episode of "The Wire"), ANDE can process a broad range of samples, including small blood stains; handled objects such as bottles, cups, and weapons; and

Rost9 / Shutterstock.com

tissues including muscle, liver, bone, and teeth.

ANDE's success in bringing the technology to market resulted from creating a product based on the needs of potential end customers.

"We worked closely with Special Operations Command (SOCOM), the Federal Bureau of Investigations (FBI), and Department of Homeland Security (DHS) to incorporate their specific requirements, instead of building a product in a vacuum and hoping someone would need it" explains Selden.

SOCOM, DHS, and the FBI subjected ANDE to rigorous in-field performance assessments and pilot studies over a period of five years. The resulting feedback helped ANDE fine-tune the system's ease of use, transportability, and automatic database connection. The feedback also allowed ANDE to address related challenges facing public safety authorities, including chain of custody of samples, protection of privacy, and policy issues, significantly reducing barriers to the adoption of Rapid DNA technology.

"The SBIR had a substantial impact on the company and, even more importantly, on societal safety," said Selden.

Law enforcement agencies around the country are adopting the ANDE system. In a 2017 Memorial Day shooting, the Miami Beach police successfully used ANDE to process DNA evidence from a recovered handgun. They found a match with an individual already in custody.

"ANDE gives us the ability to solve crimes quickly, to rule out the innocent, and to identify and to pursue that bad guy with all of our resources," said former Boston Police Commissioner Ed Davis.

The new system is cost-effective, fast, and easy to use. The ANDE instrument is about the size of a microwave oven, needs only electricity to work, and does not use fragile materials or supplies that require refrigeration. Users collect a DNA sample from a handled object or weapon with the Radio-Frequency Identification (RFID) enabled swab, insert the swab into a protective tube affixed with a unique bar code, then lock the swab into the system's cartridge. The cartridge can hold a maximum of five samples at a time, and includes the chemical agents needed to process the samples. In under two hours, ANDE returns a DNA ID, sometimes called a DNA fingerprint, tracked via the RFID chip and matched against a local, state, military, or disaster victim database.

In 2016, the FBI announced that ANDE received National DNA Index System approval, which represents the first and only FBI certification of a fully automated system for Rapid DNA analysis. And in August 2017, the Rapid DNA Act, a bipartisan bill passed unanimously by the U.S. House and Senate, was signed into law. ANDE will allow police officers in the 30 states with arrestee-testing laws to take a cheek swab from a suspect and use it to search through the FBI's new Rapid DNA Index System database. When a match is made to an unsolved crime, the suspect can be held based on this lead. This is a major change to previous practice, in which individuals were released well before conventional DNA analysis could be performed.

"The SBIR had a substantial impact on the company and, even more importantly, on societal safety," said Selden. "The [contract] enabled us to expand the utility of the system, with major military and civilian applications in law enforcement, border and port protection, human trafficking prevention, and disaster victim identification. The SBIR program provides a tremendous benefit to our country, allowing small companies to pursue big ideas."

NetBio, Inc. (ANDE Corp.)

Waltham, MA • SBIR contract: H92222-11-C-0030 • Agency: SOCOM • Topic: H-SB09.1-001, Low Cost and Rapid DNA-Based Biometric Device

LOST IN SPACE

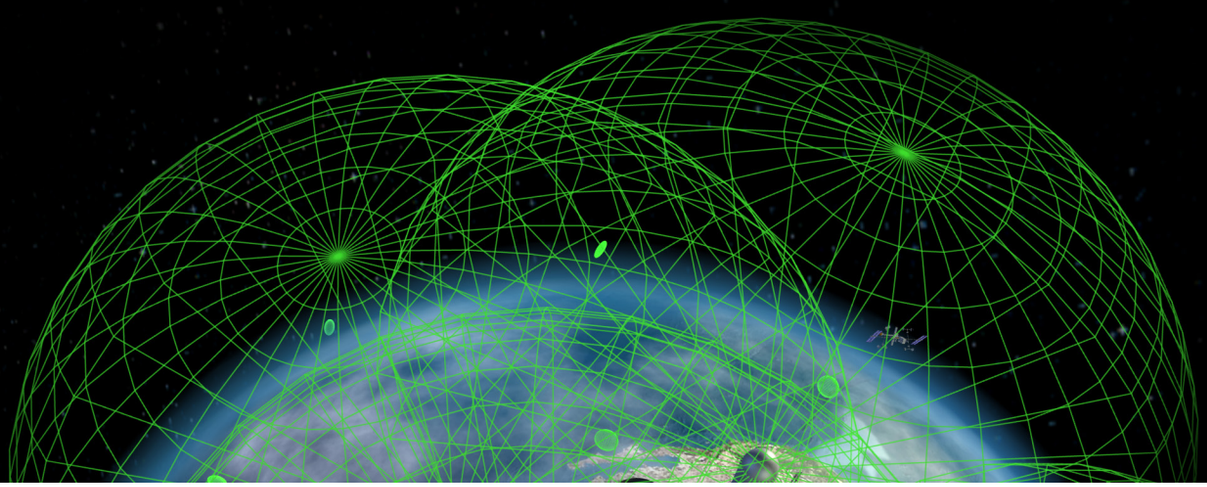
Oceanit's global surveillance network tracks orbiting satellites, debris, and asteroids

Remember when almost the only objects visible in the night sky were natural: the moon, stars, meteors, and comets? Probably not, because all that changed in the late 1950s with the expansion of commercial air travel and the launch of Sputnik, the first artificial earth satellite. Since then, thousands of space-based objects, including derelict spacecraft and Elon Musk's red Tesla roadster, litter the heavens. According to the United States Strategic Command, there are 17,852 unnatural objects orbiting the Earth large enough to be tracked, and literally millions of bits of debris, smaller than 10 cm, that are difficult to see.

Debris can collide with other objects, including satellites or even the International Space Station (ISS), to dangerous effect. As a result, in 1979, the National Aeronautics and Space Administration (NASA) developed their Orbital Debris Program. Since then, space has been increasingly militarized with spy and eavesdropping satellites, the Global Positioning System (GPS), and defense communications systems.

So how do we know what's up there?

Oceanit, a Honolulu, Hawaii-based small business, founded in 1985 by Dr. Patrick Sullivan, has



shutterstock.com / Oleksiy Mark

the answer. An innovative 'Mind to Market' company, Oceanit transforms concepts from fundamental science into products and services, including sensor and communication systems, software, and advanced materials—such as coatings, fabrics, and industrial products—for both commercial and military users.

With support from the Department of Defense's (DoD) Small Business Innovation Research (SBIR) program, Oceanit developed the High Accuracy Network Determination System (HANDS). HANDS provides continuous autonomous tracking of space objects 22,000 miles above Earth. The technology was built as a global network of autonomous telescopes to accurately track space-based objects by fusing observations from many sites around the world.

Dr. Sullivan credits the SBIR program with reducing the technical and market risks, making it possible for Oceanit to create this innovative technology.

Sullivan, Oceanit's chief executive officer, described HANDS as being similar to an air traffic control system for space. "We can characterize satellites, asteroids, and debris. There are so many objects in space now. The debris patch has gotten huge and space is more congested than ever. There are military players and communications satellites, which we all rely on. In addition, small companies are putting up inexpensive objects that can work in swarms, changing the economics of sending satellites into space. We created the ability to track space objects 24 hours a day, seven days a week, for minimal cost."

In the 1990s, the DoD's Air Force Research Lab (AFRL) was interested in investing in new ideas for Space Situational Awareness (SSA). Oceanit, true to its reputation of being willing to try new things, was an early pioneer in the field. SSA monitors everything in the near-earth environment, including the sun, solar wind, ionosphere and thermosphere. It detects near-earth objects (NEO) such as asteroids, and active and inactive satellites. In the early years, SSA was predominantly conducted via a few big radar stations run by National Laboratories.

During their research, Oceanit demonstrated that small optics, connected around the planet, could provide accurate and valuable information on low-earth orbit (LEO) and high-earth orbit (HEO), including geosynchronous earth orbit (GEO) objects, rather than relying on the larger radar stations.

"We demonstrated that we could collect quality optic information for a fraction of the cost of traditional methods (i.e. large optics). We started with a Phase I Small Business Innovation Research (SBIR) contract to develop the concept. In Phases II and III we further developed and ultimately built the HANDS global network system," said Sullivan.

Until Oceanit started building and testing HANDS, the AFRL was doubtful the required accuracy could be achieved. Scientists and engineers at AFRL were certain that the physics would not work.

Dr. Sullivan said, "Through another project, we learned that one inexpensive, simple sensor had little value, but aggregating data from many small sensors could provide value in spades. We then turned the problem to the sky and thought we could do this for space. We showed the Air Force the data, proving the science and creating new ways to think about what is actually possible. The biggest achievement was to meet the challenge of demonstrating sub arcsecond accuracy with small optics. We had the confidence to experiment and demonstrate results. And we did. Data speak volumes over a powerpoint presentation. The SBIR program gave us the flexibility to explore the possibilities."

Dr. Patrick Sullivan

Oceanit built a system of 9 to 10 stations and could track 95 percent of

Global network locations of HANDS telescope sites.

space all day, every day. They ran the initial proof-of-concept system as a full-scale pilot demonstration for several years, feeding data into a classified network. Then they developed the fully autonomous, operational and secured HANDS system.

While the achievements were monumental, there were challenges along the way. For example, in some remote locations, the Oceanit team had to build domes to protect their equipment from rat infestations. And the initial version had been built on an unstable software platform that kept crashing, requiring them to switch to another, more robust program. Throughout the ups and downs, Dr. Sullivan credits the SBIR program with reducing the technical and market risks, making it possible for Oceanit to create this innovative technology.

"We had problems (that) we could not imagine until we were in them. We had to rebuild things because, as we have learned over and over, innovation is messy. So, we continuously saw what worked, improvised, and upgraded accordingly. If you're willing to discover and are open to learning along the way, there is no limit to what you can do," said Sullivan.

Oceanit is leveraging insights from HANDS for other discoveries, such as a synthetic optic nerve that can be used for high-agility robotics including autonomous cars, and smart materials with myriad applications.

"When we first developed HANDS, the potential security threat in space was much smaller than it is today. With the emergence of China and other countries developing space agendas, the U.S. interest has significantly increased. Plus, commercial space has made "the final frontier" much more accessible to just about anyone, making HANDS more relevant than ever. Oceanit is also working on other technologies that can be employed to find responsible solutions to combat some of the world's most difficult problems like climate change, health and wellness, and others," said Sullivan.

Oceanit Laboratories, Inc.

Honolulu, HI • SBIR contract: F29601-01-C-0175 • Agency: Air Force • Topic: AF99-036, High Accuracy, Automated Satellite Surveillance Network

CAN YOU SEE ME NOW?

Phase Sensitive Innovations' novel imaging technology sees through the fog

Getting shot down isn't the only threat faced by helicopter pilots flying in combat zones. In certain environments, the elements can be as dangerous as the enemy.

In Iraq and Afghanistan, for instance, the thick dust created when a helicopter hovers close to the ground can cause even experienced pilots to crash. Degraded visuals sometimes lead to controlled flight into terrain (CFIT), an accident scenario in which an aircraft, under pilot control, is unintentionally flown into an obstacle. In a CFIT situation, the pilot and crew are unaware of the imminent disaster until it is too late.

During recent wartime operations in desert theaters, the potential for CFIT necessitated that countless missions be modified. Operations that may have required the delivery of 100 marines into a contested area had to be adjusted because the helicopter could only handle 30 to 50 personnel in one transport. Due to dust clouds and the resulting lack of visibility, called "brownout" conditions, the pilot would have to wait for the air to clear, or do a second personnel drop in another area. Both options put soldiers at considerable risk.

In the late 1990s and early 2000s, a small group of researchers at the University of Delaware tried to solve the problem. Fortuitously, they were already working on a Defense Advanced Research Projects Agency (DARPA) funded millimeter-wave imaging project. Their goal was to identify frequencies of interest to the military. Situated between the microwave and infrared section of the electromagnetic spectrum, millimeter waves are electromagnetic radiation with wavelengths in the range of 10mm to 1mm (with corresponding frequencies of 30 to 300GHz). However, without electronic components that could generate or receive millimeter waves, this range of the spectrum was largely unused and represented a treasure chest of new opportunity.

"It was all about understanding what you see in these frequencies. The goal was to create a detector for passive imaging—basically a cross between radar and camera that can see in the dark without any light bulbs or transmitters. Imagine an infrared camera but with longer waves, so it can see through things," said Dennis Prather, now President of Phase Sensitive Innovations (PSI).

