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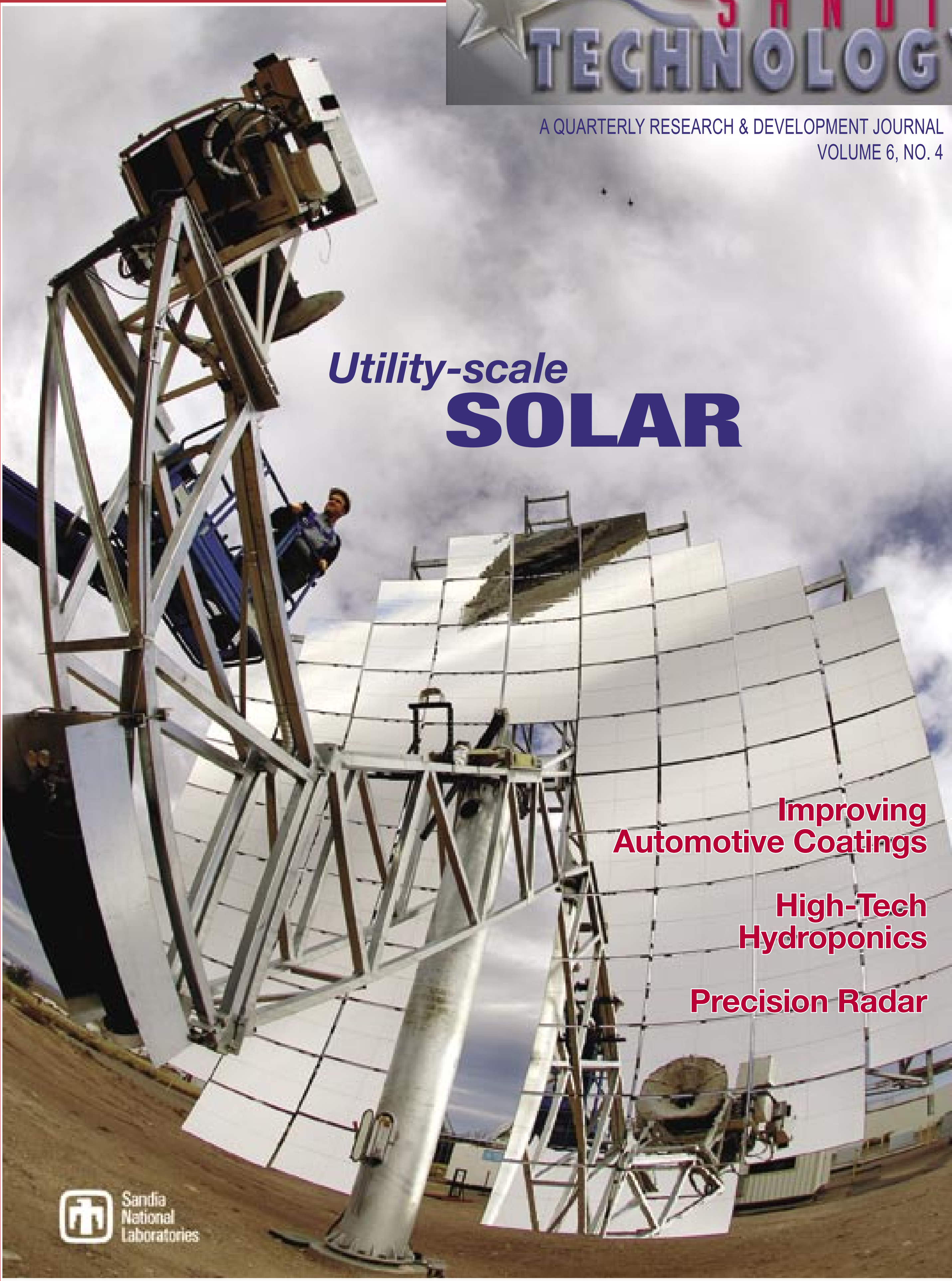

Utility-scale SOLAR

Improving Automotive Coatings

High-Tech Hydroponics

Precision Radar

Sandia National Laboratories

What is LDRD

Sandia's world-class science, technology, and engineering work define the Labs' value to the nation. These capabilities must remain on the cutting edge, because the security of the U.S. depends directly upon them. Sandia's Laboratory Directed Research and Development (LDRD) Program provides the flexibility to invest in long-term, high-risk, and potentially high-payoff research and development that stretch the Labs' science and technology capabilities.

LDRD supports Sandia's four primary strategic business objectives: nuclear weapons; nonproliferation and materials assessment; energy and infrastructure assurance; and military technologies and applications; and an emerging strategic objective in homeland security. LDRD also promotes creative and innovative research and development by funding projects that are discretionary, short term, and often high risk, attracting exceptional research talent from across many disciplines.

When the LDRD logo appears in this issue, it indicates that at some state in the history of the technology or program, LDRD funding played a critical role.

On the Cover:

Chuck Andraka makes adjustments to a Stirling Energy Systems, Inc., solar dish-engine system installed at Sandia's National Solar Test Facility late in 2004.
(Photo by Randy Montoya)

Sandia Technology (ISSN: 1547-5190) is a quarterly journal published by Sandia National Laboratories. Sandia is a multiprogram engineering and science laboratory operated by Sandia Corporation, a Lockheed Martin company, for the Department of Energy. With main facilities in Albuquerque, New Mexico, and Livermore, California, Sandia has broad-based research and development responsibilities for nuclear weapons, arms control, energy, the environment, economic competitiveness, and other areas of importance to the needs of the nation. The Laboratories' principal mission is to support national defense policies, by ensuring that the nuclear weapon stockpile meets the highest standards of safety, reliability, security, use control, and military performance. For more information on Sandia, see our Web site at *http://www.sandia.gov.*

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Winter Issue 2005

FROM THE *Editor*

Dear Readers,

The Winter 2005 issue of *Sandia Technology* looks across several of Sandia's research sectors at developments making their way through the R&D world. It's a "war and peace" issue in a sense. We discuss some projects being developed with support of our armed forces in mind. We also showcase technologies that can help us avoid war by better using our resources and creativity.

Sandia's work with the U.S. Navy is an example of the former. Sandia engineers, using a "system of sytems" approach, are looking at ways of making an aircraft carrier a more efficient place, requiring fewer sailors without loss of capabilities.

Another of Sandia's leading-edge research areas, synthetic aperture radar (SAR) technologies, is designed primarily to support the military. As this issues shows, a valuable peacetime use also has been found for the Rapid Terrain Visualization software developed to effectively use SAR.

Our researchers and engineers continue to work closely with private industry as demonstrated in articles on cooperative efforts with PPG Industries and Solar Energy Systems. It's been a while since *Sandia Technology* reported on the Labs' solar research, but the dish-Stirling project now under way represents an ambitious step for making solar power a bigger contributor to the U.S. power grid.

Among our other articles is an interesting one on a technology that allows humans to see motion in the nanometer range — usually well beyond our human powers to resolve. And last but not least, U.S. Senator Jeff Bingaman comments on Sandia's role as a national laboratory in our Insights column.

