SANDIA NATIONAL LABORATORIES

TECH TRANSFER Success Stories 2012

Securing a peaceful and free world through technology

Sandia National Laboratories

Front Cover: Sandia's GEMINI-Scout Mine Rescue Robot is equipped to handle any number of obstacles, including rubble piles and flooded rooms, to help rescuers reach trapped miners safely and efficiently. (Photo by Randy Montoya)

innovation
through partnerships

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Acoustic Wave Biosensor: Rapid Point-of-Care Medical Diagnostics

Sandia National Laboratories, Adaptive Methods, Inc., University of New Mexico Health Sciences Center

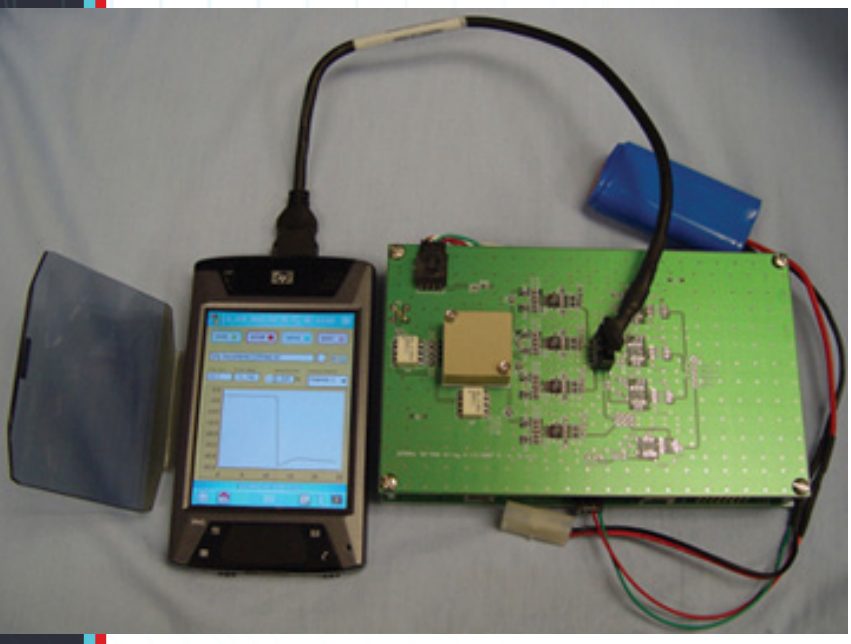
Problem

As world terrorist attacks have increased, the fear of widespread release of biological toxins weighs on the minds of security officials. Such an event could result in an extreme emergency situation. Identifying the biological agents and the levels experienced by those exposed is critical to defusing an environmental crisis. A tool providing rapid detection and identification of a pathogen at the point-of-care with little or no sample preparation is ideal. Sandia National Laboratories, in conjunction with the University of New Mexico Health Sciences Center, has created just that. The Acoustic Wave Biosensor provides fast, low-cost diagnostic results and offers sensitivity that exceeds traditional techniques.

Innovative Edge

The Acoustic Wave Biosensor is a handheld, battery-powered, easily transported detection system that identifies a wide range of medically relevant pathogens based on their biomolecular signature. Pathogens detected include viruses, proteins, bacteria, and DNA. Complex, real-world environmental samples including air, water, food, and soil are easily analyzed by the system. Detection occurs within minutes at the point-of-care, be it in a physician's office, a hospital, or at the scene of a biodefense or biomedical emergency.

Sandia's shear horizontal surface Acoustic Wave Biosensor array is the key to the effectiveness of the detection system. The array, functionalized with select ligands – antibodies, peptides, or single-strand DNA, depending on the application — acts as a miniature analytical balance by weighing the amount of pathogen that binds to its surface. Selective pathogen binding occurs based on the ligand that is employed. The sensor behaves similar to a spring: as more pathogen binds, the bouncing of the spring decreases. By analyzing the speed of the bouncing, the amount of pathogen present can be accurately determined. System control, data analysis, and reporting of the relevant information are all performed by a simple personal digital assistant (PDA).



Commercialization and Industry Impact

Originally developed for environmental sensing applications, Sandia's Acoustic Wave Biosensor technology became available for licensing in January 2009. Now, through an agreement with Sandia and the University of New Mexico Health Sciences Center, Adaptive Methods, Inc. is working to commercialize this R&D 100 award-winning technology into a handheld device suitable for use in a variety of situations. Health care providers, first responders, and military personnel will have a tool that provides rapid and accurate detection/identification of biological pathogens.

Acoustic Wave Biosensor instrument with PDA controller and rechargeable battery. Sensor arrays fit in the tan enclosure on the circuit board.

Biomimetic Membranes for Water Purification

Sandia National Laboratories, University of New Mexico

Problem

Scarcity of clean water leads to disease, death and often international tension. In many parts of the world, access to potable water is limited. The clean water supply faces further stresses due to its required use in a number of industrial processes. Desalination, the process of making fresh water from seawater, is used around the world to increase the supply of fresh water where water is scarce, but the process can be costly. Reverse osmosis (RO) is currently the best method of desalination, but the energy requirements and costs for this process are tremendous and offset the benefits. Australia has met its water supply demand with freshwater dams and water catchments in the past, but has been unable to do so in the last decade due to a significant lack of rainfall. As a result, Australia has come to rely on desalination for providing fresh water. At the Perth Seawater Desalination Plant, over half of the energy budget is used to establish the pressure drop needed to push the water through a semi-permeable membrane. By optimizing ion exclusion while facilitating rapid water transport, the amount of energy required to push fluid through the membrane can be reduced and drawbacks of current methods can be mitigated.

Innovative Edge

Inspired by how the human body filters water, Sandia, in conjunction with the University of New Mexico, has developed a synthetic biomimetic membrane that can be used for water desalination that requires significantly less energy than any other RO membrane on the market. Project lead Susan Rempe, Sandia, stated, "… our initial membranes achieved a 10-fold improvement in water purification efficiency compared with state-of-the-art RO membranes."

By combining experimental and multi-scale modeling techniques of natural biological channels, the science of the interface between water samples, ions, and pores was investigated to determine the molecular structure-function relationships pertinent to water desalination. Based on the results, the selective new membranes were created by combining evaporation-induced self-assembly of nanopores with atomic layer deposition (ALD), allowing specific tuning of both pore size and surface chemistry. By controlling these two elements, ion exclusion can be optimized while maximizing the flow of water through the pore channel.

Commercialization and Industry Impact

The principal application of biomimetic membranes is water purification. Based on performances observed in small-scale studies, the improved water flux of these membranes is predicted to reduce excess energy costs by 88%, translating into an annual $1.45M savings for a modest 100 mL/day desalination plant. Potential further applications of the membrane technology include liquid and gas separations, carbon dioxide capture and removal, and lithium-ion battery technology.

The biomimetic membrane technology is patent pending and further development is currently underway. This technology has great commercial potential and Sandia is working to identify companies interested in bringing the product to market.

Nanoporous biomimetic membrane on a nanostructured support used for water desalination testing.

CANARY: Event Detection Software

Sandia National Laboratories, Environmental Protection Agency's National Homeland Security Research Center, Open Source

Problem

Whether heavy rain sweeps extra minerals into groundwater reservoirs or terrorists pollute water supplies with radiological material, contaminations to drinking water systems pose serious threats to national safety and security. With the threat of devastating consequences including widespread illness, chronic health problems, and death, accurately detecting contaminations as quickly as possible helps water utility authorities and law enforcement mitigate danger. Although many detection technologies are currently deployed monitoring drinking water supplies for select contaminants, there is no single system that reliably detects the majority of contaminants of concern.

