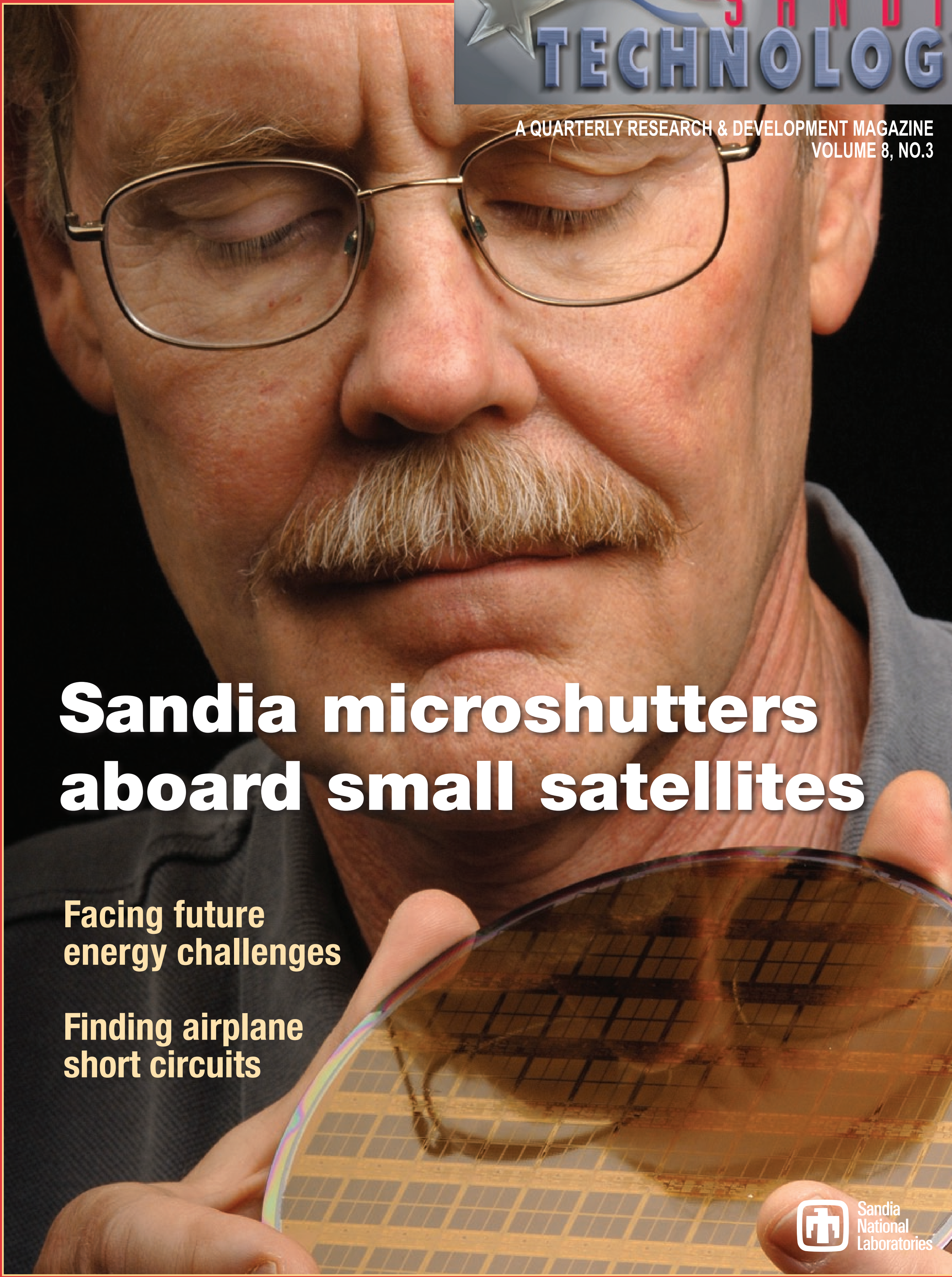
FALL • 2006

SANDIA TECHNOLOGY

A QUARTERLY RESEARCH & DEVELOPMENT MAGAZINE
VOLUME 8, NO.3



Sandia microshutters aboard small satellites

Facing future energy challenges

Finding airplane short circuits

Sandia National Laboratories

What is LDRD

Sandia's world-class science, technology, and engineering work defines 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 stretches the Labs' science and technology capabilities.

LDRD supports Sandia's four primary strategic business objectives: nuclear weapons; energy resources and nonproliferation; defense systems and assessments; and homeland security and defense. 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:

Sandia's Jim Allen examines a louver-laden wafer with moving grillworks of shutters. Shutter slats measure six microns wide and 1,800 microns long.
(Photo by Randy Montoya)

Sandia Technology (ISSN: 1547-5190) is a quarterly magazine 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 website at *www.sandia.gov*

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FROM THE *Editor*

Dear Readers,

Sandia National Laboratories has just recorded its 74th and 75th R&D 100 awards. These are the latest in a series of engineering and scientific accomplishments going back to 1976. In that year, two Sandia engineers won for the development of a machine for solder coating and hot-air leveling.

In recent years, more and more of the awards have been won in partnerships between Sandia, our academic partners, and companies out there in private industry. Thanks to the State University of New York, the University of Illinois, Cray Inc., the High Power Battery Systems Company, and General Atomics, that trend continues.

Another observation about these awards and the fact that we have been a consistent winner over the years is that our engineering expertise has sparkled in this competition. Although these pages are often full of the term “researchers” and “scientists,” the truth is that Sandia is a premier engineering laboratory, where science and application come together.

At mid-summer, Sandia’s technical staff included 2,580 engineers of various types, with a heavy emphasis on electrical and mechanical engineering. Another 630 technical staff members are grouped under the educational heading of “computer” by our HR statisticians. No doubt a significant number of them are also engineering graduates. We’ve got physicists, mathematicians, chemists, and earth scientists as well, but Sandia has always had an eye — and a reputation — for successfully tackling engineering challenges.

The rest of this issue is a testament to that fact, with articles on wind energy, energy security, nanotechnology, aircraft safety, high-temperature electronics, and several successful Sandia-private sector work agreements.