Will Keener
Editor

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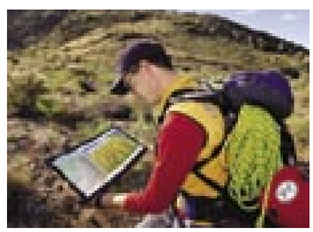

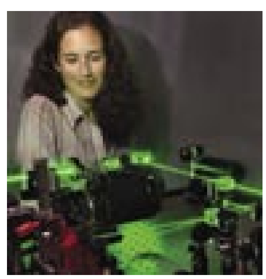

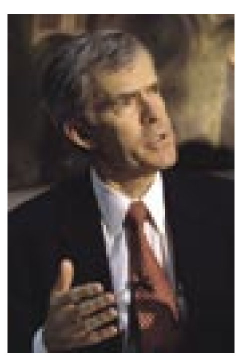

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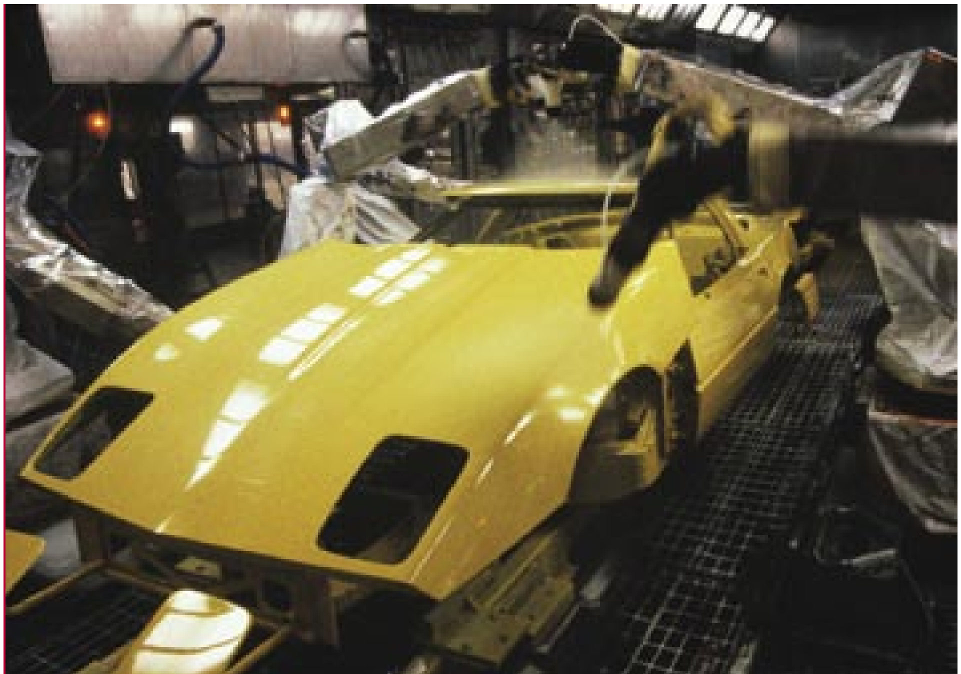
INSIGHTS *Inside back cover*
By U.S. Senator Jeff Bingaman

Improving
Automotive coatings

Sandia, in cooperation with PPG Industries, has developed an optical instrument capable of submicron-level mapping of the surface of automotive clearcoats as they form to better understand the processing operation.



Sandia researchers are working with PPG Industries to improve automotive clearcoat application

"Clearcoats" applied over layers of automotive paint not only enhance automobile appearance, but also serve as a first line of defense against attack from moisture, acid rain, and ultraviolet radiation. Defects in these coatings can seriously compromise appearance and performance, and are costly to repair. As a result, clearcoat manufacturers, such as PPG Industries, are seeking to improve the formulation of their coatings to perform these tasks better.

As part of a Cooperative Research and Development Agreement with PPG Industries, Sandia has developed an optical instrument capable of mapping the surface of automotive clearcoats as they form to better understand the processing operation.

Successful development of advanced coatings requires a fundamental understanding of the interplay among the coating formulation, the application method, and processing conditions. Thus, characterization tools that can provide information about coating properties throughout the processing protocol are of extreme interest.

Optical profiler

Known as an optical profiler, it is loosely based upon known technology but has been optimized to provide a digital three-dimensional profile of both wet and dry clearcoats. The profiler can operate at a distance so that measurements can be made looking into an oven for characterization of the coatings during thermal processing.

The profiler features a wide field of view, submicron depth resolution, and fast acquisition times. The Sandia team has also developed a measurement technique that enables the profiler to be used for measurement of the surface tension of wet films during processing. Such measurements have not previously been possible.

In the new technique, a pulse of air from a tiny nozzle creates a small, circular depression in the coating, and the surface-tension-driven leveling that follows is measured. The leveling data, when combined with information about the coating viscosity, offer a new perspective on the behavior of the surface tension.

The new tool enables PPG to understand the behavior of coatings in ways that were not previously possible. Visualization and measurement of surface topography during processing allow investigation of processes such as leveling and re-flow. In addition, researchers can observe the onset and evolution of defects, such as those known in the industry as "craters" and "orange peel." They anticipate that the surface tension information provided by the profiler will enable them to tailor coatings to simultaneously achieve improved appearance and chemical resistance, and ultimately lead to improved, defect-resistant coating technologies.

The research/development team is led by Michael B. Sinclair of Sandia, and P. Kamarchik and R. Stiger of PPG Industries, Allison Park, Pennsylvania.

The new tool enables PPG to understand the behavior of coatings in ways that were not previously possible.

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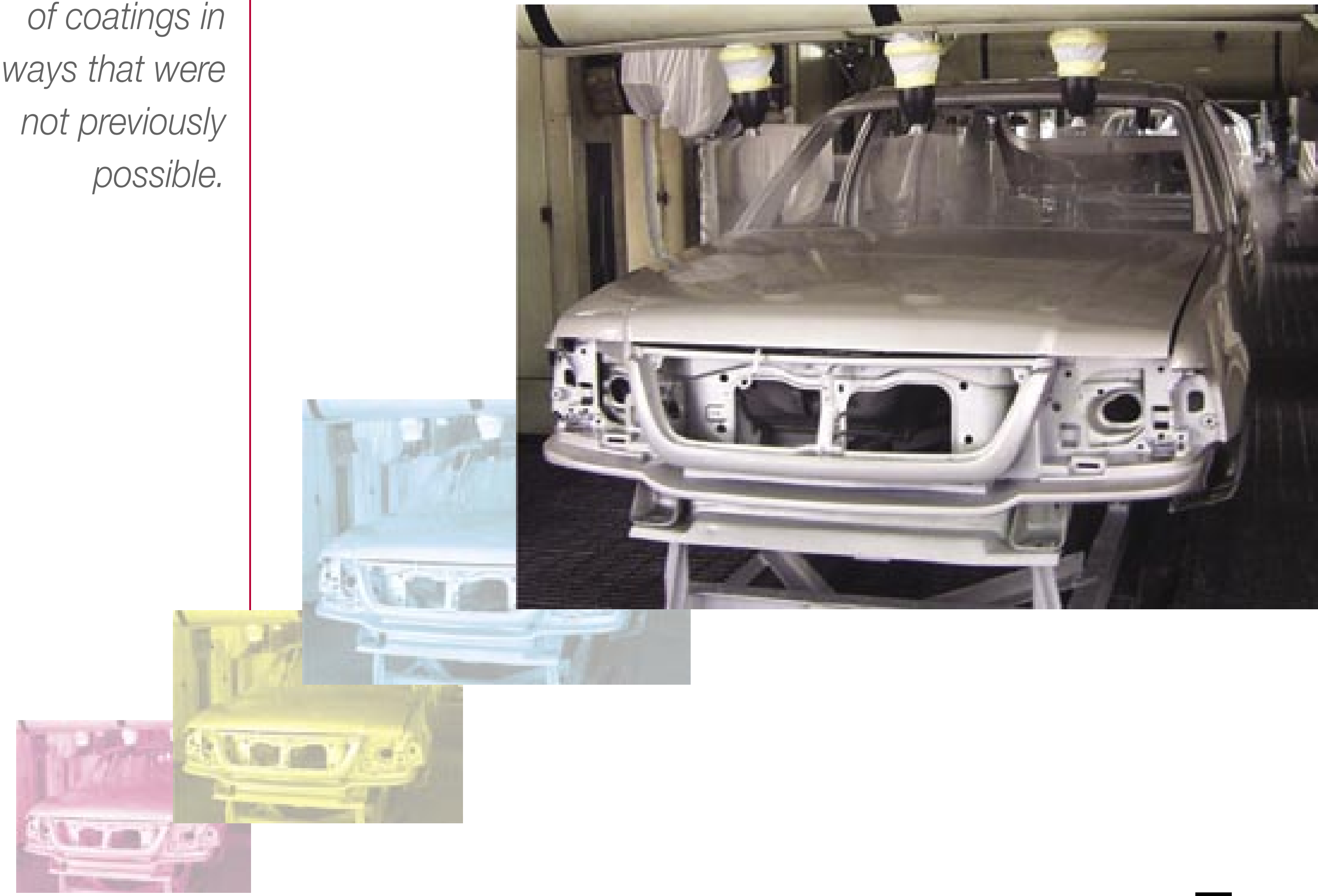