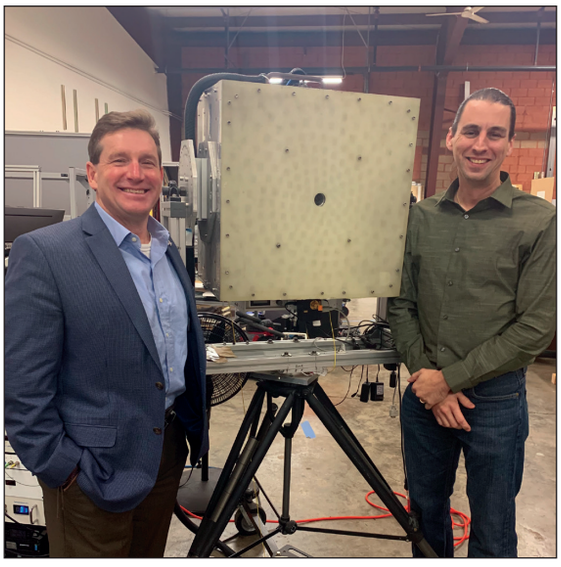
Leveraging their work, the university research group eventually formed PSI in order to respond to a Small Business Innovation Research (SBIR) solicitation from the U.S. Navy. The initial objective was to create a device to see through blowing sand. "The Navy wanted to see what things look like in those frequencies," Prather said. "Mechanical scan systems had been the state of the art until then. But they are big, heavy, and bulky. Size, weight, and power (SWaP) matter. The old technology, at hundreds of pounds, is not low SWaP and it could not be widely deployed on military platforms. Our approach is very different. We have low SWaP and better performance. To do this, we had to invent the devices that make the system work."

"The SBIR program gave rise to the birth of our company and kept us from going out of business when times were lean."

According to Chris Schuetz, chief technology officer of PSI, four teams proposed an idea. PSI and one other received Phase I SBIR contracts. "Most technology developments over the last two decades have been improved by fiber optics, which is one of the lowest-loss transmission mediums known to man. We said, if we are going to look at signals in the millimeter wave spectrum, we need to turn them into light first, and then use fiber optics to route and transmit the light."

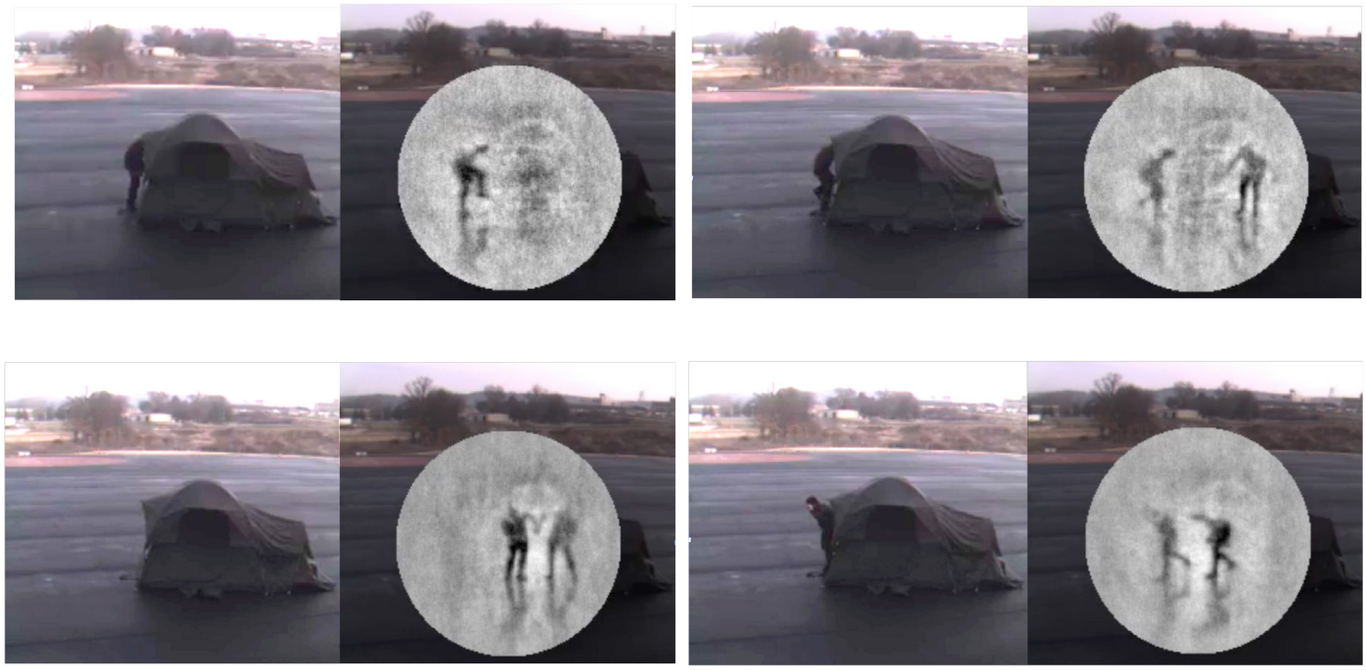
In order to do that, the company needed to create devices that encoded the technology about 3 to 4 times faster. On the way to achieving their objectives, PSI thus made the world's fastest optical modulators. The technology can encode signals over any radio frequency band, turn it into light, and route it using low-loss fibers. This development allowed the company to build an array of antennas that enable real-time video millimeter wave imagers, which is exactly what the military wanted. Schuetz added that the "idea was conceived in 2001 on a napkin. It has been successfully demonstrated on a helicopter and is now in the final stages of commercialization. It has been an amazing ride."

Prather further explained, "Our technological breakthrough offers a whole different way of seeing the world." Millimeter-wave technology allows the user to see through darkness, dust, smoke, clothes, plywood, tarps, tents, snow, and smog, to name a few. An especially attractive and unique feature of PSI's system is that it is not an active system, meaning it does not illuminate the scene. Rather, it visualizes passive signals from the environment similar to an infrared imaging system, which is important for avoiding detection from other sources —a key capability for military countermeasures.



Dennis Prather, left, and Chris Schuetz, with a passive millimeter wave imaging system built by PSI.

PSI has received a number of Department of Defense (DoD) Phase II SBIR contracts to continue work on the imaging technology. "If I can see things in a different part of the spectrum that allows me to see through things, I can use it for a host of other applications," said Prather. "For example, person-borne improvised explosive devices (PBIED). We can monitor a public gathering



The imaging technology developed by Phase Sensitive Innovations has a number of applications, including persistent surveillance.

and see people from a distance to determine if they are a threat to the greater population. In this way, it can be used as a persistent surveillance tool." Prather went on to explain a critical element of the technology, using airport security as an example. "That is considered a 'cooperative environment' where people voluntarily comply with security screenings. But what if we are considering 'uncooperative environments,' such as people intending to do harm? It turns out if someone has a concealed object, we can see that really well." Prather imagined a scenario in which the Las Vegas Mandalay Bay hotel entrance might have been equipped with his technology on that fateful day in October, 2017. Law enforcement would have been able to implement countermeasures the moment the gunman entered the building with firearms in his golf bag. Fifty-eight lives might have been spared.

The largest impact of the technology is still to come. Since it is composed of unique proprietary parts and not off-the-shelf components, PSI is necessarily ramping up its manufacturing capability to meet expected demand. In partnership with the Office of Secretary of Defense, Manufacturing Technology (OSD, ManTech), PSI is building out a 15,000 square foot state-of-the-art manufacturing facility under a SBIR Phase III effort.

Reflecting on their success, Prather remarked, "The SBIR program gave rise to the birth of our company and kept us from going out of business when times were lean. And it has allowed us to develop the technology for manufacturing. This capability would not exist otherwise, period. Considering the money invested, the return is enormous."

For the helicopter pilot who only has half a second to determine what is around him, PSI's technology is more than a return on investment, it is a life saver.

Phase Sensitive Innovations

Newark, DE • SBIR contract: N00024-11-C-4195 • Agency: Navy • Topic: N092-133, EW Countermeasures Against Passive MMW Sensors

SEPARATION ANXIETY

A LOW-IMPACT, LOW-STRESS SATELLITE SEPARATION SYSTEM BENEFITS BOTH THE MILITARY AND COMMERCIAL SECTORS

Few sights are as thrilling as a rocket launch. The roar of accelerating engines, the plume of exhaust, the bright spot of flame at the base of the rocket. Finally, liftoff. But what if you're a business owner with an expensive satellite strapped to that rocket—perhaps by nothing more than a tightly cinched steel band? The thrill would quickly turn into white-knuckled anxiety.

"If the band cracks open when it's on the launch pad or in orbit, you've lost that quarter billion dollar spacecraft and a quarter billion dollar rocket," said Walter Holemans, founder of Planetary Systems Corporation (PSC). "That scares people, as it should."

Challenges surrounding satellite launch and separation from the launch vehicle were daunting enough when only the military was launching satellites. But the recent surge in commercial space flight has made satellite separation a major issue for civilian entrepreneurs and investors as well. Holemans knew there had to be a better system. Considering the problem, the PSC team realized that some of the trouble with existing satellite separation technology was inherent to its basic design, which can strain bands to breaking.

Nasa / Bill Engalls

"They drive the tension up to six thousand pounds, about the weight of an SUV," Holemans said. "So we took that entire design and inverted it—instead of a tensile element on the outside, we put a compressive element in the inside."

This idea became the basis for PSC's Lightband satellite separation system, developed with support from the Air Force Small Business Innovation Research (SBIR) program. Lightband eliminates the two major problems of standard separation systems: fracturing and shock from the explosives used to break open the band to release the satellite.

"Because it's in compression, cracks don't mean anything. They'll just sit there," Holemans said.

And the Lightband eliminates shock risk by using electric motors to trigger separation rather than pyrotechnics.

"With the prior technology, an explosive bolt-cutter cut the bolt that held the band together. Imagine pointing a gun at a quarter-inch diameter bolt and just blowing it off," Holemans said. "It's like hitting a satellite with a hammer."

The motorized separation system has another benefit as well: its reusability helps satellite designers improve reliability even while saving money.

"Engineers on the ground have to test things associated with the separation, and if they've got a pyrotechnic, they can only test it once. That can cost thousands, sometimes tens of thousands, a shot," Holemans said. "And the bolts they cut can also costs thousands of dollars. So engineers look at the costs and say, 'Whoa, do we really have to do this test?' Our system uses electric motors, so you can test and reset all day long."

The Lightband's compact weight—about five pounds, versus roughly fifteen pounds in the previous technology—is another money saver for satellite developers.

Launch costs can be calculated per pound of satellite, Holemans said, "so saving ten pounds of weight saves $200,000 or more in launch costs. That's more than the cost of the Lightband. For end users, it's a no-brainer."

Along with development, the SBIR program also helped Holemans and his PSC team with the last, crucial piece needed for the Lightband's success: proving it worked in actual missions.

"It's very important to prove that you've been exhaustive in your ground tests. But getting an actual record of space flight—that's what people really need to see," Holemans said. "The people we worked with at the Air Force Research Lab understood this very clearly, and they guided us through that process." With SBIR support, PSC was able to demonstrate the technology to major aerospace players like Lockheed and Boeing, in addition to the Department of Defense, Holemans said.

Along with development, the SBIR program also helped Holemans and his PSC team with the last, crucial piece needed for the Lightband's success: proving it worked in actual missions.

The Lightband satellite separation technology is now used with a wide range of spacecraft, from commercial imaging satellites to university research and military craft.

"DoD, NASA, commercial space, universities—our Lightbands have even gone to the moon a couple of times," Holemans said. He credits the SBIR program for much of the Lightband's success. "The SBIR program was just wonderful across the board. We got to work with people who really knew what they needed."

Holemans noted that his own success can be attributed in large part to good government leadership, as shown through the SBIR process. He is grateful for the support and excited about the future. "We have ten employees with good jobs," he said. "And because we only do separation systems, the government now has the benefit of an expert company that's U.S.-owned and operated."

THAT'S A WRAP

A LOW-COST, ANTIBACTERIAL INNOVATION AIDS IN BURN TREATMENT

The first out-of-laboratory tests of a novel treatment for burn wounds took place in the trauma unit at University of Florida Shands Hospital system in Gainesville, Florida, in 2009. Nurses placed standard silver dressings on two wounds and then Quick-Med Technology's FDA-approved BIOGUARD gauze over the silver dressing on one wound and Brunswick gauze over the other.

Director of the Institute for Wound Research at the hospital, Dr. Gregory Schultz, remembers the test. "Basically, when the nursing staff took down the dressings, the Brunswick gauze was green with Pseudomonas [bacteria]," Schultz said. "In contrast, the BIOGUARD dressing was essentially sterile—just pure white."

