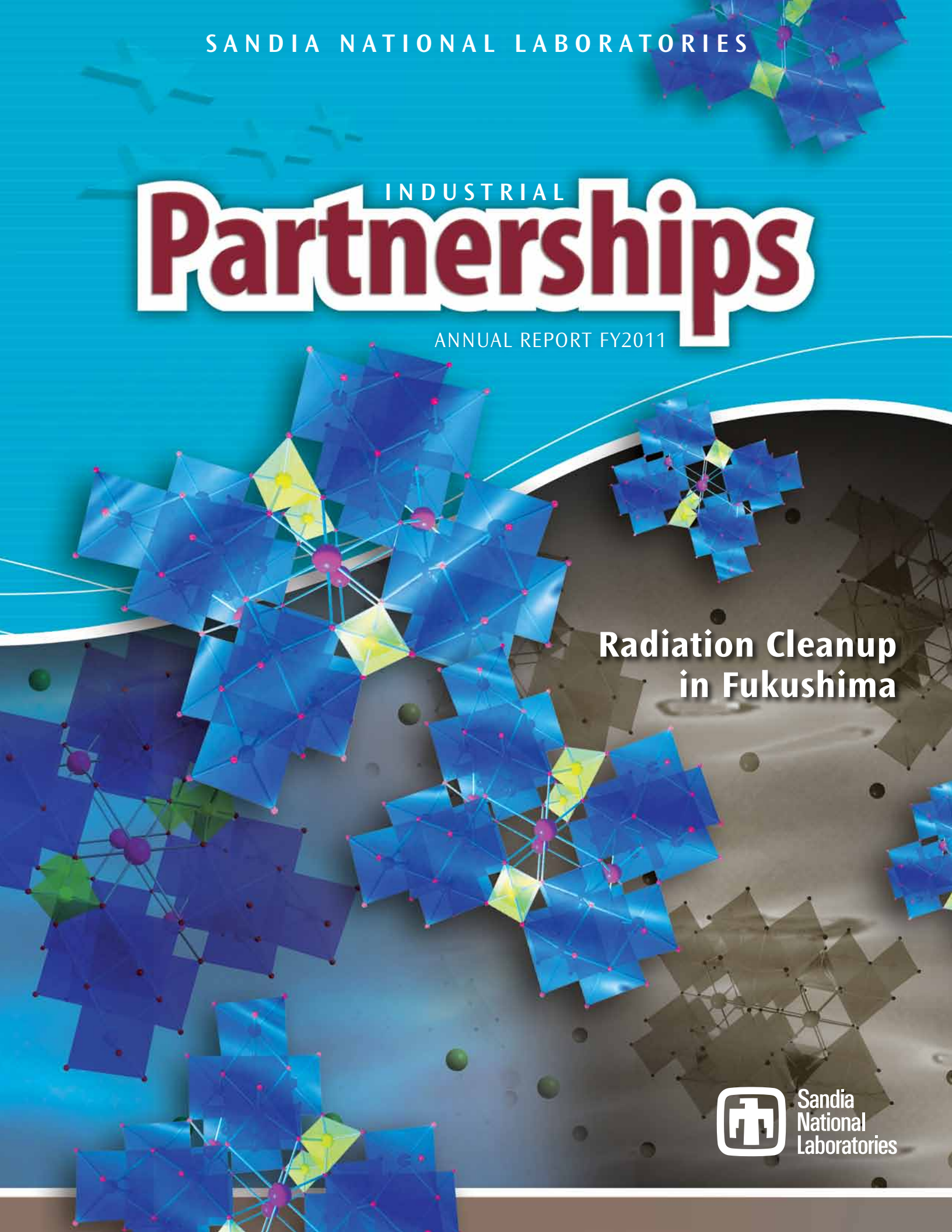
SANDIA NATIONAL LABORATORIES

INDUSTRIAL Partnerships

ANNUAL REPORT FY2011

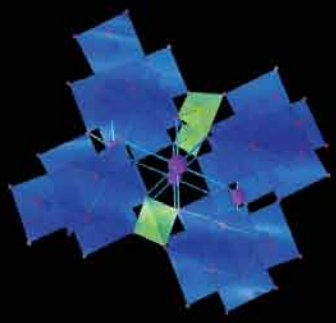


Radiation Cleanup in Fukushima

Sandia National Laboratories

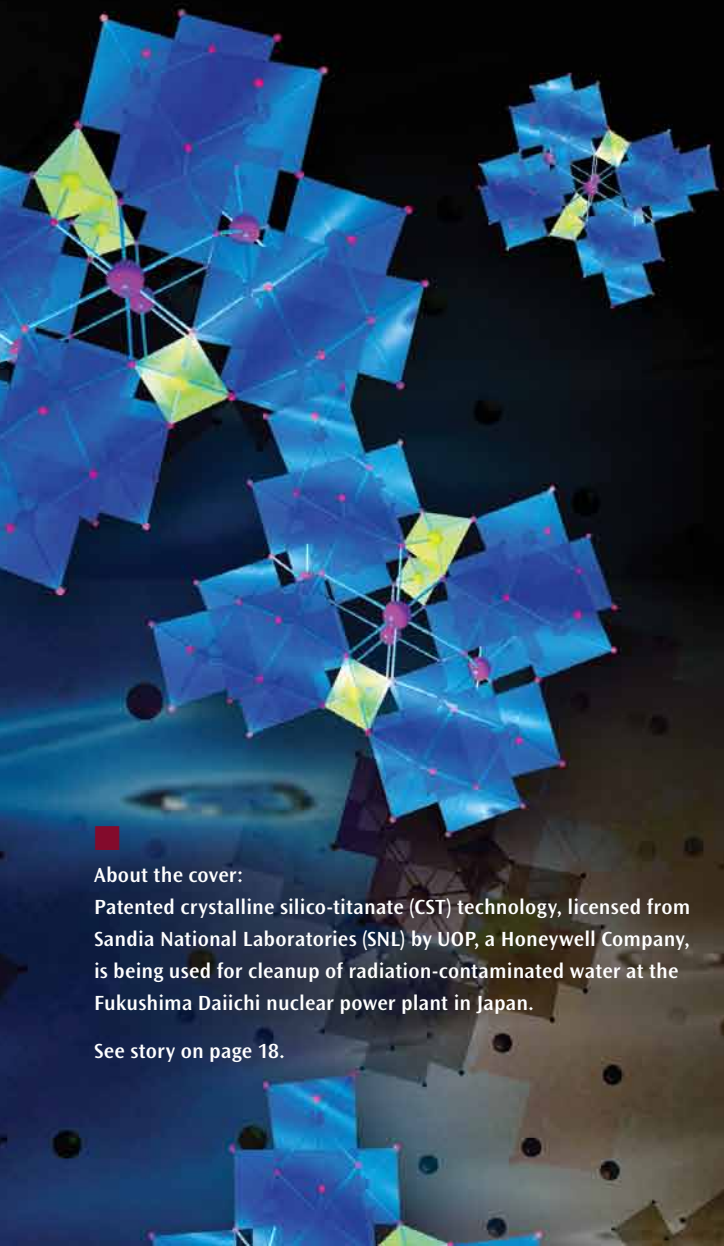
"Sandia's Industrial Partnerships Program not only supports innovation, but also accelerates its transfer to the private sector. It is through strong public-private partnerships that we will transform our current energy system and support U.S. competitiveness."

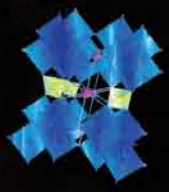
Dr. Karina L. Edmonds
Technology Transfer Coordinator
U.S. Department of Energy



"These partnerships embody the innovation, productivity, and entrepreneurialism that enable our nation to maintain leadership in science and engineering — ultimately strengthening our nation's security."

Dan Sanchez
DOE Technology Partnerships Manager
NNSA Sandia Site Office





About the cover:
Patented crystalline silico-titanate (CST) technology, licensed from Sandia National Laboratories (SNL) by UOP, a Honeywell Company, is being used for cleanup of radiation-contaminated water at the Fukushima Daiichi nuclear power plant in Japan.

See story on page 18.

Table of Contents

Introduction

Dr. Harold (Hal) Morgan
Senior Manager (Retired)
Industrial Partnerships
Sandia National Laboratories

Dr. J. Stephen Rottler
Vice President, Science and Technology
Chief Technology Officer
Sandia National Laboratories

Sharing Technology a Two-Way Street Where All Partners Benefit

Industrial partnerships help Sandia National Laboratories (SNL) achieve its national security and technology transfer missions. In this report we showcase a small selection of our industrial partnerships which have demonstrated success in the past year. These partnerships include those with U.S. companies, academia, international organizations, and government agencies.

We work with industry primarily through Cooperative Research and Development Agreements (CRADAs), Work for Others (WFO) agreements, and licensing agreements. We also work with industry through innovative public-private partnerships that leverage SNL technologies for economic competitiveness and job creation.

In this FY2011 report you will read about some of the achievements of the SNL Industrial Partnerships Program, including:

- Developing cleaner, more efficient internal combustion engines
- Advancing aerodynamic testing of new aerospace vehicles
- Creating microthrusters, or "rockets on a chip," to propel mini-satellites
- Manufacturing the world's smallest atomic clock
- Reducing the size and cost of thermal batteries by developing thin-film coatings
- Lowering the cost of energy-efficient solid state lighting by improving manufacturing methods
- Helping first responders prepare for emergencies with new technology
- Cleaning up radioactive waste worldwide, including in Fukushima, Japan, with crystalline silico-titanates

> ***"Our partnerships with industry, academia, and other organizations enable Sandia to share technology for the U.S. public good. While these relationships benefit our partners, they also allow us to deliver on our national security missions and advance the frontiers of science and engineering."***
>
> *Dr. J. Stephen Rottler*
> *Vice President, Science and Technology*
> *Chief Technology Officer*
> *Sandia National Laboratories*

- Overcoming issues preventing fuel cells from being used in vehicles operating in dry climates
- Researching infrastructure materials so hydrogen fuel can be more widely used for carbon-neutral energy
- Leveraging local and regional partnerships to promote technology transfer

While our intent is to share technology for the public good, it is not a one-way street with technology only flowing out of the Labs. SNL also benefits from our industry partnerships. Our missions in national security present extremely complex problems which no institution can solve on its own. Working with our partners provides insights and improved technology to better solve these problems. This reciprocity means everyone benefits: SNL, companies, and the public.

We are proud that SNL's industrial partnerships enhance the Laboratories' ability to execute its core national security missions while strengthening partnering organizations.

General Motors

"GM and Sandia have a rich history of significant collaboration. The result is cleaner, more efficient combustion engines on the road today than would have otherwise been possible."

Dr. Gary Smyth
Executive Director
General Motors

Daniel Dedrick, an SNL researcher, handles a complex metal hydride within an inert production and storage environment.

Clean Combustion Engines Advanced with Predictive Simulation Tools

Sandia National Laboratories (SNL) has been working with General Motors (GM) for over 30 years. In the last few years, this partnership has become a Strategic Alliance, which includes a Cooperative Research and Development Agreement (CRADA), making it easier for the partners to work together.