Will Keener
Editor

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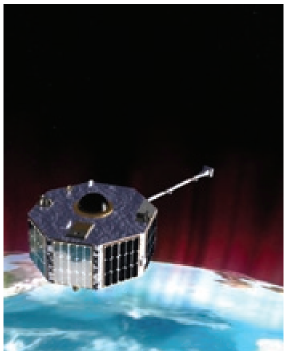
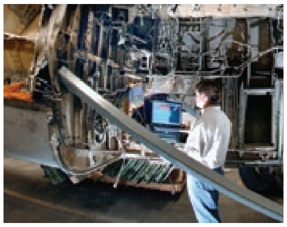
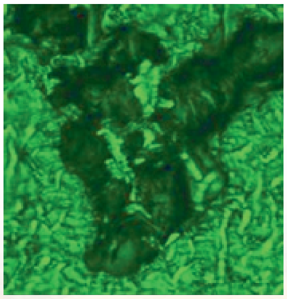
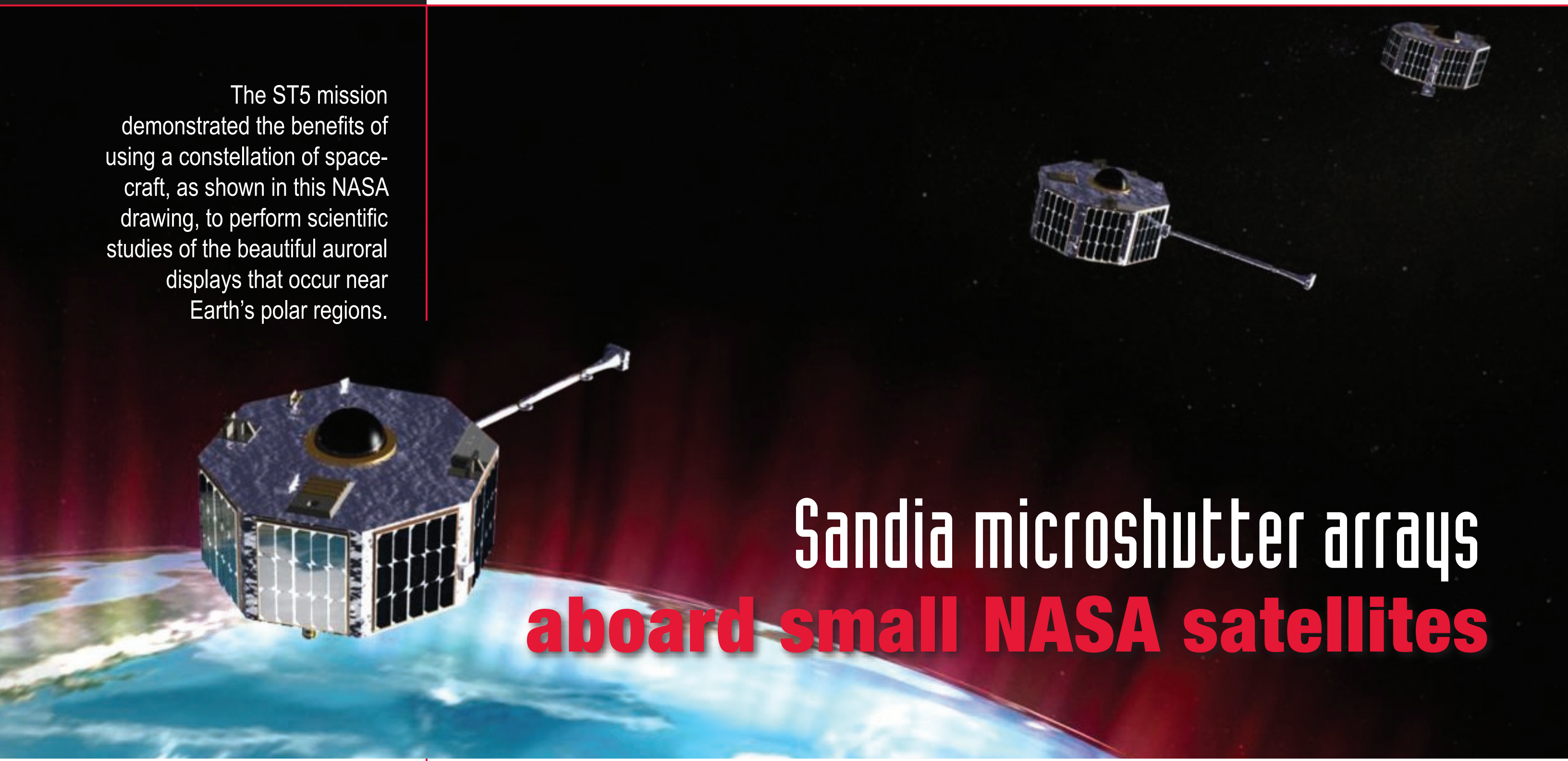


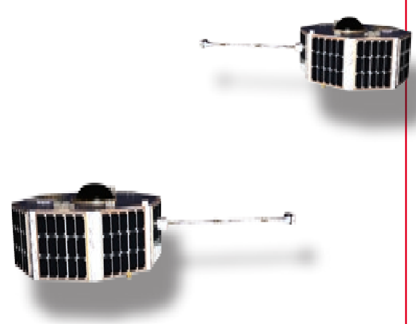






The ST5 mission demonstrated the benefits of using a constellation of space-craft, as shown in this NASA drawing, to perform scientific studies of the beautiful auroral displays that occur near Earth's polar regions.

Sandia microshutter arrays aboard small NASA satellites



Satellite designers pay special attention to electronics temperatures. If circuit boards get too hot, they can fail. If batteries get too cold, they can degrade faster or perform intermittently.

Temperatures inside satellites can fluctuate to both extremes, heating up when in sunlight or cooling way down when in Earth's shadow, for example. The heat generated by the electronics themselves can be trapped inside the satellite. Larger satellites have sophisticated, and heftier, thermal control systems. Smaller ones, like the 55-pound Space Technology 5 experimental microsatellites — each roughly the size of a wedding cake — require smaller, lighter-weight, and, ideally, lower-tech approaches.

In 2001 researchers from Johns Hopkins University's Applied Physics Lab were attending a MEMS (microelectromechanical systems) short course at Sandia when the need for innovative microsatellite thermal control methods came up. The visitors were part of a Johns Hopkins team supporting the then-planned ST5 mission.

A collaboration was launched, and Sandia project lead Jim Allen and a team of MEMS designers worked with the Johns Hopkins researchers to design, using Sandia's SUMMiT V™ technology, a MEMS device featuring a moving grillwork of shutters with slats that are six microns wide and 1,800 microns long. (A human hair is about 100 microns thick.)

The arrays of small shutters, moved back and forth by electrostatic actuators, expose either the gilded and highly reflective grillwork surface or a dark silicon substrate to maximize or minimize heat transfer through the satellite's skin as needed. The electrostatic actuators — themselves arrays of intermeshing, spring-loaded comb's teeth pulled together by electrostatic attraction — are a proven micromotion staple also developed at Sandia.

Satellite skin

Two of the three ST5 satellites have on their top and bottom decks four-inch-square arrays of micro-louvers. A single array includes some 2,600 individual electrostatically driven devices. Each device — grillwork and actuator together — is

Arrays of tiny shutters made at Sandia are serving much the same purpose as home window blinds — helping regulate interior temperatures — aboard small experimental satellites launched in March as part of NASA's ST5 mission. The mission demonstrated innovative technologies for a new generation of autonomous microsatellites.

approximately the size of the cross on this letter "t."

Sandia's Microelectronics Development Laboratory fabricated and delivered 12 louver-laden wafers for the ST5 satellites to Johns Hopkins in October 2002. Johns Hopkins performed the packaging, integration, and space-qualification testing.

Each array weighs just grams and consumes nanowatts of power when changing states, from open to closed or vice versa, and no power (only voltage) to maintain a position.

In all, Sandia has 90 square centimeters of louvers flying aboard two of the three microsatellites, which have been in an elliptical polar orbit 200 to 3,000 miles above Earth since March 22. The three-month experimental mission ended June 22, but as of late summer the satellites continued to operate.

"The MEMS variable-emittance louvers have performed successfully during their three-month mission," says Ann Darrin, program manager at Johns Hopkins Applied Physics Lab. "This is the first time a fully space-qualified device of this type has ever been flown [in space], and the first to be flown on the outside of a satellite."

Ten new tools

As a result of ST5, spacecraft designers have 10 new tools to work with, says Ray Taylor of NASA's Science Mission Directorate, speaking of the new technologies flown on the mission. "And tools that are not only smaller, lower power, and less expensive, but because of ST5 they will be proven in space," he says. "Therefore, they can be used with a high degree of confidence in future missions."

"I'm kind of in awe that these MEMS devices are in space," says Sandia's Allen. "It's a pretty cool milestone for MEMS devices. I think it's great that Sandia could be a part of it."