Innovative Edge

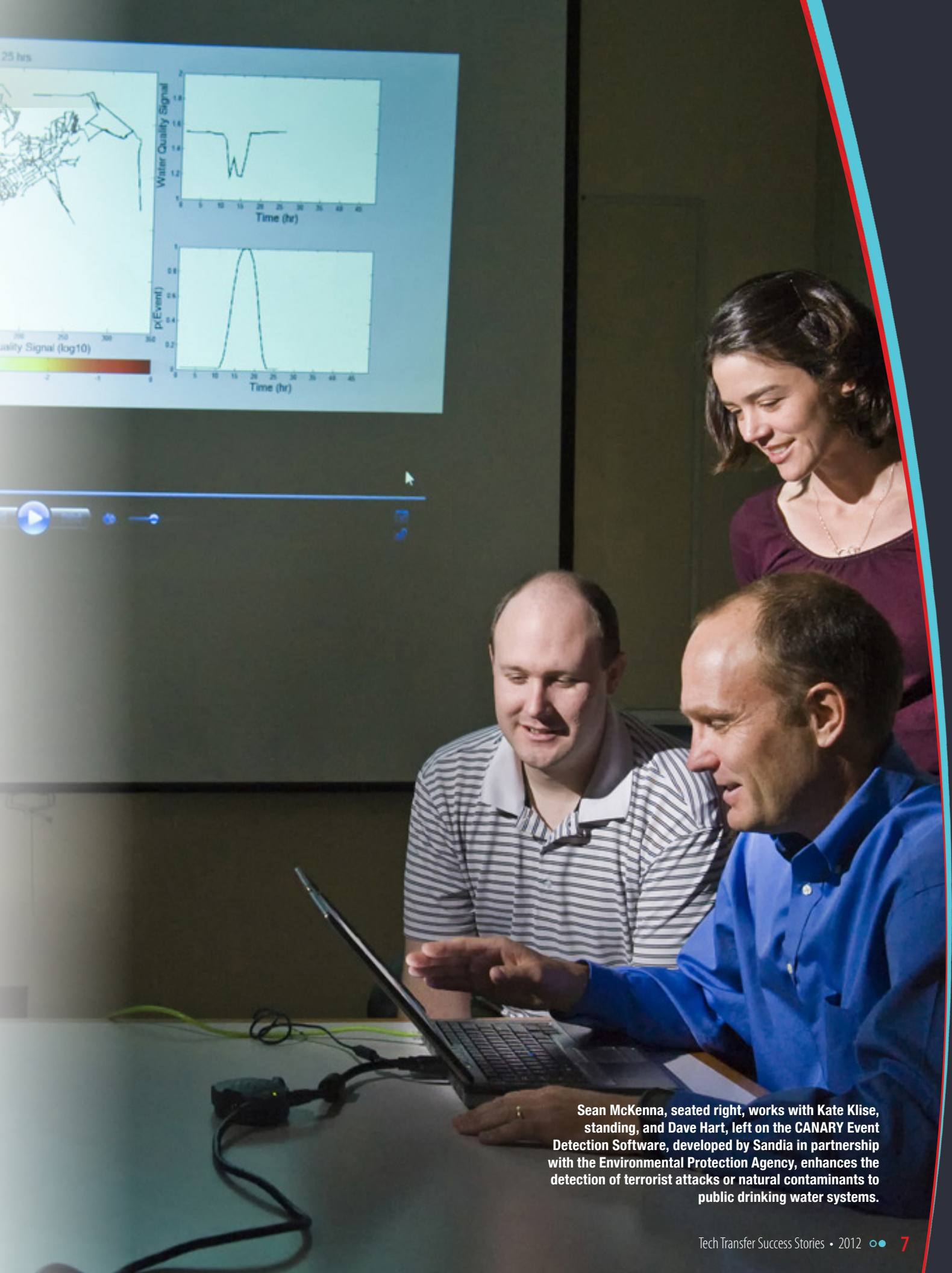
In partnership with the U.S. Environmental Protection Agency's National Homeland Security Research Center, Sandia developed CANARY software to immediately detect changes in water quality. This open-source software leverages existing water utility investments in sensor and supervisory control and data acquisition system hardware to continuously analyze signals from networked sensors for unusual responses. Analyzing subtle changes in water quality measured by multiple sensors and time series analysis, CANARY tracks data over successive time intervals to accurately predict when a water quality alarm is real.

Commercialization and Industry Impact

CANARY is released as freely available, open-source software, and is currently operating in several large U.S. utilities and in Singapore. The software is compatible with sensor technologies and information technology programs existing at most water utilities, and it can be configured by the end-user for utility-specific applications.

Harry Seah, director of the Technology and Water Quality Office at the Public Utilities Board (PUB), Singapore's national water authority, wrote in a letter that the software provided a "quantum leap" in the utility's practice. "With the implementation of CANARY, relative changes in the patterns [of three water characteristics] can be used to uncover water quality events, even if each individual parameter lies within the alarm limits," Seah wrote. "This dramatically improves PUB's ability to respond to water quality changes, and allows PUB to arrest poor quality water before [it reaches] the consumers."

CANARY was originally designed for water security purposes, but the dual-use benefits have been recognized by a number of utilities. With CANARY, operators better understand the data transmitted by their sensors and are able to improve management of the water systems. Several utilities have reported that using the software has enhanced the day-to-day water quality management within their distribution networks, in addition to providing improved security from contamination.



Sean McKenna, seated right, works with Kate Klise, standing, and Dave Hart, left on the CANARY Event Detection Software, developed by Sandia in partnership with the Environmental Protection Agency, enhances the detection of terrorist attacks or natural contaminants to public drinking water systems.

Chip-Scale Atomic Clock

Sandia National Laboratories, Draper Laboratory, Symmetricom, Inc.