The Alliance has broken new ground in how the national laboratories work with industry leaders. There's a dedicated SNL liaison to GM and a GM liaison to SNL. The liaisons create continuity and provide a person dedicated to facilitating communication between appropriate individuals in the two large and complex organizations. This model expedites collaborations on key technologies and systems analysis to address the most critical issues including working to strengthen U.S. positions in energy efficiency, energy security, technology innovation, and global competitiveness.

Research areas being focused on include systems modeling for energy, infrastructure, and future generation vehicles; energy storage-advanced batteries and hydrogen storage; clean advanced combustion; and future generation vehicle networks and sustainable communities.

Combustion is an area that GM and SNL have worked on extensively over the years. Currently, GM and SNL are addressing clean advanced combustion using many technologies and may include the Predictive Simulation of Internal Combustion Engines (PreSICE) in the future.

Because of their relatively low cost, high performance, and ability to utilize renewable fuels, internal combustion engines—including those in hybrid vehicles—will continue to be critical to our transportation infrastructure for decades. Achievable advances in engine technology can improve the fuel economy of automobiles by over 50% and trucks by over 30%.

The use of predictive simulation tools for enhancing combustion engine performance will result in direct economic benefit through reduced time-to-market and reduced development costs. Dramatic increases in fuel efficiency will increase the nation's energy security and simultaneously reduce greenhouse emissions.

A PreSICE workshop with participants from industry, including GM, the national laboratories, including SNL, and universities was held in March 2011 to identify research needs. While workshop participants agreed enhanced efficiency is achievable, they also agreed that dramatic increases in engine efficiency can only be reached by developing new design tools that fully leverage the computational simulation capabilities of the nation.

The final appropriation for the DOE Office of Science in 2012 included $10 million for this effort. The GM-SNL Strategic Alliance will be a key partnership helping to achieve the PreSICE program goals.

Lockheed Martin

"Lockheed Martin is committed to using Open Innovation—the art of leveraging the best ideas and expertise from anywhere in the world, to improve affordability and capability of our systems."

Dr. John D. Evans
Vice President
Technology and Innovation
Lockheed Martin Corporation

F-35C Lightning II carrier variant aircraft CF-2 performing Jet Blast Deflector (JBD) tests at Joint Base McGuire-Dix-Lakehurst in New Jersey.

Particle Image Velocimetry Tests Complex Aerospace Designs

Sandia National Laboratories (SNL) has been working with Particle Image Velocimetry (PIV) for aerodynamic testing for years and is recognized as a world leader. This laser-based diagnostic technique is used in wind tunnels, often to test scale models of flight vehicles or individual flight components.

Lockheed Martin came to longtime partner SNL, to help them with applying PIV techniques to their own wind tunnel in Grand Prairie, Texas. The wind tunnel, much larger than the one at SNL, helps Lockheed Martin test flight vehicles and their components.

With PIV, a large quantity of small tracer particles is seeded into a wind tunnel. The particles are illuminated with a double-pulsed laser sheet and imaged with a specialized digital camera. Particle patterns are tracked as they move from the first camera exposure to the second, and velocity vectors are calculated. PIV can reveal far more information than can be obtained from traditional instrumentation.

SNL has been working with Lockheed Martin to make advances which will enable testing of complex vehicle geometries at high speeds. By combining their Texas wind tunnel, with its larger size and higher speed airflow, with SNL's PIV expertise, Lockheed Martin will be able to better predict how new aerospace vehicles will perform.

One example of how PIV technology is being used by Lockheed Martin is in testing a new hemispherical optical turret design. PIV testing can show the airflow around the turret and any turbulence, which might affect the optical characteristics of beams emanating from the turret. The test results can be used to determine if the design of the turret needs to be changed to minimize adverse effects.

Research and development (R&D) interactions between SNL and Lockheed Martin are extremely diverse. In recent years the partners have collaborated on research projects in areas of mutual strategic interest such as energy, cyber security, nanotechnologies, active and passive sensing, directed energy, modeling and simulation, and autonomous systems.

Technology partnerships provide Lockheed Martin access to SNL's established and innovative R&D program, advanced concepts and discriminator technologies, as well as a cadre of scientists and engineers with systems engineering expertise and a comprehensive knowledge of global technologies in areas of Lockheed Martin focus. For Sandians, technology partnerships provide opportunities to collaborate with peers and to see their advanced technologies transitioned into Lockheed Martin products that protect the nation and its armed forces.

One of the most valued vehicles for collaboration is Lockheed Martin's Open Innovation program, led by Corporate Engineering & Technology Business Innovation. As the company works to expand in new and developing markets, having ready access to skills outside their historical core capabilities is essential. The Open Innovation program provides Lockheed Martin the opportunity to collaborate on R&D programs with trusted partners like SNL.

Northrop Grumman

"Northrop Grumman looks forward to the many collaborative opportunities this CRADA provides and a long and productive working relationship between Sandia and Northrop Grumman."

Eric M. Sepp
Program Manager
Full Spectrum Initiatives
Northrop Grumman Corporation

Alex Tappan, Principal Member of Technical Staff from SNL, inspects a MEMS Digital Thruster in front of the equipment that is used to fuel the devices with propellant.

Microthruster Improvements Propel Tiny Spacecraft into Wider Use

Small satellites are a big deal these days, with mini-, micro-, nano- and pico-satellites. There are even femto-satellites, each weighing less than 100 grams. Although tiny spacecraft are already in use for some applications, work is continuing on micropropulsion systems for them.

Sandia National Laboratories (SNL) and Northrop Grumman Corporation (NGC) are collaborating under a Cooperative Research and Development Agreement (CRADA) to improve the performance of microthrusters, or "rockets on a chip," which can provide impulse for small vehicles, such as satellites.

Microthrusters are individual micro-electromechanical systems (MEMS) which can be manufactured using semiconductor fabrication techniques. Each the size of a poppy seed, microthrusters can be manufactured in arrays to produce controlled "impulse bits" of thrust.

The NGC-led MEMS Digital Thruster Program is producing microthrusters for orbital insertion and control, and attitude control functions on small satellites. Propulsion is adjusted in increments by igniting individual thrusters, several thrusters at once, or by firing thrusters in controlled sequences. Microthrusters are so small and light, the propulsion function can be combined with the satellite structure to deliver the required mission delta-v (change in velocity) while minimizing the added weight.

One of the challenges in putting together microthrusters is loading the propellant, and SNL has expertise in advanced manufacturing techniques in propellant loading, as well as in microscale combustion and high-speed diagnostics. SNL has been working to improve performance over what was initially achieved in the late '90s.

Under a recently awarded Air Force Research Laboratory (AFRL) contract, SNL will be performing characterization on both the igniters and the propellant, and the U.S. Air Force Academy, with Cadet participation, will be performing wind tunnel tests to characterize the performance of NGC-fabricated microthrusters. Under a previous Defense Advanced Research Projects Agency (DARPA) contract, thrust from the microthrusters was demonstrated in both the laboratory and in space on board an experimental sounding rocket.

SNL and NGC have worked together for many years to advance a wide range of technologies. In 2011, the microthruster project was renewed and expanded with an Umbrella CRADA, allowing even more collaboration.

Over the years, the partners have studied and developed electron beam (EB) polymer matrix composite (PMC) curing technology, unmanned air vehicle (UAV) persistence capabilities, and worked on other technologies applicable to SNL's and NGC's national security missions.

With the goal of developing and commercializing innovative technologies, SNL and NGC have joined forces in various disciplines including electronic systems, aerospace, defense, and systems engineering. In the coming months, the partners hope to collaboratively study and develop a high-power solar electric propulsion flight system extensible to NASA's future transportation and exploration needs.

"The success of CSAC can be primarily attributed to the highly productive collaboration between technical experts in multiple fields from Symmetricom, Sandia National Laboratories, and the Charles Stark Draper Laboratory. The application-specific laser source, developed by Sandia, was a key enabling technology to the success of CSAC."

Dr. Robert Lutwak
Chief Scientist
Symmetricom

Darwin Serkland, researcher from SNL, measures the wavelength of a tiny laser needed to drive an atomic clock.

World's Smallest Atomic Clock Slashes Size and Power Needs

Technical breakthroughs led to a Chip Scale Atomic Clock (CSAC) that achieved an 80% reduction in size and reduced power consumption by 98%. This has enabled high-performance timing in man-portable applications for the first time, because an atomic clock can now be powered with a few AA batteries rather than a car battery. The CSAC continues to provide precise timing signals even when GPS satellite reception is impaired: inside buildings, under water, underground, and in stormy weather.

Despite having the word "atomic" in its name, an atomic clock does not use radioactivity as an energy source. Instead, where an old-fashioned clock uses a spring-powered series of gears, an atomic clock counts quantum-mechanical oscillations of cesium atoms excited by a tiny laser beam to determine the passage of time.

The CSAC was developed by a Defense Advanced Research Projects Agency (DARPA)-funded team, led by Symmetricom, and supported by Draper Laboratory and Sandia National Laboratories (SNL).

SNL developed a semiconductor vertical-cavity surface-emitting laser (VCSEL) that reduces power consumption of the internal light source by 99.9% relative to the atomic vapor discharge lamps used in previous atomic clock products since the 1960s. Draper developed a micro-machined cesium vapor cell that reduced thermal power consumption by 99.5% relative to previous atomic vapor cells. Symmetricom designed the clock electronics and integrated the components into a complete functioning atomic clock.