Shaping future
Aircraft carrier operations

Doing more with fewer workers — the prevailing practice in the private business community — has found its way to the U.S. Navy. Beginning with a four-month evaluation of current Navy air wing operations, structure, and improvement alternatives, Sandia is now conducting an in-depth analysis of the alternatives established during the evaluation.

In its next-generation aircraft carrier, the Navy, with assistance from Sandia, is seeking to reduce manpower by 10 to 30 percent, but not by heaping more work on individual sailors. The goal is to use increased technology and improvements to carrier air wing flight operations, maintenance, and support functions to reduce the overall workload per sailor.

"We will be probing each of these areas to find ways to maintain or improve air wing performance while reducing personnel and making the remaining jobs more desirable," says Jeff Brewer, Sandia engineer and project principal investigator. "This will be done while simultaneously improving the air wing staffing decision-making process."

In the first phase of the project, Sandia conducted a four-month evaluation of current Navy air wing operations, structure, and improvement alternatives.

Now, in the second phase, Sandia is conducting a six-month, in-depth analysis of those alternatives. The actual carrier that will result in 2013 or 2014 will be designated as the CVN 78, the Navy's 78th aircraft carrier.

"The idea is not to simply have fewer people on board who work harder than previous crews," says Brewer, "but to enable organizational changes, technology improvements, and work practice changes to achieve the desired operational capability of the air wing and make jobs more desirable for the personnel in the system."

Approach

The Sandia team is reviewing Navy documentation for aircraft currently in use and those anticipated to be in service in 2020.

The team will review flight operations, maintenance, and other support operations both in the Atlantic and Pacific fleets. Sandia will work with Navy teams that have developed computational models of how these operations are currently performed. The team will work with the designers of the new aircraft

Sandia engineer Jeff Brewer uses a "system of systems" approach to help the U.S. Navy create the next generation of aircraft carriers.

System of systems refers to a collection of systems that results in emergent behaviors that cannot be explained by individual system analysis.

carrier to generate substantial changes that may improve flight operations and support functions.

Items of particular interest include the definitions and scope of the tasks and functions performed within individual jobs, and staffing levels for various types of jobs and tasks. This includes formal schooling, on-the-job training, self-study, testing of skills involved to prepare people for those jobs, and the tools and techniques used to execute these tasks.

Brewer says the actual execution methods for flight operations, support jobs, and the design of the spaces aboard current aircraft carriers where these tasks are performed will be analyzed. This knowledge will be combined with the designs envisioned for the next-generation aircraft carrier. The complexity of carrier flight operations and the associated support functions requires an unusually high level of system understanding and computational modeling to achieve optimal combinations of personnel, equipment, and procedures.

"The concept of operations under which an aircraft carrier is asked to function can change rapidly," Brewer says. "There currently isn't a detailed, rapid, and robust analytical tool for probing this particular complex system."

System of systems analysis

Creating a "system of systems" analysis capability that enables greater quantitative understanding of the aircraft carrier environment is key to the project, says Brewer.

System of systems refers to a collection of systems that results in emergent behaviors that cannot be explained by individual system analysis. This includes monitoring system performance at a sufficient level of detail and enabling rapid "what if" or tradeoff analyses to aid in decision making by Navy leaders.

In this project, building a comprehensive system of systems capability to monitor and analyze carrier air wing operations may involve linking a number of computer models that have been developed independently. In addition, new models may be built where necessary, and merged into a computational architecture that becomes a systemwide metric-based computational engine including a mix of discrete-event simulation and optimization algorithms.

"The hope is that we will be able to utilize a number of the modeling and simulation technologies developed for other major programs such as the Army's Future Combat System and Lockheed Martin's Joint Strike Fighter program," says Robert Cranwell, Sandia engineer and project manager for the Navy Manpower Study program. "Use of these technologies has proven to be very successful in supporting these programs."

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Lowering the threat
Of future water wars

Disputes over scarce resources, such as fresh water, are potential trigger points for war in the 21st century. Since much of the world's fresh water is used for agriculture, reducing the amount of water needed to grow forage for livestock leaves more water for human consumption, as well as for residential and industrial uses.

Sandia's Ron Pate checks a tray of forage in a greenhouse just north of the U.S.-Mexico border in Santa Teresa, New Mexico.

Hydroponic methods, also known as "controlled environment agriculture," are an alternative for growing forage that use only a fraction of the amount of water required for conventional farming methods, with significantly higher productivity per acre. Sandia is overseeing a high-tech hydroponics project just north of the U.S.-Mexico border that takes this increasingly popular agricultural practice to the next level by applying wireless sensor technology to collect round-the-clock data on the greenhouse ecosystem. Researchers will use this data to help them grow hydroponic crops even more efficiently.

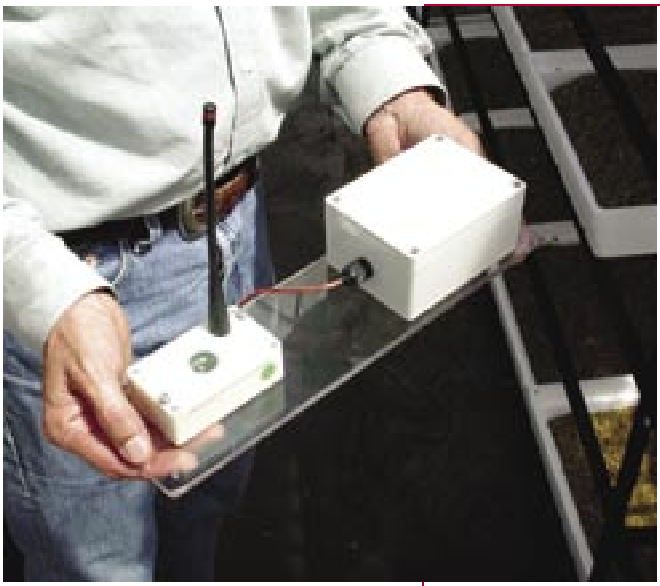
A national security interest

Sandia's interest in the project stems from the strong potential for water to become a source of disputes, and possibly war.