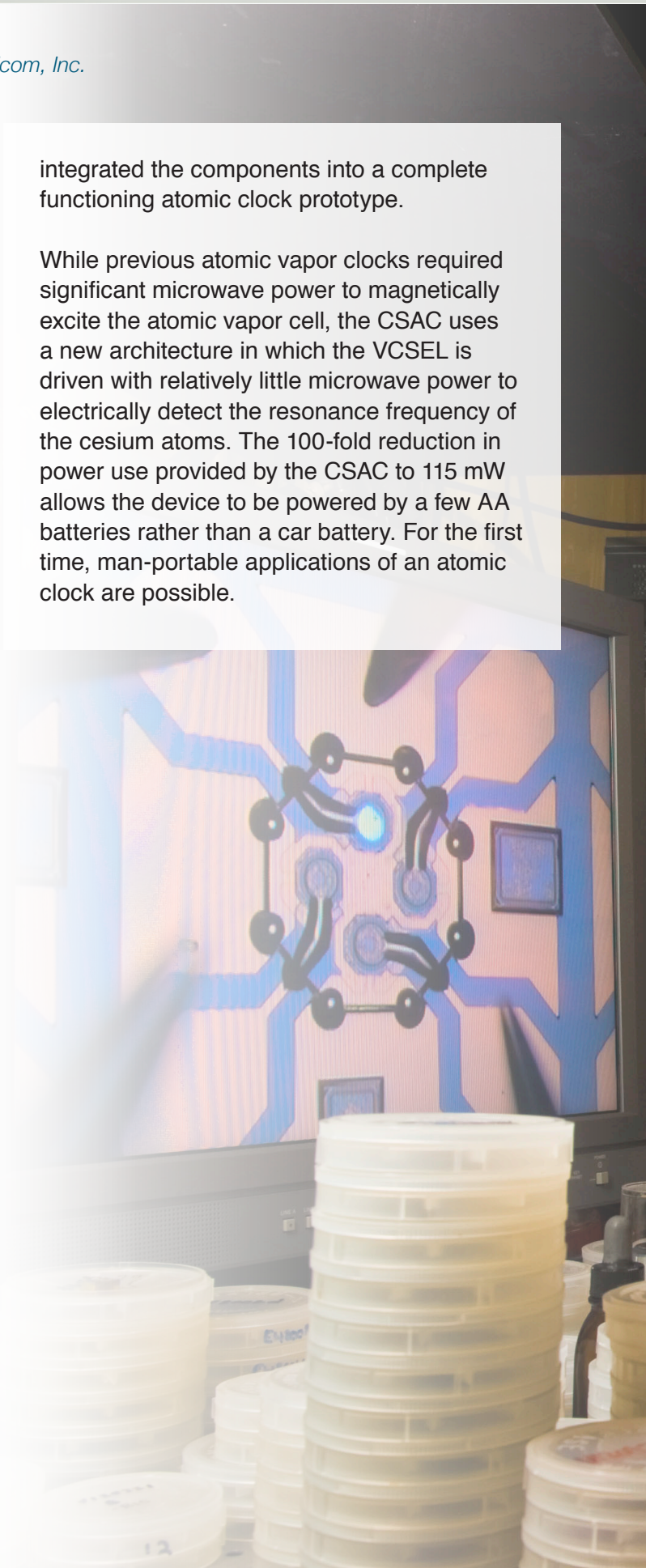
Problem

Atomic clocks are the most precise time keepers available. They keep time more accurately than the rotation of the earth and the movement of the stars. Without the exacting measurements provided by atomic clocks, Global Positioning System (GPS) navigation would be impossible, the internet would not synchronize, and position of the planets would not be known with enough accuracy for space probes and landers to be launched and monitored. However, the size and power requirements of atomic clocks have traditionally been restrictive and portability of the clocks or their associated devices has not been an option. Sandia recently developed a technology that facilitated the production of the Chip-Scale Atomic Clock (CSAC), a device that allows such portability by achieving a 99% reduction in size and power consumption relative to prior state-of-the-art atomic clocks, opening the door to a world of new applications.

Innovative Edge

Funded by the Defense Advanced Research Projects Agency (DARPA), the CSAC was developed by a Symmetricom-led team, with support from Draper Laboratory and Sandia. At the outset of the project, no low-power single-frequency lasers were commercially available – particularly lasers operating at the higher-performance wavelengths necessary for atomic clocks. Sandia developed a microscopic semiconductor vertical-cavity surface-emitting laser (VCSEL) that reduces power consumption of the internal light source by 99.9% relative to the atomic vapor lamps used prior to this. In conjunction, Draper Labs developed a MEMS-fabricated cesium vapor cell that achieved a 99.5% reduction in atomic vapor cell power consumption. As the team lead, Symmetricom planned the clock architecture, designed the electronics, and integrated the components into a complete functioning atomic clock prototype.

While previous atomic vapor clocks required significant microwave power to magnetically excite the atomic vapor cell, the CSAC uses a new architecture in which the VCSEL is driven with relatively little microwave power to electrically detect the resonance frequency of the cesium atoms. The 100-fold reduction in power use provided by the CSAC to 115 mW allows the device to be powered by a few AA batteries rather than a car battery. For the first time, man-portable applications of an atomic clock are possible.



Commercialization and Industry Impact

The CSAC provides precise timing signals even when GPS satellite reception is impaired: inside buildings, underwater, and in adverse weather. Symmetricom released the first commercial CSAC in early 2011. Sandia is also developing a follow-on technology for DARPA: a trapped-ion-based clock. Researchers are working on the first compact prototype which will improve timing and accuracy at a similar size, weight, and power to the CSAC.

Darwin Serkland measures the wavelength of a tiny laser called a VCSEL, or vertical-cavity surface-emitting laser. The image on the monitor (left) shows a bright circle of light emitted from a VCSEL operating at the wavelength of 894 nanometers needed to drive the atomic clock.

DAKOTA

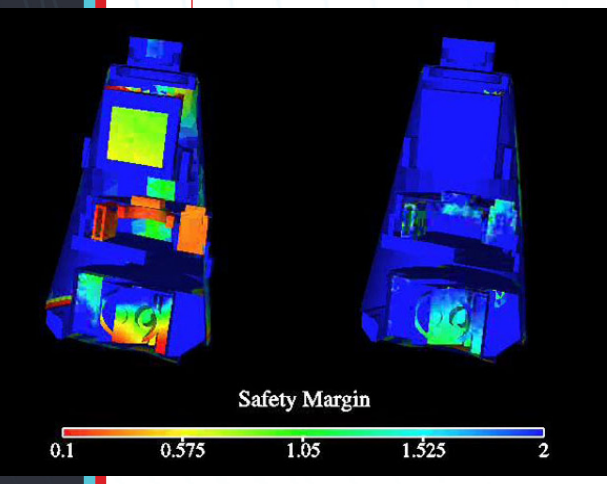
Sandia National Laboratories, Open Source

Background

Since experiments are increasingly costly to perform and require significant investments of time and manpower, researchers are turning to computational models to solve a number of fundamental science and engineering problems. Independent of many "real world" constraints, simulations serve as an efficient testing alternative, allowing researchers to analyze phenomena of interest quickly and thoroughly since any number of simulated scenarios can be applied to the model. However, issues of accuracy and reliability plague the use of computational models. Researchers must be able to gauge the accuracy of their models and optimize them to produce reliable, realistic results.

Innovative Edge

Sandia developed and released its Design Analysis Kit for Optimization and Terascale Applications (DAKOTA) software as an open-source tool assisting researchers in assessing the accuracy of their models. Complete with mathematical and statistical methods for sensitivity analysis, uncertainty quantification, design optimization, and parameter estimation, DAKOTA unifies diverse algorithms to provide best-in-class mixed deterministic and probabilistic analysis of nearly any computational model. Answering important questions such as how reliable or variable the system is and what models or parameters best match experimental data, DAKOTA helps researchers know if their simulations are accurate, and how they can be optimized to produce the most realistic, reliable data.



Left shows results without DAKOTA with violated response levels; right shows optimized design with DAKOTA.

Commercialization and Industry Impact

DAKOTA 5.1 was released and deployed in December 2010, and runs on high-performance computing platforms, as well as on PC and Mac desktop computers. Freely available as open-source software, DAKOTA is used widely by academic, government, and corporate institutions. For example, DAKOTA is used as part of a Cooperative Research and Development Agreement (CRADA) between Sandia and Goodyear Tire and Rubber Company to optimize tire profiles and calibrate tire material models to experimental data. In this capacity, DAKOTA helps researchers tune mechanics models such as the Sandia-developed SIERRA, to maximize performance and best-fit data.

DAKOTA also plays a key role in the Consortium for Advanced Simulation of Light Water Reactors (CASL), where its sensitivity and uncertainty analysis algorithms are used in conjunction with computational models of nuclear reactor cores. The resulting analysis helps prioritize data collection investments. Because DAKOTA is capable of better characterizing reactor operations and associated uncertainties, CASL adds to the technical basis for crucial reactor power updates and life extensions.

Since its initial public release, nearly 8,000 unique registrations have been received from around the world, permitting download, including companies such as General Electric, Eurocopter, National Aeronautics and Space Administration Jet Propulsion Laboratory, BASF Corporation, Gohypersonic, Siemens, Ausy, and Chalmers.

Demand Response Inverter

Sandia National Laboratories, Princeton Power Systems, Inc.

Problem

Reducing the nation's dependence on petroleum for power production is a priority. Promising sources of alternate energy currently under development include sunlight, wind, tides, and geothermal heat. One of the most predictable is solar – the sun rises and sets everyday. However, solar energy also faces a classic problem: the sun is not always shining. A passing cloud can reduce a one-megawatt solar array from 100% to 10% in a matter of seconds. Because of this intermittency, integration of solar power into today's electricity grid is limited. In an effort to alleviate these issues and improve throughput for solar-based renewable energy solutions, Sandia and Princeton Power Systems have teamed up to develop the Demand Response Inverter (DRI).