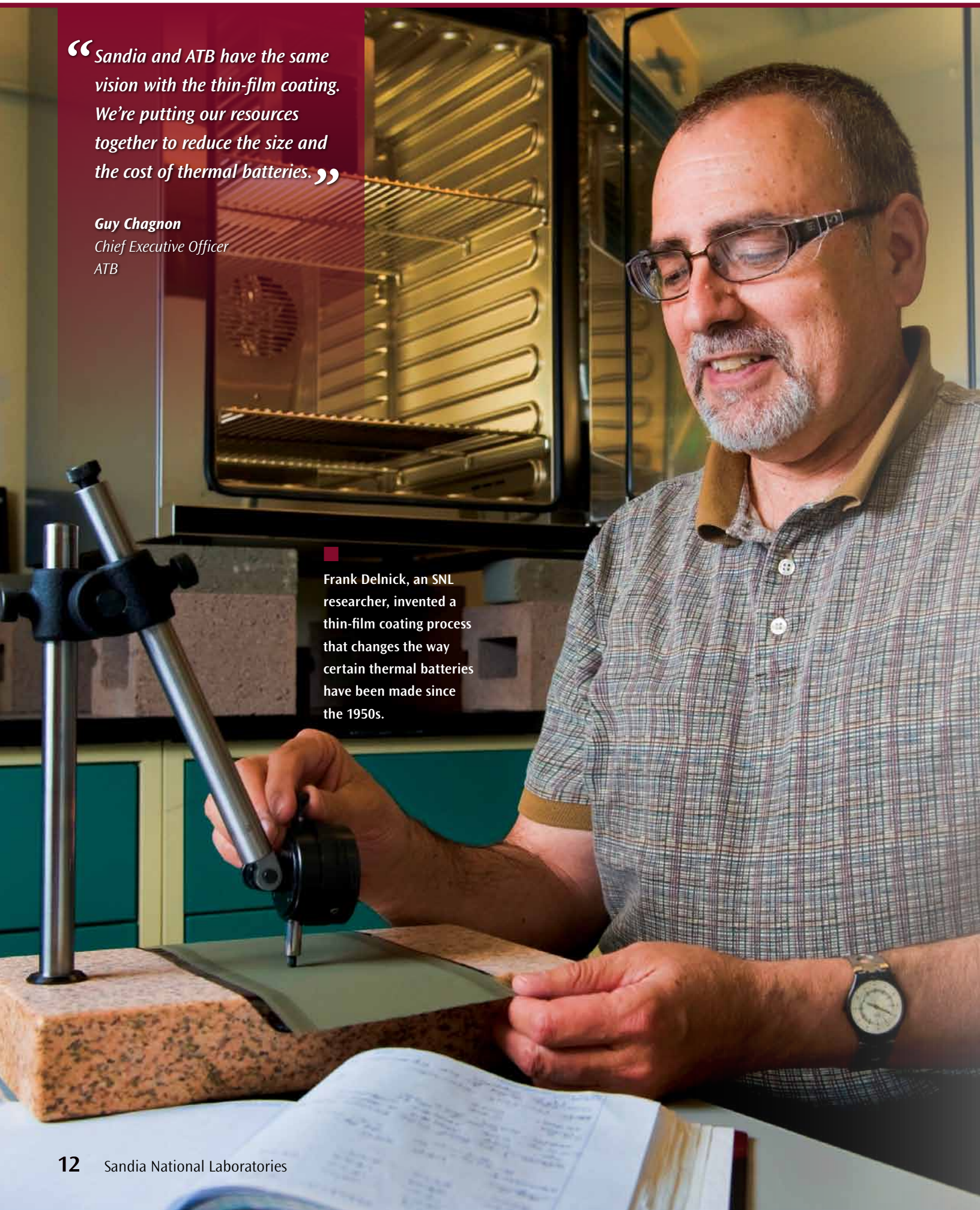
Symmetricom released the first commercial CSAC product in early 2011, the model SA.45s, which is marketed as "the world's smallest atomic clock," with multiple product options becoming available throughout the year optimized for various applications.

The CSAC's small size, light weight, and extremely low power can help in a number of portable military systems including GPS receivers, IED backpack jammers, and backpack radio systems. As advances in military electronics bring the networked battlefield to the individual warfighter, lightweight and low-power equipment is crucial, especially in rugged terrain.

With uses for civil and military unmanned aerial vehicles (UAVs) rapidly expanding, there is increasing pressure to limit the size, weight, and power of payloads. The CSAC helps in all three areas.

Another application is for underwater sensors such as those used in seismic research and oil exploration. Sensors designed to lie on the ocean floor will typically include a hydrophone, a geophone, and a very stable clock to time-stamp the data collected. Because GPS signals can't penetrate water, oven-controlled crystal oscillators (OCXOs) have been used. The CSAC requires much less battery power and provides higher performance than an OCXO, resulting in smaller sensors with much longer mission life.

Few DARPA technologies make it to full industrial commercialization for both military and industrial applications, so having the CSAC released as a commercial product is seen as a big success. Achieving the project's ambitious goals demanded teamwork and innovation, which the project partners delivered.



"Sandia and ATB have the same vision with the thin-film coating. We're putting our resources together to reduce the size and the cost of thermal batteries."

Guy Chagnon
Chief Executive Officer
ATB

Frank Delnick, an SNL researcher, invented a thin-film coating process that changes the way certain thermal batteries have been made since the 1950s.

Thin-Film Coatings Cut Cost and Size of Thermal Batteries

Thermal batteries are getting a manufacturing makeover thanks to a new thin-film coating process invented at Sandia National Laboratories (SNL). ATB, a U.S. manufacturer of thermal batteries, is collaborating with SNL on the development of a new coating process for large-scale industrial production.

A thermal battery is a nonrechargeable, single-use energy source that can remain inert for years at room temperature before becoming activated at temperatures as high as 600°C (1,100°F). SNL's coating process innovations will change the way some thermal batteries have been made since the 1950s. SNL's process uses relatively inexpensive equipment common in the paint industry that coats the battery components as thin films onto stainless steel foil. The coatings are held together and bonded to the foil using a patented binder. It is expected that thin-film thermal batteries made using this new coating process will perform much better in high-shock environments and will be much more amenable to automated manufacturing.

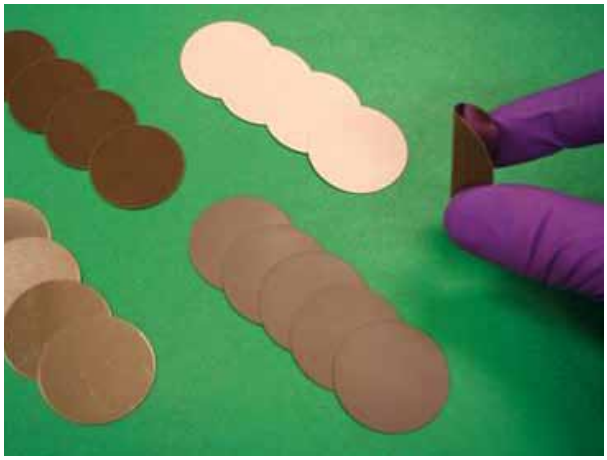
SNL's expertise in thermal batteries stems from their use in nuclear weapons and other munitions. SNL has developed approximately 30 thermal battery designs since 1975. ATB conducts research in thermal batteries with the goal of improving their battery products' performance for air, space, and defense reserve power systems.

The goal of the Cooperative Research and Development Agreement (CRADA) with ATB is to jointly develop thin-film coatings that will slash the time and materials needed to make thermal batteries. On average, thermal batteries made with thin-film coatings use one-fifth to one-half the materials needed in their conventionally manufactured counterparts.

Traditional thermal batteries are made by pressing powdered materials into electro-chemically active pellets used as the anode, cathode, and separator of the battery. The pellets must be a certain thickness to maintain mechanical integrity and prevent them from falling apart when handled. The amount of material needed to achieve mechanical stability can be up to 10 times greater than what is needed to make the battery work. Therefore, considerable reduction in size can be achieved by making the components thinner.

The new process also could allow manufacturers to produce different shapes of thermal batteries. Current thermal batteries are cylindrical and range in size from a man's thumb to a one-pound coffee can.

ATB employees have visited SNL to learn more about the process, and the company is busy readying its facility to begin developing the new manufacturing process. If the research and development is successful, large-scale manufacturing could begin by late 2013.



"Veeco's collaboration with Sandia has helped us lower MOCVD cost of ownership through improved modeling and better temperature control."

Dr. Bill Quinn
Chief Technologist
Veeco Instruments

Technologist Jeff Kempisty of SNL removes an InGaN LED wafer from the Veeco MOCVD system.

Research Driving Down the Costs of Efficient LED Lighting

Solid state lighting (SSL), which uses light emitting diodes (LEDs), has the potential to be 10 times more energy-efficient than traditional incandescent light bulbs. Currently, 20% of energy usage in the U.S. goes to lighting. SSL technology can potentially cut U.S. lighting energy usage, reducing the electricity consumption for lighting by one-fourth.

That's why since 2003, the U.S. DOE has invested with industry partners in research and development of LED technologies. While costs are dropping and many product improvements have been made, the work continues to make LED lighting a competitive option in more lighting applications.

As part of this national effort, Veeco, a leading equipment supplier, and Philips Lumileds, a solid state lighting manufacturer, are working with Sandia National Laboratories (SNL) to drive down the cost of high-brightness LEDs (HB-LEDs) by implementing process simulation tools and by improving temperature measurement and control methods to increase metal organic chemical vapor deposition (MOCVD) yield. MOCVD is the critical enabling technology for the production of LEDs.

The overall objective of this two-year program is to develop high-volume MOCVD systems that provide a four times reduction in the cost of epitaxial growth for LED devices, with the ultimate goal of a 10 times reduction in LED costs.

Computational Fluid Dynamic (CFD) models are used by Veeco to design indium gallium nitride (InGaN) MOCVD growth systems. The actual experimental GaN non-uniformity is about four times greater than predicted because the model does not take into account the effects of kinetics and thermodynamics in chemical reactions. To more accurately predict MOCVD growth processes, Veeco's expertise in fluid dynamic modeling is being combined with SNL's specific experience modeling III-Nitride based chemistry.

Temperature is the primary driving force for the majority of reactions that take place in the LED growth process; therefore it is important to accurately and directly measure the GaN layer temperature. UV and mid-IR pyrometry are promising technologies to enable direct GaN layer or sapphire wafer temperature measurement on production MOCVD reactors.