"A large proportion of freshwater usage around the world is agricultural," says Sandia's Peter Davies. "The ability to reduce the amount of water needed for it and thus lessen the possibility of international conflict is extremely important to the security of the United States and the world."

The potential savings in water is particularly important in New Mexico and the American Southwest, Mexico, the Middle East, certain lands between India and Pakistan, and northern China. In all these places, the majority of water use is for irrigated agriculture rather than for direct human consumption and other uses.

Preliminary indications are that hydroponic greenhouses in New Mexico, for example, could reduce the current 800,000 acre-feet of water to 11,000 acre-feet to produce an equivalent amount (dry weight) of livestock forage, and the land needed to less than 1,000 acres instead of



Wireless sensors are used to monitor precisely the amount of water used to grow the crops and the environment inside the greenhouse.

The sensors monitor light, temperature, relative humidity, and air pressure approximately every minute, and every few hours transmit this information by phone line to a remote computer for analysis.

260,000 acres — the current amount used for New Mexico production of alfalfa.

Eighty percent of New Mexico's water use is agricultural. Over half goes toward growing forage, most of which is alfalfa. Similar water use patterns exist in many places in the world.

How it works

Coming from the Greek words for "water," and "labor," hydroponics involves growing plants in nutrient-enriched water. In the Sandia experiment, the forage plants rely on the nutrition present in seed that is germinated, precisely watered, and harvested after about 10 days of growth.

Conventional farming methods in arid regions lose huge amounts of water through evaporation and overabsorption by soil. Over time, this can also lead to excess soil salinity and reduced agricultural productivity. Neither are factors in hydroponic greenhouses.

Researchers are testing an array of 27 wireless sensors in a 26-foot-by-59-foot greenhouse located just west of El Paso in Santa Teresa, New Mexico. The sensors monitor light, temperature, relative humidity, and air pressure approximately every minute, and every few hours transmit this information by phone line to a remote computer for analysis. Consumption of water, seed, and labor are monitored during the active phase of growth.

"We want to be aware of microclimate variances," says Sandia project leader Ron Pate. "We want to know how feed grows from changes in temperature and location and time of watering. That will help us modify the design and operation of the greenhouses."

While Mexican researchers are using hydroponic greenhouses in the State of Chihuahua to grow livestock feed during the current drought, technical questions regarding optimizing the water saved, evaluating nutritional value, and determining optimum light have yet to be determined. The Sandia project goes a step further in its use of an array of sensors and the number of crops being studied (corn, wheat, triticale, sorghum, barley, and oats).

Potential energy benefits

Taking advantage of the ability of hydroponic greenhouses to control sunlight reaching the plants, experiments are also planned to use the blocked light to create solar-generated electrical power. (Greenhouse pumps, timers, and sensors are already powered by freestanding solar modules.)

"Greenhouses could be a solar source," says Sandia's Vipin Gupta. "The challenge is to create reliable, effective materials to use that part of the spectrum the plant is not interested in using to produce power that can be put on a grid as well as operate the greenhouse." Commercial interest has been expressed in this project.

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LDRD

Precision Radar

A radar originally developed by Sandia for military surveillance and reconnaissance applications is helping a volunteer search and rescue group save lives. After the use of one of the maps in the rescue of a New Mexico hiker, Sandia SAR experts say the same technology could be useful in other search and rescue missions in mountainous terrain.

Sandia researcher Bill Scherzinger, president of the Albuquerque Mountain Rescue Council, looks at a SAR map and a standard topographic map used in search and rescue missions.

Called Rapid Terrain Visualization (RTV), a new precision-mapping technology using synthetic aperture radar (SAR) can be used to generate highly detailed terrain maps that are even more precise than the topographic maps produced by the U.S. Geological Survey (USGS). Developed for the military, these maps include detailed information about heights, locations of crevices and cliffs, and even types of vegetation — all highly useful in rugged terrain.

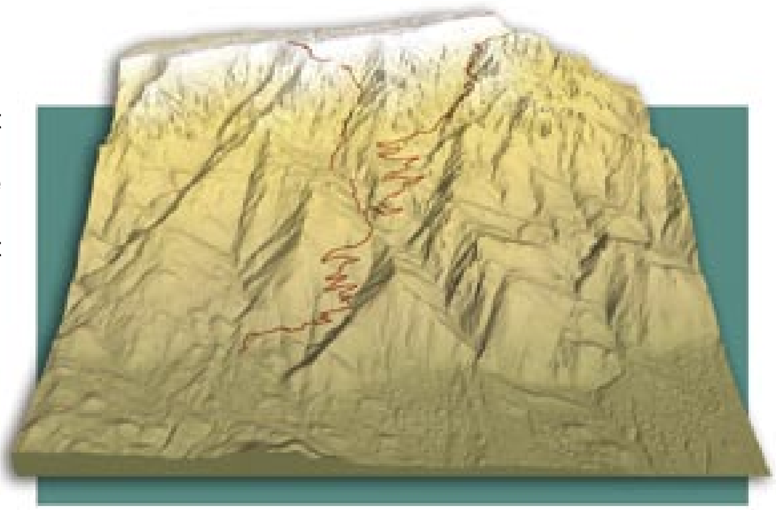
Nonmilitary uses have already begun to suggest themselves as well. "There's no doubt that if we didn't have the RTV SAR maps, reaching the stranded hiker would have been even more difficult than it was," says Sandia's Bill Scherzinger of a 12-hour rescue mission in 2003. Scherzinger is president of the Albuquerque Mountain Rescue Council (AMRC) and participated in the rescue. "We expect to continue to use the RTV SAR in future rescue missions where it seems like it will help the most."

A new application

It started with a conversation between Sandia's Dale Dubbert, a former rescue council volunteer, and Sandia researcher Steve Attaway, a longtime member of AMRC. "We talked about Sandia's capabilities to do precision terrain maps and realized that this technology could be useful in search and rescue missions," Dubbert says.

The RTV mapping system uses interferometric synthetic aperture radar (IFSAR). SAR is a type of radar for producing high-resolution imagery, day or night and regardless of weather conditions. IFSAR is a variation of that technology that can produce highly accurate terrain maps using data acquired by a moving aircraft equipped with two antennae offset in elevation.

The IFSAR maps are accurate to within about a meter. No other mapping system in the world achieves this level of accuracy with the ability to image large areas in real time. The maps are an order



This SAR image shows the west face of the Sandia Mountains. Members of the Albuquerque Mountain Rescue Council used detailed versions of it to rescue a man in November 2003.

Using the RTV SAR maps to help plan the rescue, one team was sent to a nearby canyon to better determine the hiker's exact location.

of magnitude more precise than the standard USGS topographic maps typically used in search and rescue missions.