For information about the Space Technology 5 mission's technology and detailed results, visit: http://www.nasa.gov/st5

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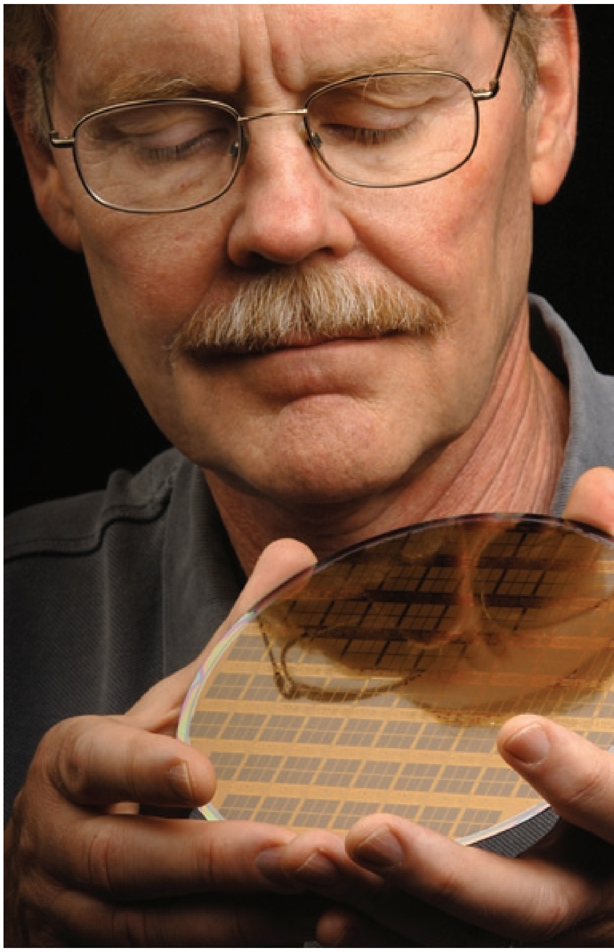
NASA's Space Technology 5 was launched from Vandenberg Air Force Base, California, on a Pegasus XL rocket like the one shown here.



Sandia's Jim Allen examines a louver-laden wafer with moving grillworks of shutters. Shutter slats measure six microns wide and 1,800 microns long.

NEWS NOTES

Sandia wins two R&D 100 Awards

Supercomputer processing of simulations, like the one shown here, are more efficient with Compute Process Allocator. (Photo by Randy Montoya)

Heated to 250 degrees C and crushed under 60 tons of pressure, the battery at the right continued to function as expected.

Researchers at Sandia National Laboratories and their collaborators have won two R&D 100 awards, which are presented by *R&D Magazine* in recognition of the 100 most technologically significant products introduced into the marketplace over the past year.

Sandia winners include:

- **Compute Process Allocator**, a computer algorithm technology that increases processing efficiency on massively parallel supercomputers. Developed in conjunction with colleagues at the State University of New York and the University of Illinois, the technology was licensed to Cray Inc. in 2005.
- **HTSS10V**, a solid-state, fluoride-based battery that is safer than traditional batteries in high-temperature applications, such as oil, gas, and geothermal drilling. HTSS10V was developed in conjunction with the High Power Battery Systems Company in Nizhny Novgorod, Russia, and General Atomics.

"I congratulate the researchers who have won these awards, which highlight the power and promise of DOE's investment in science and technology," Secretary of Energy Samuel W. Bodman said. "Through the efforts of dedicated and innovative scientists and engineers at our national laboratories, DOE is helping to enhance our nation's energy.

The **Compute Process Allocator's** principal application is to maximize throughput on massively parallel supercomputers by managing how processors are assigned to particular computing jobs, given a stream of computing jobs submitted to a job queue. Applications vary and include nanoscience, astrophysics, global climate change, and military missions.

The CPA assigns each job to a set of processors, which are exclusively dedicated to the job until completion. The CPA obtains maximum throughput by choosing processors for a job that are physically near each other, minimizing communication and bandwidth inefficiencies.

In experiments at Sandia, the optimized node allocation strategy employed by CPA increased throughput by 23 percent, in effect, processing five jobs in the time normally required to process four. The CPA is scalable to tens of thousands of processors and is currently being used on supercomputers at Sandia (Red Storm), Oak Ridge National Laboratory, Engineer Research and Development Center Major Shared Resource Center, Pittsburgh Supercomputing Center, and the Swiss Scientific Computing Center.

HTSS10V solid-state fluoride ion batteries have nearly the same energy density as lithium sulfuryl batteries, while being inherently safe. The battery consists of nontoxic fluoride, and all three battery components — anode, cathode, and ionic conductor — are solid, making it the best and safest choice for high-temperature activities. Traditional lithium batteries are at risk of exploding or leaking chemicals under high-temperature uses. Solid-state battery technology offers the largest temperature range — room temperature to 500 degrees Celsius — of any battery technology.

Other advantages of solid-state batteries include the ability to be flown on commercial aircraft and to be stored safely on drill rigs. Longer shelf life and greater reliability give HTSS10V batteries advantages for battery backup on life support systems during emergencies and possibilities for laptop computer applications.

Limited production of the batteries began in 2005 at Russia's VNIIEF Institute. Under a joint program with Sandia and General Atomics, the batteries will be produced in Sarov, Russia, and in San Diego, California, for oil and gas drilling use.

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A preemptive spark, lasting for nanoseconds, can help find potentially dangerous short circuits hidden in the miles of wiring behind the panels of aging commercial airliners. Patented by Sandia, the rapid technique may make it financially feasible for airlines to quickly diagnose and repair the hard-to-locate intermittent faults that have plagued the industry and cost millions of dollars due to aircraft downtime.

Finding airplane short circuits before they cause trouble

The challenge to aeronautical engineers has been how to locate an intermittent wiring fault before — not after — it becomes a problem and scuttles an aircraft. Intermittent electrical short circuits in aging commercial airliners range from the trivial to the deadly. They can make cabin lights blink, air conditioning falter, or even cause fatal crashes, as with flights SwissAir 111 and TWA 800.

The trick of the Sandia-patented Pulsed Arrested Spark Discharge, or PASD, is to make the short circuit appear before it normally would and to do so on the ground so that technicians can fix it. To achieve this, the Sandia method sends a nanosecond pulse of electricity, fiercely propelled by high voltage, along airplane wiring bundles. The tiny pulse is powerfully driven so that it can jump gaps in slightly frayed insulation but has so little energy that it is harmless.

Because the voltage is higher than that normally used in airplanes, the electrical pulse will jump like a rabbit from the smallest wiring insulation fault (which to ordinary instrumentation seems undamaged) either to the bulkhead or to another nearby damaged wire. That spark — like static electricity leaping from hand to doorknob — in effect lights up the invisibly damaged spot like a tracer bullet lights up a night target. The amount of time it takes for the

Larry Schneider (left) and Mike Dinallo prepare to employ the PASD diagnostic on a wiring bundle in the cockpit of a retired Boeing 737. (Photo by Randy Montoya)

LDRD

Inspecting electrical wiring in the wheel well of a retired Boeing 727 at Sandia's FAA Airworthiness Assurance NDI Validation Center. The wing on the 727 has been removed. (Photo by Randy Montoya)

current to return to its source is analyzed by the automated test-set to tell within inches how far the break is from the test entry point.

The device, about the size of a small suitcase, can be plugged into aircraft-installed wire harnesses, 40 wires at a time, to check for the very small insulation breaks associated with intermittent faults.

"Rather than reacting to a problem, these systems can find a fault before it manifests into a catastrophic event," says Sandia team leader Larry Schneider. "Rather than ripping apart the fuselage for access to a faulty harness that may run the length of the plane, airline mechanics will be able to use this new tool to efficiently locate and repair the intermittent fault."

Pinhole size

Sporadic short circuits occur where two exposed conductors, or a conductor and aircraft frame, make temporary contact during flight. Vibrations caused by turbulence may cause wires to touch, interrupting power to sensitive electronics and possibly damaging wires. These conditions are tricky to diagnose when the aircraft is on the ground because the shorting wires often have shifted back to a non shorted state. Sometimes these breaks can barely be seen by the naked eye because missing insulation may be the size of a pinhole and nearly invisible. Traditional wire-test systems have great difficulty finding these faults.