When the nurses changed the contaminated Brunswick gauze dressings, he added, "a huge amount of bacteria was aerosolized—onto the patient, the nurses, the bed, and the floor. But there were no bugs growing on the BIOGUARD dressing—it killed all of them. It took the nursing staff about three patients to say, 'Enough—no more conventional gauze in the trauma unit.'"

The tests were enabled through a Small Business Innovation Research (SBIR) contract that addressed the U.S. Army's need for better treatment of vesicant, or chemical-weapon burns. Although outlawed by two international agreements, sulfur mustard agent—a particularly cruel method of chemical warfare used in WWI—surfaced in the late 20th century among terrorist groups, and has been used in Middle East conflicts. Effects of the gas are slow to emerge, severely wounding but not killing its victims, and forcing the affected force to retrench to treat its wounded.

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In 2005, in response to escalated incidents of sulfur mustard use, and aware of Quick-Med's progress with a technology known as NIMBUS (Novel Intrinsically Microbicidial Utility Substrate), the U.S. Army awarded an SBIR contract to Quick-Med.

The NIMBUS technology centers on an active antimicrobial agent, a large polymer called polyDADMAC. When bonded to a gauze dressing and placed over a burn injury, polyDADMAC displaces stabilizing calcium ions on the cell membrane of bacteria. Basically, it creates holes in the cell wall. And because the polyDADMAC molecule is so large, it cannot enter the cell where mutation might create bacterial resistance.

Tests have shown that polyDADMAC, incorporated in the BIOGUARD dressings, is 99.99 percent efficient in killing Methicillin resistant *S. aureus* (MRSA), *Psuedomonas aeruginosa*, and *Escherichia coli* (E. coli), among other bacterial strains.

Burn victims face many challenges. Wounds discharge fluid at a high rate and bandages need to be changed frequently. The warmth and moisture of the wound can nurture bacterial populations, which can double in number in a little over 20 minutes. Sometimes bacteria form biofilms that protect the bacteria from antibiotics and the patient's immune system. Burn victims die more frequently from the results of infection than from the burn itself, according to Quick-Med President Dr. Bernd Liesenfeld.

In this context, NIMBUS addressed several major issues related to burn treatment. NIMBUS-treated fabric kills bacteria rapidly without the risk of creating resistant bacteria. NIMBUS can also be made with a superabsorbent quality that doubles or triples the time needed between bandage changes. There is also less odor in the wound dressings.

The technology was featured in TIME magazine's 2006 annual issue on innovation, and received Food and Drug Administration (FDA) clearance in 2009.

Liesenfeld noted that the SBIRs "helped us to really better understand what we could do with the technology ... It was a validation and a really good showpiece—and definitely helped with our research and commercialization."

Liesenfeld, a materials engineer at Quick-Med when the SBIR was awarded, developed the system that allowed for commercial application of the NIMBUS polymer, polyDADMAC, on a fabric. Schultz, who contributed research to the SBIR contract, remembers that the process of bonding was amazingly simple—they simply soaked the fabric in a bath containing a solution of polyDADMAC.

When treated and dried, the polymer was permanently bonded to the fabric—what the engineers referred to as dehydration bonding. At the time, Schultz noted, silver dressings were becoming popular, but were many times more expensive than Quick-Med's BIOGUARD.

Quick-Med was in a position to commercialize BIOGUARD in 2009, licensing it to Derma Sciences, Inc., which was acquired by Integra Life Sciences in 2018. Liesenfeld noted that the SBIRs "helped us to really better understand what we could do with the technology and show some fantastic research results. It was a validation and a really good showpiece—and definitely helped with our research and commercialization."

Dr. Bernd Liesenfeld

Since that time, Quick-Med has distinguished itself with another, possibly more far-reaching, innovation. Using an approach similar to NIMBUS, Liesenfeld used hydrogen peroxide—a common, natural antimicrobial

Creative Commons: WillMcC

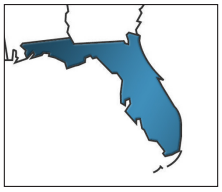
University of Florida Shands Hospital provided the first out-of-laboratory tests for Quick-Med's revolutionary burn treatment technology. Dr. Gregory Schultz, inset, is the hospital's director of the Institute for Wound Research.

agent—in its Stay Fresh™ technology, sequestering hydrogen peroxide into a dry phase and then applying it to a fabric with a binding agent. This treatment inhibits the growth of bacteria and fungi on the textile, and also eliminates odors.

As to bacterial resistance, peroxide in the body is a biogenic process and has been functioning for thousands of generations, Liesenfeld said, "so we don't see any resistance to it. We feel very secure in saying that the chemistry doesn't engender resistant species. That's the binding thread that goes through our research."

In 2018, the clothing conglomerate Phillips Van Heusen licensed Stay Fresh for manufacture of a series of garments.

Schultz is very impressed with the potential for the use of the technology in hospitals. "When you get a hospital-acquired infection, it's usually not from the surgeon's hands in the OR," he said. "It's usually from all the contaminated surfaces that surround the patient— bed linens, drapes, privacy curtains."



According to Schultz, they tested Stay Fresh fabrics through 50 industrial launderings. "It absorbed peroxide used in the industrial washing cycle, effectively recharging its antimicrobial activity," he said, and maintained a sterile surface through all the washings. Other informal studies were conducted in the operating room with clothing made from Stay Fresh fabric. "We cultured the bugs from treated and non-treated scrubs," Schultz said. "The anesthesiologist's pants or shirts, especially if they got splattered with blood, urine, or spit, could be hugely contaminated if the fabric was not treated with a microbicide. On scrubs treated with Stay Fresh, however, there were almost no bugs. That was when we realized this was going to have a big impact."

Quick-Med Technologies, Inc.

Gainesville, FL • SBIR contract: W81XWH-06-C-0024 • Agency: ARMY • Topic: A05-131, Chemical Casualty Care: Wound Dressings Designed to Speed Wound Closure Following Debridement of Cutaneous Vesicant Injuries

TechLink

MAINTENANCE on the HORIZON

U.S. Army photo by Capt. Tyson Friant, 1st Armored Division Combat Aviation Brigade Public Affairs

High tech equipment can be expensive. And when you're talking about aerospace, wind turbines, rail, and medical equipment, it can be *really* expensive. Expensive to buy and expensive to maintain. Consider the rotor on a helicopter. While some parts on the rotor may have been designed to last 20 years, sometimes they fail early. Do you do costly physical inspections? Is there a way to save money on maintenance and still stay safe?

To minimize cost while maximizing asset availability, military and commercial aircraft operators are now using predictive maintenance. Sentient Science, originally based in Idaho Falls, Idaho, now with business headquarters in Buffalo, New York, and research facilities in Idaho Falls and West Lafayette, Indiana, received a Small Business Innovation Research (SBIR) contract from the Navy to accurately forecast the remaining life of critical components—specifically, rolling element bearings.

Data from Sentient Science's initial phase of research resulted in another SBIR contract to create a database of information that could be used to represent the physics of bearing failure accurately enough to model bearings in any type of application. Sentient Science modeled damage progression on healthy bearings to simulate how long they took to fail. This helped the military improve bearing life for rotating components, like those in Black Hawk helicopters and gears in F-35s.

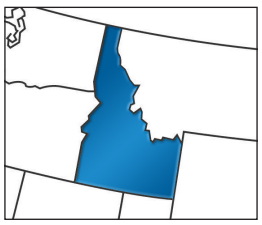
Materials fascinate the people at Sentient Science. They like to take wind turbines apart to see what each

piece is made of. They take samples of components retrieved from the field and do stress measurements, looking at their microscopic structure. All this information goes into a database and becomes part of a mathematical model. Then they take the operational real-world data and continue refining the model.

The detail they go into is amazing. Since the same part may be highly different depending on where it's from, they include information on each manufacturer, the location where the part was made, and the material source. NASA has evaluated their approach and found it to be highly accurate. Their scientists have transformed the industry – physical testing is no longer needed. By using data models, more data points can be tested in less time.

The work that Sentient Science did for the Navy eventually resulted in Digital Clone Live, Sentient Science's software tool. Digital Clone Live provides 18-month rolling forecasts based on models of the physics of failure. Now the military can tell if it's safe for a Black Hawk helicopter to make one more mission before installing new bearings, and a wind energy operator can tell when a turbine part needs replacing without going out to inspect it.

Purchasing decisions can now also be made based on the projected longevity of a product. One bearing might cost more initially, but if it lasts longer, it can be cheaper over its lifetime. By knowing who makes it, where it was made, and what it is made of, Sentient Science is helping buyers understand which equipment will last the longest. Their models even take into account the environment in which the equipment will be used, since cold weather makes parts brittle and blowing sand can wear out components in different ways. In the end, DigitalClone Live is not just an engineering tool but an asset management tool as well.



Because DigitalClone Live's predictions are often better than that of the manufacturer's, vendors are also getting involved in the process. DigitalClone Live can help them make their products better and show them how to extend the life of an asset. When a new gearbox comes onto the market, Sentient Science often gets the design from the original manufacturer so they can put it straight into the modeling process. They can then let customers know if this gearbox will last five years longer than another one they might purchase.

Bolander said, "SBIR was the genesis for the entire technology. There would be no other way for a small company to build this type of technology."

Sentient Science started out working with the military and NASA. And while these entities are still a big part of their pedigree, they've also expanded into the civilian marketplace. In the realm of renewable energy, their goal is to decrease wind energy costs by 13 percent. The company is also expanding into rail and heavy industry.

Nathan Bolander, the Chief Scientist at Sentient Science, thinks that 3-D printing is going to be a "game changer" in the years to come. For example, if you want to put a part on an aircraft, you have to prove it's as safe as the previous version. 3-D printed materials will have different behaviors between printings, so the type of modeling that Sentient Science provides will be even more important.

Whatever the future holds for Sentient Science, this small company could not have built this world-class technology without SBIR. As Bolander said, "SBIR was the genesis for the entire technology. There would be no other way for a small company to build this type of technology…we could not have done it without SBIR."

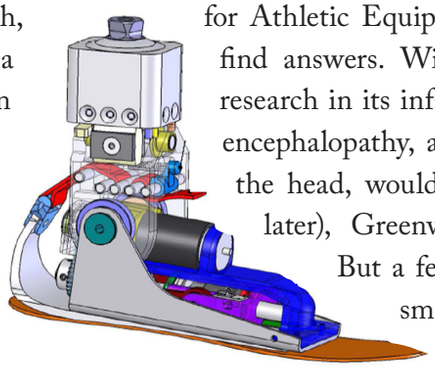
Sentient Science (Sentient Corp.)

Idaho Falls, ID (Buffalo, NY) • SBIR contract: N68335-04-C-0003 • Agency: Navy • Topic: N02-195, Fault-to-Failure Progression Modeling of Propulsion System and Drive Train Bearings for Prognostic and Useful Performance Life Remaining Predictions

A STEP UP

With Help from an SBIR, A New Hampshire Company Creates Cutting Edge Prosthetics

One cold night in Park City, Utah, Rick Greenwald found himself at a party with some of the best skiers in the world.



The year was 1992, and Greenwald, a biomedical engineer by training, was near his home in advance of the upcoming Winter Olympics in France. The night was a fun one, Greenwald remembers, full of the lighthearted carousing to be expected from athletes with the biggest event of their careers on the horizon.

But a few of the revelers stood out. They were quieter, staring into their drinks as if lost in thought.

During a quiet moment, Greenwald asked a friend who the skiers were.

"Those are the aerialists," his friend told him, referring to skiers who launch themselves off jumps into twists and flips as high as 60 feet in the air.

As someone who had lived in and skied the mountains of the Northeast, Greenwald's interest was piqued. The next day, he attended a practice session to watch the aerialists. Most of the time, the skiers landed their jumps without any problem. But one out of every six or seven went awry, whipping the skiers' heads—clad in their helmets, which turned out to be kayaking helmets—into the hard-packed snow.

"I said, 'What is that doing to them?'" Greenwald later recalled.

With grant funding from U.S. Olympic Committee and the National Operating Committee on Standards for Athletic Equipment (NOCSAE), he set out to find answers. With head impact and concussion research in its infancy (CTE, or chronic traumatic encephalopathy, associated with repeated blows to the head, wouldn't be discovered until a decade later), Greenwald found the going difficult. But a few years later, with the advent of smaller, more cost-effective sensor technology, he secured a Small Business Innovation Research (SBIR) award from the National Institutes for Health for work on developing head impact exposure monitoring technology that was eventually commercialized for use in football through sports equipment manufacturer Riddell.

