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# SANDIA TECHNOLOGY

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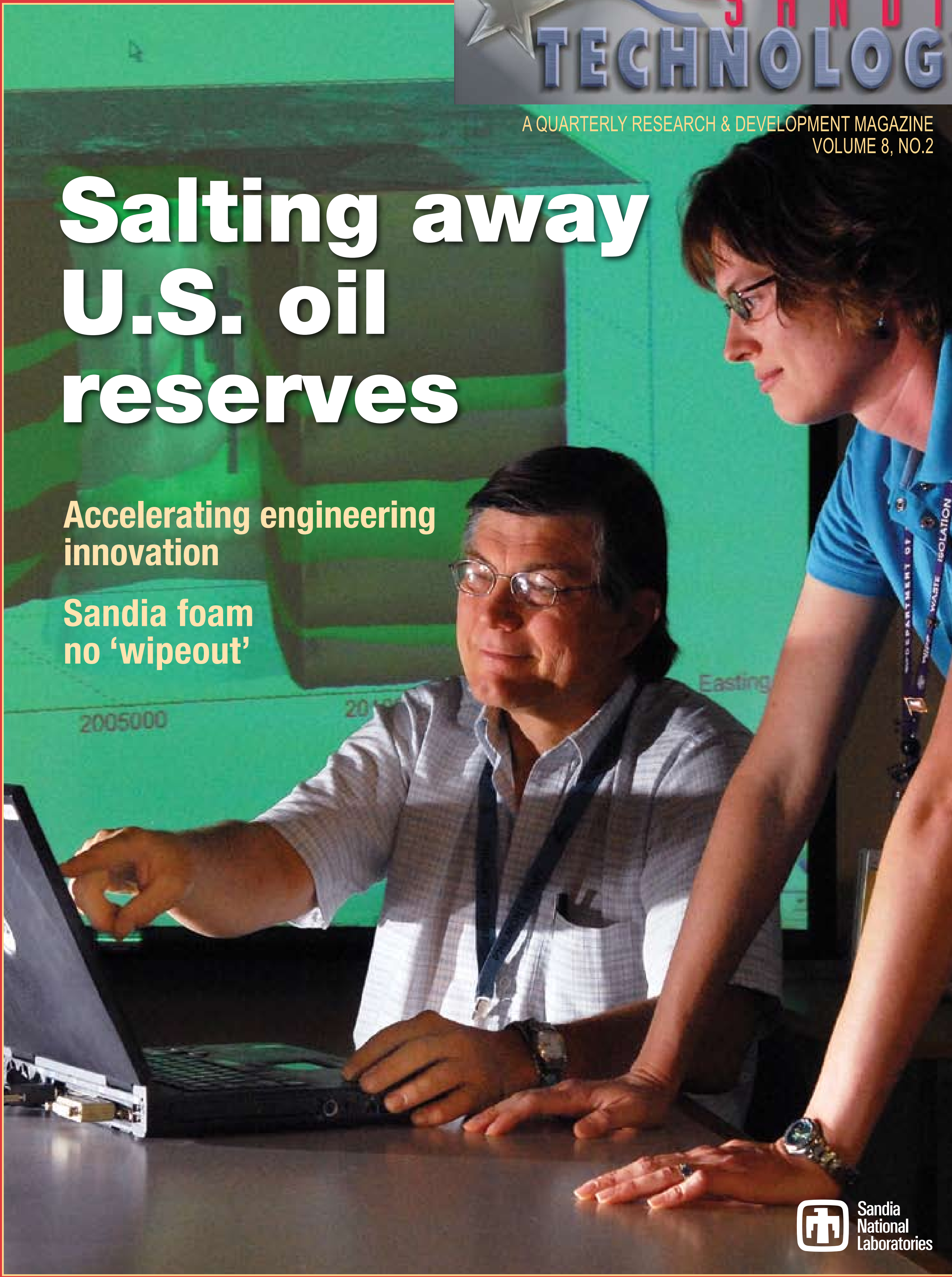


# Salting away U.S. oil reserves

## Accelerating engineering innovation

## Sandia foam no 'wipeout'

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 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; as well as 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:

Sandia researchers are working to support the Department of Energy in an effort to increase the size of the U.S. Strategic Petroleum Reserve. Here two researchers study possible placement of oil caverns in a salt dome. (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,

Since President George Bush visited Sandia last summer, the Labs' energy efforts have been much in the spotlight. As this issue of *Sandia Technology* shows, that continues to be the case.