Dubbert provided the AMRC with map data of the Sandia Mountains (located at the eastern edge of Albuquerque), obtained while the RTV SAR was installed on a deHavilland DHC-7 Army aircraft. A few months later, on a chilly November evening, the search and rescue group used the precision maps for the first time.

Put to the test

Attaway got a call just before sundown telling him that his help was needed in rescuing a hiker lost in the Sandia Mountains. After collecting additional information on the hiker's location, he created detailed, color RTV SAR maps of the area where the man was believed to be.

Attaway met the other rescuers at the Sandia tram (an aerial lift that takes people from the base of the mountains to the peak). The plan was to have rescuers take the tram to the top and hike down to the stranded hiker, who was climbing up the mountain using the tram cables as a guide when he became lost and called for help using his cell phone. Rescuers spotted him from the tram as he waved his flashlight as a beacon.

"But seeing him and getting to him were two different things," Attaway says.

The terrain in the area is extremely rugged and difficult to navigate, even for members of the rescue group, who are experts in using compasses, GPS, and topographic maps. The crew turned to the RTV SAR maps for help.

"The maps were color-coded for height and gave estimates of ground roughness," Scherzinger says. "They also distinguished individual rock formations — known to the rock climbers in our group — that are not seen on the topographic maps."

The rescuers determined that the hiker was not near the bottom of the canyon as initially believed, but instead in a narrow slot near the top of a ridge called Dragon's Tail that was impossible to access without technical rock climbing skills.

Using the RTV SAR maps to help plan the rescue, one team was sent to a nearby canyon to better determine the hiker's exact location. A second team went along the treacherous ridgeline of Dragon's Tail. The first team made voice contact with the man from the bottom of the bluffs at about 3 a.m. Three hours later, the second team rappelled to the hiker, following a ridgeline that was one of the most difficult and risky routes the rescue group had ever attempted. Another four-hour hike using climbing gear and ropes was necessary to bring the man to safety. The entire rescue took more than 12 hours.

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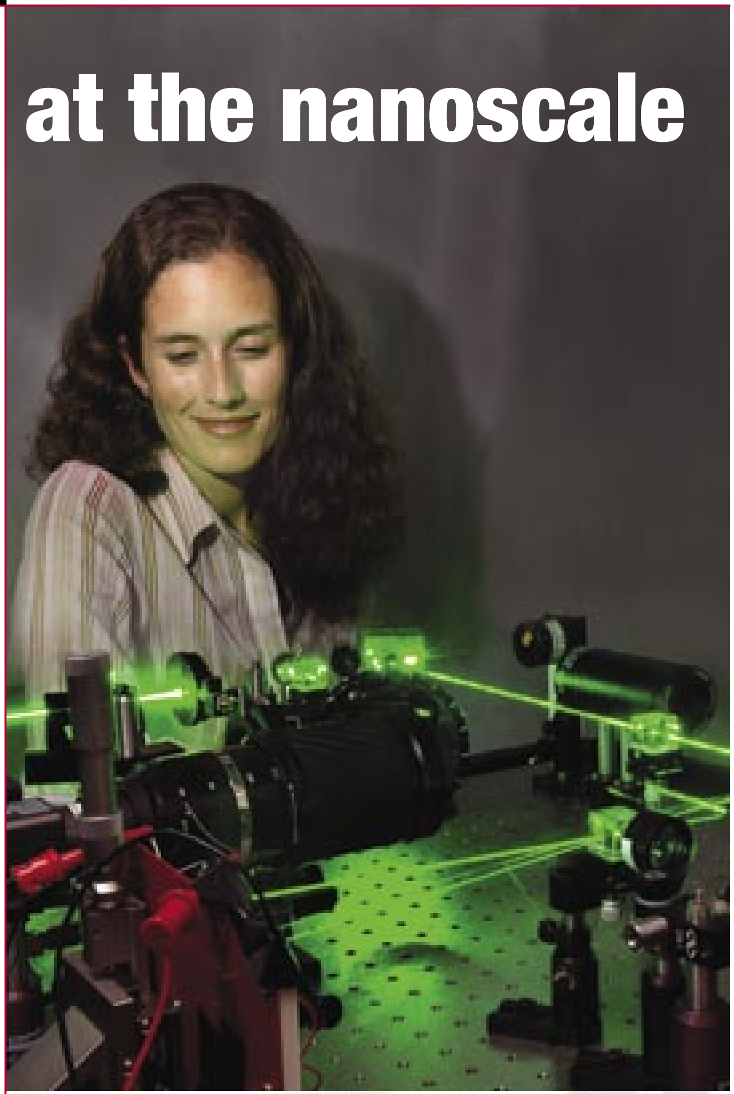
Sensing motion at the nanoscale

By exploiting a formerly unrecognized property of optics, Sandia researchers have developed a device that allows the naked eye to see motion of 10 nanometers. A nanometer is one-thousandth of a micrometer, or one millionth of a meter. The device can measure objects in the size range of individual atoms.



Sandia researcher Bianca Keeler studies very fine motion formerly unobservable by human eye, but now revealed by a laser beam interacting with an unusual diffraction grating fabricated at Sandia's Microelectronics Development Laboratory. The photo was taken by Randy Montoya using an eye-safe laser.

Imagine a tiny motion detector that is 1,000 times more sensitive than any known.

A new Sandia detector's small size — and ability to be mass produced using the same processes for manufacturing silicon computer chips — makes it promising for use in sensors measuring the earth's seismic activity, for skid and traction control in cars, and possible defense applications.

Manipulating optics

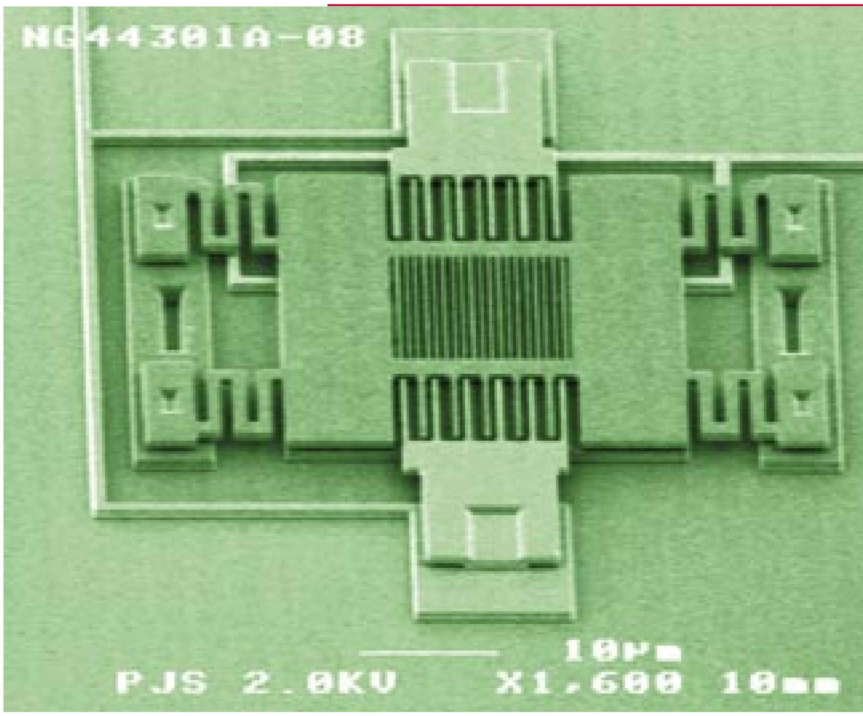
Like shadows projected onto a wall by shining light through the fingers of one hand moving over the fingers of the other, the relatively simple measuring device depends upon a formerly unrecognized property of optics: light diffracted from very small gratings that move very small lateral distances undergoes a relatively big, and thus easily measurable, change in reflection.