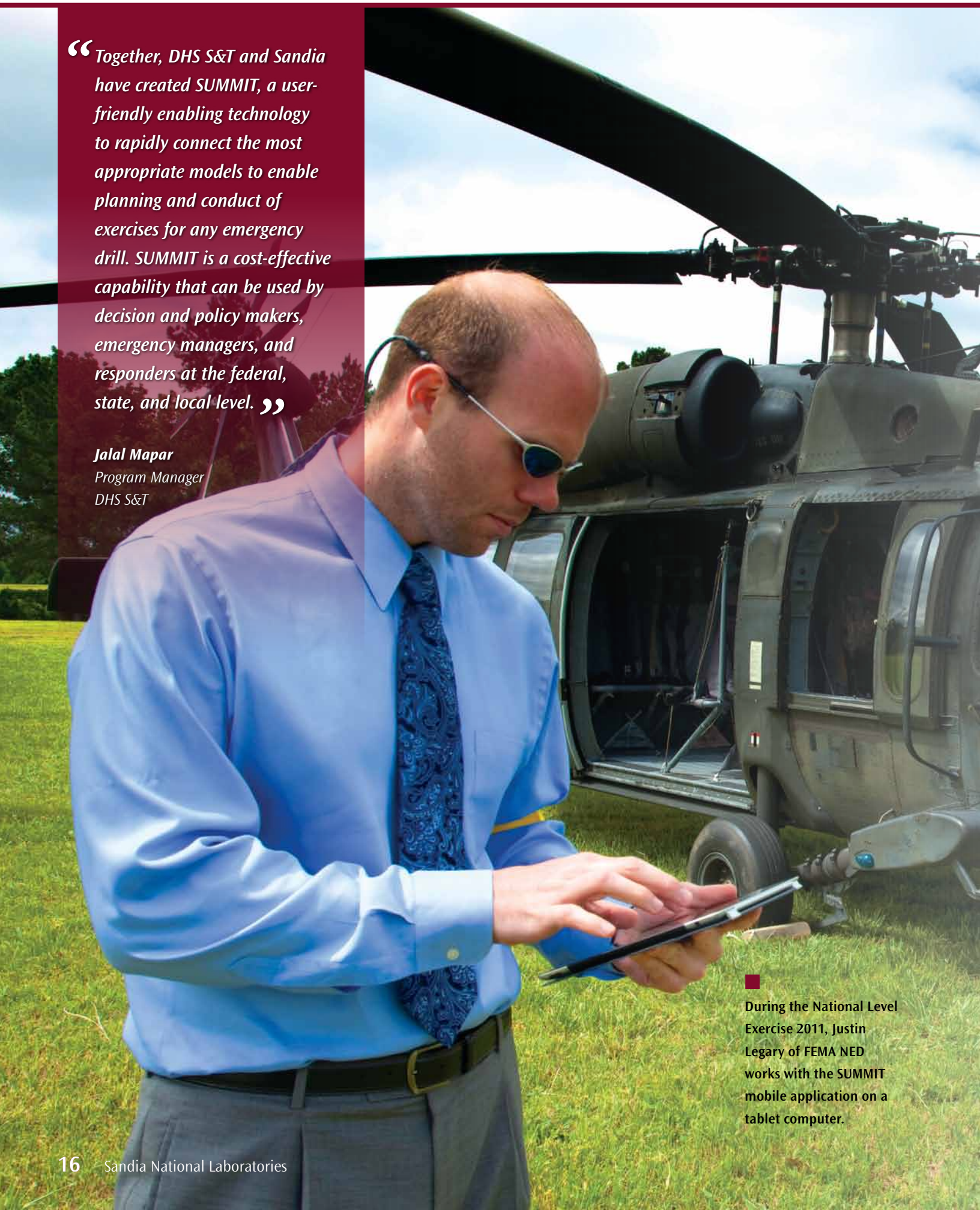
SNL has provided a prototype near UV pyrometer that will be jointly developed with Veeco for use with Veeco's production MOCVD reactors. Philips Lumileds is evaluating the UV pyrometer for accuracy and repeatability in a high volume LED manufacturing environment. A mid-IR pyrometer is also being developed by SNL to be used for direct substrate temperature measurements. Sapphire substrates, the primary substrate used for HB-LED growth, absorb mid-IR wavelengths and therefore make bare substrate pyrometry measurements possible.

Veeco has already made improvements to its high-throughput MaxBright™ multireactor MOCVD system, with more to come. This means the partnership between Veeco and SNL has already yielded results, and is well on its way to achieving its goal of driving down the cost of HB-LEDs, making them more competitive with existing lighting in order to reduce our country's energy use.

Department of Homeland Security

"Together, DHS S&T and Sandia have created SUMMIT, a user-friendly enabling technology to rapidly connect the most appropriate models to enable planning and conduct of exercises for any emergency drill. SUMMIT is a cost-effective capability that can be used by decision and policy makers, emergency managers, and responders at the federal, state, and local level."

Jalal Mapar
Program Manager
DHS S&T



During the National Level Exercise 2011, Justin Legary of FEMA NED works with the SUMMIT mobile application on a tablet computer.

Technology Helps First Responders Prepare for Next Disaster

Exercise planners have an inherent challenge in creating drill scenarios that can be vividly imagined and acted upon by participants. Typically, first responders playing in an exercise must pretend and dream up how a damaged building might look. With SUMMIT, there's no more pretending.

SUMMIT, or the Standard Unified Modeling, Mapping and Integration Toolkit, is being created by the Department of Homeland Security Science and Technology Directorate (DHS S&T) and its transition partner, the Federal Emergency Management Agency (FEMA) National Exercise Division (NED). Sandia National Laboratories (SNL) is the principal architect for the SUMMIT system.

The emergency preparedness community relies on planning and exercises to develop knowledge. Exercises improve understanding of appropriate mitigation and response strategies, as well as of real-time "what if" trade-offs that may be needed during an event. Planning, training, exercise, and operational activities are increasingly making use of modeling and simulation tools, and their underlying data, to increase realism and fidelity.

The DHS S&T realized that disaster preparedness exercise scenarios being used by FEMA NED were not easily reusable, for example in a new location. Previous efforts with SNL utilizing modeling and simulation technologies for emergency preparedness produced a team with the capabilities to create a solution. The team realized what was needed was a new architecture that could be used to easily discover, access, and link together the most appropriate models for each emergency exercise.

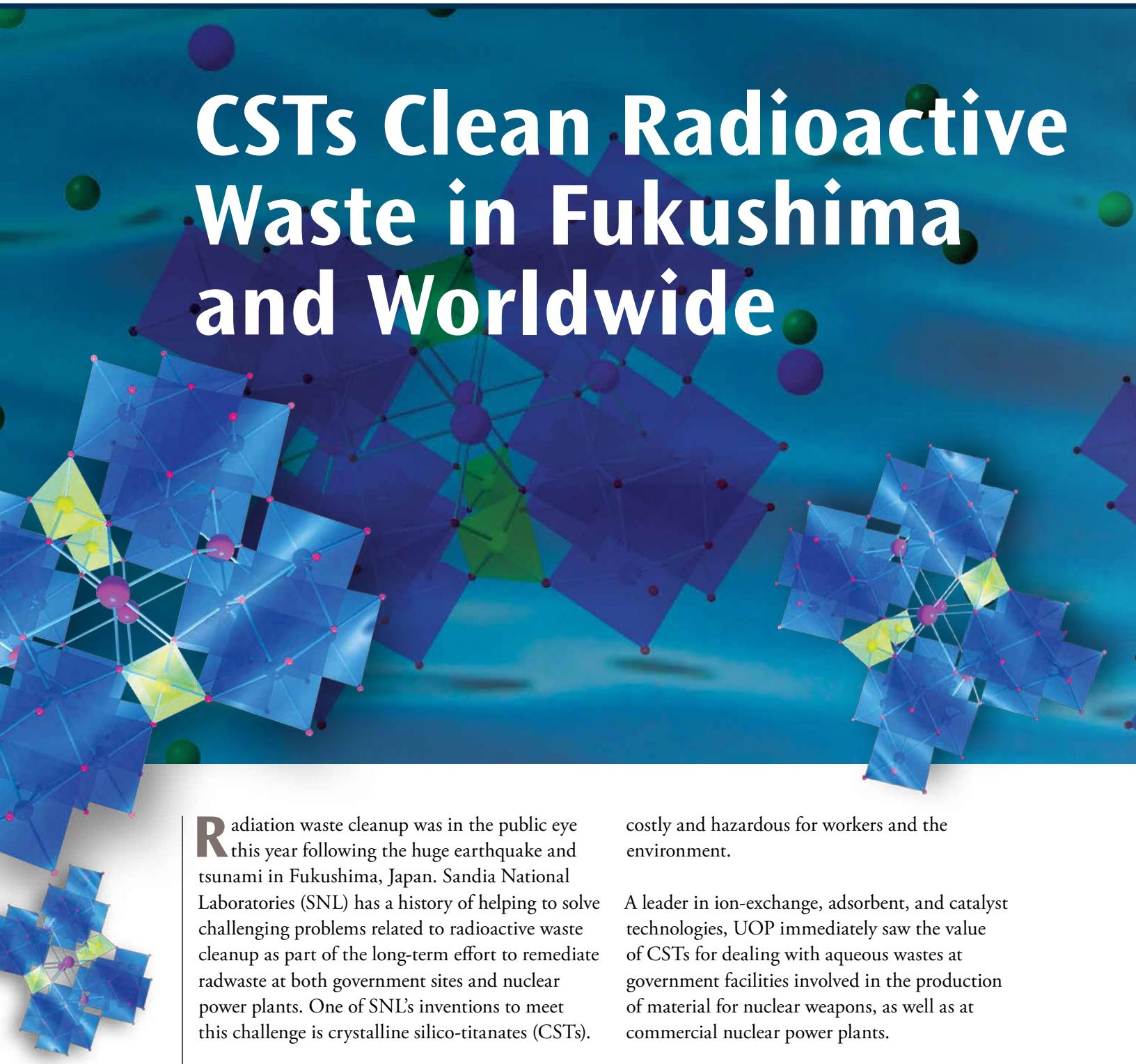
SUMMIT is a model federation architecture designed to let many computer models work together. The SUMMIT architecture allows disparate modeling technologies to communicate by using DHS open standards and creates a more seamless user experience.

Trying to coordinate all parts of a disaster exercise can be quite challenging, and the ability to keep data generation and requests synchronized is critical to exercise success. By using a single architecture, as is found in SUMMIT, synchronizing elements is much easier. At National Level Exercise 2011 (NLE 11), a massive nationwide emergency preparedness exercise, SUMMIT was used to give controllers a common operating view and coordinate events.

SUMMIT enhances the nation's emergency management and preparedness activities by leveraging massive federal and private sector investments in modeling and simulation capabilities. For example, if federal disaster emergency preparedness professionals conduct a large scale earthquake exercise, state and local jurisdictions can reuse generated data through SUMMIT since it allows regeneration of the scenario in the new location.

This technology transfer is proceeding smoothly due to cooperative efforts by all the partners. As the architect of the SUMMIT software, SNL is gaining even more competency with modeling and simulation, and emergency preparedness skills required by its partnering federal agencies. The DHS S&T is helping their operational component partners by delivering the next generation technology, designed and engineered by SNL, and FEMA NED is upgrading its capability to perform future national preparedness exercises.