Sandia's efforts to help the Department of Energy select and prepare sites for expansion of the critical Strategic Petroleum Reserve (SPR) along the U.S. Gulf Coast are featured on page 9. This work involves a panoply of scientists and engineers from the labs looking at historic, geologic, economic, mechanical engineering, environmental, and other aspects of the project. Once the sites for the expansion are selected, Sandia will continue to be involved, as it has since the inception of the SPR.

We also showcase a number of Sandia projects, from a university contest to develop creative micro-electromechanical devices to a foam product that is environmentally benign and may offer new hopes for the U.S. surfboard industry.

Perhaps the most important story in the issue, however, isn't a technical one. Sandia President Tom Hunter has made it a priority for Sandia to be involved in addressing the "gathering storm" of issues surrounding our educational system and the future technical workforce needed to keep America economically sound and secure. Last year, Tom sat on a panel with President Bush to discuss approaches to improve our education system and demonstrate the importance of science and engineering to the economy. This spring, Sandia went one step further, hosting U.S. leaders to discuss next steps. That story begins on the following page.

**Will Keener**
Editor

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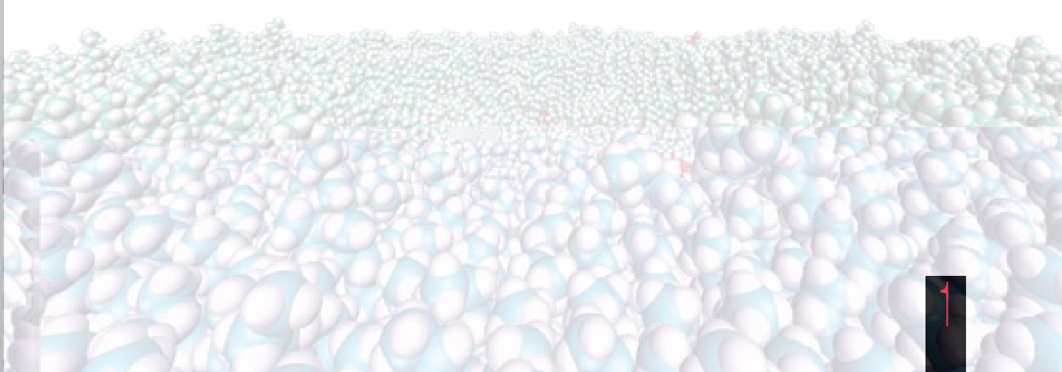

*Making math and science exciting for young people, re-thinking how engineering is done, and exploring what drives creativity and innovation were among topics discussed by about 50 leaders from industry, universities, government, and national laboratories in Albuquerque this spring. The Accelerating Engineering Innovation Summit, hosted by Sandia, focused on creating a highly qualified science and engineering workforce for the future as a linchpin to American industrial competitiveness and national security.*

# Accelerating engineering innovation

In his opening remarks, Sandia's Tom Hunter summarized the conclusions of a National Academies of Science report released last fall. "The security of our nation may depend more on a commitment to research and education than on any other factor including the strength of our military," said the Sandia President and Director. His audience: the Accelerating Engineering Innovation Summit, a spring gathering of industry, government, university, and national laboratory leaders, convened in Albuquerque.

Compiled by a blue-ribbon panel of business leaders, scientists, and educators led by retired Lockheed Martin Chairman Norm Augustine, the report referenced by Hunter, called *Rising Above the Gathering Storm*, made strong recommendations for federal action to enhance U.S. science and technology and maintain competitiveness in the 21st century.

Growing from that report was President Bush's American Competitiveness Initiative. The initiative calls for $5.9 billion in federal funding next year to increase investments in research and development, strengthen education, and encourage entrepreneurship. It also includes additional funding during a 10-year period for research and development tax incentives. The National Academies identified accelerating engineering innovation as a critical element in achieving the goals of the American Competitiveness Initiative.


Above: *Rising Above the Gathering Storm* made strong recommendations to enhance U.S. science and technology.

Left: Intel's Chairman Craig Barrett and Sandia's Tom Hunter. (Photo by Bill Doty)

## Involvement from the top

In February, Hunter participated in a panel discussion, led by President Bush, with Intel CEO Craig Barrett and others to discuss some ideas for addressing science and technology education and economic competitiveness.