Innovative Edge

The DRI is a power flow control system that integrates renewable energy sources with buildings and the electric grid. By increasing renewable energy throughput, this technology dynamically manages the generation and dispatch of solar energy. The added flexibility and responsiveness of this approach mitigates renewable energy intermittency, providing very high conversion efficiency and reliability. Recognized with an R&D 100 award in 2011, the DRI provides valuable grid-support functionality. It encourages high penetration of photovoltaic power systems into the electrical grid, adding value both for the system owner and local utility.

Commercialization & Industry Impact

Guiding and reviewing Princeton Power Systems Inc.'s product design from technical development to commercialization, Sandia helped ensure the DRI's commercial viability. Success required acute attention to details such as performance, cost, and manufacturability. As a first-of-its-kind product, the DRI was made commercially available in 2010. "What we tried to do with the DRI is make it a real turnkey, one-box solution that arrives on site and is flexible," states Princeton Power Systems' co-founder Darren Hammell in the September/October 2011 edition of Solar Today. "The DRI is a promising technology that can provide a paradigm shift in the field of Renewable Energy Systems," says Ward Bower, Sandia's developer. It sets a new bar in the state of power electronics systems by facilitating the transition from passive, dispersed installations to highly-integrated, utility-supported behind-the-meter photovoltaics deployments.

100kw Demand Response Inverter (shown with optional disconnects).

GEMINI-Scout Mine Rescue Robot

Sandia National Laboratories, Black-I Robotics

Problem

When miners are trapped underground, a quick response can mean the difference between life and death. However, finding miners after an accident requires technology that can meet the need for a timely response while navigating obstacles and gathering important information about the situation, including the presence of poisonous gases, flooded tunnels, explosive vapors, and unstable walls and roofs.

Innovative Edge

Sandia partnered with the National Institute for Occupational Safety and Health, with guidance from the U.S. Department of Labor Mine Safety and Health Administration, to create the GEMINI-Scout Mine Rescue Robot. Currently licensed to Black-I Robotics, the GEMINI-Scout is an unmanned ground vehicle designed to help rescue crews move safely and efficiently through hazardous environments and assess situational conditions including structural quality, operational status, air quality, and temperature. Through an integrated sensor suite design, this platform is equipped with the necessary cameras, microphones, and sensors to act as the eyes and ears of the rescue crew, while also providing valuable information about air quality (O2, CO, and methane) and enabling two-way communication between rescue crews and potential survivors.

With its dual-track chassis design, the GEMINI platform also has the mobility to travel across rough terrain, trek through standing water, and travel over obstacles. Whether placed in structured or unstructured terrain, it can move over significant rock and rubble piles, and has the ability to travel through water and mud up to 18 inches deep, using elevated pan and tilt cameras for navigation.

Commercialization and Industry Impact

Through an exclusive license with Sandia, Black-I Robotics agreed to further develop, manufacture, and commercialize the GEMINI Scout Unmanned Ground Vehicle in 2011. The Tyngsboro, Massachusetts business purposes the vehicle primarily for underground mine rescue operations in extremely hazardous environments. Coupling the robust, all-terrain robotic chassis with unique patented articulating sections for spanning ditches and extreme rocky or irregular terrains, Black-I Robotics excels in rapid prototyping and fielding new unmanned technologies.

Promising to benefit first responders including police, firefighters, and medical personnel, the GEMINI-Scout Mine Rescue Robot was also honored with a 2011 award by the Federal Laboratory Consortium for Technology Transfer.

GEMINI-Scout Mine Rescue Robot.

Micro Power Source

Sandia National Laboratories, Front Edge Technology, Inc., Pacific Northwest National Laboratory (PNNL), University of California at Los Angeles (UCLA)

Problem

Everyone has experienced it: The batteries on your electronic device running out at the most inopportune moment. But what if the batteries had the ability to recharge themselves? What if they were covered by a thin photovoltaic (PV) film that could harvest energy from the sun? Just as on rooftops, the PV surface could convert the sunlight to electricity, thereby recharging the battery in the process. Sandia, working with Pacific Northwest National Laboratory (PNNL) and University of California at Los Angeles (UCLA), has developed the Micro Power Source, a system that integrates a lithium-ion-based solid electrolyte battery with an ultra-thin PV cell, producing a self-charging battery.

Innovative Edge

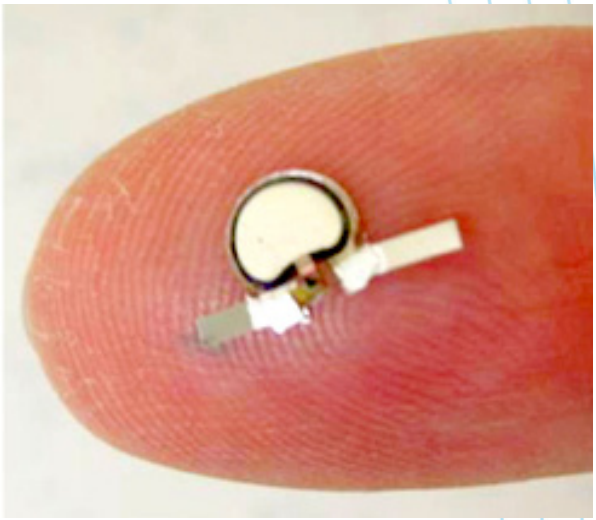
The micro power source is an ultra-small form factor, energy harvesting (self-charging) power source that occupies a volume of only 1 μL, yet possesses a high peak-power density greater than 1,000 W/L. Resembling a small disk, the entire system is environmentally sealed with a polymer coating and is very small. The battery is a solid-state system employing a lithium phosphorus oxynitride (LiPON) electrolyte and is charged by an energy harvesting PV device.

Originally funded by Defense Advanced Research Projects Agency, the device features Sandia's Microsystems and Engineering Sciences Applications fabricated ultra-thin PV cells; Front Edge Technology's thin film rechargeable lithium cells and masking technique for manufacturing thin film batteries; PNNL's ultra-thin sealing material; and UCLA Nanofabrication Lab's assembly and packaging techniques. The construction of the battery and the PV are based on existing manufacturing technologies that are amenable to volume manufacturing scale-up.

Commercialization & Industry Impact

While DARPA's applications are not available, the micro power source has the potential to revolutionize a number of commercial industries such as handheld electronics, cyber security, and alternative energy.

The micro power source technology lends itself to a number of commercial applications including active smart cards, self-powered radio frequency identification tags, self-powered portable memory devices, in-situ power for industrial process monitors, and remote untethered sensors and transmitters. The system became available in February 2009. While initially available for the above uses, the form factor and energy harvester can be easily changed to open up many other application spaces. Front Edge Technology, Inc. has plans to market this product in the future.



The rechargeable, ultra-small micro power source.

Microresonator Filters and Frequency References

Sandia National Laboratories, Rockwell Collins

Problem

Cell phones have become a staple in society. From making a simple phone call to browsing the web, using location services, cell phones provide a myriad of daily services. But imagine if, when using these applications, sounds and information from those nearby were scrambled in. What if others' conversations could be heard on your phone? Fortunately, this is not the case due to the exceptional radio frequency filters found in the devices. With all the applications available, new 3G and 4G devices could require more than 26 filters to keep them functioning smoothly. Microresonators developed at Sandia operate as chip-sized filters when grouped together, providing ultra-small scale frequency selection in radios and other electronic devices.