"There was nothing in the (optics) literature to predict that this would happen," says Sandia's Dustin Carr of the device. Carr, who gained recognition as a graduate student at Cornell for his creation of a nanoguitar and was selected in 2004 as one of the year's top 100 researchers under the age of 35 by *Technology Review*, the science magazine published at the Massachusetts Institute of Technology.

A patent application has been submitted for the device, which is still in the laboratory stage.

Small size matters

Fabricated out of polysilicon by standard lithography techniques like those used to make microelectromechanical (MEMS) devices, the Sandia system uses two tiny comb-like structures laid one over the other. The bottom comb is locked rigidly in place while the top comb is secured only by horizontal springs. Any tiny motion sends the top comb skittering



Scanning electron micrograph of the device. The top grating layer is suspended by four springs and actuated by two side comb drives. The second, fixed grating layer is hidden below the first. The area of the grating itself is 10 microns x 10 microns.

Another use would be for skid and traction control in cars, detecting whether the back end of the car is moving in a different direction from the front end.

over the bottom comb, laterally deforming the grating.

A tiny disturbance changes by an unexpectedly large amount the amplitude of light — in the visible to near-infrared range — diffracted from a tiny laser beam shining upon the apparatus. The device's small size is key to its ability to exploit this phenomenon. Features are in the 100 to 200 nanometer (nm) range, with 300 nm between the top and bottom combs and 600 to 900 nm between comb teeth. Sub-wavelength interference effects cause the visual display.

Multiple uses

"Making use of the effect is fairly obvious once you realize it happens," Carr says. The measuring device is a kind of accelerometer, about the size of the inexpensive MEMS devices that open automobile air bags. Fabricated by the same processes that mass-produce silicon computer chips, the device has multiple possible uses.

"If you can make very sensitive detectors very cheaply and very small, there are huge applications," says Carr. "Made small, synchronized, cheap, and placed on every block, we could take data from all these sensors at once and measure the motion of the earth when there's not an earthquake. So we could learn what leads up to one."

Another use would be for skid and traction control in cars, detecting if the back end of the car is moving in a different direction from the front end. The device also has potential defense applications.

"Such devices also could take the place of inertial navigation systems," Carr says. These typically require large gyroscopes to keep commercial airplanes moving on a preset course. "We could have handheld-sized devices on Volkswagens that would work even in a tunnel."

Carr estimates that it'll be three to five years before any devices are available for use.

"To my understanding, it is the first time anyone has tried to manipulate the optical near-field region in order to affect changes to the far-field characteristics of a grating, says James Walker, former director of Advanced Technologies at Tellium, Inc., former manager of the MEMS Network Element Sub-systems Group at Lucent, Bell Laboratories, and now an independent consultant and patent agent. The ability to do this is a direct result of the nanoscale nature of the device. Due to its high responsivity-to-displacement ratio, I see it having significant, far-reaching application in areas as diverse as chemical sensing, infrared imaging, accelerometry, and displays."

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Chuck Andraka makes adjustments to a Stirling Energy Systems, Inc., solar dish-engine system installed at Sandia's National Solar Test Facility late in 2004. (Photos by Randy Montoya)

Sandia and Stirling Energy Systems, of Phoenix, Arizona, have a dream: a collection of dish-engine solar systems that operates from dawn to dusk without human intervention to provide energy to clusters of homes, small industries, or on an even larger scale, to whole communities. Now they are moving forward to make the dream a reality.

Utility-scale solar

Solar dish-engine project heating up

Sandia is joining forces with Stirling Energy Systems (SES), Inc., of Phoenix, Arizona, to test six new solar dish-engine systems at Sandia's National Solar Thermal Test Facility. The systems could provide enough electricity to power 40 homes and pave the way for even larger system networks, or fields, providing power to southwestern U.S. utility companies, officials say.

One dish-engine system has been installed at the solar test facility, just south of Albuquerque, New Mexico, and five are under construction, according to Chuck Andraka, Sandia project leader. Upon completion early in 2005, the six-dish mini power array will produce up to 150 kilowatts of grid ready electricity, he says.

"This will be the largest array of solar dish-Stirling systems in the world," says Andraka. "Ultimately SES envisions systems placed in solar dish farms to provide electricity to utility companies." Andraka and other Sandia staff members are working with the company to assemble the five new systems.

Each dish-engine unit consists of 82 mirrors, formed into the concave shape of a shallow dish. This dish focuses the sun's energy on a receiver, which transmits the heat energy to a specially designed engine. The Stirling engine is a sealed system filled with hydrogen. As the gas heats and cools, internal pressure rises and falls, driving pistons inside and producing mechanical power. The mechanical power drives a generator and makes electricity.

Once the units are installed, researchers from both Sandia and SES will determine how best to integrate their power and look at reliability and performance issues.

Working in unison

The steel frame for each unit is fabricated by Schuff Steel, of Phoenix, and the mirrors are provided by Paneltec, of Lafayette, Colorado. The mirrors are laminated onto a honeycomb aluminum structure invented and patented by Sandia engineer Rich Diver. Engines will be assembled at Sandia's engine test facility, a part of the National Solar Thermal Test Facility.

Once the units are installed, researchers from both Sandia and SES will determine how best to integrate their power and look at reliability and performance issues. "It's one thing to have one system that we can operate, but a whole other thing to have six that must work in unison," says Chuck.

Sandia Researcher Chuck Andraka (left) talks with Bob Liden, Stirling Energy Systems executive vice president and general manager.

The goal is to create a unit that will operate automatically without the on-site presence of a person. It would start up each morning, operate through the day, respond to clouds and wind as needed, and finally shut itself down at day's end. Ideally, the system will be monitored and controlled via Internet, says Andraka. The controls also must be scalable to even large systems.

Right now, each prototype unit costs $150,000, says Bob Liden, SES executive vice president and general manager. Once in production, those costs could be reduced to less than $50,000 per unit, he estimates, making the cost of energy competitive with conventional fuel technologies.

Artist's rendering of a field of dish-Stirling engine systems.

Solar electricity generation is an option for power in parts of the country that are sunny, like New Mexico, Arizona, California, and Nevada, Liden notes. Units could be linked together to provide utility-scale power. A solar dish farm covering 11 square miles could produce as much power as the Hoover Dam, he says.

Another application is the operation of stand-alone units in remote, off-grid areas, such as the Navajo reservation. A unit could supply power to several homes, Liden says, and solar has already been demonstrated as an effective means of pumping water in rural areas.

30 percent conversion

Dish-Stirling systems work at higher efficiencies than other current solar technologies, with a net solar-to-electric conversion rate of about 30 percent. "This

"This on-site teaming is a new way of doing business in the energy field."

is the perfect type of electricity generation for the Southwest," says Liden. "It's a renewable resource, pollution free, and the maintenance of a solar farm is minimal.