Sandia hosted the spring summit to bring together potential partners, to explore ways to improve engineering education and accelerate engineering innovation, and to discuss how government, industry, universities, and the national labs might work together, particularly in the area of nanoengineering. The Labs took advantage of the meeting to showcase one of the newest buildings at the Albuquerque site, part of the half-billion-dollar MESA (Microsystems and Engineering Sciences Applications) complex, designed to provide the tools, resources, and infrastructure to advance engineering research into the new century.

Hunter said that one of the challenges the group and the nation face is doing a better job of promoting engineering as an exciting career with good income potential. Recruiting students to engineering fields can be challenging in a society that doesn't place a strong emphasis in science and engineering, as it did during the time of Sputnik and the U.S.-U.S.S.R. space race of the late 1950s.

Intel's Barrett — recently named company chairman — said the country needs another initiative like Sputnik to excite kids about math and science. He suggested that dealing with the energy crisis could be the focus. "You really need to set a national strategy or priority and show that it can be solved and in fact is important to the government; science and technology is important to us all," he said.

## Role of education

Cultivating a highly qualified workforce to undertake next-generation engineering for its national security missions is of particular importance to Sandia. This may require rethinking how engineering


Participants exchange ideas at the Accelerating Engineering Innovation Summit (Photo by Bill Doty)

is done and taught to enable us "to leap-frog ahead" and get to the creative results faster, Hunter said. For example, computing needs to be regarded less as a means for calculating and more as a means of learning and idea sharing, he said.

Barrett described concerns that America's K-16 education system is discouraging kids who might be interested in math and science. One problem is a lack of qualified teachers for science and math. Another problem is that the U.S. educational system is not setting high enough expectation levels, he said. Barrett talked about the potential of charter schools and competition within the K-12 educational system as potentially a positive force for improving quality.

Also on the meeting agenda were panel and small-group discussions to identify and address key aspects of the engineering innovation dilemma through multi-institutional partnerships. In addition to representatives from Sandia and Intel, Goodyear, Microsoft, ExxonMobil, IBM, Lockheed Martin, HP, and Procter & Gamble were also represented. Engineering deans and senior executives from Harvard, University of Florida, University of Wisconsin, University of Illinois, University of Michigan, Rose-Hulman Institute of Technology, University of Texas, University of California, Harvey Mudd College, Yale, MIT, University of New Mexico, and Rensselaer Polytechnic Institute represented the academic community. Other representatives from the Council on Competitiveness, the U.S. House Science Committee, Sen. Jeff Bingaman's office, DOE, NNSA, and Oak Ridge and Los Alamos national laboratories were among the participants.

## Examining the obstacles

Sessions hosted by Sandia Vice President and Chief Technology Officer Rick Stulen featured panel discussions by representatives from the three key communities. During these sessions, panelists laid out their views on the obstacles that stand in the way of advancing U.S. engineering to the next level.

Perhaps the single dominant theme among the three panels was that the communities need to get better — much better — at collaboration. Senior executives at the meeting agreed that U.S. industry is increasingly turning to foreign universities and institutes for partnerships to develop advanced technology, in part because it takes too long to develop an agreement here in the U.S.

The industry panel called for engineering graduates who can communicate well, understand the competitive market, are strongly grounded in math and science, and are not simply trained but rather have the capacity to think and learn.

There was also general consensus that effective teaming is vital to innovation. As one panelist put it, the Eureka moment is no longer the lone researcher saying "aha," but two people — or more — coming to the realization that they can discover and innovate more effectively by working together than by working alone.

Stulen noted that there are models for effective partnering between any two of the three communities: government, academia, and industry. The missing model, he said, is a sustainable and agile approach to successful partnering among all three communities. Such models exist in Europe and Asia, but because of different funding and sociopolitical environments, these approaches haven't been as widely successful in the U.S.

"Institutions that learn how to partner effectively are going to win — and nations that learn how to partner are going to win," said another participant.