Innovative Edge

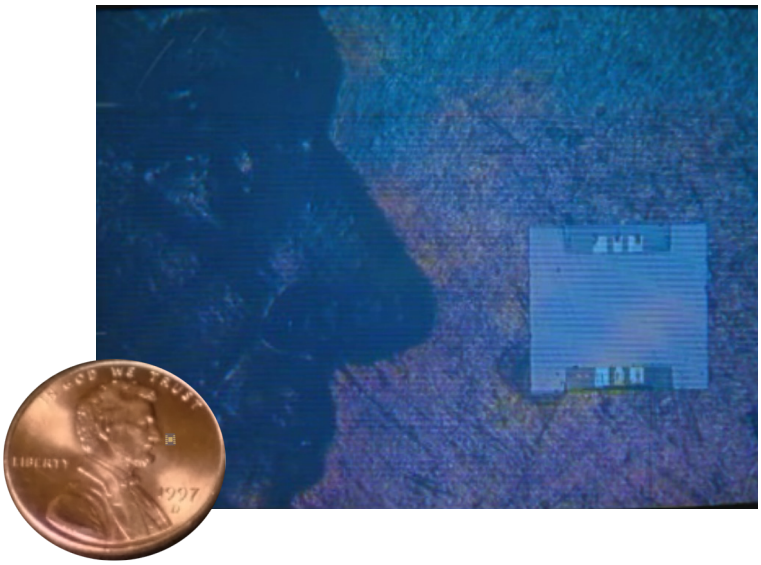
Sandia's microresonators are miniature acoustic resonators that have highly precise sound. They are manufactured using the same technologies that mass-produce integrated circuits (IC) and offer several advantages compared to existing acoustic resonator technologies. These advantages include greater frequency diversity, smaller size, and superior integration with complementary metal-oxide semiconductor (CMOS) transistors.

The size and resonance frequency of the microresonator plate is determined lithographically using computer-aided design (CAD), allowing any frequency between 32 kHz and 10 GHz to be formed on a single chip. This range follows an order of magnitude wider than existing technologies and is capable of including time signals, AM and FM radio, cell phone, Wi-Fi, Bluetooth, and military radar and satellite communications bands.

Commercialization and Industry Impact

The principal application of microresonators is radio frequency filtering and the technology serves two distinct markets. First, microresonators enable consumer electronics, namely mobile communications. With next generation (3G and 4G) mobile handsets, microresonators offer the ability to reduce costs and component numbers by realizing many of these filters on a single chip, despite the filters' varying operating frequencies.

Secondly, microresonator technology is of great value to defense and military radio operations. Military radios require higher performance than consumer wireless handsets, and higher performance is generally achieved through additional stages of filtering. When applied to intermediate frequency (IF) filtering in high-performance defense radios and radars, microresonators reduce size and cost compared to current solutions by more than 100 times. Rockwell Collins, a company focused on developing the technology for defense applications, licensed the technology from Sandia in July 2010.



Microresonator filter next to Lincoln's nose on a U.S. penny.

Multifunctional Optical Coatings by Rapid Self-Assembly

Sandia National Laboratories, Lockheed Martin Aeronautics, University of New Mexico, Davidson College

Problem

Optical coatings are ubiquitous, appearing on items that range from electronic devices, photographic lenses, and windows to aircraft sensors, photovoltaic cells, and lightweight plastic goggles for troops in the field. The coatings are applied to materials such as glass and ceramics, which protect or alter the way the material reflects and transmits light. However, the two main methods of applying these coatings – sputtering and chemical vapor deposition (CVD) – are expensive, require highly specialized personnel, and can be hazardous due to the extreme conditions required for the processes. Sandia has developed a technique for applying optical coatings that eliminates these problems. The Multifunctional Optical Coatings by Rapid Self-Assembly process takes place at room temperature using ambient conditions, yet produces a coating competitive with current technologies.

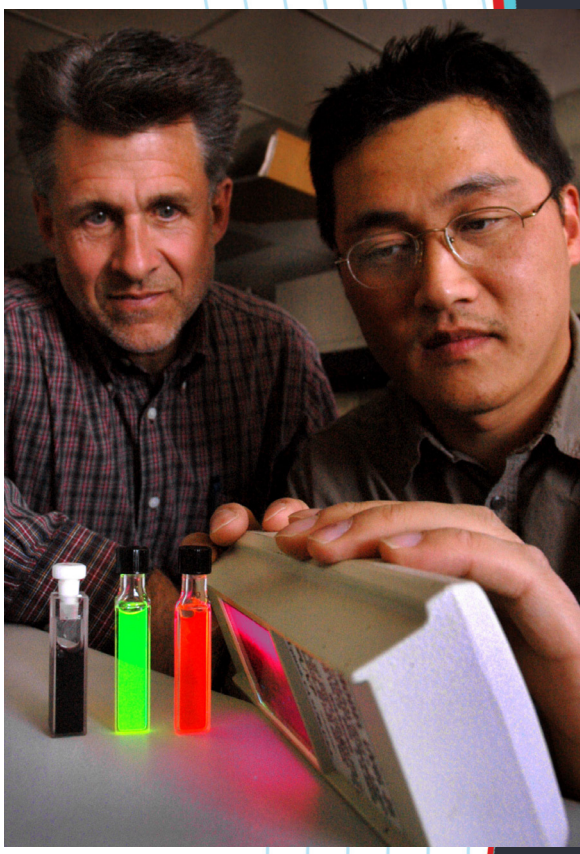
Innovative Edge

Sandia's method for applying the film uses commercially available polymers, dissolving them in common solvents at a normal temperature and pressure, and then using a simple spin, dip, or spray technique to coat the surface. Evaporation of the solvents induces self-assembly, forming multifunctional films with a nanostructured surface, low surface energy, controllable porosity, and a specific desired refractive index. Using a variety of near-ambient processes, the chemical and physical nature of the polymer film can be modified to provide different functions and properties depending on the application. The ability to adjust the material parameters of the film at different stages (synthesis, deposition, or post-deposition) provides a powerful new degree of freedom. In addition, Sandia's method is compatible with conventional spray processing and, therefore, is not subject to the equipment and facility limitations of traditional deposition processes. This allows a wider range of applications, including the coating of large or complex parts.

Commercialization & Industry Impact

Sandia developed the 2010 R&D 100 award-winning Multifunctional Optical Coatings process in conjunction with Lockheed Martin through a Cooperative Research and Development Agreement (CRADA). The goal of the partnership was threefold: to develop the technology; to identify applications for industry, the DoD, DOE and NASA; and to integrate the technology into current product lines. Applications for the coatings range from reducing corrosion on aircraft transparencies and architectural windows to protecting photovoltaics.

Other areas that could benefit from this coating process include high-definition flat panel displays, sensor coatings for both biological and chemical sensors, and low-k materials for next generation memory chips.



Jeff Brinker (left) and Hongyou Fan observe satisfactory fluorescence by their well-trained nanocrystals in water solution. The dark vial holds gold nanocrystals; the orange and green are semiconductor nanocrystals.

Nanoporous Particle-Supported Lipid Bilayers

Sandia National Laboratories, University of New Mexico (UNM), University of New Mexico Cancer Center

Problem

Treatment options for cancer are usually non-specific and physically taxing on patients already in a weakened state. New methods for delivering drugs specifically to the cancer cells, while avoiding widespread damage to healthy cells, would provide optimal treatment. Researchers at Sandia, working with UNM and the UNM Cancer Center, produced a drug delivery system that shows a 10,000-fold greater affinity for liver cancer cells than for normal liver cells. This system offers a number of advantages over traditional drug therapies for liver cancer, including improved specificity and decreased toxicity. The hybrid system promises to mitigate the side effects of conventional chemotherapy and may allow for the use of unique drug combinations based on individual needs in various types of cancers.