CSTs Clean Radioactive Waste in Fukushima and Worldwide

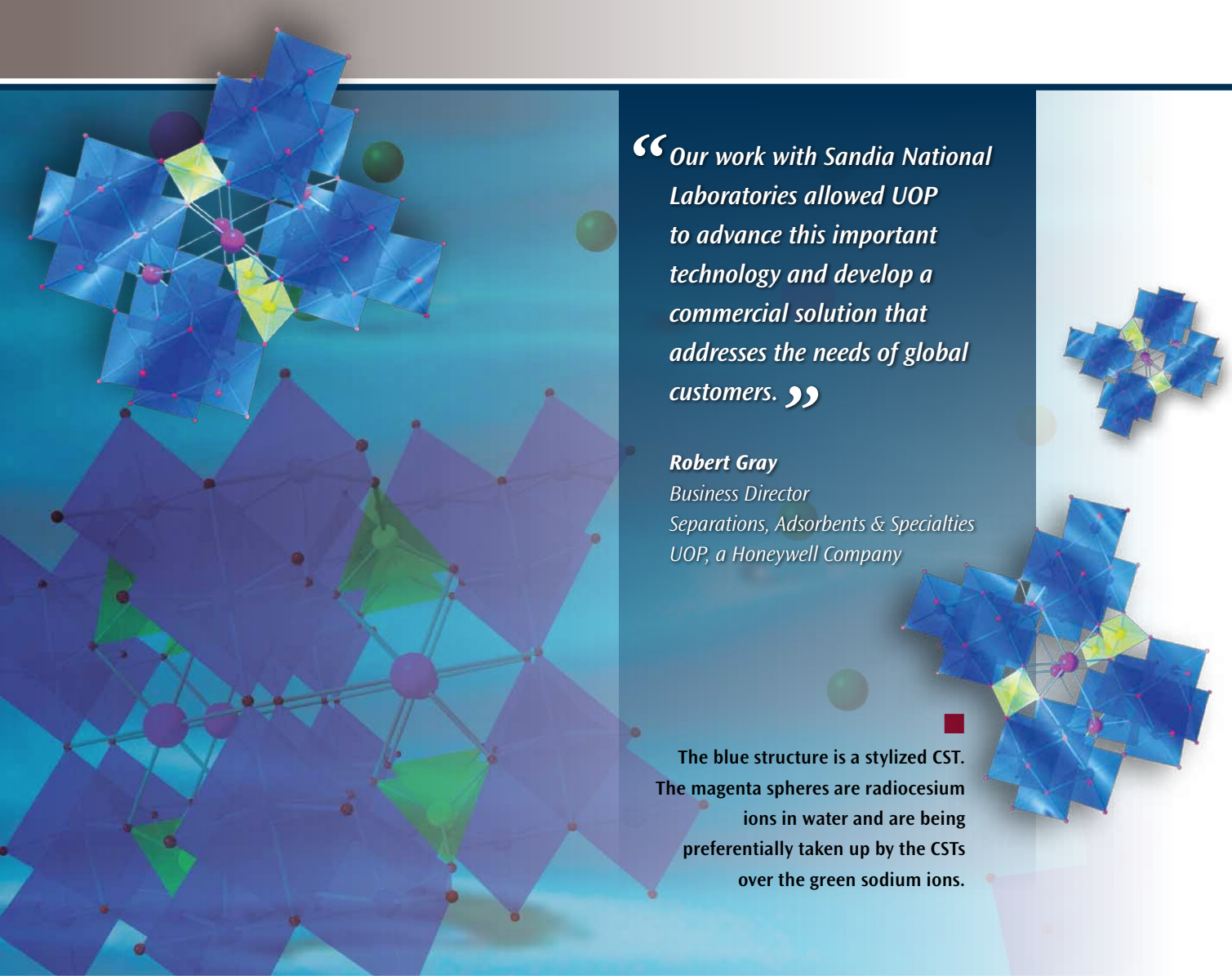


Radiation waste cleanup was in the public eye this year following the huge earthquake and tsunami in Fukushima, Japan. Sandia National Laboratories (SNL) has a history of helping to solve challenging problems related to radioactive waste cleanup as part of the long-term effort to remediate radwaste at both government sites and nuclear power plants. One of SNL's inventions to meet this challenge is crystalline silico-titanates (CSTs).

UOP, a Honeywell Company, first licensed CST technology from SNL in 1994, shortly after the material was invented. CSTs are inorganic ion exchangers used to separate highly radioactive elements such as cesium from radwaste solutions. By removing the high level elements like cesium using CSTs, the remaining lower level radioactive waste can be treated in a way which will be less costly and hazardous for workers and the environment.

A leader in ion-exchange, adsorbent, and catalyst technologies, UOP immediately saw the value of CSTs for dealing with aqueous wastes at government facilities involved in the production of material for nuclear weapons, as well as at commercial nuclear power plants.

A need for materials which could selectively remove contaminants from aqueous solutions, such as those found in tanks at the government's Hanford Site in Washington state, led SNL chemist Bob Dosch and Texas A&M chemical engineering professor Ray Anthony to recognize that a certain class of synthetic zeolites was far more effective in capturing certain radioactive



> *"Our work with Sandia National Laboratories allowed UOP to advance this important technology and develop a commercial solution that addresses the needs of global customers."*

Robert Gray
Business Director
Separations, Adsorbents & Specialties
UOP, a Honeywell Company

The blue structure is a stylized CST. The magenta spheres are radiocesium ions in water and are being preferentially taken up by the CSTs over the green sodium ions.

elements, like cesium, than other available technologies. They invented CSTs, molecularly engineered ion exchangers which could be sized specifically for cesium or other elements.

A Cooperative Research and Development Agreement (CRADA) with SNL allowed for commercial development of the CST technology by UOP. In 1996, work on CSTs by UOP, SNL, and Texas A&M led to an R&D 100 award for development of the commercially ready product. UOP continues to market the CSTs as part of its IONSIV Ion Exchanger product line.

In 2011, UOP renegotiated an exclusive license for the patented CST technology, and continued working with SNL on additional mutually beneficial opportunities in the use of ion exchange in waste cleanup. SNL has a broad and expanding portfolio of materials which selectively scavenge contaminants such as arsenic, radioiodine, actinides, and strontium.

"Our work with Sandia National Laboratories allowed UOP to advance this important technology and develop a commercial solution that addresses the needs of global customers," said Robert Gray, business director for Separations, Adsorbents & Specialties for Honeywell's UOP. "Today, the UOP IONSIV products are successfully being used for cleanup of radiation-contaminated water at the Fukushima Daiichi nuclear power plant in Japan, and we are committed to bringing the benefits of this solution to a range of waste remediation applications going forward."

Automotive Fuel Cell Corporation

"The close partnership between Sandia and AFCC has resulted in a very unique and promising technology for future automotive applications."

Dr. Rajeev Vohra
Manager R&D
AFCC

SNL researcher Cy Fujimoto demonstrates his new flexible hydrocarbon polymer electrolyte membrane, which could be a key factor in realizing a hydrogen car.

Hydrocarbon Membrane Fuels the Success of Future Generation Vehicles

While every car manufacturer, such as GM and Ford, has developed their own hydrogen fuel cell vehicle, the systems are complex and costly. For example, fuel cell vehicles run optimally when the air and hydrogen fuel is humidified, which requires high pressures and additional systems controls. Hydrogen is normally recirculated in the fuel loop, and nitrogen buildup due to crossover from the air side causes unwanted purging of fuel which affects overall vehicle range.

At Sandia National Laboratory (SNL), researcher Cy Fujimoto, in partnership with Automotive Fuel Cell Cooperation (AFCC), is developing a polymer electrolyte membrane (PEM) that can operate optimally with minimum on-board humidification and low gas crossover.

The work of Fujimoto and other SNL researchers is part of a Cooperative Research and Development Agreement (CRADA) with AFCC, a private joint venture company in Canada, formed by combining the automotive fuel cell business of Ballard Power Systems with the fuel cell stack development departments of Daimler and Ford.

AFCC is striving to make automotive fuel cells an affordable and reliable alternative solution to address energy and climate change issues. Their mission is to deliver fuel cell stacks to Daimler and Ford's fuel cell vehicle programs that provide the best balance of reliability, quality, and functionality while meeting cost targets.

Fuel cells use hydrogen fuel and oxygen from the air to produce electricity. PEM material allows only the positive hydrogen ions (protons) to pass through it to the cathode. That's why PEM fuel cells are also known as proton exchange membrane fuel cells. A single cell cannot provide enough to power a vehicle, so cells are assembled into fuel cell stacks.

SNL's research into a hydrocarbon membrane for automotive use is now focusing on automakers' needs, which include high proton conductivity with low water content and reduced gas crossover. With the type of membrane used in automotive fuel cells currently, pathways for the protons shrink as the material dehydrates. This results in increased internal cell resistance and diminished function of the fuel cell in cars operating in dry climates without humidification.

The SNL hydrocarbon PEM material allows for larger pathways for proton movement, even in low humidity climates. It can perform well in both dry and wet environments. This means one of the obstacles to widespread use of fuel cell systems in vehicles, their durability and performance, especially in some temperature and humidity ranges, can be overcome.

Another major challenge is to get the cost of manufacturing the membrane low enough to be practical for mass production, something SNL researchers are working on with AFCC. Efforts are underway to "scale up the chemistry" to lower costs.

Developing a fuel cell membrane that can meet the automotive targets set out by automakers and the U.S. DOE can have a very positive impact on the U.S. economy. An improved hydrocarbon membrane developed at SNL has a good chance to be the material of choice for future generation fuel cell vehicles.

"Unequivocally Sandia's strong research record and industrial experience on hydrogen materials compatibility has helped I²CNER better coordinate its research activities toward issue-driven objectives."

Dr. Petros Sofronis
Director
I²CNER

Brian Somerday, an SNL researcher, prepares to load a hydrogen pressure vessel into a laboratory furnace.

Hydrogen Infrastructure Research Aids Energy Independence Goal

Sandia National Laboratories' (SNL) unique experimental capabilities to quantify the effects of hydrogen on structural materials at high pressures are one of the reasons it was chosen to be a part of I^{2}CNER, the International Institute for Carbon-Neutral Energy Research.

I^{2}CNER is an international consortium, one of six research institutes that comprise the World Premier International Research Center Initiative (WPI) established by the Japanese Ministry for Education, Culture, Sports, Science and Technology in 2007. WPI provides support for research and development (R&D) projects, and encourages international collaboration among leading researchers.

Working towards energy independence is a goal that fits under the umbrella of SNL's national security mission. Leadership in the I^{2}CNER initiative provides an opportunity to coordinate with international experts to address big, complex problems.

The main objective of I^{2}CNER is to develop the science required for the removal of barriers facing the use of hydrogen for carbon neutral energy. Materials selection for infrastructure components such as tanks, tubes, valves, and pipelines is one of the barriers facing the use of hydrogen as a fuel.

As Lead of the Hydrogen Structural Materials program area of I^{2}CNER, Brian Somerday of SNL is directing I^{2}CNER work on the science needed to understand the behavior of materials when exposed to hydrogen. Hydrogen can degrade materials in ways that can lead to failure or reduced lifetimes. The experiments and analysis performed in this program can help develop new materials which will be either higher performing, lower cost, or both. By understanding the interactions of hydrogen with metals and alloys, materials with resistance to hydrogen fatigue and fracture can be developed.

I^{2}CNER's research goals strongly overlap with SNL's interests. The institute's technical areas include hydrogen production, fuel cells, thermophysical properties, hydrogen storage materials, and carbon capture and storage.

Although based at Kyushu University in Japan, I^{2}CNER is unique in that its director is Professor Petros Sofronis of the University of Illinois, a longtime collaborator with SNL. Professor Sofronis has most recently been conducting hydrogen embrittlement R&D at the University of Illinois, funded by the DOE Office of Energy Efficiency and Renewable Energy (EERE).

The collaboration with I^{2}CNER is complementary to SNL's Hydrogen Program and its presence in the Livermore Valley Open Campus in California. One of the Program goals is to perform as an international R&D center, an objective supported by the U.S. DOE since global collaborations are crucial to solving difficult problems in hydrogen.

By working as part of an international team to increase safety and reduce costs for the use of hydrogen as an energy source, SNL is helping to make carbon-neutral energy a reality.

"Working with SNL provides technologies and expertise that would typically never be available to a small company such as ours. The support we receive from SNL and others allows us to be successful and continue to grow."

Dr. Victor Esch
President and CEO
nanoMR

nanoMR scientists, Amena Rashid and Douglas Standridge, analyze bacteria isolated from infected blood.