It was one of Greenwald's first experience with SBIR, or its sister program, Small Business Technology Transfer (STTR), through his product development company Simbex, located in Lebanon, New Hampshire, and it wouldn't be his last. Together with serial entrepreneur and amputee Robert Dean, the company began its first forays into lower limb prosthetics, securing several Phase II SBIR awards to commercialize technology for automated volume management of lower limb prostheses. At a conference hosted by the American Academy of Orthotists and Prosthetists, Greenwald found himself seated next to Hugh Herr, PhD, the famed MIT biophysicist and renowned climber who himself is a bilateral amputee. Herr was interested in commercializing his bionic limb technologies that marry human physiology with electromechanical systems. Together

the pair set out to build a new company—powered by Herr's intellectual property and MIT research and Greenwald's product development experience—which they called iWalk.

"It was hard to commercialize that technology," Greenwald said. "There were many technical and financial challenges to overcome"

With big names and cutting edge technology behind the project, iWalk accrued a slew of funding, including an STTR contract for a proof of concept and feasibility studies in 2005.

"The best use of SBIR funding is when you use those funds to drive commercialization forward rapidly and realize that the value of your company can increase dramatically following the use of an SBIR," Greenwald said. "It's not trivial money; it's real, important non-dilutive funding."

The problem the company was trying to solve was how to build a prosthesis that could push itself off the ground. With the help of the STTR, which requires collaboration with a research institution such as MIT, the company created a novel bionic prosthesis called the BioM, complete with series elastic actuators and a lithium battery that create powered propulsion, mimicking the muscles of the lower leg.

"This technology gives you that ability to have powered propulsion, improved balance, as well as the equivalent of standing on your toes. The idea is you get a more normal gait, can walk faster and for a longer time without getting tired," Greenwald said.

According to Troy Turner, then the manager for the Department of Defense Military Amputee Research Program within the U.S. Army Medical Research and Materiel Command (USAMRMC) who authored the STTR topic and oversaw the award of the STTR contract, iWalk's approach ticked all the necessary boxes for the DoD.

"We needed a military do-it-all prosthetic foot, something that was going to be rugged and not a burden and that would help the wearer walk along" Turner said. "As it turned out, the iWalk Powerfoot answered that question to a large degree."

Turner, who is now the CEO of Mesquite Road Consulting Group, said the USAMRMC still uses the Powerfoot as an example of the success of the STTR funding program for visiting VIPs such as Senators, Congressmen, General Officers, and other VIP's.

"It became a symbiotic and beneficial relationship because they paid as much attention to us as a customer as their own customers, and not just as a funding agency," Turner said. "The Simbex/MIT STTR responded strongly to all those things we were looking for."

Following its early success that saw the technology spread from military service members to the general public, iWalk and its technology changed names several times before, in 2017, it was purchased by German prosthetics giant Ottobock HealthCare.

Greenwald and Simbex continue to help develop products with the assistance of the SBIR program, including a bed support system to prevent pressure ulcers and fall prevention technology for physical therapy and rehabilitation, among others.

"Turning university-based technology into commercialized opportunities, that's where the SBIR program has always been so valuable," Greenwald said. "It's a great program.

"The best thing we can do is keep helping accelerate tech development for products that help people's lives," he added. "That's what motivates our staff and that's a passion that we'll continue as long as possible."

Rick Greenwald

Simbex

Lebanon, NH • STTR contract: W81XWH-06-C-0392 • Agency: Army • Topic: A06-T031, A powered foot and ankle prosthesis for improved maneuverability and reduced metabolic cost.

THE NEXT BEST THING to REAL

For SIMmersion, training first responders is more than a game

An adult patient comes into a crowded hospital emergency room in the midst of flu season, presenting with chicken pox-like symptoms. In the rush, the attending doctor forgets to ask a few critical questions. When did the symptoms begin? Did the patient have chicken pox as a child? He also doesn't think to palpate the stomach. As a result, what could become a smallpox epidemic is overlooked, with potentially catastrophic consequences.

"The difference between two and four days in a biological event makes a big difference," said Laura Humm, chief operating officer of SIMmersion, a Maryland company which has spent nearly two decades developing interactive simulations for a broad range of applications for first responder, law enforcement, healthcare providers, and a variety of other fields.

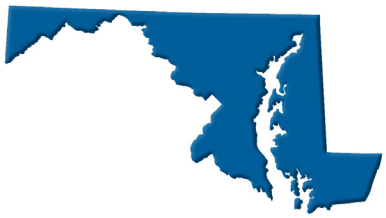
Through a Small Business Innovation Research (SBIR) contract with the U.S. Army's Medical Research and Materiel Command (USAMRMC), SIMmersion developed an interactive simulation to help first responders react to scenarios like the one described above, as part of an effort to address critical chemical, biological, radiological, and nuclear events. When using their training, learners interact with videos of trained actor playing a patient, helping them distinguish between chicken pox and conditions such as smallpox and Marburg hemorrhagic fever, asking questions and performing virtual medical exams.

Following the end of the initial SBIR contract in 2009, the improved, research-backed technology paved the way for SIMmersion to receive funding from a wide range of government agencies.

The simulations are powerful training tools, according to Dr. Dale Olsen, the company's president and CEO, because of the real-time responses they provide, reinforcing training and making extreme scenarios such as bioterrorism and suicide threats real. "The key is practice with feedback, which is proven in research to build real skills in the field," Olsen said.

Learning how to interact with patients in a potential mass casualty scenario is very different from learning how to fire a rifle, but they do have one thing in common, Olsen added. In both cases, traditional training methods—videotapes and role-playing with coworkers—aren't particularly helpful.

"If I'm going to teach you to become a marksman and I show you 500 hours of video of people shooting guns, that's not going to help you," he said.



Role-playing scenarios also rarely work because coworkers posing as patients are often no better trained in the specifics of the situation than those being trained—and no one involved "wants to look stupid."

Olsen began his work with training simulations in the 1990s, while working at the Johns Hopkins University Applied Physics Laboratory. He developed an early simulation system which trained new agents at the Federal Bureau of Investigation how to conduct basic criminal investigation interviews, interacting with a videotaped character named Mike Simmen to identify efforts at deception. The simulation has been deployed more than 30,000 times and led to demand for other interactive training simulations, including training to help Army chaplains work effectively with suicidal soldiers.

In 2002, Olsen licensed the simulation technology he developed from the university and launched SIMmersion. But the newly created company faced daunting challenges as it modernized the software driving its simulations. The company needed to pioneer a market for a new type of technology that had not seen before.

"We had lessons to learn and skills to build as we created additional simulations and developed the technology," he said.

In 2006, SIMmersion received the SBIR award from USAMRMC, and worked closely with the National Capital Area Medical Simulation Center and the Henry M. Jackson Foundation to bring its simulation technology up to date. The SBIR funding provided the ability to develop more interactive simulation technology and refine it for specific scenarios, as well as to conduct research studies on the impact of the training that helped give the company's simulations greater credibility in the field.

Dr. Dale Olsen, president and CEO of SIMmersion: "We are contributing to a lot of different communities and saving lots of lives."

The SBIR award also helped SIMmersion learn how to integrate educational material—specific training and lessons—directly into the simulations at appropriate times, said Humm. "It really honed our skill in creating a training package beyond a simulation that included all three elements—knowledge acquisition, practice, and comprehensive feedback."

The SBIR also charted a path forward for the small company. "It taught us what products had marketability," Olsen said. "It was transitional as we were trying to spin out as a separate company without a huge organization behind us. It really helped us get moving."

Following the end of the initial SBIR contract in 2009, the improved, research-backed technology paved the way for SIMmersion to receive funding from a wide range of government agencies. The company has since been awarded nearly a dozen contracts from the National Institutes of Health and two additional SBIRs from the Department of Defense, as well as a contract from the Centers for Disease Control.

Today, SIMmersion's government and private sector clients include major retailers, the FBI, Mayo Clinic, Kaiser Permanente, a broad range of universities and law enforcement agencies, and the National Institutes of Health. The National Suicide Prevention Center uses its simulations to train personnel manning the national suicide hotline. Its simulations cover scenarios faced by law enforcement, healthcare, drug counselors, social workers, and medical personnel, and have received positive feedback from the professionals using them.

"Officers accepted the virtual reality training and were impressed with it," James W. Parlow of Winona University said of a simulation conducted with Minnesota law enforcement officials. "One officer commented that this was 'a video game for cops rather than about cops.' At the conclusion of the training session, officers stated that the techniques would assist not only in their interviews with suspects but also in everyday conversations and field inquiries."

Ongoing contracts are funding research that may touch even more lives. For example, SIMmersion technology was part of a research study conducted by Yale and Northwestern University to assess whether simulated job interviews could help people with mental illness, including veterans suffering from post-traumatic stress syndrome, obtain employment. Study subjects who used the training improved their interview skills and increased their confidence. The research showed that those who used the simulation were nine times more likely to be given a job offer as compared with subjects who did not.

"We are contributing to a lot of different communities and saving lots of lives," said Olsen.

SIMmersion, LLC

Columbia, MD • SBIR contract: W81XWH-05-C-0042 • Agency: Army • Topic: A04-182, Medical Simulation Training for First Response to Chemical, Biological, Radiological, Nuclear Events

POWER WASH

Polishing the microchips that power clean-energy technology

As Earth's population grows, the global demand for energy is predicted to rise, and with no immediate end in sight. By 2040, the world's energy consumption will increase by 56 percent, according to a 2013 report by the U.S. Energy Information Administration.

To meet these demands, clean-energy technologies like solar cells, wind turbines, electric vehicles, and light-emitting diodes (LEDs) have come forward as viable alternatives to fossil fuels. Worldwide adoption continues to increase as the technologies become cheaper and more efficient.

A key contributor to the development of improved clean energy technology is Gainsville, Florida, based Sinmat, Inc. The company, founded in 2000 by a husband and wife team, specializes in polishing slurries that transform the rough surfaces of extremely hard materials into flawless façades. Sinmat's products contain a unique mix of nanoparticles and chemicals that help produce the smooth, defect-free surfaces essential for making high-performance, high-efficiency semiconductor chips. Many of those chips find a home in clean energy devices, as well as in consumer electronics such as smartphones and wearables.

"Normally these material surfaces have a lot of defects like scratches and other things which can

negatively affect the quality of the device," said Sinmat co-founder Rajiv Singh. "That is why the polishing process is so important—it serves as the final touch-up for the surface."

Over the last two decades, Sinmat has been well-recognized and awarded for its efforts. The company and its co-founder, Deepika Singh, were praised by then-President Barack Obama at a 2009 clean energy event in Washington, D.C. "Sinmat is developing new ways to manufacture microchips that can help power smarter energy systems, from more fuel-efficient hybrid cars to more responsive, efficient lighting for homes and businesses," said Obama.

The R&D 100 Awards—known as the "Oscars of Innovation"—recognized the company in 2004, 2005, 2008, and 2009 for developing one of the top 100 technology products in each of those years. More recently, Sinmat won the 2017 Manufacturing Business of the Year at the Gainesville Area Chamber of Commerce Business Awards.

Rajiv and Deepika Singh leveraged their research backgrounds in materials science and engineering into commercial success with Sinmat. The company has profited each year since it has been in business, and has been awarded millions of dollars in federal funding, including multiple Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) contracts from the Department of Defense. They credit the SBIR/STTR program for both spurring technology development as well as helping them find commercial partners.

"Had it not been for the SBIR program, we would not have had a successful product because it not only gave us funding, but also it found us an end user who was very willing to work with us," said Rajiv. "We were able to connect with some of the manufacturers who were in need of this technology, which helped us launch our products into the field."

Rajiv Singh: "Had it not been for the SBIR program, we would not have had a successful product."

Rajiv Singh

Along with co-founding Sinmat, Rajiv is a professor at the University of Florida in the Department of Materials Science and Engineering. He specialized in a manufacturing process known as chemical-mechanical planarization (CMP), a critical step in semiconductor fabrication which smooths surfaces through a combination of chemical and mechanical forces. It removes unwanted irregularities on a thin slice of material called a wafer—usually made of silicon—to achieve a flawless surface upon which layers of integrated circuitry are built. During CMP, the wafer is pressed against a rotating polishing pad that is flooded with a slurry containing chemicals and particles. It is then cut into individual chips for use in various electronic devices.

Rajiv initially developed slurries for softer materials but soon became interested in polishing ultra-hard materials such as silicon carbide, a compound whose unique properties make it ideal for high-efficiency and high-power applications. In recent years, this synthetically-produced crystalline compound of silicon and carbon has emerged as a viable alternative prized for its advantages over silicon: high operating temperature, low losses, high thermal conductivity, and other attractive features.