Innovative Edge

Sandia's hybrid system consists of silica nanoparticles encapsulated by a lipid bilayer (called a liposome), the combination of which is referred to as a protocell. The core of the nanoparticle allows it to serve as a vehicle for cancer drugs that have been tailored to destroy a particular type of cancer. The lipid bilayer provides a protective coating during transportation in the bloodstream to prevent the chemotherapeutic drugs from leaking out before reaching its target. Peptides bound to the surface of the particle provide specificity for the cancer cells, and polyethylene glycol (PEG) prevents unwanted interactions with noncancerous cells. Once bound, the particle can then transfer the drugs into the cancer cell.

The current FDA-approved nanoparticle delivery strategy uses liposomes themselves to contain and deliver the cargo. In a head-to-head comparison of targeted liposomes and protocells having identical membrane and peptide compositions, the greater cargo capacity, stability, and targeting efficacy of protocells leads to orders of magnitude greater cytotoxicity directed specifically to human liver cancer cells.

Commercialization and Industry Impact

Though long lead times for widespread use of new therapies is typical, UNM's Cancer Research and Treatment Center is currently testing this method on human cancer cells in culture and will soon test it in mice. Researchers estimate that protocells may be ready for testing in humans in as few as five years. As testing progresses, researchers will continue to optimize the system. Performance of the delivery system depends on the size of the silica particle as well as its electrical charge and hydrophobicity, so optimization of these attributes continues in an effort to achieve the most effective delivery system.

Sandia postdoc Carlee Ashley introduces a buffer into a protocell solution as UNM professor Jeffrey Brinker watches.

Portals 4.0 Interconnect API

Sandia National Laboratories, Intel, University of New Mexico

Problem

Computational capabilities have increased immensely over the past two decades. Computing jobs are no longer run solely on one processor. Rather, simulations are now run on supercomputers containing thousands of processors (cores), allowing results that were previously impossible. For example, recent capability class routine massively parallel simulations now run in 24 hours, where they would have taken over ten years just a decade ago. Successful completion of the job relies on efficient communication among the numerous processors running simultaneously (in parallel). As the number of parallel processors increases, so does the need for an effective interface between the individual devices in the computer network, or nodes. Portals, developed by Sandia, is an effective message passing interface that is designed to allow scalable, high-performance network communication between all nodes of a parallel computing system.

Innovative Edge

Portals application programming interface (API) is a low-level interconnect for distributed memory massively parallel computing systems. The Portals API provide low latency, high bandwidth, and high message rates, as well as the ability to efficiently support a variety of higher-level communication paradigms. Sandia, Intel, and the University of New Mexico began working on the concept of Portals in the early 1990s. Since that time, a series of design phases and upgrades have been instituted, leading to Portals 4.0.

Portals 4.0 are well suited to massively parallel processing and embedded systems. They represent an adaption of the data movement layer developed for massively parallel processing platforms, such as the 4500-node Intel TeraFLOPS machine. Portals 4.0 are targeted to the next generation of machines that employ advanced network interface architectures to support enhanced network processing offload capabilities resulting in a highly scalable computing system.

Commercialization & Industry Impact

Working together under a Cooperative Research and Development Agreement (CRADA), Sandia and Intel created an open-source implementation of the Portals 4.0 API specification suitable for answering a number of important questions regarding performance and potential design tradeoffs. The implementation guided the specification design to ensure successful targeting to a variety of high-performance interconnect hardware. In addition to broadening the appeal of Portals beyond Sandia's applications, the implementation and knowledge gained through this collaboration has helped Intel move forward on decisions regarding interconnect and system design.

Kathye Chavez inspects a component in one of the many cabinets that make up Sandia's Red Sky. Portals 4.0 Interconnect API works to provide an effective messaging interface to allow scalable, high-performance parallel computing on such systems as Red Sky.

Solar Glitter

Sandia National Laboratories, Emcore, Endicott Interconnect Technologies, International Micro Industries, National Renewable Energy Laboratory, Universal Instruments

Problem

Our expanding use of electronic equipment has increased the demand for reliable, affordable energy sources to power them. Concern over environmental damage caused by the use of fossil fuels is driving energy providers to seek out alternate renewable power sources. Sun and wind are both viable options, but of these, only solar power has the potential for widespread portable use. Traditionally, the collection and conversion of sunlight to electricity has been expensive. However, Sandia scientists have developed glitter-sized photovoltaic (PV) cells that have the potential to achieve the cost breakthrough necessary to move solar energy into the mainstream.

Innovative Edge

The miniaturized solar cells are produced using Sandia's Microsystems-Enabled Photovoltaics (MEPV) technology, which employs microdesign and microfabrication techniques common to the semiconductor, LCD, and microsystems industries. The PV cells are then "printed" onto a low-cost substrate with embedded contacts and microlenses for focusing sunlight onto the cells. The small size of the collectors makes versatile applications possible. "Eventually, units could be mass-produced and wrapped around unusual shapes," said Greg Nielson, lead investigator for the project. If integrated into buildings, tents, and potentially clothing, MEPV technology would allow users such as hunters, hikers, and military personnel to recharge batteries for phones, cameras, and other electronic devices while in the field.

Commercialization and Industry Impact

Continued MEPV development is focused on making this 2011 Federal Laboratory Consortium award-winning technology the most efficient, versatile, and inexpensive way to produce electricity for three distinct markets: power utilities, building owners, and individuals. MEPV can be combined with new manufacturing and installation concepts to achieve a price point, making solar energy a competitive energy source. Likely initial users include those requiring logistical or tactical power such as warfighters and early responders, but applications could be as far reaching as satellites and remote sensing devices.

Sandia's role in MEPV technology development has been to design, fabricate, and test MEPV cells, modules, systems, and devices. A number of mutually beneficial partnerships were instrumental in bringing the technology to fruition. Partners including companies (Endicott Interconnect Technologies, EMCORE, International Micro Ind., and UI), laboratories (NREL), and universities (UCF, USF) provided the expertise required to move the technology forward as an increasingly efficient, reliable, and affordable energy alternative. As of mid-2011, six patents had been filed for various aspects of the technology and talks with additional potential partners currently continue.

Greg Nielson (center) and coworkers hold up samples of the solar glitter cells.

Solution Deposition Planarization

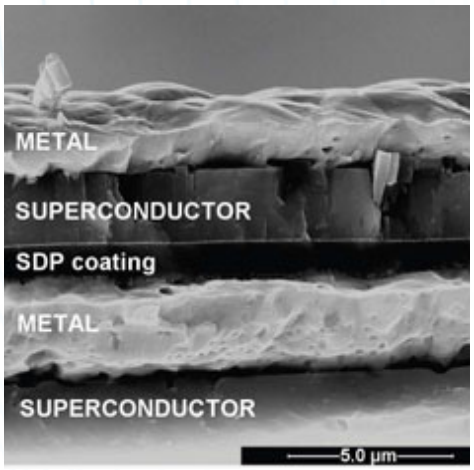
Sandia National Laboratories, Los Alamos National Laboratory, Superconducting Technologies Inc., Superpower

Problem

The electric grid relies on transmission of power from the production source – be it a coal-fired plant, solar array, or wind farm – to the customer. Energy transmission results in a great deal of energy loss due to resistance in the conducting material. Superconducting wires offer zero power dissipation and higher maximum current densities when contrasted with traditional copper or aluminum analogues, but it also requires costly manufacturing techniques. This state-of-the-art wire has the potential to impact electric power transmission as fiber optics has for communications. However, production costs must be reduced before it can achieve this potential. In an effort to lower manufacturing costs and to support higher power densities, Sandia collaborated with Los Alamos National Laboratory to develop solution deposition planarization (SDP), a process used in the creation of lower-cost superconducting wire.