To overcome many problems besetting the promising technique, the DOE's National Nuclear Security Administration and the U.S. Navy initially supported the research, followed by the Federal Aviation Administration, to the tune of about $2 million. It took two years for Astronics, of Redmond, Washington, to adapt it to its suite of tools, which were developed over years of research to locate wire breaches with the potential for electrical shorting.

"Wiring insulation grown defective over time can cause malfunctions or even fires. . . "

— Larry Schneider Sandia team leader

Says Astronics team leader Mike Ballas, "We really value PASD technology. We licensed it, turned it into a practical portable test unit targeted for the aviation industry to find intermittent faults, and we believe it's the best way now to do the job. It's a nice complement to our patented technology."

"It would have been unfortunate if PASD had been developed and then remained stuck in a lab. Integration of the technique [with Astronics' ArcSafe technologies] is a real success story," says Robert Pappas, FAA project manager for aging aircraft research and the first to recognize the value of Sandia's original research proposal in 1998.

Gaining acceptance

There are still problems to surmount in gaining acceptance of the method, says Mike Walz, current FAA overseer of the project. For one thing, he says, "What PASD looks like is an electrostatic discharge [ESD] — something aircraft manufacturers work hard to keep out of their wiring system."

Astronics welcomed the addition of PASD because of other problems involving the varying resistance of wires over long distances, particularly in the branched wiring systems prevalent in aircraft. This was a problem for earlier versions of the company's ArcSafe, which used a DC current to detect breaks. Varying resistance meant it was difficult to accurately locate an intermittent fault, since electrical return signals were inconsistent, especially on complex wire geometries. (The DC method remains the most effective for identifying ordinary faults, and Astronics has retained it for quick fault screening.)

To enhance its fault-locating ability, Astronics developed a method that allows a PASD pulse to ride on the DC current like a rider on a horse. The DC current provides support for the high-voltage pulse, which then can accurately locate critical breaches in wire insulators, even those occurring on branched wire harnesses, even a hundred feet from its starting point in.

Kevin Howard prepares to acquire PASD data on electrical wiring in the wheel well of a retired Boeing 727. (Photo by Randy Montoya)

Devil in the details

"Wiring insulation grown defective over time can cause malfunctions or even fires, but is devilishly hard to spot and even harder [once spotted] to [exactly] locate," says Sandia's Schneider. "Other methods have faltered when confronted with the varying resistances of bundles of wires, or the difficulty of providing the exact location of the defect as wiring bundles branch into other bundles. This nondestructive, inexpensive method not only detects cracking or pinholes but also is able to pinpoint the defect's precise location to facilitate wire replacement."

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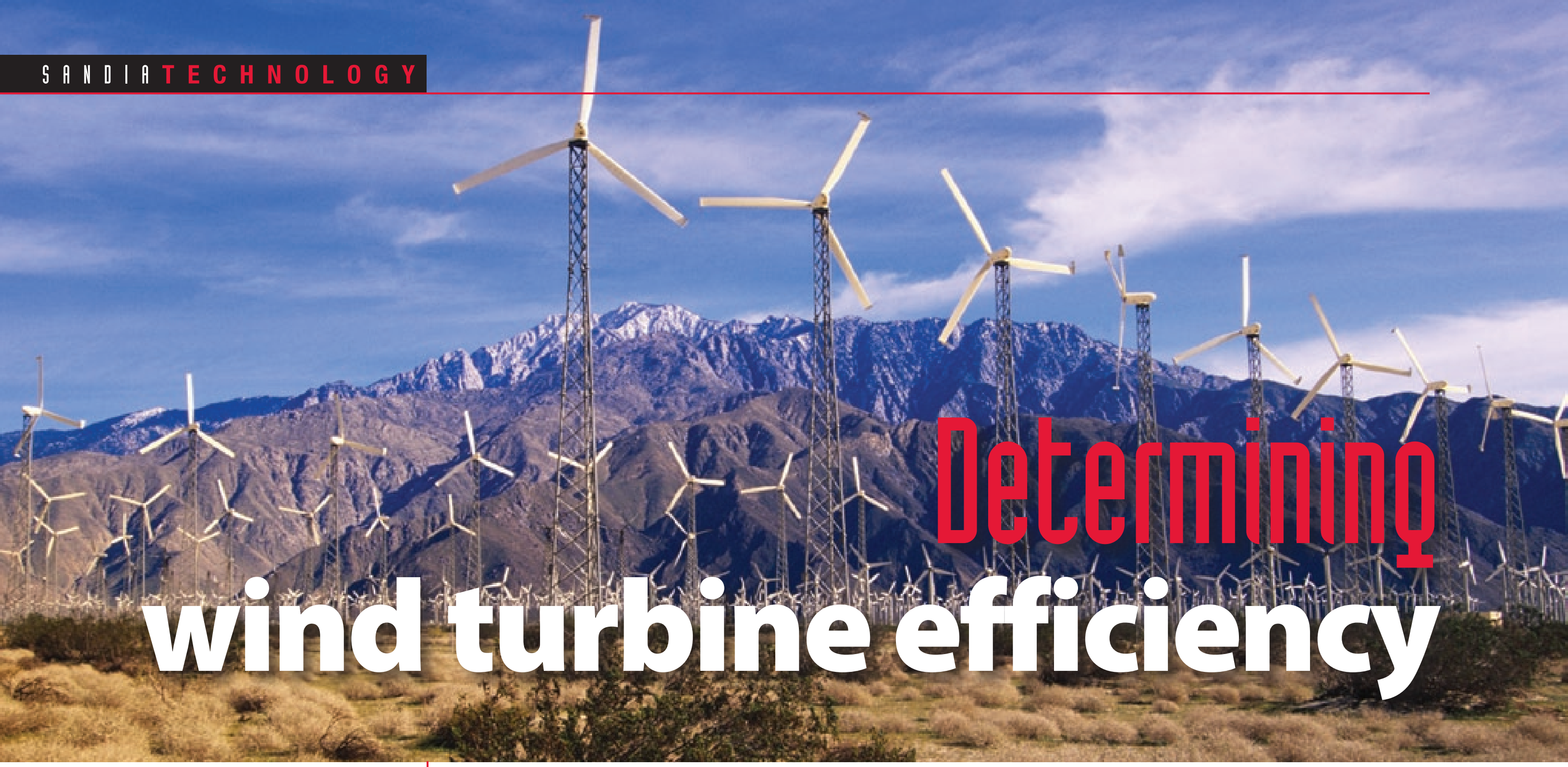


Determining wind turbine efficiency

Throughout most regions of the U.S. and in other places around the world, wind turbines are being used with increasing frequency to generate electricity. As power utilities gear up to generate this environmentally friendly form of energy, engineers are working to determine the efficiency and health of the turbines.

Housed in an environmentally protected aluminum box, ATLAS II is capable of sampling a large number of signals at once to characterize the inflow, the operational state, and the structural response of a single wind turbine or a group.

ATLAS II is small, operates continuously, uses off-the-shelf components, and has lightning protection on all channels to increase reliability. "The system provides us with sufficient data to help us understand how our turbine blade designs perform in real-world conditions, allowing us to improve on the original design and our design codes," says Jose Zayas, the project lead. Zayas has been working on ATLAS II since its inception in 1999.

Last year he and his Sandia team completed a project with GE Energy and the National Renewable Energy Laboratory (NREL) to monitor the performance of a GE wind turbine at a Great Plains site about 30 miles south of Lamar, Colorado. The team will soon start monitoring a new project with Texas Tech University.

The GE Energy/NREL/Sandia collaboration involved testing a 1.5-megawatt, 80-meter-tall turbine with a rotor diameter of 70.6 meters. GE Energy is the largest wind turbine manufacturer in the U.S. and sells them to developers — such as Florida Power & Light — all over the world. Wind plant operators sell the electricity to utilities, who in turn supply the power to consumers.