Stirling and Sandia have been working together testing different types of solar electric generation dish engines since 1998. The company presently has 10 staff members on site at the national test facility and five additional workers who split time between Phoenix and Albuquerque. "This on-site teaming is a new way of doing business in the energy field," says Andraka. "There is no more effective way of providing technology transfer."

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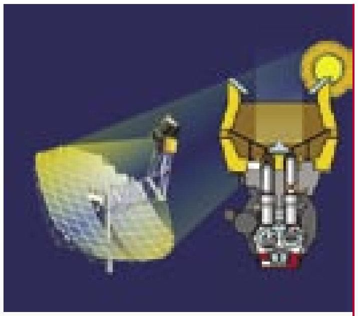


The gases used inside a Stirling engine never leave the engine. There are no exhaust valves as in a gasoline or diesel engine and there are no explosions taking place.

Stirling engines
Quiet, clean, and efficient

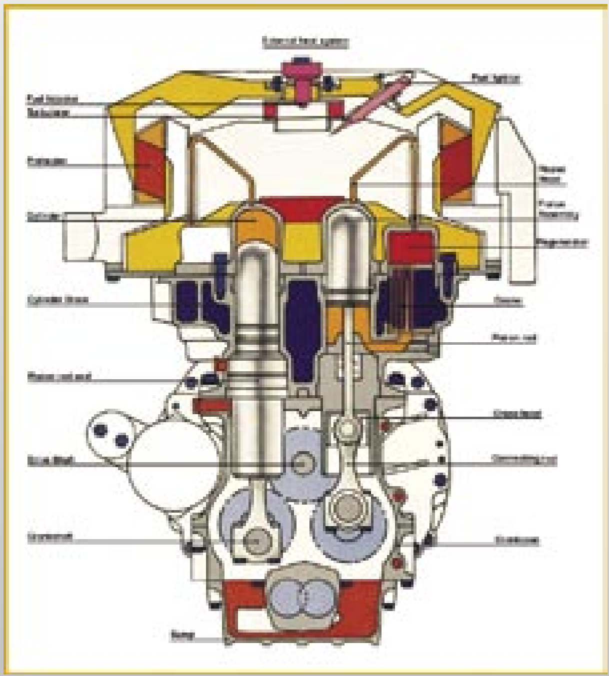
In 1816, Robert Stirling, a minister in the Church of Scotland, applied for a patent for his Economiser in Edinburgh. Although he preached into his 80s, Stirling built heat engines in his home workshop as a hobby.

Some 100 years later, the term "Stirling engine" was coined to describe all types of closed-cycle regenerative-gas engines. Today, Stirling engines are used in some very specialized applications, like in submarines or auxiliary power generators, where quiet operation is important.

Stirling engines are powered by the expansion of a heated gas, followed by the compression of the gas when cooled. The engine contains a fixed amount of gas, transferred back and forth between a "cold" and a "hot" end. A "displacer piston" moves the gas between the two ends and the "power piston" changes the internal volume as the gas expands and contracts.

The gases used inside a Stirling engine never leave the engine. There are no exhaust valves as in a gasoline or diesel engine and there are no explosions taking place. Hence the engines are very quiet. The Stirling cycle uses an external heat source.

Working with Boeing, Sandia and the National Renewable Energy Lab, Stirling Energy Systems has taken its solar dish-Stirling technology well beyond the research and development stage, with more than 17 years of recorded operating history. Since 1984, the SES dish-Stirling equipment has held the world's efficiency record for converting solar energy into grid-quality electricity.



Pursuing high-tech Law enforcement

"Crime Scene Investigations: El Paso" may not have the glitter of "CSI: Miami," but the El Paso Police Department has some technology and an approach that many in law enforcement very much admire. Through the help of the Border Research and Technology Center — operated by Sandia — and some strong local initiative, this department is providing national leadership.

When the El Paso Police Department first received camera equipment through the Border Research and Technology Center (BRTC) program, Cmdr. Mike Czerwinsky was a lieutenant in the city's vice unit, which sought to use the equipment to provide better evidence for prosecution. Working with Sgt. Darwin Armitage, a detective known affectionately as "Radar," the vice team put the equipment to work with a bang. In its first test, an undercover detective transmitted a conversation at a bar with a tiny camera hidden in a pager, while Armitage sat in the lobby nearby and watched and recorded the entire transaction using a briefcase full of equipment.

"Our old equipment was bulky, hard to hide, costly, and expensive to maintain," says Sgt. Armitage, who worked with Sandia's Richard Sparks to put the equipment, dubbed the "Investigator's Toolkit" into use. "The new equipment had all the pieces — time-and-date stamps, recording units, cameras, transmitters — and everything was off the shelf."

The resulting tapes cut the number of vice cases going to court by about 50 percent, generating instead an increase in plea bargain cases. "This had a direct impact on our operations," says Czerwinsky.

Next Czerwinsky pressed Armitage to develop the technology for forensics use. The idea was to use the same concept, transferring the technology to major crime scenes. To improve investigations and avoid crime scene contamination, a crime scene tech would wirelessly transmit a video feed to a nearby command post where the investigators could view it.

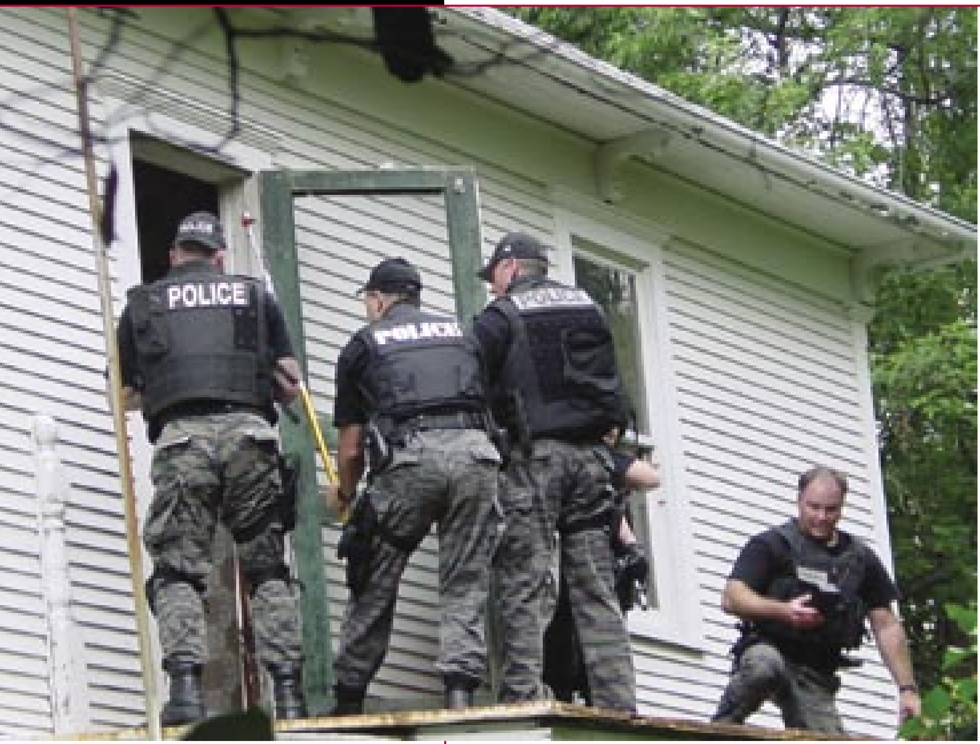
Sgt. Darwin Armitage checks out SWAT helmet he helped design for the El Paso Police Department. Armitage has used Sandia's Investigator's Toolkit successfully for a number of projects in recent years.