Innovative Edge

A precisely aligned crystal structure is required for superconducting wire to achieve its high electrical current capacity. Creating the required degree of alignment involves the use of SDP in conjuction with ion beam assisted deposition (IBAD). In IBAD, a single-crystal-like oxide template is applied to the metal substrate, then the superconducting layer is deposited on the thin 5-nm IBAD layer. SDP provides the smooth surface required to achieve the desired thinness.



Solution deposition planarization.

The SDP process involves dip-coating rough metal tapes in a liquid precursor mixture and then annealing the coating to reduce roughness. The planarized coating then enables kilometer-length deposition of ion beam-textured templates and bi-axially oriented superconductor films at high speeds and low production costs. In addition, the SDP process eliminates toxic waste and removes three expensive processing steps to achieve high performance superconducting wires.

Commercialization and Industry Impact

Superpower and Superconducting Technologies Inc. are implementing SDP as a critical process in their production of high power density-supporting superconducting wire. Superconducting Technologies Inc. uses SDP in its manufacturing process to produce the Conductus 2G high temperature superconducting wire and describes SDP as an “inexpensive process, which provides a smooth starting surface while eliminating the need to polish the template, reducing both cost and chemical waste.”

Lower manufacturing costs for superconducting wire will facilitate greater use of the robust, efficient material. Superconducting wires will revolutionize efficient power transmission by enabling new products such as smaller motors and wind turbines, as well as nearly-zero energy loss long-length direct current energy transmission lines for use with renewable energy technologies.

Stingray

Sandia National Laboratories, Team Technologies Inc.

Problem

Each day, improvised explosive devices (IEDs) threaten the lives and safety of soldiers and civilians both at home and abroad. If identified in time, IEDs can be removed from the scene and detonated safely. However, detonating a device obliterates important forensic information that can be used to trace the IED to its source. Disablement tools are currently under development to preserve this important information while eliminating the threat of an IED.

Innovative Edge

Stingray is the first coherent fluid blade disablement tool based on technology that forms water into a single blade capable of cutting through steel. When in use, a wall of water shoots from the back of the device that is not only capable of disabling munitions, but can also precisely tear through "soft targets" such as backpacks, when necessary. Stingray's light, compact design makes the device portable, allowing it to be easily positioned at the most effective distance from its target. Whether the IED target is along the road, in the trunk of a vehicle, or in a safe, backpack, or propane tank, the coherent blade travels fast enough to disrupt the target ahead of the gases from the explosion, mechanically disabling the target instead of detonating it.

Commercialization & Industry Impact

Sandia licensed its fluid blade disablement technology to TEAM Technologies Inc. to make and sell Stingray for the explosive ordnance disposal community. During the technology transfer, Sandia researchers continued to work closely with TEAM providing information needed to improve Stingray's design and battlefield performance. Optimizing the device's design to be more efficient and enabling greater penetration while using fewer explosives, the strong collaboration enabled rapid commercialization, requiring only seven months from the signing of the licensing agreement to the delivery of the first products to the war fighter. The strong collaboration between Sandia and TEAM was also honored with a 2011 Federal Laboratory Consortium Excellence in Technology Transfer award.

Since mid-2010, over 4,000 units of Stingray have been shipped and are saving lives in war zones.

A simulated scenario in which the water blade is employed on the target.

SUMMIT

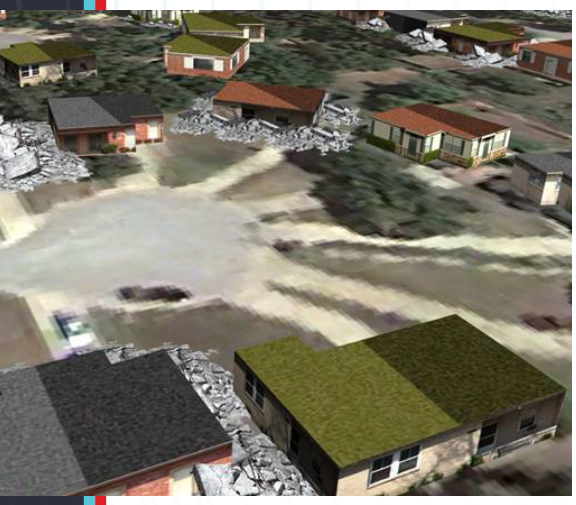
Sandia National Laboratories, Emergency Preparedness Community

Problem

Natural disasters such as Hurricane Katrina in New Orleans and the tsunami in Japan in 2011 create emergency situations that must be dealt with quickly and effectively in order to minimize injury and loss of life. Simulating such events before they occur can help emergency responders fine-tune their preparations. To create the most accurate modeling scenarios, exercise planners need to know critical details of the event, such as infrastructure damage and numbers of immediate casualties or displaced citizens. Current modeling and simulation tools provide individual pieces of the desired information; however, until now, there has been no automated method for sharing information from the various models and compiling it into usable data to allow rapid and accurate assessment of the overall situation. Sandia has developed a new software architecture, the Standard Unified Modeling, Mapping & Integration Toolkit (SUMMIT), that provides this coupling ability.

Innovative Edge

SUMMIT was developed with funding from the Department of Homeland Security's (DHS) Science and Technology (S&T) Directorate and the Federal Emergency Management Agency's (FEMA) National Exercise and Simulation Center to help emergency planners more effectively use and integrate advanced modeling and simulation capabilities. These agencies have spent years designing models and simulations for disaster planning, but the various systems could not work together or share information. SUMMIT knits together different models to allow planners to quickly swap data and to set up new scenarios with existing information within minutes or even seconds. It is platform independent and can run on a desktop, laptop, or even on handheld devices such as smartphones or iPads.



SUMMIT links together models and provides an integrated view of data results. The software offers a graphical view of damaged areas, making it easier for exercise participants to comprehend what is going on in the exercise and make better decisions.

SUMMIT users do not have to be experts in modeling and simulation. Rather, relevant information is simply entered into the system. The system then links to the appropriate models, distributes the data to the models in the proper format, performs any necessary translations to ensure consistency, then generates an integrated picture that can be used in the exercise. SUMMIT also allows for the recycling of the analysis. For example, if federal disaster emergency preparedness professionals conduct a large-scale earthquake exercise, the data generated through SUMMIT can be used by another entity to reproduce the emergency situation in a new location. This leads to overall cost savings by better leveraging the exercise funding.

Commercialization and Industry Impact

SUMMIT technology is currently being transitioned to FEMA's National Exercise Division (NED) where it will be made available to the U.S. emergency preparedness community. Additional federal and international agencies are pursuing DHS S&T to leverage SUMMIT for their own use, including potentially acting as additional transition partners. During the transition period, Sandia is making SUMMIT freely available for government use and is pursuing open source licensing avenues.

Ultra-high-voltage Silicon Carbide (SiC) Thyristors

Sandia National Laboratories, DOE Energy Storage Program, GeneSiC Semiconductor, Inc., and U.S. Army Armament Research, Development, and Engineering Center (ARDEC)

Problem

Increasing demand for power creates numerous challenges for ensuring reliable power for consumers. Because the current electricity grid is aging, updating it is essential to improving the nation's energy security. Greater use of renewable energies, such as wind or solar, will help to provide safer, more secure electricity for customers and will reduce our nation's dependence on fossil fuels. Many energy technologies, particularly renewables, generate direct current (DC) power which must be converted to alternating current (AC) before use. Power switches, known as thyristors, perform this conversion and are crucial to a reliable electrical grid. Current switches have been inefficient and require cooling efforts to ensure proper function. New silicon carbide (SiC) thyristors developed by Sandia and GeneSiC improve performance over traditional silicon-based units by offering high temperature, high frequency operation that increases power system efficiency and reliability.