The GE turbine was equipped with four ATLAS II units, collecting a total of 67 measurements, including 12 to characterize the inflow, eight to characterize the operational state of the turbine, and 24 to characterize the structural response. The system collected data continuously, 24 hours a day, seven days a week. The four

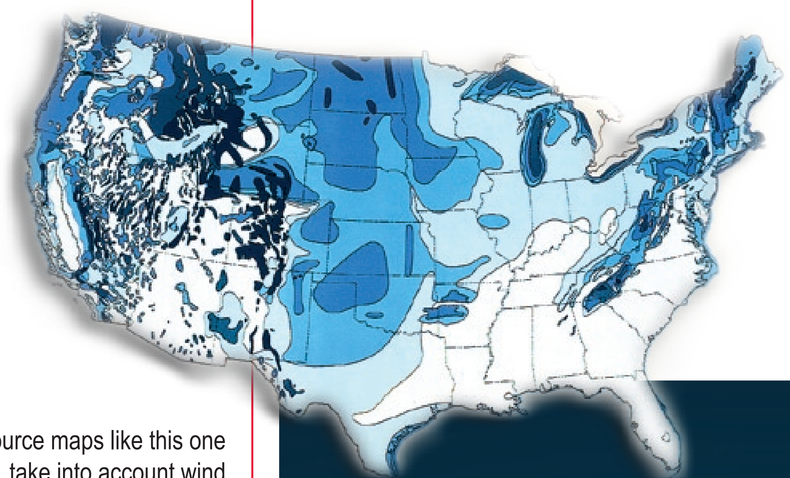
ATLAS II project lead Jose Zayas with advanced blades that will be tested at Bushland, Texas.

units were placed at various locations on the turbine, and a GPS time stamp was used to maintain synchronization between the units. All data streams were merged at the base of the turbine, where ATLAS II software compressed the data and stored them on a local computer.

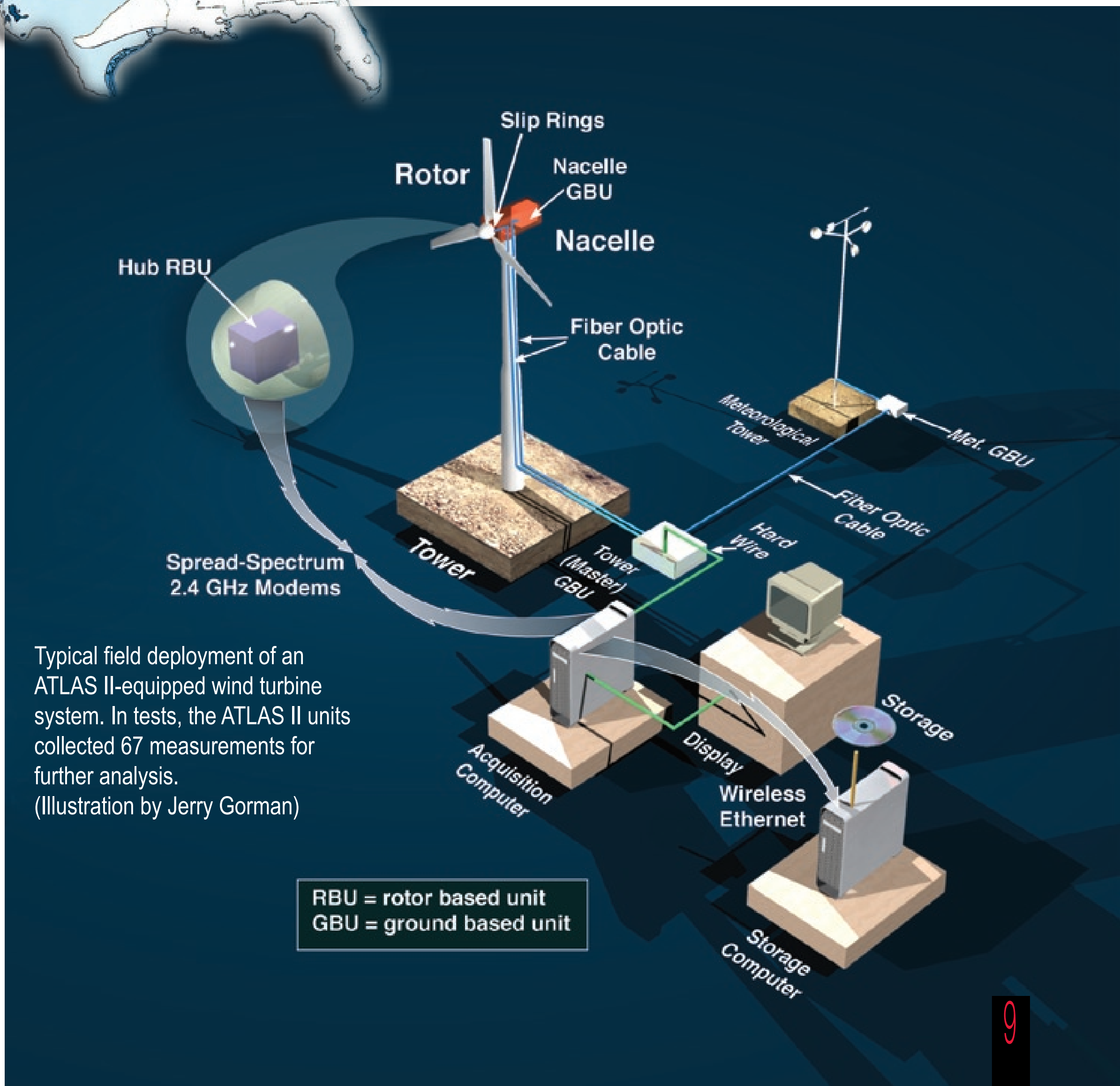
Data collection efforts continued for four months, with more than 17,000 data records collected, for a total of 285 Gigabytes of data. Because the turbine was located at a remote site, the data were transmitted to NREL via a satellite link and later passed to Sandia. In places where there is access to the Internet, the data can be monitored in real time.

The Texas Tech project began in August with an environmental monitoring box placed on a 200-meter meteorological tower at a test site near the campus in Lubbock. The university is expected to eventually erect a utility-size wind turbine. The ATLAS II will be used to collect data from the turbine.

Sandia also is planning three experiments using the ATLAS II to monitor the performance of three advanced blade designs on a test turbine it operates in conjunction with the U.S. Department of Agriculture's research station in Bushland, Texas.



Wind resource maps like this one from NREL take into account wind speed and terrain factors to arrive at a wind classification system. Most of the U.S. is suitable for wind energy, with the exception of the southeastern U.S.



Typical field deployment of an ATLAS II-equipped wind turbine system. In tests, the ATLAS II units collected 67 measurements for further analysis.
(Illustration by Jerry Gorman)

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Testing living cells' influence on nanostructure growth

When the space shuttle Discovery lifted off July 4, it carried unusual cargo — simple brewer's yeast housed in microscopic glass structures — as part of a Sandia-University of New Mexico experiment. The tiny yeast samples are being tested outside the International Space Station fully exposed to cosmic radiation and the vacuum of outer space.

Far above us, arrays of single-cell creatures are circling Earth in nanostructures. The devices are riding on the International Space Station to test whether nanostructures whose formations were directed by yeast and other single cells can create more secure homes for their occupants — even in the vacuum and radiation of outer space — than those created by more standard chemical procedures. The ride is courtesy of Sandia National Laboratories, the University of New Mexico, NASA, and the U.S. Air Force.

"Cheap, tiny, and very lightweight sensors of chemical or biological agents could be made from long-lived cells that require no upkeep, yet sense and then communicate effectively with each other and their external environment," says Sandia consultant Helen Baca, lead author on a paper about the experiments published July 21 in *Science*. Sandia Fellow and UNM professor Jeff Brinker advised Baca on the project, which was part of her doctoral research.