But silicon carbide is exceedingly hard, and polishing the material is difficult without creating defects that can affect chip performance. Companies would use aggressive techniques and hard particles like diamond, but they would lead to damage and scratches on the microscopic scale. Rajiv and Deepika predicted that the semiconductor industry would soon demand better ways to polish such ultra-hard materials. They decided to commercialize his CMP research by co-founding Sinmat.

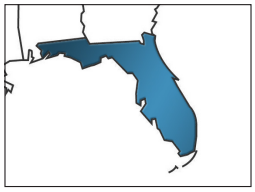
"We wanted to see our innovations reach the market, which is why we co-founded Sinmat," said Deepika. "We combined our expertise and the spirit of

Sinmat was co-founded by Deepika Singh, and is now one of the leading global suppliers of CMP technologies.

innovation to develop chemical-mechanical polishing solutions for the semiconductor industry."

Rajiv designed slurries by including an unexpected ingredient: soft nanoparticles. These soft-surfaced particles have been found to provide a high polishing rate for silicon carbide, up to ten times faster than previous processes. Instead of taking several days to produce an inferior product, Sinmat's slurries can achieve atomically smooth surfaces, with no damage, in hours' time.

Today, Sinmat is a leading global supplier of CMP technologies, and holds over 35 patents. More than half of the silicon carbide wafers manufactured in the world use the company's technology. Its unique polishing slurries have proven valuable not only for silicon carbide but also for materials like gallium nitride, sapphire, and diamond. "Any application where power is being transferred—electric vehicles, hybrid vehicles, transformers, power converters for wind energy or solar energy—these chips are used," said Rajiv. "Also, we expect the demand for these chips to increase in the next several years due to an increase in devices for high-speed communications and radar systems."



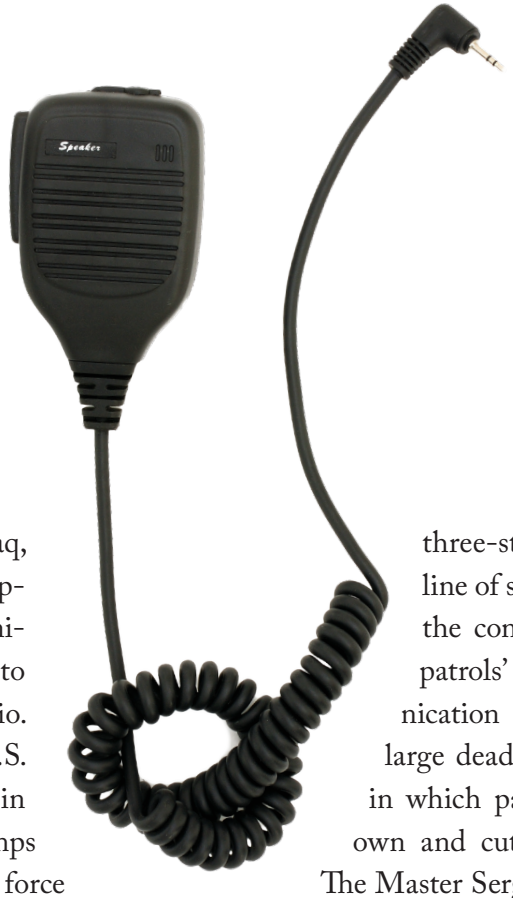
Sinmat, Inc.

Gainesville, FL • STTR contract: HQ0006-06-C-7382 • Agency: MDA • Topic: MDA04-T018, Rapid Atomic Level, Mechano Chemical Polishing of Silicon Carbide Substrates

TechLink

GOOOD MORNING, IRAQ!

A WARFIGHTER PROVIDES THE SPARK BEHIND A REVOLUTION IN LONG-RANGE COMMUNICATIONS



Teamdaddy / Shutterstock.com

In the blistering heat of Sadr City, Iraq, Master Sergeant Rebecca Thompson-Schmidt sat in her communication booth, desperately attempting to check in with her patrols over the radio. It was the summer of 2007 and the U.S. Army was testing out its first aerostats in Iraq—large, tethered "eye in the sky" blimps equipped with cameras and tasked with a force protection mission.

While these blimps, as part of the Persistent Threat Detection System (PTDS), were providing good visual information, patrols often couldn't radio for back-up while driving and walking the densely populated residential streets. Sadr City was strewn with two and three-story buildings interrupting the line of sight and thus reception between the command post's antennas and the patrols' mobile radios. Radio communication would go in and out, creating large dead zones and smaller black spots, in which patrols were completely on their own and cut off from the command post. The Master Sergeant understood the precarious nature of the situation: "Even if it's just half a block, that's plenty of time to get into serious trouble." While Thompson-Schmidt was focused on her patrols, she was in grave danger herself. Since communication centers had to be so close to widely visible antennas, operators like Thompson-Schmidt were vulnerable targets for

enemy attacks, just like the patrols themselves.

An expert problem solver, Thompson-Schmidt methodically assessed her resources for addressing the problem, all the while knowing that any wasted time could mean grave injury or death. "When it comes to saving lives, things have to move very quickly." When the idea hit her, it seemed obvious, but no one else had thought of it until that moment. Looking at the "eye in the sky" tethered blimp, she wondered: Why can't I put some of my antennas up there?

Having antennas up that high would allow an unobstructed line of sight between antennas and radios, ensuring uninterrupted radio transmission. Thompson-Schmidt got to work immediately creating what she dubbed a "Frankenstein" system by taking heavy radios and their antennas — which would normally be mounted on trucks — and instead hanging them on the aerostat transmitting signals downward. One major problem with this solution was the weight of the radios and antennas on the blimp and the necessity to take the aerostat down every week to reprogram the radios. This was a dangerous task because the blimps were so large and easily visible that any maintenance activity quickly invited enemy fire.

What started with Master Sergeant Thompson-Schmidt reaching out to Syntonics now rapidly became a collaboration among several key players.

On her search for a fitting solution, she came across the Fiber Optic Remote Antenna eXtension (FORAX) system developed by Syntonics, an RF-over-Fiber system that was successfully being used at the Pentagon. On 9/11 when one of the hijacked planes crashed into the Pentagon, it destroyed antennas on the roof and a radio room on the top floor right below those antennas, disrupting radio communications for the Navy. Traditionally, coaxial cables that connected radios and antennas only worked over short distances before rapidly losing transmission quality, making it necessary to keep the radios and their antennas dangerously close together and making the radio communications controllers an easy target for enemies. Fast forward to 2005 when major renovation efforts at the Pentagon included installing fiber optic cables. With Syntonics' RF-over-Fiber technology, transforming radio frequency (RF) signals into light and then back to electricity, resulting in a data transmission system that was unaffected by the distance between the data transmitter and receiver. While the new Pentagon antennas remained on the roof, the radio communications rooms were relocated to the subbasement of the Pentagon. Another important characteristic of fiber optic cables compared to traditional cables is that they do not "leak", therefore providing a secure option for highly classified military settings, such as putting radios inside Sensitive Compartmented Information Facilities (SCIF).

By 2007, Syntonics was a few years into developing the FORAX technology, connecting radios to their distant antennas using optical fibers. The initial research and development resulted from a Small Business Innovation Research (SBIR) award through the U.S. Special Operations Command (SOCOM) and was later extended by SBIR awards from the Navy and the Joint Tactical Radio System program.

Rebecca Thompson-Schmidt

Master Sergeant Rebecca Thompson-Schmidt and Bruce Montgomery.

When a request for quotation from Baghdad arrived at Syntonics, Bruce Montgomery, the company's president, wasted no time emailing back a proposal the same day. He received a purchase order the very next morning. What started with

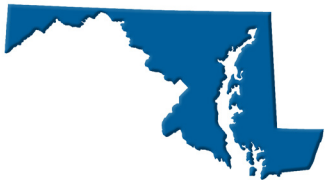
U.S. Navy Photo / Released

The one-fiber, multi-radio system known as HARC uses tethered "eye-in-the-sky" aerostats to position the hardware.

Master Sergeant Thompson-Schmidt reaching out to Syntonics now rapidly became a collaboration among several key players including the U.S. Army Communications – Electronics Research, Development and Engineering Center (CERDEC), U.S. Central Command (CENTCOM), and Yuma Proving Ground (YPG).

Thompson-Schmidt needed light-weight antennas mounted on the blimp and connected to six radios on the ground in her unit's Tactical Operations Center and in safe distance from the antennas. Montgomery quickly realized that the normal FORAX system wouldn't work for this specific situation because the aerostat only had one optical fiber available, not two optical fibers for each radio as was usual for the FORAX system.

Syntonics developed a new approach for a one-fiber/multi-radio aerostat system they called High Antennas for Radio Communications (HARC). Two months after the first contact, in October 2007, a team of Syntonics and Army personnel met at YPG to demonstrate the feasibility of the HARC system. Syntonics and YPG staff drove a HMMWV heading away from a PTDS aerostat stationed at YPG and outfitted with a breadboard HARC system. They drove East on I-8 from Yuma and didn't lose radio contact until mountains blocked the line-of-sight between the aerostat and the vehicle.



Having proved the feasibility of HARC, Syntonics feverishly worked on building two prototypes for Baghdad, Iraq and Kandahar, Afghanistan. Montgomery explained the daily impact of the SBIR technology: "With HARC, the Army's combat net radios stay in the Tactical Operations Center—secure and convenient on the ground – while a lightweight HARC payload, including special antennas installed to mitigate co-site interference, flies high

overhead. HARC systems have been fielded downrange since early 2010 on the Army's medium and large aerostats. HARC is a proven technology that enables almost any line-of sight communication radio to loft its antennas for military and public safety applications."

Warfighters wrestle a HARC system into an armored truck at a forward operating base in Afghanistan.

Thanks to the technology's enormous success, Syntonics has delivered more than 100 HARC systems since 2007 under what is now an Army Program of Record: Persistent Surveillance Systems-Tethered. In 2013, the company won a prestigious Tibbetts award for their exceptional effort.

Bruce Montgomery is excited about taking HARC to yet another level. "The HARC system has a proven ability to dramatically extend radio communications range for tactical commanders," he said. "We continue to focus on improving the safety of our warfighters. Tethered aerostats are large, highly visible, require helium, and easily become enemy targets compromising the safety of our troops. We are now working on using tethered electric drones instead. Drones are much more agile, smaller, less visible and easier to use in an active combat zone." Montgomery thinks that tethered drones acting as mobile "sky hooks" to hold antennas high overhead could usher in a new era of uniquely customizable extended range radio communication systems that can be deployed wherever and whenever needed. This focus on continuous improvement and incorporation of cutting-edge technology into existing products is a hallmark of Syntonics and its leadership, making the company an ideal SBIR partner.

Bruce Montgomery is quick to point out that his number one priority is providing solutions that keep warfighters safe. He said that Master Sergeant Thompson-Schmidt was, "the spark that caused the explosion" and set in motion this incredible success story. By the time HARC was initially deployed, Thompson-Schmidt had been rotated out of Sadr City and never saw the system in action. Now retired, Thompson-Schmidt and Montgomery stayed in touch and finally met in October 2009, at Fort Carson, Colorado, where Thompson-Schmidt worked at the Tactical Support Branch of the Department of Information Management. Syntonics was visiting to test yet another HARC system on a different Army aerostat.

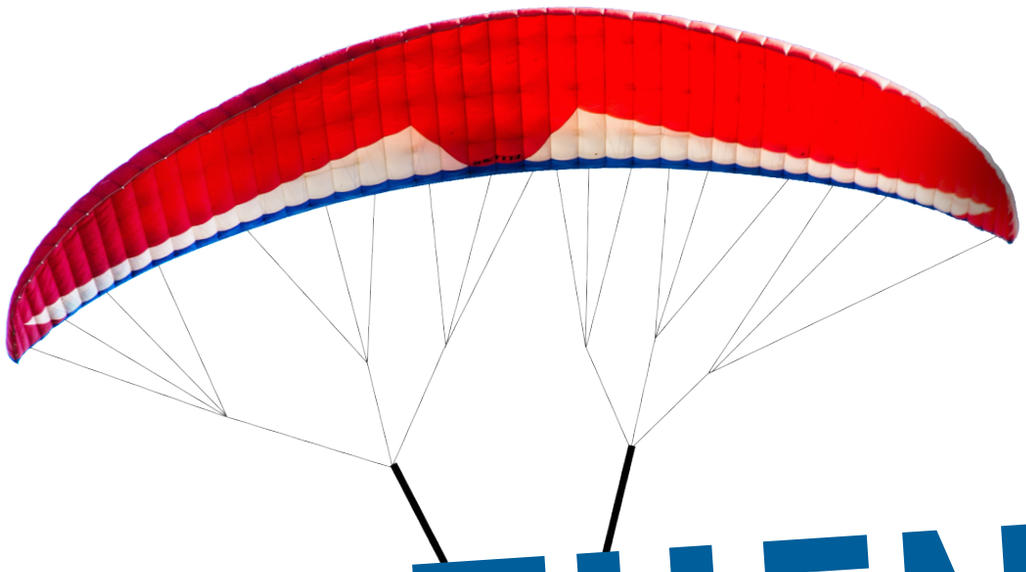
The meeting was a highlight for both. Montgomery said how special it was to meet the ingenious soldier who started it all, and how honored he was to have been an integral part of finding this life-saving solution. Thompson-Schmidt said of the experience: "I consider it one of my most accomplished efforts, right up there with making First Sergeant. It's amazing that Mr. Montgomery has kept me in the loop. It means a lot that we both continue to follow HARC's story and its ever-expanding abilities to save the lives of our warfighters."