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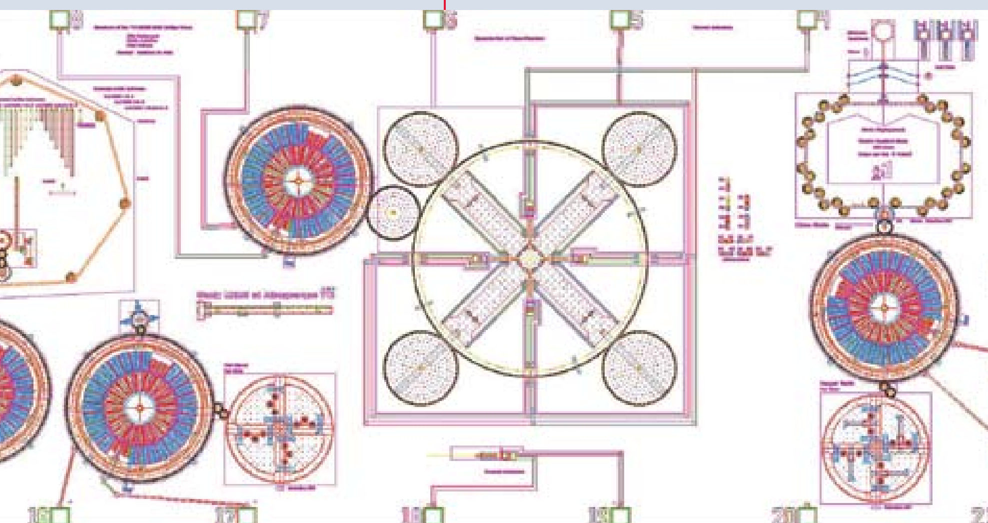
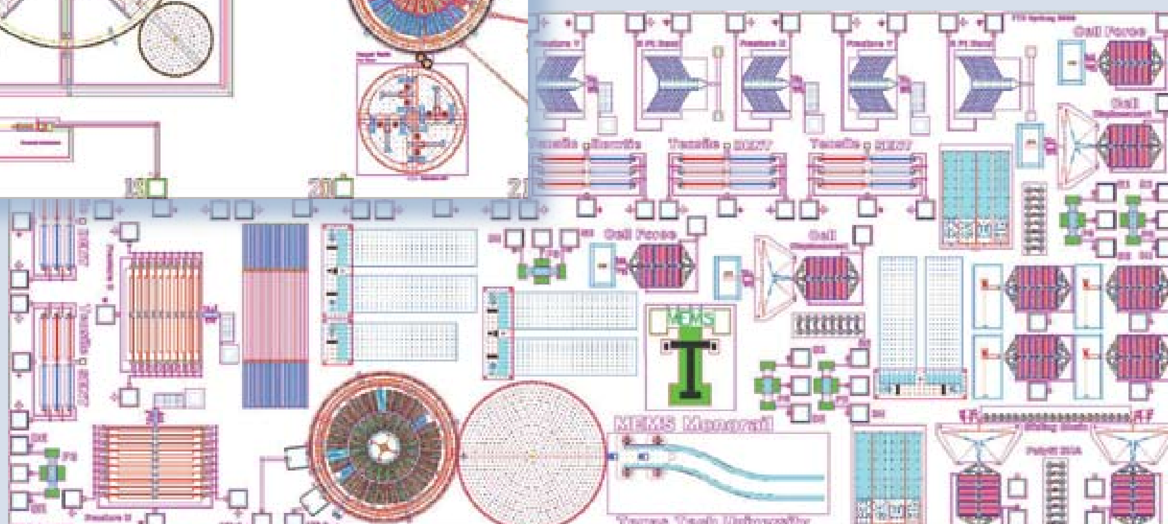
# Winners Think Small

An exceedingly small monorail and a chain with links about a sixth the diameter of a human hair were among the remarkable devices created by the imaginative yet detail-oriented winners of Sandia's 2006 MEMS University Alliance (UA) Design Competition.






Above: TVI's winning MEMS Novel Device design includes innovative concepts for micro-chain and micro-belt drives as well as out-of-plane gears.

Right: Texas Tech's winning MEMS Device Characterization design includes structures for the measurement of material properties and a biocell for the characterization of cells and tissues.

Team representatives from Texas Tech and Albuquerque Technical Vocational Institute (TVI) visited Sandia in mid-May to present their designs for review and to tour Sandia's micro-system facilities. Among the designs produced by Texas Tech's winning team were a MEMS (micro-electromechanical systems) monorail and a method to mechanically characterize biocells.

"The Sandia Design Competition is the centerpiece of our MEMS curriculum. We believe the educational benefits are excellent," said Texas Tech Professor Tim Dallas, who, along with student Jay Friend, led the effort that won the Characterization/Reliability/Material and Surface Science category. Dallas praised the Sandia-originated SUMMiT design process, which allowed his students to participate in interesting research. He expressed hope that "testing and characterization of the fabricated devices will lead to publishable results."