Groups of such long-lived cells may serve as models to investigate how tuberculosis bacteria survive long periods of dormancy within human bodies and they may be used to generate signals to repel harmful bacteria from the surfaces of surgical tools. The experiment may also offer a simple way to genetically modify cells.

Customized construction

In the paper in *Science*, Baca explains that a team of researchers from Sandia and UNM, under Brinker's leadership, demonstrated that common yeast cells (as well as bacterial and some mammalian cells) customize the construction of nanocompartments built for them. These nanocompartments — imagine a kind of tiny apartment house — form when single cells are added to a clear, aqueous solution of silica and phospholipids (cell membrane molecules), and the slurry is then dried on a surface.

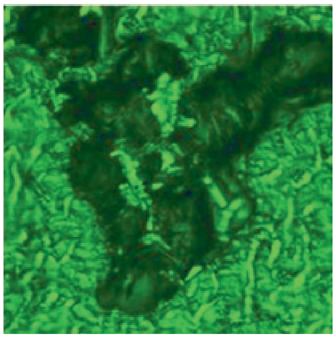
Ordinarily, the drying of lipid-silica solutions produces an ordered porous nanostructure by a process known as molecular self-assembly. This can be visualized as a kind of tract housing. In the current experiments, however, live yeast or bacteria alter the construction process. During drying, the cells actively organize lipids into a multi layered cell membrane that serves as an interface between the cell and the surrounding silica nanostructure and acts as a template, helping to direct the formation of the surrounding silica nanostructure.

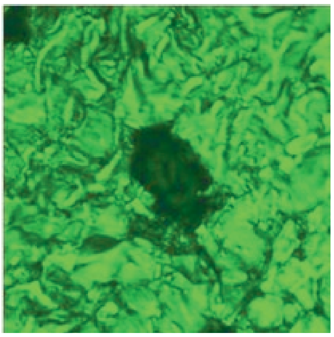
This improved architecture seamlessly retains water, needed by the cell to stay alive. Further, by eliminating stresses ordinarily caused by drying, the nanostructure forms without fine-line cracks. These improvements help maintain the functionality of the cell and the accessibility of its surface.

The cells are self-sustaining — they do not need external buffers and even survive being placed in a vacuum. To study their use as cell-based sensors for extreme environments, samples of the yeast- and bacteria-containing nanostructures were launched on the U.S. space shuttle *Discovery*. On the International Space Station, experiments are being performed to determine cell longevity when exposed to the radiation and vacuum of outer space.

Water reservoir

"Ordinarily, exposed to such extreme conditions, the cells would turn into



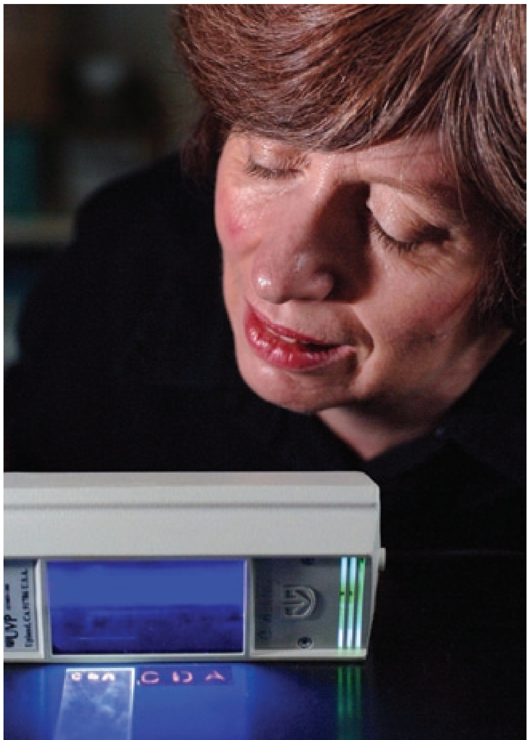


Topographical confocal projections of cells, which have integrated onto predefined lipid-silica films. The darker parts are the cells that have redistributed the green fluorescent lipid from the plane of the thin film into three dimensions around the cells. (Slides by Eric Carnes)

raisins," says Brinker. But previous testing has shown "a remarkable coherency of the cell-lipid-silica interface and the ability of the lipid-silica nanostructure to serve as a reservoir for water; no cracking or shrinkage is observed. The cells are maintained in the necessary fluidic environment."

"We know they can withstand quite a bit of radiation," says Baca. The samples have survived exposure to powerful X-rays and the vacuum of an electron microscope, The entrapped cells easily absorb other nanocomponents inserted at the cellular interface. Because of this, a cell can internalize new DNA, providing an efficient form of genetic modification of cells without the usual procedures of heat shock or cumbersome puncturing procedures that can result in cell death. For example, the yeast can be modified to glow fluorescent green when they contact a harmful chemical or biotoxin. Because such nanostructures are cheap, extremely light and small, and easy to make, they could conceivably be attached to insects and their emanations read remotely by beams from unmanned aircraft.

The method also makes it easier to prepare individual cells for laboratory investigation under microscopes. "Normally, to visually examine a cell, researchers use time-consuming fixation or solvent extraction techniques," says Brinker. "We can spin-coat a cell in seconds, pop the cell into an electron microscope, and it doesn't shrink when air is evacuated from the microscope chamber." (Spin-coating refers to deposition of the cell slurry on a spinning substrate until dry.)



Helen Baca looks over the letters "CDA," standing for cell-directed assembly, prepared by UNM grad student Eric Carnes, who for the picture stained an estimated 10 billion yeast cells with nucleic acid. (Photo by Randy Montoya)

Understanding TB

Assistant Professor Graham Timmins of UNM's College of Pharmacy notes that the encapsulated cells' unusual longevity may serve as a model for persistent infections such as tuberculosis, which has a long latency period. TB bacteria can remain dormant for 30 to 50 years and then reactivate to cause disease. Presently, the state of the dormant bacterium is not understood. Timmins and Brinker are discussing further experiments to validate the model.

Finally, building the cells into a coating with a high enough density might elicit from them a defensive, multi cellular signal of an unpleasant nature that discourages unwanted biofilm formation on the coated surface — important for avoiding infections that could be carried by implants and catheters.

The cell's ability to sense and respond to its environment is what forms these unique nanostructures, says Brinker. During spin-coating, the cells react to the increasing concentrations of materials in the developing silica nanostructure by expelling water and developing varying levels of acidity. This in turn influences the form of the silica nanostructure, reduces stress, and ultimately improves the living conditions of the ensconced cellular tenants.

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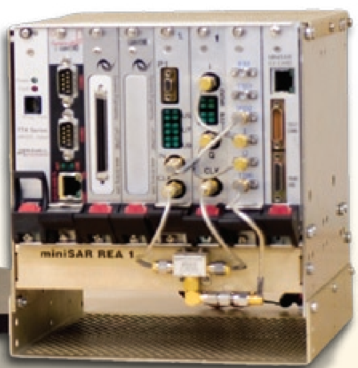
MiniSAR soaring with new deal

A newly announced agreement between Sandia and Rockwell Collins will lead to development of miniSAR (below) for use with unmanned aerial vehicles like Shadow 200 (at right).



Aerospace company Rockwell Collins, an industry leader in surveillance solutions worldwide, will spend several million dollars over the next two years to turn Sandia-developed miniSAR technology into a product that can be deployed on a Shadow 200 tactical unmanned aerial vehicle.

MiniSAR is a small synthetic aperture radar system that can "see" through clouds and in the dark.

Sandia Director of Industrial Communications Jerry Langheim and Rockwell Collins' Director of Business Alliances Steve Kennell are managers of the relationship.