Two views of a HARC system.

Syntonics, LLC

Columbia, MD

SBIR contract: H92222-04-C-0026 • Agency: SOCOM • Topic: SOCOM03-005, Antenna Enhancements for SOF Applications
SBIR contract: N00039-11-C-0005 • Agency: Navy • Topic: N07-149, RF-over-Fiber Links for the JTRS GMR



IF...THEN

POWERFUL, EASY-TO-USE SOFTWARE FOR CONTINGENCY CONTRACTING

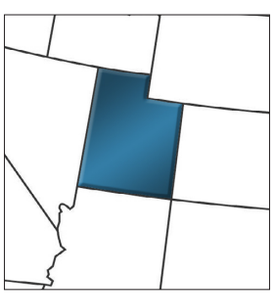
A devastating typhoon hits the Philippines. Pirates in Somalia begin attacking commercial vessels. Insurgent forces in Pakistan threaten regional security. The Ebola virus breaks out in Guinea. Cameroon requests U.S. support in the fight against ISIS.

United States military forces can be called upon at any moment to respond in a spectrum of ways to military conflicts, political unrest, natural disasters, humanitarian crises, and other "contingencies" around the globe. Supplying those forces with what they need, and when and where they need it, is called contingency contracting. While government contracting can be tangled enough in a stable, ongoing operation, the complexities double-down when contracts have to be executed fast, potentially with lives on the line.

Contingency contracting often takes place in "immature" business environments, at a rapid pace, with large numbers of contracts sometimes operating at high dollar amounts. As the experts say, contingency contracting—with both its intricate rules and intentional flexibility—is not for the uninitiated. Contracting personnel need clearly written and comprehensive requirements documents (called "requirements packages," or RPs) in order to guarantee that incident commanders are able to secure the appropriate goods and services to house, clothe, feed, arm, and protect their people.

The weakness of existing methods was revealed when inspectors general and Government Accountability Office studies showed that the lack of quality RPs during contingency operations in Iraq and Afghanistan contributed to waste and abuse, and seriously degraded the speed and accuracy of contracting efforts in support of deployed warfighters. Something had to be done, and the Air Force responded by looking for alternatives that could simplify the RP process and rapidly improve quality.

The Air Force found what it was looking for, thanks to the Small Business Innovation Research Program (SBIR). In 2003, Utah-based Total Quality Systems (TQS) began working under an Air Force SBIR contract with the specific goal of improving the acquisition process for F-16 sustainment. But over a handful of years, the vision for that work broadened. The company refined what began as their Decision Support Software into a powerful, web-based application that provided just what contracting officers and their commanders needed—a systematic, efficient approach to contingency contracting. Dubbed cASM (Contingency Acquisition Support Model), the application works something like online tax preparation software, and incorporates three functions: planning, requirements package generation, and reporting.



"The idea is to input data once, then use that information many times to create the needed documents, while reducing the number of document errors to save the warfighter time," said Steve Hepburn, TQS Director of Business Development.

The cASM tool automatically creates an initial draft for each acquisition document based on user responses to a tailored questionnaire generated by the software. As part of the process, the software selects the appropriate set of Federal Acquisition Regulation documents and forms based on the type of acquisition, estimated dollar amount, and competitive nature of the acquisition. The end result is an accurate, standardized procurement RP, with faster delivery of life-support products and services to the warfighter in any environment. The specific benefits of cASM include improved speed and quality of acquisitions, timely and accurate information to leadership, and improved accountability. In addition to those benefits and other efficiencies, cASM's paperless, electronic signature system means no more venturing out in dangerous, unsecure areas just to get a "wet" signature.

The company refined what began as their Decision Support Software into a powerful, web-based application that provided just what contracting officers and their commanders needed.

"There is also long-term value added in using cASM in the home-base/garrison environment, to train the way we fight," Hepburn adds, referring to the axiom, "train the way you fight, fight the way you train." When push comes to shove, people fall back on their training—so if personnel involved in contingency contracting operations use cASM in exercises and classrooms during times of business-as-usual, they'll be able to move quickly and efficiently when

U.S. Air Force photo by Staff Sgt. Eboni Reams (dvidshub)

the next incident triggers a need to pick up the pace.

With cASM now widely adopted by the Department of Defense, TQS was awarded an Indefinite Delivery Indefinite Quantity (IDIQ) contract by the Air Force Life Cycle Management Center (AFLCMC) to continue development and support for a Joint Service cASM application. Recognizing cASM's tremendous value, the SBIR program presented TQS with the prestigious Tibbetts Award in 2011.

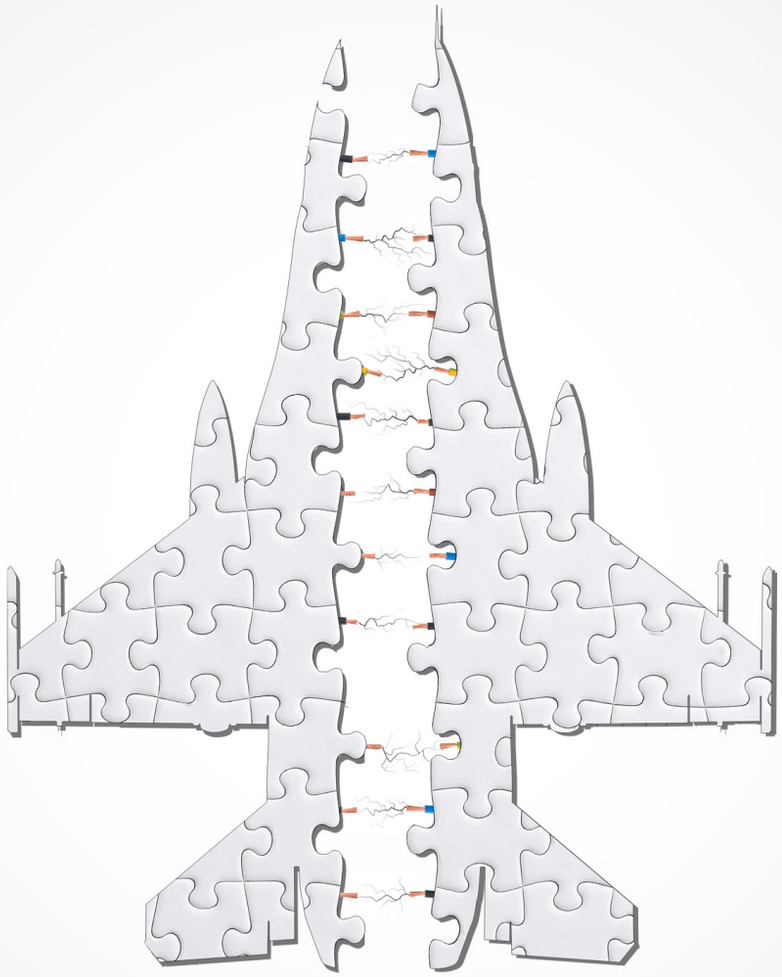
Military contingency operations are never easy, and mission success depends in large part on getting deployed troops the right supplies in the most timely manner. Because cASM effectively eliminates so many of the burdens and delays inherent in traditional contingency contracting, it has contributed greatly to the U.S. military's operational success at home and around the globe, and is an outstanding example of how the Air Force SBIR Program helps meet our warfighters' ongoing needs.

Airmen negotiate during a contingency exercise.

U.S. Air Force photo by Staff Sgt. Eboni Reams (dvidshub)

FINDING FAULT

A BREAKTHROUGH SYSTEM TO TEST FOR INTERMITTENT FAULTS IN ELECTRONIC COMPONENTS



On December 28, 2014, an AirAsia jet on its way to Singapore crashed into the Java Sea, killing all 162 people onboard. Pieces of the wreckage hauled up from the sea floor, including the flight data and cockpit voice recorders, revealed that a cracked piece of soldering on a circuit board had created a discontinuity in the plane's electronic equipment, setting off a tragic chain of events.

Consistent breaks in the electrical connections of electronic components are usually not difficult to isolate and repair. But intermittent faults—breaks that occur at irregular intervals or only during specific conditions—can be extremely challenging to troubleshoot. In the AirAsia jet, the same fault caused by the cracked soldering had occurred a number of times during flights over the previous year, but because the fault could not be replicated on the ground, the part was never replaced.

When ground testing fails to find the source of an intermittent malfunction, the result is labeled "No Fault Found" (NFF). Maintainers must then decide whether to reinstall the part or shelve it. In the early 2000s, the Office of the Secretary of Defense noted that NFF

maintenance problems were reducing mission readiness, putting aircraft and aircrew at risk, and costing the Department of Defense an estimated $2 billion annually. Intermittent faults are a particularly serious issue for military avionics because of harsh conditions encountered during flight. Extreme temperatures, high G loading, and vibration all contribute to stress-related electronic discontinuities. Conventional test equipment is effective in troubleshooting hard failures, but has serious limitations when it comes to detecting intermittent failures.

In 2001, Utah-based Total Quality Systems (TQS) entered into an Air Force Small Business Innovation Research (SBIR) contract to find a solution to the intermittent fault problem, specifically targeted at the Modular Low Power Radio Frequency (MLPRF) radar system on the F-16. The MLPRF, valued at over $300,000 per unit, was prone to the highest NFF rates of all the electronic "boxes" on the aircraft.

Teaming with Universal Synaptics Corporation (USC), TQS developed the game-changing Intermittent Fault Detection and Isolation System (IFDIS), which evaluates connection networks in aeronautical assemblies in a simulated flight environment. The IFDIS consists of an electro-magnetic shaker system, an environmental test chamber, a custom Interface Test Adapter, control software, and USC's Intermittent Fault Detector. Unlike traditional bench-test methods, the IFDIS can simultaneously and continuously monitor a virtually unlimited number of circuit paths and channels. When an intermittent fault occurs in any circuit, the event is detected and the faulty path identified in a matter of minutes.

During IFDIS testing, TQS asked the Air Force to send them all the MLPRF boxes that had been judged unrepairable, as well as boxes that had been sent for repair with repeated NFF results. By the end of testing in February 2009, over $10 million in MLPRF assets had been effectively repaired and returned to service—an impressive return on the relatively small SBIR investment.

"The unique electronics subassembly in the IFDIS detects any interruption in current flow as short as 50 nanoseconds in any of the thousands of circuit paths in the chassis being evaluated," said Steve Hepburn, Director of Business Development at TQS. "The significance of very short interruptions in current flow is that they are a direct measure of discontinuity—the root cause of an intermittent fault."

Because the IFDIS enables intermittent failures to be detected and isolated to a single point, it facilitates repair, increases aircraft availability, decreases operation and maintenance costs—and potentially saves lives.

When an intermittent fault occurs in any circuit, the event is detected and the faulty path identified in a matter of minutes.

TQS created a number of IFDIS models specifically for the Air Force, which has realized $56 million in cost savings to date, including $42 million in reclaimed assets.

The Navy has purchased another IFDIS model for use with the F-18, and the Army, NASA, the Australian and South Korean militaries, and commercial airlines have also expressed interest in the IFDIS.

"For nearly two decades, TQS has applied systems engineering methods to restore reliability and reduce our customers' cost of fleet ownership," said Hepburn. "SBIR awards have allowed the company to grow from a focus on root-cause failure analysis engineering services into the realm of software engineering and development and systems engineering and manufacturing."

The exacting fault-finding of the IFDIS is yet another illustration of the solid connection between innovation and return on investment to the Department of Defense. With support from the SBIR program, the IFDIS is saving lives, improving warfighter and aircraft readiness, and saving many millions of taxpayer dollars in the bargain.