Armitage developed the concept of attaching a transmitter to a handheld video camera, where the scene could be surveyed, objects could be looked at closely by zooming, and a record could be made without touching any objects. One strong plus was that detectives outside the scene could direct the recording. The first use of the technology on an actual homicide proved to be "a home run," says Czerwinsky.

Detectives observing the scene on a monitor outside a victim's home noticed some mail on a desk and asked the recording technician to zoom in. A return address on one of the letters identified a person incarcerated at an out-of-state detention facility. This in turn provided investigators a possible motive early in the investigation.

"In a homicide the first 24 to 48 hours are critical to solving a case, and this is a tool that helps save time on a number of fronts," says Czerwinsky. The tape provides help to both the field investigators and those conducting interviews away from the site, helping them to get a better idea of what happened. "You can't articulate some of this information without the video," Czerwinsky notes.

"In the area of teleforensics, the El Paso Police Department is the pathfinding



Police in La Vista, Nebraska, used Sandia's Investigator's Toolkit to develop a pole camera for use in this hostage exercise. As officers enter a suspect's house, the pole camera provides video images to a neck-worn monitor of an officer on the team (kneeling) and to other officers in a nearby command vehicle.

This tool provides important information at critical incidents, as "what the SWAT officer sees" is transmitted to a command post to supplement the decision-making process.

agency," says Sandia's Chris Aldridge, who is the BRTC director, based in San Diego, California. The center, with National Institute of Justice funding, helped the El Paso department get started with some equipment in 1999. From there Czerwinsky and his team have taken the project to new levels.

For Aldridge, the BRTC is a way to work with a multitude of law enforcement and legal agencies to strengthen technology capabilities and awareness. The BRTC is part of the National Law Enforcement and Corrections Technology Center system, a program of the research and development arm of the Department of Justice. The Center has paired Sandia with a number of agencies in this technology transfer effort. The results in El Paso have been particularly successful.

At a scene now, with the addition of a special SUV mobile command center and 27-inch monitor, the recording technician can transmit information to help the crime scene unit determine what special resources may be needed, help detectives understand what happened and when, and help others, such as medical examiners, speed their work. "The bottom line is it accelerates the investigation. You can't replace lost time," Czerwinsky says.

Phase 3: Critical events

As a police commander, Czerwinsky has taken the camera technology toward what he calls "phase three." Armitage, in consultation with Sandia's Sparks, has developed a pole camera (for peeking around corners) and a helmet camera as extensions of the original Investigator's Toolkit.

The two devices, with implications for riots, hostage situations, or other critical events, were tested at a mock high school hostage exercise. This tool provides important information at critical incidents, as "what the SWAT officer sees" is transmitted to a command post to supplement the decision-making process. "It's an invaluable tool when split-second decisions have to be made," Czerwinsky says.

Cost has been a driving force in all of these efforts. Armitage describes working with BRTC as a 'What do you want?' arrangement. "We want plug-and-play equipment that we can build upon for different needs. We want inexpensive equipment that will interface, not several proprietary competing systems," says Armitage.

Because 80 percent of U.S. law enforcement agencies have 50 or fewer officers or less, "a place with 25 deputies just isn't going to have the budget for most of this expensive stuff," Czerwinsky adds. "The center is a place where you have the labs and where we have a national law enforcement technology council. These people speak our language. This is where it is coming together. Chris Aldridge and Richard Sparks have been instrumental in opening doors for us," Czerwinsky says.

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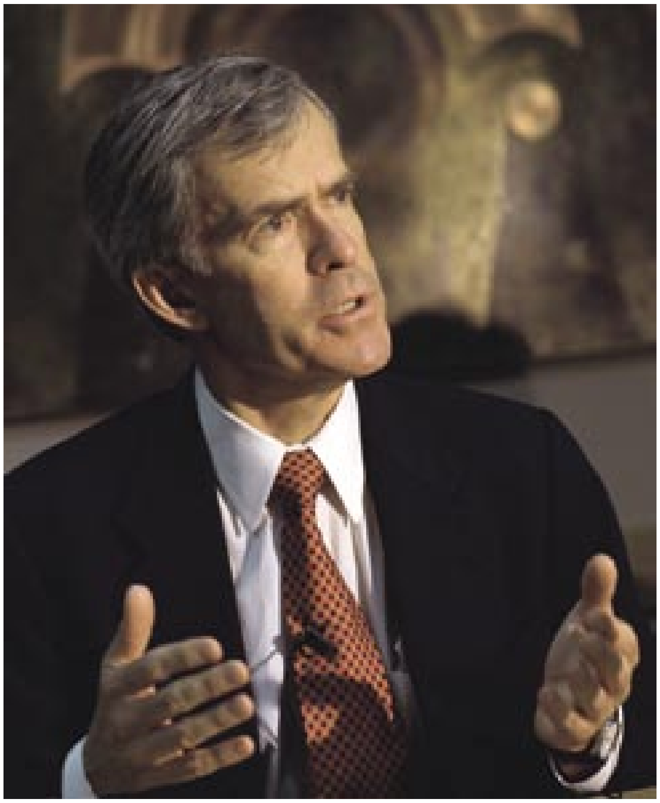
INSIGHTS

By U.S. Senator Jeff Bingaman



"Clearly, technology has been proven as essential in aiding law enforcement, whether by solving crimes or preventing them."

Sandia National Laboratories does an outstanding job meeting its primary mission, namely supporting the country's stockpile stewardship program. But it would be a mistake to view Sandia as merely a nuclear weapons laboratory. Sandia is home to some of the most important and exciting scientific research and development happening right now in our country, programs I am proud to strongly support, including nanotechnology and renewable energies that have significant applications in our everyday lives.

One area where Sandia has made an important contribution is in law enforcement. A decade ago, I was pleased to help secure $41 million in authorized funding for an initiative between the Department of Defense and the Department of Justice aimed at enhancing law enforcement capabilities and peacekeeping activities. This initiative funds targeted coordinated action between federal agencies, such as the Border Research and Technology Center (see story on page 15.)

Through its School Security Technology Center, which I was pleased to help create several years ago, Sandia has also been an extremely valuable resource for schools across the country. The center offers security expertise, effectively deterring crime on campuses and making schools safer.

Clearly, technology has been proven as essential in aiding law enforcement, whether by solving crimes or preventing them. In the years to come, I will be working hard to ensure that Sandia continues to play an important role researching and developing the kind of technology that protects our communities and improves our quality of life.

The author, Sen. Jeff Bingaman, D-NM, was born and raised in Silver City, New Mexico. He earned a Bachelor of Arts degree from Harvard University and then entered the Stanford University School of Law, graduating in 1968. Bingaman was elected Attorney General of New Mexico in 1978. He was elected to the U.S. Senate in 1982, where he continues to serve.

"Clearly, technology has been proven as essential in aiding law enforcement, whether by solving crimes or preventing them. In the years to come, I will be working hard to ensure that Sandia continues to play an important role researching and developing the kind of technology that protects our communities and improves our quality of life."

U.S. Senator Jeff Bingaman

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