Langheim and other members of Sandia's Defense Systems and Assessments (DS&A) Strategic Management Unit have worked with Rockwell Collins for the past three years to identify a viable market opportunity for miniSAR. Rockwell is now ready to move forward.

"The miniature SAR product is targeted for use on both manned and unmanned vehicle platforms, to provide small, persistent surveillance, intelligence, and reconnaissance capability to the military," says Ron Hornish, vice president and general manager of Sensor Systems for Rockwell Collins Government Systems. Because of its compact size, the miniSAR product could free up payload space for additional communication systems and integrated products and services.

"Sandia's strategic objectives include partnering with industry to transition advanced capabilities developed at the national labs to the end-user," says Brett Remund, deputy director, Microwave Intelligence, Surveillance, and Reconnaissance. "This partnership provides a strong and complementary match to achieve these objectives, bringing advanced radar remote sensing capability to the warfighter."

"I can't overstate the importance of these kinds of strategic relationships," says Jerry McDowell, DS&A vice president. "Sandia's science, technology, and engineering can benefit the nation and our DoD customers through industrial alliances. We have great expectations for this alliance."

"It takes teamwork to hand off the baton in a relay race and we believe that Sandia and Rockwell are uniquely suited to take miniSAR the distance together," says Rockwell Collins' Kennell. "We share a vision and expect to see more from this alliance in the future," says McDowell.

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With concerns that energy demand will rapidly increase over the next several years while fossil fuels diminish, Sandia researchers are looking at a new way to meet growing energy challenges — energy surety. "We have taken our surety know-how [from weapons] and applied it to energy," says Rush Robinett, senior manager of Sandia's Energy and Infrastructure Futures Group. ". . .we are looking at what energy practices can best answer our current needs while not making compromises for future generations."

Report faces future energy challenges

Energy surety takes an integrated approach to achieving safety, security, reliability, recoverability and sustainability objectives for the nation's civilian and military energy systems. Patterned after Sandia's application of surety principles to weapons systems over several decades, the approach includes choosing the best mix of fuels and applying conservation principles to all steps, starting with energy production and ending with final use. The approach even uses what would normally be characterized as waste heat and mass.

Margie Tatro, director of Energy, Infrastructure and Knowledge Systems Center, Rush Robinett, a senior manager in the center, and others in the center have designed the new model and detailed it in a recently-released internal report: *Toward an Energy Surety Future*.

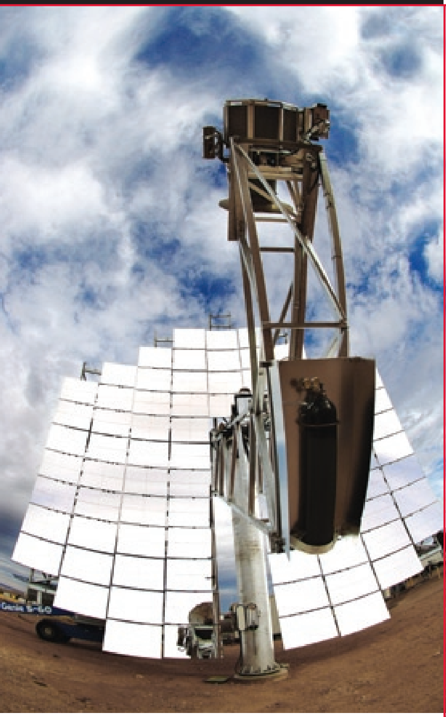
Tatro says that, in developing the energy surety approach, "the sustainability model was the most difficult to create because sustainability was not a system requirement in the original weapons system surety approach."

The energy surety approach is part of Sandia's effort to support the Department of Energy's National Energy Policy goals, which include diversifying the country's energy mix and reducing dependence on foreign petroleum; reducing greenhouse gas emissions and other environmental impacts; creating a more flexible, more reliable, and higher-capacity U.S. energy infrastructure; and improving efficiency and productivity.

For the past 100 years, this country has been largely dependent on liquid fossil fuels — especially petroleum — for transportation, electricity, and even food production.

Today, with the price of oil becoming unpredictable, together with increased energy consumption worldwide — particularly in China and India — and oil being concentrated in volatile countries, it's time to manage our fuels better, Robinett says.

"Energy is all around us — just look at the power of hurricanes and tsunamis," Robinett adds. "It's not the lack of energy that's the problem, it's a knowledge shortage of how to manage and harness that energy. We believe the energy surety approach is the best way to do this. If we don't follow this model, the whole world,



Solar thermal (above), photovoltaic (right), and wind energy (below) generation will all contribute to the future U.S. energy mix. (Photos by Randy Montoya)

including the U.S., could find itself living a lifestyle like that of the developing nations."

The report outlines a three-step strategy for moving toward better matching of energy resources with energy needs:

Step one. Squeeze every unit of available energy from the current supplies. This goes beyond the implementation of higher-efficiency electricity-consuming devices (lighting, appliances, and motors) and vehicles (diesels and hybrids) to include waste-to-energy options such as the extraction of methane from landfills and the conversion of biomass wastes to liquid fuels. Making better use of limited fossil supplies will allow the country to "buy time" while it moves down the path towards energy surety, Tatro says.

Holding the world's population to a level that the earth can sustain and capping energy demand at some point are also parts of step one. At the same time, consumer needs for energy must be reduced. The traditional view of an expanding world population and economy must level off or it could surge to the point of "resource exhaustion, social upheaval, disease epidemic, and then collapse," notes the report. An ultimate plan must have some commitment to hold growing populations in check.

A key aspect of step one is limiting the use of fossil fuels — although the magnitude of energy potentially recoverable from those fuels may never be known. Conservation must be a major part of the surety plan.

Step two. Store energy for later use when there is no wind, the sun is obscured, or an energy supply is disrupted. Currently, energy storage techniques are used in limited ways, ranging from battery-powered units to manag brief interruptions to the Strategic Petroleum Reserve. Examples that could provide expanded energy storage include solar production of

hydrogen for fuel cells, solar-powered conversion of carbon dioxide and water to liquid fuels, and energy storage from solar thermal collectors.

Step three. Learn how to reproduce the sun's fusion process on Earth in a safe, secure, reliable, and sustainable way. "Though we do not know if fusion can succeed as a practical terrestrial energy source, we believe that its promise is worth extensive investment," the report states.

"While it might not be possible to fully accomplish all the goals in the energy surety model, striving toward them is far better than blindly marching toward energy depletion, environmental exhaustion, and esthetic despair, only to discover that the scarce remaining resources are inadequate to meet needs," Robinett says. "The big question now is how to make this happen in the real world. The driver may very well be people's pocketbooks, caused by highly unpredictable fuel prices, coupled with increasing threats of terrorism."