Innovative Edge

These packaged power devices are the world's first commercially available high voltage, high frequency, high current, high temperature, single-chip SiC-based thyristors. They can reduce the size and weight of existing next-generation smart grid power electronics systems, allowing greater application in such areas as weapons systems and pulsed power. SiC-based thyristors offer 10x higher voltage, 100x faster switching frequencies, and higher temperature operation when compared to conventional silicon-based thyristors, leading to improved system efficiency for both economic and environmental benefits.

Creation of the SiC-based thyristors led the Sandia team to develop, implement, and integrate a number of new technologies. Developers implemented new design and fabrication techniques to support increased voltage ratings. They developed novel gate-anode designs for high current devices and improved the SiC fabrication processes. In order to accurately characterize devices with ultra-high operating ratings, researchers established advanced measurement techniques, circuits, and components and created a new soldering technology to allow wire-bondless packaging.

Commercialization & Industry Impact

This leading-edge device is the world's first commercially available high voltage SiC-based power device. Targeted research applications include grid-tied solar inverters, wind-power inverters, and trigger control for pulsed power weapon systems. In a 2010 press release, Dr. Ranbir Singh, President of GeneSiC stated, "GeneSiC has recently completed delivery of [a family of] thyristors to multiple customers conducting research in renewable energy, Army and Naval power system applications."

High frequency, silicon carbide thyristors are expected to revolutionize grid infrastructure.

X-Ray Toolkit

Sandia National Laboratories, WMD Technologies, ORI Inc.

Problem

Emergency situations can unfold rapidly. Because of this, emergency responders must be able to assess the scene and take immediate action to mitigate danger. When minutes can mean the difference between a bomb's detonation and a bomb's disablement, it is important to have tools to help emergency responders rapidly assess a device and provide an accurate and precise means to mitigate the threat.

Innovative Edge

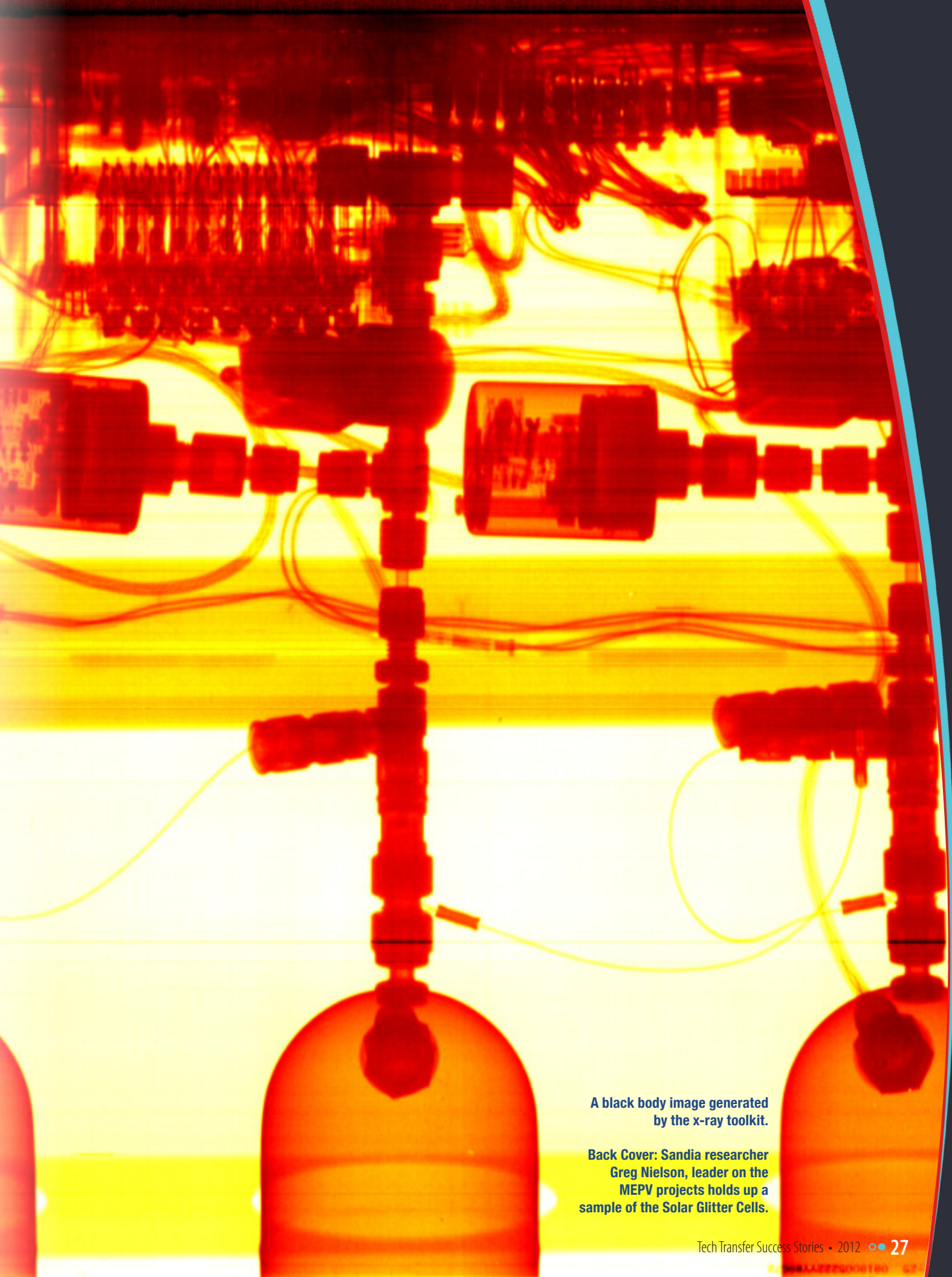
The X-Ray Toolkit (XTK) is a radiograph acquisition and processing software program designed specifically for explosive ordnance disposal technicians. Compatible with most fielded x-ray systems, this easy-to-use multifunctional tool enables emergency responders to quickly capture, analyze, and distribute radiograph images of suspect devices.

XTK supports image acquisition from a variety of commercial scanners and provides image enhancement, measurement, and markup tools through a modern, user-friendly interface. It also provides features including mosaic-stitching, dose prediction, file management, sharing tools, and the ability to create training scenarios and after-action reports.

Commercialization and Industry Impact

Sandia made XTK software available online at no cost to government institutions, including branches of the Department of Defense, Federal Bureau of Investigation, and state and local bomb squads. "It was very important to us that cost didn't prevent the technology from helping those who needed it," said Scott Gladwell, Sandia's project lead. "We wanted to get the technology out there so it could start saving lives." Deployed in every state, XTK is currently in use by over 1,000 registered users. Part of the curriculum at the Federal Bureau of Investigation's Hazardous Devices School in Huntsville, Alabama, where all certified state and local bomb technicians are trained, XTK is rapidly becoming the most commonly used x-ray software in the emergency response community.

Sandia also licensed complimentary XTK hardware in the form of Grid Aim targeting and aiming kits and a training curriculum to industrial partners WMD Technologies and ORI Inc. As a measure to meet the growing demand for equipment and training, these companies used Sandia's transferred technology to develop a suite of products that can be used with XTK software to generate detailed images and analysis of 3D devices. For example, products like the Grid Aim Board Set serve reference and measurement functions during image analysis, while a variety of "system" packages are also available as nearly comprehensive toolkits for radiograph generation and analysis. These packages include hardware such as internal bore aiming lasers, tripods, source locator plates, weapons blocks, geared heads, Grid Aim boards, spare weapons sleeves and clips, and other complimentary devices.



A black body image generated by the x-ray toolkit.

Back Cover: Sandia researcher Greg Nielson, leader on the MEPV projects holds up a sample of the Solar Glitter Cells.

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Sandia National Laboratories

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