Devices Rapidly Detect Pathogens Using Team-Developed Technology

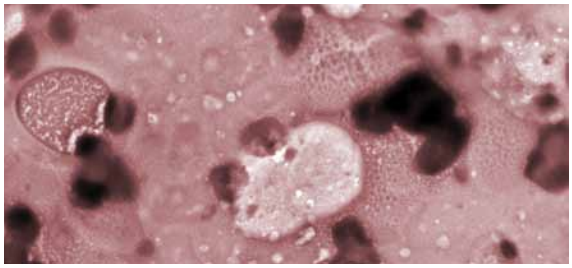
While Sandia National Laboratories (SNL), like other federal laboratories, partners with a number of universities, the partnership with STC.UNM is extraordinary. STC.UNM (STC), a nonprofit corporation formed and owned entirely by the University of New Mexico (UNM), works closely with SNL to promote technology transfer.

An overarching Memorandum of Understanding (MOU) between SNL, UNM, and STC specifies how jointly owned intellectual property is handled. However, partnership and collaboration between STC and SNL go beyond the formal MOU and required interaction.

Since the first joint technology licensed in 1993, STC and SNL continue to work together as a team, developing technologies as partners, and as partners, deciding which organization should take the lead in commercializing each new development. Currently there are 114 jointly owned invention disclosures, with seven new joint inventions in 2011. One of the companies to come out of this partnership is nanoMR.

nanoMR is a life sciences business that develops novel diagnostic systems for the rapid, ultrasensitive detection of pathogens in whole blood. nanoMR's systems couple immuno-chemistry with patented nuclear magnetic resonance (NMR) technology to produce small, simple, inexpensive devices that offer unparalleled speed and sensitivity. This proprietary technology can detect blood-borne infections in less than two hours compared to the 48 hours or more required for conventional culturing.

The technology was first developed by the team of Todd Alam, PhD at SNL, Laurel Sillerud, PhD, research associate professor in UNM's School of Medicine, and Andrew McDowell of ABQMR. The technology has since been further developed for market by nanoMR, with help from UNM, ABQMR, SNL, STC.UNM, and others.



nanoMR's first product addresses the blood culture market. Severe sepsis affects 750,000 people each year in the United States, killing approximately a third of those with the disease and costing the average hospital over $7 million a year. The nanoMR Pathogen Capture System has demonstrated performance for both Gram negative and Gram positive bacteria, and various fungal targets. Performance has been validated to <1 bacterium /mL in spiked samples, through polymerase chain reaction (PCR) identification, and also in clinical studies in comparison to standard blood culture.

In 2011, nanoMR received funds from a 48D Tax Qualified Therapeutic Discovery Project grant as well as $13 million in Series B funding, allowing them to hire new talent, develop commercial instruments, perform clinical studies, and prepare for product launch.

The partnership between STC and SNL creates commercial development, economic impact, and public benefit for New Mexico and taxpayers across the U.S. Evidence of the increasing success of this partnership is increased commercialization activity and successful startups such as nanoMR.

"The partnership with i-GATE has made it easier for businesses and the state of California to engage with Sandia and its assets, helping to push our economic goals forward."

Louis Stewart
Deputy Director
Innovation and Entrepreneurship
Governor's Office of Business & Economic Development

California Energy Commissioner Carla Peterman and James Bartridge (CEC) discuss electric vehicle technologies with Fraser Murison Smith (right) of i-GATE NEST client, ElectraDrive.

Innovation Hub Connects Clean Tech Small Business with Labs and State

Getting connected with government officials, potential partners, investors, and technical resources isn't generally an easy task for startup companies. But for clients of the i-GATE (Innovation for Green Advanced Transportation Excellence) innovation hub, there is a mechanism in place to provide a wide range of business support.

i-GATE (www.igateihub.org) was one of the first of six innovation hubs (iHubs) to be recognized by the California Governor's Office of Economic Development. As part of the iHub program, i-GATE is an example of local and regional government, premier national research laboratories, and the business and local community collaborating to develop the technology sector to create jobs and drive regional economic growth.

The collaborative effort is administered by the City of Livermore in close partnership with Sandia National Laboratories/California (SNL/CA) and Lawrence Livermore National Laboratory (LLNL). The public-private partnership extends throughout the region with over 40 government, industry, research organization, venture capital, and academic partners, including two University of California campuses. Chevron is the latest industry partner to join.

In June 2011, the i-GATE National Energy Systems Technology (NEST) incubator opened. It acts as a small business support system to accelerate the commercialization of innovative technologies related to green transportation and clean energy. There are now eight i-GATE clients developing fuel cell, electric vehicle, battery, and ultra-light rail technologies (see CyberTran prototype, right). i-GATE continues accepting applications.

i-GATE programs offer small technology company clients business expertise, entrepreneurial education, collaboration opportunities, and technology transfer assistance. Small businesses that are part of the i-GATE program or are housed in the NEST incubator can receive assistance in contacting appropriate technical personnel, programs, and facilities at the national laboratories.

Some of the Livermore resources, such as the Combustion Research Facility at SNL/CA, and the High Performance Computing Innovation Center at LLNL, can provide major advantages to companies wishing to avail themselves of cutting-edge research tools and ready access to skilled researchers.

The collaborative i-GATE program is not only working on connecting businesses to the national laboratories, but also on helping to move SNL and LLNL technologies out of the labs.

Initiatives such as i-GATE follow a model of successful shared use campuses adjacent to federal laboratories, such as the Sandia Science & Technology Park (SS&TP) in Albuquerque, New Mexico, and the NASA-Ames Research Park in Moffett Field, California. The i-GATE program, which allows for increased access and collaboration with business partners, will help accelerate the flow of clean technologies from the labs to the marketplace.

Acquisition of Companies Reflects Growth of Industry in Park

Two companies in the Sandia Science & Technology Park (SS&TP) were acquired by Fortune 500 companies in 2011, highlighting the growth of SS&TP tenants in desirable technology areas. Being in the SS&TP has given both companies a location near Sandia National Laboratories (SNL), a desirable site for their facilities and employees, and heightened visibility with the congressional delegation.

Raytheon Company acquired key business assets of Ktech Corporation, one of Albuquerque's leading high-tech companies. Raytheon Ktech became part of Raytheon's Missile Systems product line, expanding Raytheon's capabilities and opportunities in the non-kinetic effects markets.

The purchase of the 330-employee Ktech was due to Raytheon's interest in Ktech's directed energy and pulsed power technologies, as well as the company's proximity to SNL.

Raytheon Ktech has experienced a 23% increase in sales from 2010 to 2011, while employment remains steady since the acquisition. The company continues to occupy 100,878-square-feet of tailor-made space in two buildings at the SS&TP.

Air Products acquired PolyFlow Engineering, a subsidiary of Ktech Corporation and a manufacturer of equipment for the semiconductor industry. The company has been adding employees since the acquisition, moving from just under 100 to nearly 150 by the end of 2011.

Air Products has made a seven-year commitment to the Albuquerque market, and hopes to be staying much longer. Capital investment since the acquisition has been over $200,000 in the 72,000-square-foot SS&TP facility, which is now part of the Air Products Electronic Equipment Solutions business unit.

Air Products said the PolyFlow acquisition was complementary to their $2 billion-a-year electronics and performance-materials segment, which makes products and components for the semiconductor, film transistor, photovoltaic, and light-emitting-diode industries. For the employees at the SS&TP facility, Air Products brings the advantages of a large company with a worldwide presence in the industry.

Raytheon Ktech and Air Products

"The addition of Ktech to the Raytheon family coupled with our strong partnership with SNL positions Raytheon to lead the advances in America's pulsed power and directed energy innovations."

Dr. Taylor W. Lawrence
President
Raytheon Missile Systems

"We are excited to continue our operations in the Sandia Science & Technology Park. As part of Air Products, we will play a role supporting the silicon and compound semiconductors and LCDs that power our digital world."

Curt Mitchke
Director EES-ABQ
Air Products

> *"The ability to work directly with SNL's aerospace experts has helped us to better understand our market and the opportunities it holds."*
>
> ***Lem Hunter***
> *CEO*
> *Vibrant Corporation*

Program Provides SNL Testing for FAA Approval

■ **Application Engineer Eric Biedermann of Vibrant supervises an automated nondestructive testing system.**

Having their non-destructive test (NDT) method for aircraft engine parts tested at Sandia National Laboratories' (SNL) Airworthiness Assurance Non-Destructive Inspection Validation Center was a major step for Vibrant Corporation in having the method accepted by the aerospace industry. The report from the SNL testing was used in an application to the Federal Aviation Administration (FAA) for an "Alternative Means of Compliance," which was approved.

The aerospace application for Process Compensated Resonance Testing (PCRT), an NDT technology that provides environmentally friendly, cost-effective, and fast reporting on the structural integrity of aerospace and power generation components, was developed by Vibrant. Specifically, PCRT offers increased sensitivity to defects, less engine down time, and reduced waste from blades that test negative for over-temperature conditions. PCRT replaced sample-based destructive testing methods previously used.

Vibrant, along with supply chain companies, Mechtronic Solutions, Fiore Industries, and ZTEC Instruments, requested assistance through a New Mexico Small Business Assistance (NMSBA) leveraged project. The NMSBA Program allows SNL to provide cutting-edge technologies and knowledge from laboratory experts to help solve technical challenges for small businesses in the state of New Mexico.

In addition to granting approval, the FAA recognized Vibrant and Delta TechOps, the nation's largest commercial aircraft maintainer, as winners of the 2010 FAA-ATA Non-Destructive Testing "Better Way" Award for developing and applying technology resulting in a more sensitive, reliable, and cost-effective model for inspecting and testing aviation components and systems.

FAA approval resulted in new business opportunities for Vibrant, increased contracts for the supply chain companies, and substantial cost savings to the airline industry. The use of PCRT has continued to expand, with Vibrant now doing PCRT testing for multiple original equipment manufacturers of aircraft engines. Production PCRT tests have also been developed for other components, like aircraft wheel tie bolts.

Recognition

Sandia National Laboratories (SNL) held several events this year which emphasized the importance of innovation and entrepreneurial spirit at the Labs.

Innovation and Intellectual Property Celebrations

Events were held in New Mexico and California to recognize Sandia scientists and engineers whose work has created intellectual property (IP). These celebrations paid tribute to Sandians who received patents, copyrights, royalties, Classified Intellectual Property Awards, or special awards. Their IP has contributed to SNL's IP and licensing portfolios, royalty streams, and outstanding reputation in innovation and technology transfer.

Up-and-Coming Innovators were also recognized. This award recognizes individuals who displayed enormous potential for supporting impactful innovations, exhibited entrepreneurial talent, and developed unique solutions to complex scientific challenges.

During the celebration in New Mexico, SNL recognized 105 patent holders, 39 copyright authors, and 21 Up-and-Coming Innovators. At the celebration in California, 27 patent holders, 17 copyright authors, 13 classified inventors, 45 royalty recipients, and four special award recipients were recognized.