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Applying energy surety to military bases

Jerry Ginn displays some of Sandia's battery storage capability. Energy storage is an integral part of the Energy Surety Microgrid. (Photo by Bill Doty)

The Energy Surety Microgrid for military bases would be an energy system that uses more small generation units and storage near where people live, work, and use power and less reliance on big remote plants. (Graphic by Tom Salazar)

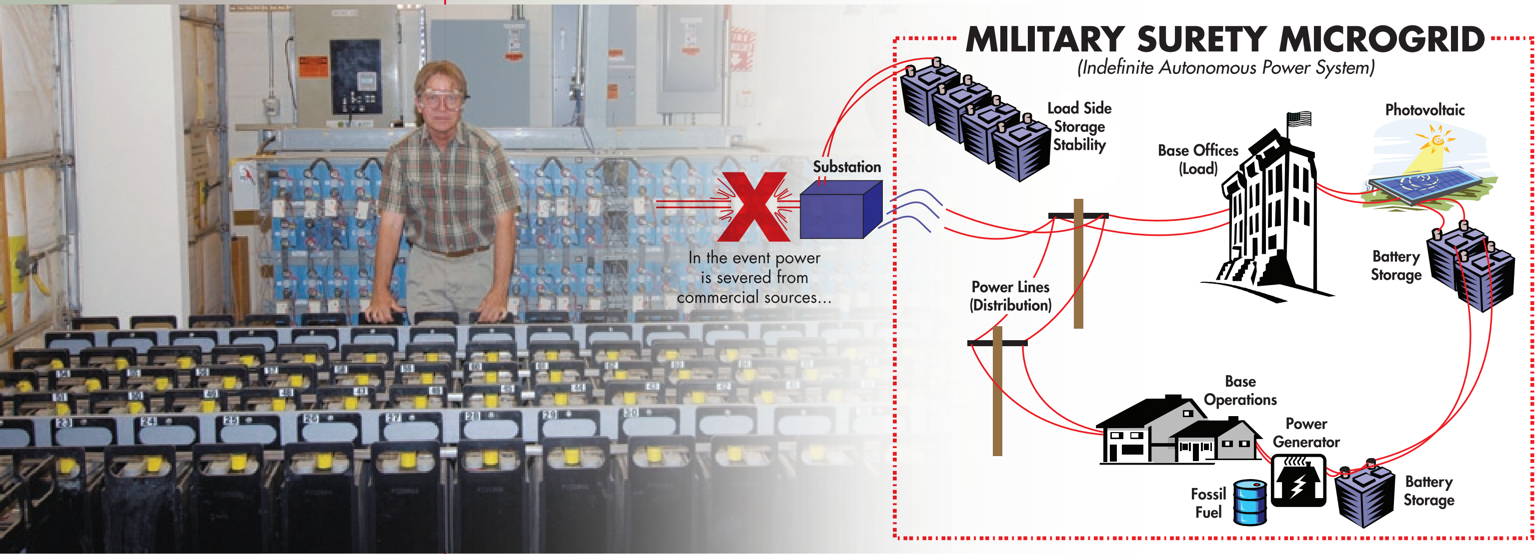
A Sandia research team headed by Dave Menicucci is applying a Labs-developed energy surety model to U.S. military bases. The team, working with the U.S. Army, is looking at how military bases can improve energy generation and transmission through a new system called Energy Surety Migrogrid.

"In today's grid system, power generators [coal, nuclear, gas] are located far from the load — the place where people live, work, and use power," Menicucci says. "This requires much distributed wiring and has a potential for power disruption." What the team envisions for military bases is an energy surety system that uses more small generation units and storage nearer the load, referred to as a microgrid, and less generation at big plants.

Energy systems with high levels of energy surety must be safe — safely supplying energy to end users; secure — using diversified energy sources; reliable — maintaining power when and where needed; sustainable — being able to be maintained indefinitely; and cost-effective — producing energy at an acceptable (and preferably lowest) cost.

Menicucci says the current grid system meets some of these criteria, while the proposed microgrid system for military bases would meet all.

It is safe — it's not introducing any new dangers. It's secure because it uses a diverse mix of fuels — solar, wind, and oil. It's reliable because it uses a variety of types of generators. There is a redundancy of generation and storage. It's sustainable because it is using renewable



These bases can operate with or without the grid. In addition to being smaller, the power generators would integrate a diversified fuel mix, include secure on-site fuel storage, and apply sustainable technology. Rush Robinett, senior manager of Sandia's Energy and Infrastructures Futures Group, says this model is "like back to the future." Military bases used to co-manufacture energy in the same area as is proposed here, he says. "Now most are totally dependent on the grid for power."

Funding for the project comes from the U.S. Army and the Sandia Laboratory Directed Research and Development LDRD program.

energies. And, it is cost-effective because it uses energy sources that are readily available and appropriate for the site.

The team is now working with the Army to develop an Energy Surety Microgrid for a soon-to-be-selected military base. Next spring a test military base will be determined, and a microgrid system will be installed and tested.

"The ultimate goal is to have microgrids at all military bases in the country and eventually in civilian communities," Menicucci says.

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High-temp electronics open new era of devices

Randy Normann (right) and Joel Henfling with high-temperature downhole tool. (Photo by Randy Montoya)

After years of just-out-of-reach promise, the era of high-temperature electronics has arrived. Sandia is taking advantage of opportunities to embrace and advance the use of this special class of electronics across diverse applications.

"This stuff is starting to become real; things are starting to happen," says Sandia engineer Randy Normann, a leader for more than a decade in the development and application of high-temperature electronics. High-temperature electronics, as the name suggests, are a class of electronics that functions effectively at temperatures that render conventional electronics ineffective and unreliable — temperatures ranging from 350 - 600º F.

Currently, high-temperature electronics come in two flavors: SOI — silicon-on-insulator, where an insulating substrate protects and shields conventional silicon components — and SiC — silicon carbide, with intrinsic high-temperature-tolerant characteristics. While both approaches have merits, the newer SiC-based electronics can be made smaller. "Smaller means faster and faster means more efficient. That sounds like a good combination," Normann says.

(A still-newer high-temperature technology based on gallium nitride is in the early stages of the development process.)

Downhole instrumentation makers are fiercely competitive, always seeking the kind of edge that high-temperature electronics can give them. "They fight to stay on the [downhole] tool the way NBA players fight to stay in the paint."

*— Randy Normann
Sandia team leader*

Jumping in

Several commercial suppliers have aggressively jumped into the high-temp electronics market to grab a piece of the action, according to Normann. The big market driver at the moment is the well-drilling and down-hole instrumentation market, but there are a host of other applications that stand to benefit from the use of these new electronics.

Normann describes high-temperature electronics as a win-win on both sides of the energy equation:

- On the supply side, it is an enabling technology for deeper oil and gas drilling, for geothermal drilling, and for use in specific application in extreme nuclear power plant environments.
- It is also an enabling technology on the consumption side, with applications in aircraft, hybrid automobiles, and the power grid.

Obvious benefits

The interest in this technology from the oil-patch is obvious. As well-drilling goes beyond 35,000-foot depths and with offshore wells costing more than $100 million, there is almost a money-is-no-object demand for better, more reliable electronics that enable drill-head steering and better data acquisition.

Downhole instrumentation makers, Normann noted, are fiercely competitive, always seeking the kind of edge that high-temperature electronics can give them. "They fight to stay on the [downhole] tool the way NBA players fight to stay in the paint."

The aircraft industry, too, is beginning to show extreme interest in high-temp electronics. For several decades, the philosopher's stone of aircraft builders has been something called "the more electric airplane." The military is interested in the concept, but it is equally compelling to commercial plane makers.

An analysis done for the Air Force Research Laboratory in Dayton, Ohio, indicates that replacing many of the hydraulic, pneumatic, mechanical, and electrical systems in an aircraft with reliable SiC-based electronic components would reduce weight and volume (thus saving fuel), along with cuts to required equipment and support personnel. The future SiC-based "more electric aircraft" stands to save the aircraft industry billions of dollars.

Hand in hand

Normann asserted that "high temperature" and "high reliability" go hand in hand; high-temperature electronics are simply more reliable than their plain-vanilla silicon cousins. That's why developers of some applications are interested in high-temperature electronics for use in locations where reliability (not temperature) is the critical factor.

Sandia can play a key role in the development, refinement, and deployment of high-temperature electronics, Normann believes.

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"Wiring insulation grown defective over time can cause malfunctions or even fires, but is devilishly hard to spot and even harder [once spotted] to [exactly] locate. Other methods have faltered when confronted with the varying resistances of bundles of wires, or the difficulty of providing the exact location of the defect as wiring bundles branch into other bundles. This nondestructive, inexpensive method not only detects cracking or pinholes but also is able to pinpoint the defect's precise location to facilitate wire replacement."

Larry Schneider,
team leader,
Pulsed Arrested Spark Discharge

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

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SAND-2006-5420P

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