BRIGHT IDEAS

Innovations in semiconductor manufacturing impact multiple industries

The name may seem obscure, but the technology—used in everything from cell phones to light bulbs and satellites—is critical to modern life. And one company, backed by Department of Defense (DoD) Small Business Innovation Research (SBIR) funding, is at the technology's cutting edge.

That company, New York-based tech firm Veeco, with R&D and production facilities in Somerset, New Jersey, has long been one of the driving forces behind metal-organic chemical vapour deposition systems, or MOCVD for short.

The technology itself, first popularized in the 1980s, is a lot like baking a complicated cake. A machine deposits thin layers of atoms onto a semiconductor wafer, stacking each layer in a specific and calculated way in order to create a material that has certain optical or electrical properties.

The resulting wafers are utilized in a variety of technologies, from cell phones, base stations, light bulbs, televisions, automobile sensors, security cameras and satellites.

Following the growth of light-based technologies in the 1990s, MOCVD systems took off. One company, Emcore, was on the forefront of this boom, building an MOCVD division that in 2003 was acquired by Veeco.

Back then, said Mark McKee, director of product marketing at Veeco, companies were trying to figure out how to scale the systems to profitable production. The company was awarded several DoD SBIR contracts that were crucial in establishing the commercialization of MOCVD systems, McKee said.

"The SBIRs gave us the first insight into if it was even feasible," he said. "They definitely helped us in terms of the modifications of the reactors and enabled us to do some initial exploration into the different material systems that we thought would have commercial opportunities."

Now, while there are several other companies sharing the MOCVD space, the ubiquitous application of the systems means that there are plenty of opportunities to go around.

"All the lightbulbs you buy are either made on our or our competitor's equipment," McKee said.

But the beauty of the Veeco systems is that they are flexible and can build according to a company's needs, McKee added, whether that be a global car brand or a cell phone manufacturer. "Every customer might have their own recipe, so they need a flexible tool that they're able to adjust," he said.

The latest and largest of these production systems can produce as many as 12,000 wafers per month, which, using LED chips as a metric, equates to as many as 70 million chips per system per month.

While LED technologies continue to evolve, Veeco is also looking to expand in several other industries, including server processing, electric power, and 5G cellular systems. Moreover, there's plenty of room for the wafer systems in the military, McKee said. Eventually the company hopes to improve their MOCVD systems to the point where they compete with popular silicon-based wafers.

"It's been a fun ride and it's exciting to see where this market is going," McKee said. "Right now, we're looking at markets, what opportunities there are, how to win and make our product even better."

Emcore Corp. (Veeco Instruments, Inc.)

Somerset, NJ (Plainview, NY) • SBIR contract: F19628-94-C-0114 • Agency: Air Force • Topic: AF93-055, Development of a Large Area, High Yield Automated MOCVD System

GAME ON!

Battlefield simulation program improves mission readiness

When a Washington State National Guard squadron, the 111th Air Support Operations Center (ASOC), deployed to Afghanistan in 2013, no one might have guessed that 70 percent of the squad was new to the mission.

"When we got in theater, our crews were so well prepared that the 111th turnover time was a week shorter than during our 2007 deployment, which caught the notice of the commanding General for the U.S. and NATO forces," said Senior Master Sergeant Greg Kassa, 111th ASOC, Camp Murray, Washington.

Kassa credited the unit's strength to its rigorous pre-deployment training with the QuickStrike ASOC Battlefield Simulation system, developed by the software development company VT MÄK with support from the Air Force Small Business Innovation Research (SBIR) program. QuickStrike leverages commercial off-the-shelf (COTS) gaming technology to produce an affordable, user-driven training suite that can be easily customized for specific scenarios and launched as needed on a single computer, over a local area network (LAN), or a wide area network (WAN).

QuickStrike fills a crucial training need identified soon after the 2001 launch of Operation Enduring Freedom. The nonlinear and asymmetric nature of the conflict, combined with regional geography and other aspects of battle, often precluded the use of artillery or other arms options for tactical support. As a result, close air support was the primary means of covering warfighters on the ground. Because ASOCs are the principal communications and coordination (C2) link between the Army ground commander and Air Force combat assets, they receive all requests for close air support and coordinate the military response. ASOC personnel were being called on to provide nearly nonstop close air support over the entire theater, making it vital that they were ready for such demanding and high-pressure responsibility on day one of their deployment.

Thanks to its High Level Architecture (HLA) compliance, QuickStrike can be integrated across platforms into larger exercises...

Conventional pre-deployment training in the form of large wargaming events can be effective under many circumstances, but they missed the mark for ASOCs in two significant ways. First, such events are not only expensive and infrequent, they're also held in centralized locations, which is logistically problematic given the high percentage of Guard personnel in ASOC units. And importantly, such events feature customized C2 systems while ASOC units in theater were more likely to be using a patchwork of networking technology and software applications.

"Our challenge was to build something focused on ASOC mission needs that would be quickly useable by someone who might be somewhat of a technology novice," said Brian Spaulding, VT MÄK's director of engineering services. "The key was allowing them to exercise their own systems so there was no learning curve."

Headquartered in Cambridge, Massachusetts, VT MÄK specializes in employing COTS software to build 3-D simulated environments for aerospace, defense, and emergency management applications. Starting with an existing COTS-based simulation product, the company worked closely with SMSgt Kassa and the 111th—and, over time, other ASOCs as well—to create a complete system for practicing a full spectrum of military security and air combat decision-making tasks. Realism and ease of use were primary objectives during development, from the intuitive graphical user interface to the groundbreaking Master Scenario Event List (MSEL) manager that allows instructors to seamlessly add events with the potential to affect decision making, but which are not typically portrayed by a simulation.

"MSEL ties the training to other activities in real time," explained Spaulding. "For example, an instructor can inject an aircraft check-in by cutting and pasting it from MSEL and pushing it out to the trainees over mIRC chat." By contrast, other training systems might require trainees to look at an Excel spreadsheet for instructions regarding something that will occur at a certain time. But with QuickStrike, all the necessary elements are in reach, making it easy for instructors to drive the simulation and quickly customize scenarios to meet immediate training needs. Instructors can also load actual air tasking orders for rehearsal in real time, a feature that helped the 111th prior to both its 2007 and 2013 deployments. The after-action-review function helps pinpoint areas of need.

VT MÄK began working under a sequence of Air Force SBIRs in 2004 to fully develop QuickStrike and get it into use. Today, in addition to being operational in all ASOCs worldwide, Active and Guard, the Air Force Integration Center has certified QuickStrike for access by the entire agency. Recent upgrades have enabled connection to Link 16, the military tactical data exchange network, further

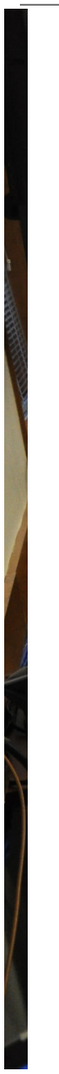


Photo: VT MAK

Photo: VT MAK

The 111th ASOC in a QuickStrike training exercise.

emulating the actual ASOC operating environment.

Promising progress in the early Air Force work spurred similar partnerships between VT MÄK and other service branches. Components of the technology suite have now been incorporated into U.S. Army and U.S. Marine Corps simulation training systems, with enhancements for each agency improving the system for all. Thanks to its High Level Architecture (HLA) compliance, QuickStrike can be integrated across platforms into larger exercises such as those supported by the Joint National Training Capability. QuickStrike can realistically replicate the Tactical Operations Centers in Afghanistan and Iraq, as well as expand to support any new major conflict scenarios.

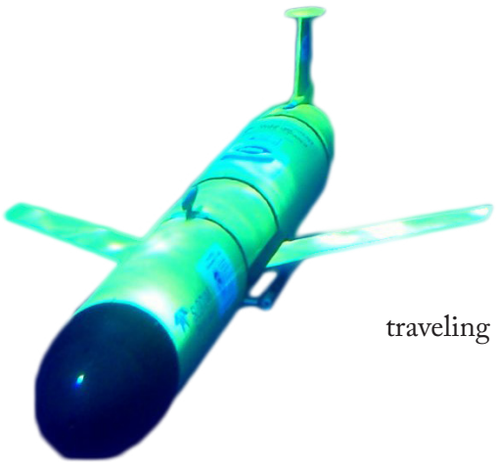
"From the ability to become graphically familiar to being able to rehearse the fight, QuickStrike is a very good baseline product that allows units to train and better prepare for whatever the next conflict may be," Kassa said.

VT MÄK commercialized the baseline system internationally as "Battle Command" and subsequently "VR-Forces," helping to secure the nation and beyond. Through NATO's Partnership for Peace, Battle Command has been fielded in the Czech Republic, Latvia, Uzbekistan, and the Ukraine. In addition, VT MÄK has a contract with the United Kingdom Ministry of Defense Air Command and Control System Integrated Project Team to further develop and field a new enhancement of Battle Command.

"QuickStrike has been ideal for what you want out of an SBIR project," said Spaulding. "It leveraged our existing product, satisfied the needs of the ASOC and then was commercialized. And it will continue to benefit from COTS product improvements as well."

SUBMERSIBLE intelligence

Created with support from a Navy STTR contract, the Slocum glider coasts autonomously through the ocean, harvesting data



The first person to sail around the world alone was Nova-Scotian adventurer Joshua Slocum. More than a century after he finished his three-year journey, the Slocum glider, an autonomous underwater vehicle, successfully completed the first trans-Atlantic passage of its kind, traveling from New Jersey to Spain.

All photos courtesy Ben Allsup, Teledyne

TechLink

The trans-Atlantic project was led by researchers and students at Rutgers University, but the Slocum glider itself was conceived of by Douglas C. Webb, founder of Webb Research Corporation, originally based in Massachusetts. And in November of 2009, After 221 days at sea and 4,591 miles traveled at the casual speed of 4 centimeters per second, the Slocum glider did credit not only to its namesake but to its creator and to the governmental contracts that supported his innovation.

Doug Webb explained, "Nowadays there is a lot of interest in autonomous vehicles, and new versions are popping up what seems like every day, but back in 1985 when I started out, it was a novel idea. Oceanography was done with ships and crews, and I said to myself, there is no need to send 30 people out on a ship." At the time there were a few propeller vehicles in use, but no gliders. Autonomous propeller vehicles operate at a certain depth, which is effective if you need a vehicle to cruise at the same depth for a period of time, for example to search for mines.

In contrast, the Slocum glider is buoyancy driven. The glider is heavier than water and first sinks beneath the surface of the water. At a certain depth, the buoyancy of the glider changes and it starts to glide upwards. The Slocum gliders are used in oceanographic research and maritime reconnaissance, because they can measure a greater variety of data points collected from a vast underwater area, as opposed to propeller vehicles that can collect data only at one specific depth and location.

The gliders perform for months at a time with minimal oversight, collecting data and providing situational awareness over extended time periods and vast areas.

Now 88 years old, Doug Webb credits many passionate scientists and engineers at the Office of Naval Research (ONR) and academic institutions such as Rutgers University with the overall success of the Slocum glider: "I am enormously grateful for the ONR support of this research. Initially, we created a buoy called Apex, which was an underwater sensor that ascended to the surface every ten days measuring properties of the water and reporting its position. Each buoy does this continually for seven years and there are currently over 3,000 in use. The technology used for this sensor was the basis on which we conceived the Slocum glider."

Webb Research received a Small Business Technology Transfer (STTR) award from the Navy to develop the Slocum glider. Because the resulting demand by the Navy was so high, Doug Webb decided the glider would be better produced at scale by a larger company.

Off Cape Town, South Africa, a Slocum glider autonomously coasts across varying depths of water.

Deployed from the Rothera research station on Adelaide Island in the Antarctic, this Slocum glider will be able to operate smoothly and without interruption for weeks at a time.

In 2008, Webb Research was sold to Teledyne – which still manufactures the gliders today.

The Slocum glider has a wide variety of applications, from academic to commercial to military. In applications such as deep-water monitoring, marine mammal mitigation, and hydrocarbon detection and measurement, it provides a safer, more affordable alternative to ship-based operations. Once deployed, the gliders can be controlled remotely and adapted to emergency conditions via rapid sensor reconfiguration. The gliders perform for months at a time with minimal oversight, collecting data and providing situational awareness over extended time periods and vast areas. Slocum gliders operate at about 1 percent of the cost of traditional, ship-based operations, are independent from extreme weather conditions, and collect data continuously, regardless of circumstances.