Besides the creation of IP, the achievements of SNL personnel often result in recognition such as R&D 100 Awards and election into, or recognition of lifetime achievements by, technical professional societies.

Entrepreneurial Spirit Awards Luncheon

The second annual Entrepreneurial Spirit Awards Luncheon, sponsored by Technology Ventures Corporation, honored eight Sandia entrepreneurs. All the honorees left SNL to explore entrepreneurial opportunities. Four of the honorees remained in the private sector, while four returned, bringing with them valuable knowledge and skills obtained in the commercial world which they leveraged to achieve new levels of success back at SNL.

NMSBA 10 Years of Innovation Celebration

The New Mexico Small Business Assistance (NMSBA) Program celebrated its 10th anniversary, as laboratory officials recognized all the projects with small businesses that have participated in the program over the years. In addition, 10 projects from 2010 were highlighted. These included the following SNL-assisted projects: AgVentures, Pesticide Application Technologies, Process Compensated Resonance Testing, Royal Fiber Spinnery, and Santa Cruz Sediment Management.

The NMSBA Program provided $4.6 million worth of technical assistance to the 339 small businesses that participated in the program in 2010.

Awards

R&D 100 Awards

- **Microresonator Filters and Frequency References,** miniature acoustic resonators which fill the need for advanced radio frequency (RF) filter and oscillator banks covering multiple RF bands required by the next generation of mobile computing devices.
- **Ultra-high-voltage Silicon Carbide Thyristor**, a semiconductor device which allows next-generation "smart grid" power electronics system to be built up to 10 times smaller and lighter than current silicon-based technologies.
- **Biomimetic Membranes for Water Purification**, synthetic membranes that mimic the nanoscale design features of natural water purification channels, achieving a tenfold improvement in efficiency compared with state-of-the-art reverse osmosis membranes.
- **Demand Response Inverter**, designed to reduce the levelized cost of energy (LCOE) of photovoltaic (PV) power by being more efficient, reliable and cost-effective than currently available inverters.

Federal Laboratory Consortium (FLC) National Awards

- **Excellence in Technology Transfer: Stingray**
  Based on a license of SNL intellectual property, TEAM Technologies began manufacturing Stingray, a water tool that disrupts improvised explosive devices (IEDs) and renders safe other explosive targets. It has been deployed by the military and is being tested for other applications.
- **State and Local Economic Development: NMSBA**
  The New Mexico Small Business Assistance (NMSBA) Program is a catalyst for the transfer of cutting-edge technology from SNL and Los Alamos National Laboratory to a wide range of small businesses across the state.
- **Interagency Partnership: CANARY**
  SNL and the U.S. Environmental Protection Agency won for their collaboration developing CANARY Event Detection Software, which protects public drinking water systems by enhancing the detection of contaminants or a terrorist attack.

FLC Mid-Continent Region Awards

- **Notable Technology Development: Gemini-Scout**
  An unmanned ground vehicle designed to go into hazardous environments, such as mines when miners are trapped, to assess conditions and communicate with survivors. SNL has licensed the Gemini-Scout to Black-I Robotics.
- **Notable Technology Development: Solar Glitter**
  Glitter-sized photovoltaic cells that could revolutionize the way solar power is collected and used. Microsystems-Enabled Photovoltaics (MEPV) are expected to be less expensive and more capable than current photovoltaic collectors.
- **Regional Partnership: STC.UNM**
  STC.UNM, a nonprofit corporation formed and owned entirely by the University of New Mexico, works closely with SNL to promote technology transfer. The partnership creates commercial development, economic impact, and public benefit for taxpayers across the U.S.

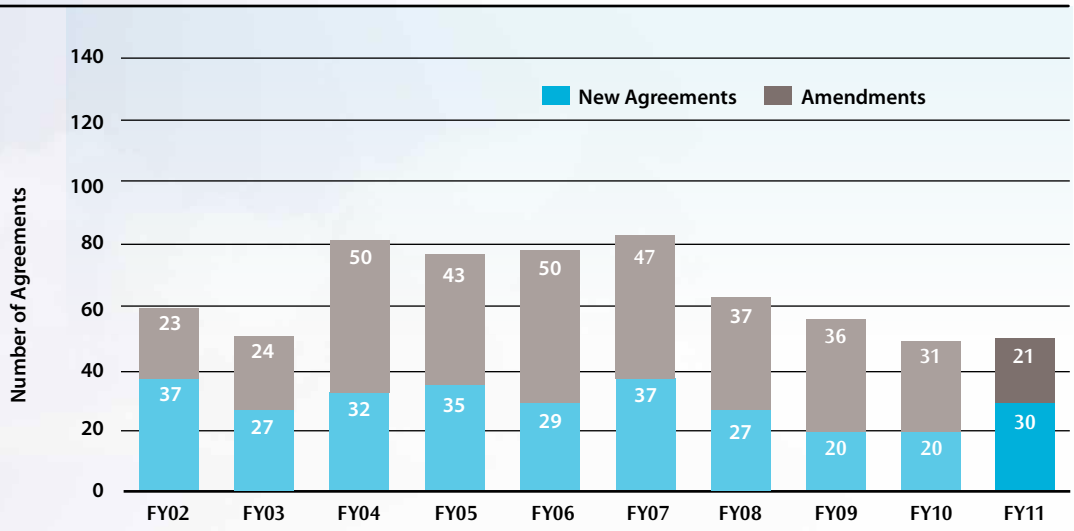
Association of University Research Parks (AURP) Awards of Excellence

- **Innovation: TEAM Technologies**
  SNL worked closely with TEAM to transfer information needed to improve and produce Stingray and sell it to the Explosive Ordnance Disposal community. The information exchange was facilitated by TEAM's presence in the Sandia Science & Technology Park.

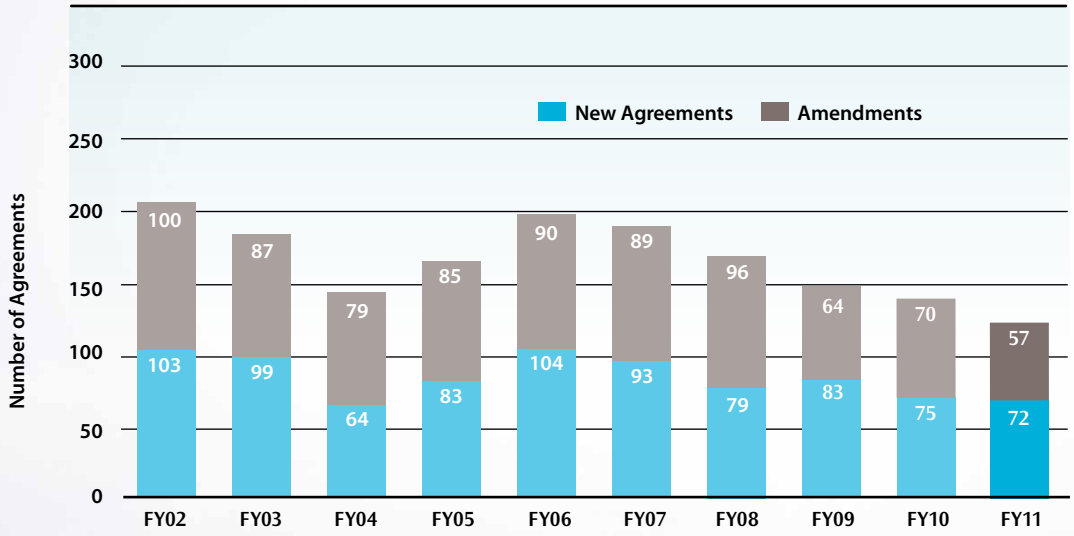
The Industrial Partnerships Program maintains a performance measurement system, summarized in this section. Included is data which has been compiled for specific program metrics that are updated annually.

CRADAs and WFO-Industrial

Sandia CRADA Program Activity

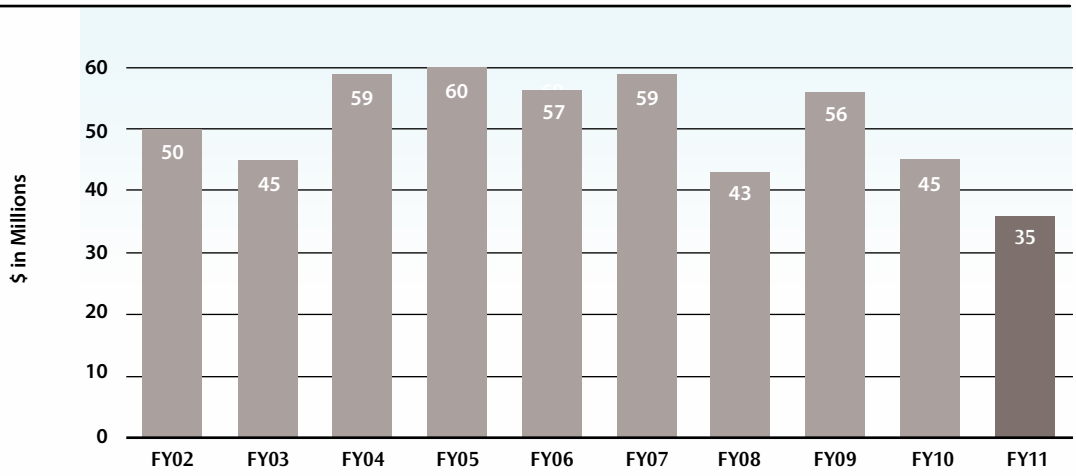


Sandia WFO-Industrial Partners Activity



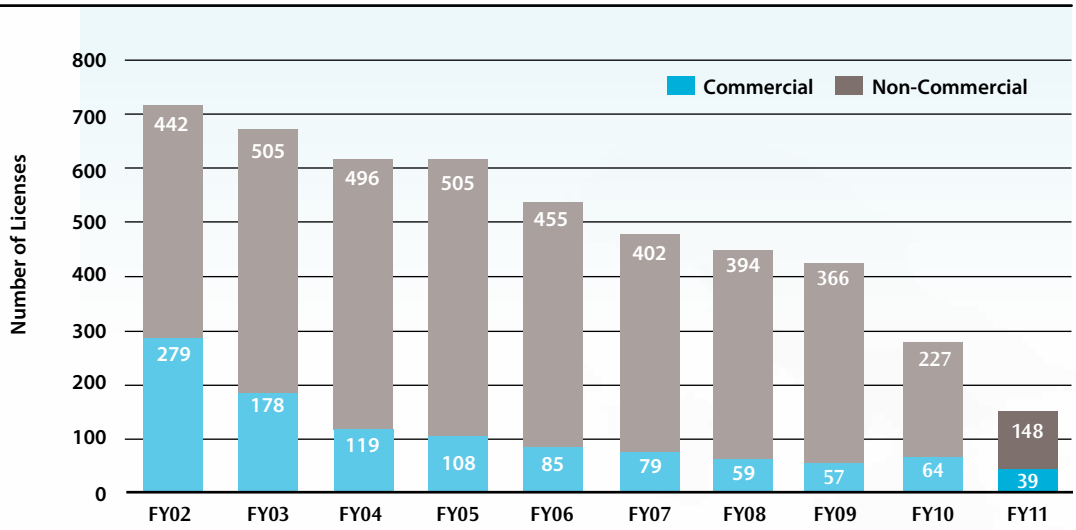
Industry Funds-In

Industry Funds-In to Sandia ($M)