After a decade of use and hundreds of millions in cost savings for military, academic, and civilian customers, the Slocum glider is still going strong. David Webb shows no signs of slowing down, either. He says he keeps "trying to retire," but to no avail. He's too excited about what's next: "Currently, we are testing a glider that's been running for 240 days," he said, "and with no external power supply, only depending on the ocean's thermal differences between the surface and the deep of the ocean, harvesting all the thermodynamic energy in its path!"

Webb Research, Corp. (Teledyne Technologies)

East Falmouth, MA (Thousand Oaks, CA) • STTR contract: N00014-98-C-0281 • Agency: Navy • Topic: N97T002, An Autonomous Gliding Vehicle for the Distributed Observation of the Littoral Environment

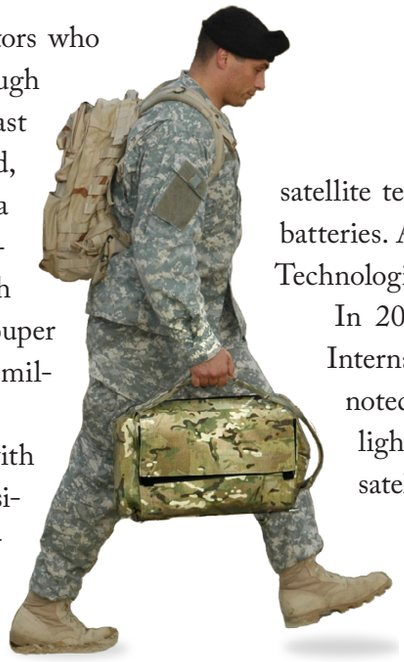
THINKING SMALL

A LIGHTWEIGHT, PORTABLE SATELLITE TERMINAL BENEFITS FORWARD OPERATORS

Rapid access to information via satellite feed is a key tactical advantage for any warfighter—but it's especially important for Special Operations Forces.

In the early 2000s, military operators who needed to receive communications through the military's standard Global Broadcast Service (GBS) had to use a 300-pound, three-foot satellite dish running off a generator. At the time, GBS was primarily used to transmit troop health and welfare information—along with Super Bowl games and NASCAR events—to military installations.

Today, thanks to advances made with support from the Air Force Small Business Innovation Research (SBIR) program, forward units can receive critical data with a 20-pound portable receive satellite terminal that runs on solar-rechargeable batteries. And that, said Mark Wheeler of AQYR Technologies, is what you call a paradigm shift.



All AQYR terminal products fit into a single airline-checkable case.

In 2001, New Hampshire-based Windmill International, Inc., AQYR's parent company, noted that the Air Force was looking for a lightweight, portable—and disposable—satellite terminal. The company won an SBIR contract to explore the possibilities. After initial design work, however, they determined that a

Photos: AQYR

disposable system wasn't feasible because of the cost of materials. Undeterred, they pressed forward to develop a portable unit that would fulfill mission needs.

"We used more of a commercial product development strategy in the SBIR contracts as opposed to a spec-driven product development strategy," said Wheeler, AQYR's director of business development. "That allowed us to address the needs of the user."

Wheeler believes this approach was key to the product's ultimate success, explaining that designers set out to create a technology that could be easily used by a warfighter not trained in satellite communications (SATCOM). For instance, the user would be able to open a unit and receive data within minutes. No tools were required for assembly, a special positioning technology would automatically align the system to receive data, and a small, laminated Quick Start Guide could lead the user through the simple steps to operate the unit.

Windmill fielded its first prototype in 2006. "We took it out and socialized it with 80 different military units," Wheeler said. "We would show it to them and explain our thinking, based on our collective background in the military." Wheeler served in the U.S. Army, and two others on the team served in the U.S. Air Force and Marines, both training as military SATCOM technicians.

"We had what we call an empathic–design philosophy, which means we understood what it meant to actually carry this stuff and use it," Wheeler said.

Windmill refined the prototypes into state-of-the-art individual satellite receive units, and by 2008, had introduced the KA-10 Suitcase Portable Receive Suite (PRS) and the Rucksack PRS. Both devices allowed reception of full-motion video for intelligence gathering, surveillance, and reconnaissance through the GBS broadcast. Working with another vendor, AQYR developed a flat, rectangular, slot array antenna that folded down into the PRS base. The antenna's small aperture design aligned well with the KA frequency band used by GBS, and the flat form wasn't as visible as a traditional dish antenna.

The primary use of GBS today is in receiving large bandwidth video files from unmanned aerial vehicle (UAV) feeds, including geospatial, satellite, and weather data. "The people who use these units most are the Tier One elements in the military," said Wheeler, "what they call 'the tip of the spear'—special operations units across the military branches, the Seals, and some units that don't have names. They're people who don't necessarily stay in the same place for very long but need to have the communications that our terminals provide."

"One of the biggest keys to our success is the fact that any terminal we make will fit into a single airline checkable case," Wheeler said. "These units can be used by a soldier, a nurse, a firefighter..."

Windmill spun-out AQYR to commercialize the products, and in 2015 AQYR received an indefinite-delivery, indefinite-quantity production (IDIP) contract to supply the U.S. military with the highly portable Rucksack and Suitcase PRSs—developed entirely through SBIR contracts. By late 2015, AQYR had manufactured and sold nearly 300 PRSs to the military for use in forward positions, places where rapid access to information is crucial to mission success. In early 2016, it was ramping up to deliver the first 150 Rucksack PRSs for the Air Force under the new contract.

"We've gotten letters from Special Forces commanders telling us that they have made it a standard that no unit will leave home without one," Wheeler said. "We've gotten a lot of feedback on how important these units are to the missions of some pretty elite elements of the military."

Compared to two-way, send-and-receive SATCOM systems, the one-way GBS broadcast feed enables much

The lightweight, portable terminal design assures forward operators access to mission-critical information.

faster transmittal of large data files, like streaming feeds UAVs. Wheeler notes that a bi-directional satellite system can be used in tandem with the Rucksack or Suitcase PRS. "You can set it down next to a two-way system and use that for bi-directional communication while this one just sits there and pulls data out of the sky for you. In many situations that kind of data is critical for mission planning and situational awareness."

AQYR has developed additional satellite terminals for the commercial market. These terminals are bi-directional, and deliver high-speed Internet and data access via satellite to workers at temporary sites. Users include medical and peace workers abroad and emergency responders. The company's Typhoon antenna was used by relief workers after the Nepal earthquake in 2015.

"One of the biggest keys to our success is the fact that any terminal we make will fit into a single airline checkable case," Wheeler said. "These units can be used by a soldier, a nurse, a firefighter. They're designed to effectively get someone communicating as fast as possible with the least amount of training."

Windmill and AQYR are proud of the role veterans played in their initial growth, and Wheeler is also quick to acknowledge that the companies' successes were a team effort. Windmill's Employee Stock Ownership Program attests to the company's commitment to its team.

And one thing all of AQYR's products have in common, he added, is that they are "100 percent" dependent on the innovations Windmill and AQYR achieved while working under their SBIR contracts.

In 2011, AQYR received the Small Business Administration's Tibbetts Award for the innovation and economic growth that resulted from development of its KA-10 Suitcase PRS.

TIDAL SHIFT

Zivko's smart-towed vehicles enable accurate data gathering while avoiding wave hazards

For both climate modeling and effective radar detection of ships, aircraft, and incoming missiles, it's often necessary to take low-altitude oceanic air samples. But the ocean's surface isn't always amenable to data collection. Rogue or "monster" waves with heights of up to 100 feet can sometimes appear without warning. Until recently, effective data gathering was limited by how close to the ocean's surface research aircraft could safely collect samples.

After experiencing several rouge waves, the U.S. Navy recognized the need to fly manned research aircraft at higher altitudes, reducing personnel safety risks, but they still needed the ability to collect useful data close to sea level.

In 1996, the Department of Defense (DoD) issued a request via its Small Business Innovation Research (SBIR) program for a towed research device. Zivko Aeronautics, Inc. (ZAI)—a woman-owned, Guthrie, Oklahoma-based small business—set to work on finding a solution.

The result is the Controlled-Towed Vehicle (CTV)—a durable, smart enclosure into which research instruments, such as thermometers, hygrometers, and Global Positioning System/ Inertial Navigation System (GPS/INS), can be placed. Towed by a specialized aircraft flying above potentially dangerous waves, the CTV is capable of being lowered over the ocean while maintaining a specified altitude. The stabilized platform is designed so that it travels below any wake turbulence produced by the main research aircraft, thus providing "clean" air data samples. The system is designed to fly in the 10-meter (32-feet) zone above the ocean—the area most known for atmospheric gradients.

Eric Zivko, ZAI President, said, "The SBIR award allowed us to design, manufacture, and test the vehicle using a Twin Otter aircraft at a government site in Monterey, California.

"We did a significant amount of engineering and development," he added. "The CTV is self-powered, self-contained, and wireless. It is lowered from the host aircraft using an electrically powered, regeneratively braked cable winch designed to be installed in the fuselage of a Twin Otter aircraft."

Initial testing was fairly uneventful. A few minor problem areas were identified but, overall, the system operated exceptionally well. The biggest hurdle was the communication link between the CTV and the system operator, located approximately 5,000 feet away. ZAI eventually settled on a commercial-off-the-shelf (COTS) autopilot solution to make communication and controllability of the CTV acceptable.

"Ultimately, work on several SBIR projects helped catapult Zivko Aeronautics into becoming an industry leader for composite instrument enclosure design and manufacturing."

Eric Zivko and Katherine Lindley

The company transitioned the technology to the Navy, which continues to use it today in conjunction with university scientists. The CTV is regularly deployed to measure flux, or exchange rates, between the air and sea boundary layers. The collected data is invaluable for climate prediction and radar propagation models, both of which have national security implications.

Dr. Haflidi (Haf) Jonsson, Chief Scientist and Research professor at the Naval Postgraduate School in Monterey (NPS), said, "The purpose of the CTV was to measure exchange rates of heat, momentum, and water vapor between the ocean and the atmosphere. Ideally, you measure these rates right on the water surface, because there may be features above the surface that alter the flow of these properties. The further away from the surface, the more likely it is that you are not measuring the surface rates. On the water, you usually are stuck with measurements in one place, or on a slowly moving ship over a small area. From an airplane, we can cover a wider area, but the compromise is the distance from the surface. To protect the pilot, our airplane is allowed to fly no lower than 30 meters above the water. The need to get closer was addressed by the CTV, which we can tow as low as 10 meters."

The flux determination is needed to measure wind, vertical wind, temperature, and water vapor density. "All parameters have to be measured at high rates (40 times per second), which can be challenging," Jonsson explained. "The exchange rates we measure influence the temperature of the overlying air, which

Photos courtesy Zivko Aeronautics

Zivko's controlled-towed vehicle (CTV) seated under its plane.

influences the weather. These rates also influence the temperature and humidity distribution in the boundary layer, which ultimately influences the transmissivity of light, radio, and radar signals in the air. This temperature and humidity distribution can greatly affect the radars' range and can also lead to radar 'dead zones' where nothing can be detected."

The CTV system not only enhanced the NPS's Twin Otter platform, it enabled data collection that has increased the Navy Research Program's potential mission capabilities.

Capitalizing on Zivko's experience, the Navy awarded the company a separate SBIR contract to develop a four-dimensional atmospheric and oceanographic instrumentation manufacturing process—something previously difficult, if not impossible, to achieve. Zivko leveraged the learning acquired from the development of the CTV to perfect a process that rapidly builds lightweight, accurate, and strong enclosures.

The Navy reports that Zivko's process, "permits rapid development of suitable molds. Their method enables the manufacture of affordable, closetolerance composite structures for high performance aircraft and offers a solution to a perennial problem in instrumentation: packaging multiple instruments together in a way that permits each instrument its necessary inputs."

The standard process involves applying fiberglass to foam, and then carving it into shape—a time and labor intensive process. Zivko does the opposite. They machine the foam into shape and then add the fiberglass coating. The novel manufacturing technique significantly reduces costs and allows the company to quickly respond to changing customer needs. As a result, the Navy is now able to collect timely meteorological and oceanographic data.

Katherine Lindley, Zivko's vice president of contracts said, "That SBIR contract indirectly led to additional work for ZAI. Ultimately, work on several SBIR projects helped catapult Zivko Aeronautics into becoming an industry leader for composite instrument enclosure design and manufacturing. Today, we work with commercial and government customers, creating user-friendly enclosures that are mounted to a variety of manned and unmanned aircraft."

Zivko Aeronautics, Inc.

Guthrie, OK • SBIR contract: N00014-97-C-02396 • Agency: Navy • Topic: N96-150, Four Dimensional (4-D) Atmospheric and Oceanographic Instrumentation