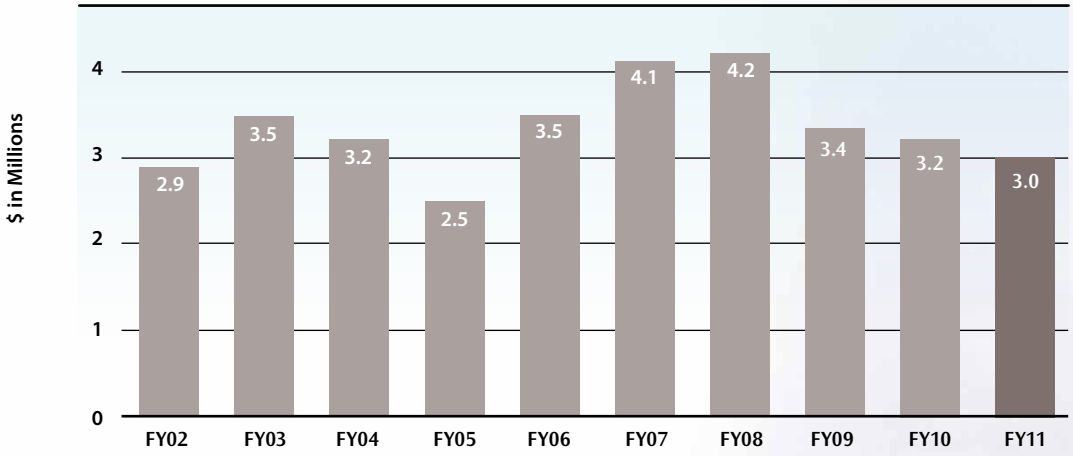


Licenses

Licenses

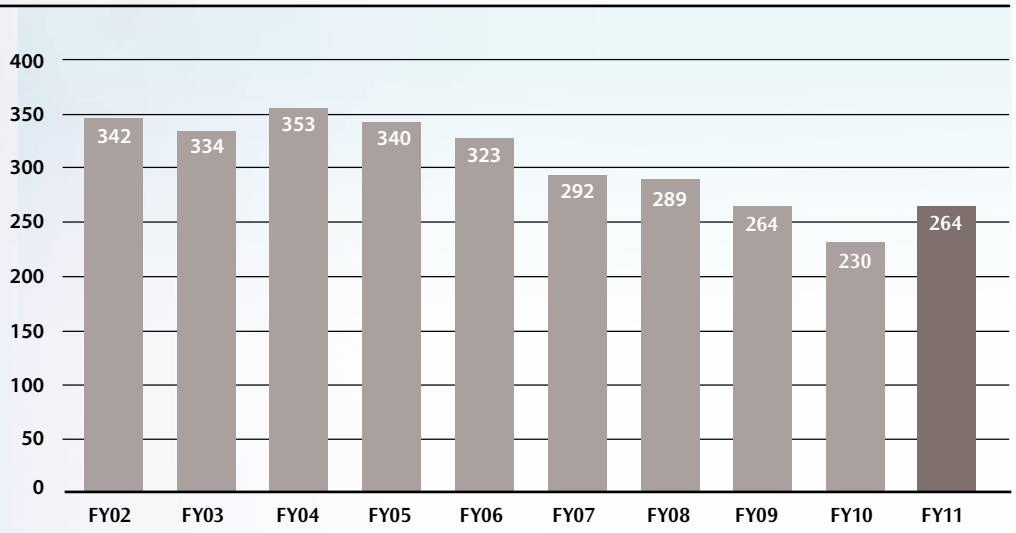


Licensing Income ($M)

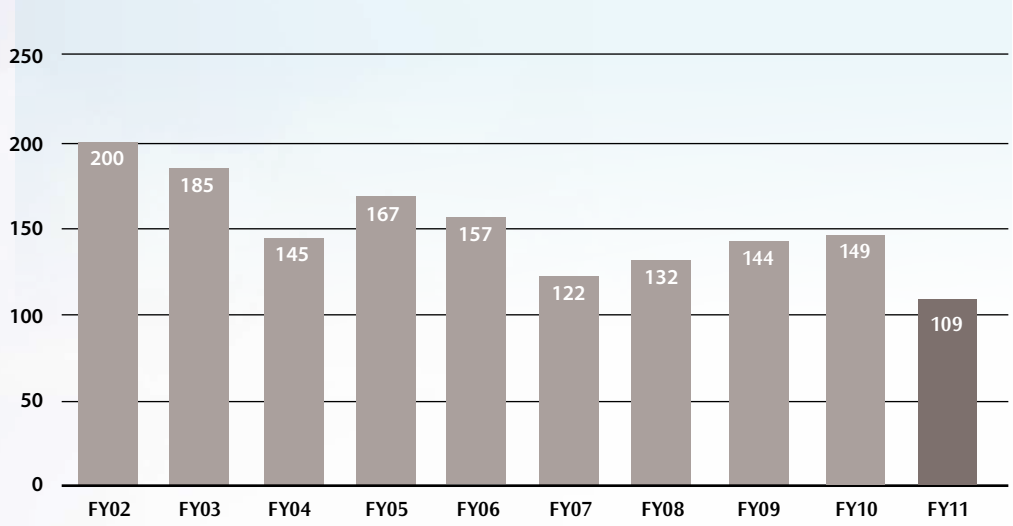


Patent Activity

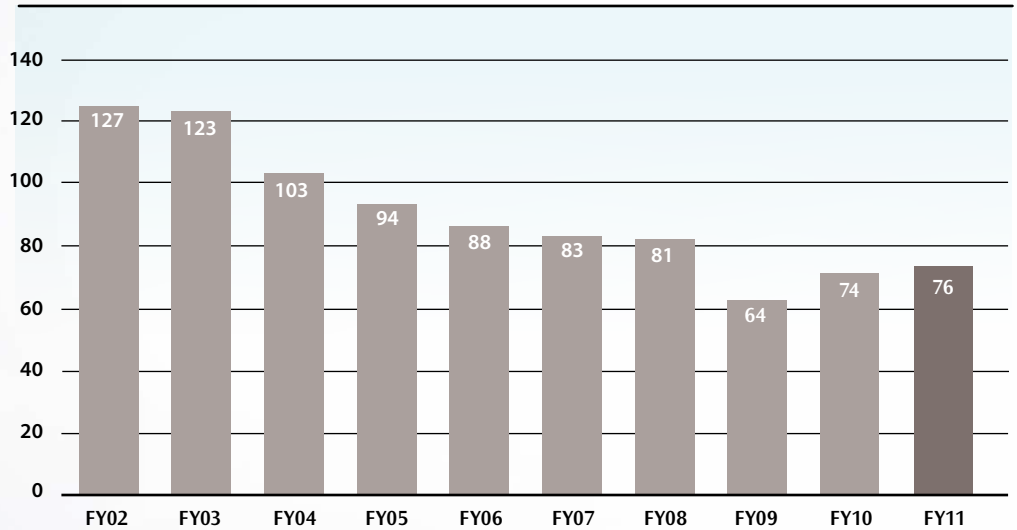
Invention Disclosures



Patent Applications



Patents Issued



Sandia Science & Technology Park (SS&TP)

Results

Companies and Organizations	31
Employees	2470
Buildings	23
Occupied Space (sq. ft.)	1M
Available Space (sq. ft.)	93K
Acres Developed	106
Acres Available	232.5
Funds In to Sandia from Companies Since 1998	$17.7M
Contracts from Sandia to Companies Since 1998	$390M
Contracts Between Companies Since 1998	$9.4M
Public Investment Since 1998	$86.6M
Private Investment Since 1998	$264.8M
Total Investment Since 1998	$351.4M
Average Salary of Full-time Jobs in Park	$71.6K
Average Salary of Full-time Jobs in Metro Albuquerque	$39.3K

Note: Park opened in 1998

New Mexico Small Business Assistance (NMSBA) Program

In 2011 the state of New Mexico, along with LANL and SNL, invested **$4.6M** to help **340** small businesses in **27** counties solve technical challenges.

	2000 - 2011
New Mexico Small Businesses Assisted	1876
Rural vs Urban Businesses	
Rural (65%)	1221
Urban (35%)	655
Combined	1876
Dollar Amount of Assistance	**$29.8M**

	2000 - 2010
Return on Investment (ROI)	1.24
(ROI is Based on Salaries of Jobs Created and Retained)	

Economic Impact

Small Business Jobs Created and Retained	2317
Mean Salary	$38K
Increase in Revenue	$107.6M
Small Business Decrease in Operating Costs	$63.6M
Investment in NM Goods/Services	$34.9M
New Funding/Financing Received	$41M

Entrepreneurial Separation to Transfer Technology (ESTT) Program

Sandia Scientists and Engineers Who Left on ESTT	**139**
To Start Companies (40%)	55
To Expand Companies (60%)	84
Companies Impacted by ESTT	**92**
Start-ups	44
Expansions	48
Licenses for Sandia IP Negotiated with ESTT Companies	**42**

Contacts

For more than two decades, Sandia National Laboratories has worked closely with industry, universities, and government agencies to bring new technologies to the marketplace.

For general questions or comments, contact partnerships@sandia.gov, or call 505-284-2001.

For information about specific partnership areas, contact the following:

Industrial Partnerships
Peter Atherton, 505-284-3768, prather@sandia.gov

Intellectual Property Management, Alliances & Licensing
Mark S. Allen, 505-844-7197, msallen@sandia.gov

Agreements
Matt Riley, 505-845-8060, jmriley@sandia.gov

Partnerships Business Development
Mary Monson, 505-844-3289, mamonso@sandia.gov

Business Development (California)
Devon Powers, 925-294-1470, dpowers@sandia.gov

Technology and Economic Development
Jackie Kerby Moore, 505-845-8107, jskerby@sandia.gov

Technology Ventures Corporation (TVC)
John Freisinger, 505-246-2882, john.j.freisinger@lmco.com

Founded in 1993 by Lockheed Martin, TVC's charter is to facilitate the commercialization of technologies developed at SNL, other laboratories, and research universities.

Partnerships Annual Report Staff

Sandia National Laboratories
Jackie Kerby Moore, *Manager*
Michael Vittitow, *Designer*
Randy Montoya, *Photographer*

Sandia Staffing Alliance, LLC
Linda von Boetticher, *Project Manager*

Global Analytic IT Services
Lloyd Wilson, *Photographer*

Freelance Contractor
Ellen Cline, *Writer*

Sandia National Laboratories

For more information on Sandia's technologies:
partnerships@sandia.gov or 505-284-2001

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND number:2012-2550P.

NNSA National Nuclear Security Administration

LOCKHEED MARTIN

U.S. DEPARTMENT OF ENERGY