Professor Matt Pleil and student Paul Tafoya from TVI won the Novel Design category with help from students Eric Steinmaus and Eddie Letellier. (TVI has since been renamed Central New Mexico Community College and was the only two-year institution in the competition.)

The group built what it believes is the world's smallest chain (11 microns per link, or about 16 percent of the average width of a human hair), complete with tensioner and a microbelt able to transfer energy from one point to another. They built orthogonal gears needed to transfer power from one plane to another (as in transferring power from transmission to wheels). Team members also built a trapped-oxide actuator that uses internal stresses to cause the structure to lift out of plane.

The winning designs will be fabricated on Sandia's SUMMiT V™ reticle set and Sandia-fabricated parts will be shared with all University Alliance members to use in their curriculum. Membership is available to any U.S. institution of higher learning.

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# Red Storm rising

Jason Repik, Cray contractor, checks out a Red Storm panel. (Photo by Randy Montoya)

A new series of measurements — the next step in evolving the criteria to determine more accurately the efficiency of supercomputers — has rated Sandia National Laboratories' Red Storm computer the best in the world in two of six new categories, and very high in two other important categories.

Red Storm had previously been judged sixth fastest computer in the world on the older but more commonly accepted Linpack test.

The two first-place benchmarks measure the efficiency of keeping track of data and of communicating data between processors. This is comparable to how well a good basketball team works its offense — rapidly passing the ball to score against an opponent.

An unusual feature of Red Storm's architecture is that the computer can do both classified and unclassified work with the throw of a few switches. The transfer does not require any movement of discs and is secure. There are no hard drives in any Red Storm processing cabinets. A part or even the whole of the machine can be temporarily devoted to a science problem, and cross over to do national security work.

The capability of the machine to put its entire computing weight behind single large jobs enabled one Sandia researcher to get an entire year's worth of calculations done in a month.

## Cray partnership

Red Storm's architecture was designed by Sandia computer specialists Jim Tomkins and Bill Camp. The pair's work has helped Sandia partner Cray Inc. sell 15 copies of the supercomputer in various sizes to U.S. government agencies and universities, and customers in Canada, England, Switzerland, and Japan. Cray holds licenses from Sandia to reproduce Red Storm architecture and some system

HPCC benchmark results available at: http://icl.cs.utk.edu/hpcc/hpcc_results.cgi

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*The Sandia-designed Red Storm supercomputer has modeled how much explosive power it would take to destroy an asteroid tracking toward Earth, how a raging fire would affect critical components in a variety of nuclear weapons, and how changes in the composition of Earth's atmosphere might impact global warming. The machine has been ranked as the world's most efficient in two of six categories.*

Sandia's Red Storm supercomputer

software, says Tomkins. Red Storm was funded by the National Nuclear Security Adminstration's Advanced Simulation and Computing program.

In the early 1990s, supercomputer manufacturers distinguished the capabilities of their products by announcing Theoretical Peak numbers. These figures represented how fast a computer with many chips in parallel circuits could run if all processors worked perfectly and in unison. The number was — at best — considered a hopeful estimate.

Next came the Linpack benchmark, which provided a real, but relatively simple series of algorithms for a supercomputer to solve. Since 1993, those interested in supercomputers watched for new Linpack numbers, published every six months, to determine and rank the fastest computers in the world. For several years, the fastest was Sandia's ASCI Red supercomputer.

Most recently, the limitations of this approach have encouraged the Linpack founders, in conjunction with supercomputer manufacturers, to develop still more realistic tests. These indicate how well supercomputers handle essential functions like the passing between processors of large amounts of data necessary to solve real-world problems.

## What's coming at you?

In this revised series of tests — called the High Performance Computing Challenge test suite — Sandia's Red Storm supercomputer has done extremely well.

"Suppose your computer is modeling a car crash," says Sandia Computing and Network Services Director Rob Leland, offering an example of a complicated problem. "You're doing calculations about when the windshield is going to break. And then the hood goes through it. This is a very discontinuous event. Out of the blue, something else enters the picture dramatically.

"This is the fundamental problem that Sandia solved in Red Storm: how to monitor what's coming at you in every stage of your calculations," he says. "You need very good communications infrastructure, because the information is concise and very intense. . . and because the incoming information is very unpredictable, you have to be aware in every direction."

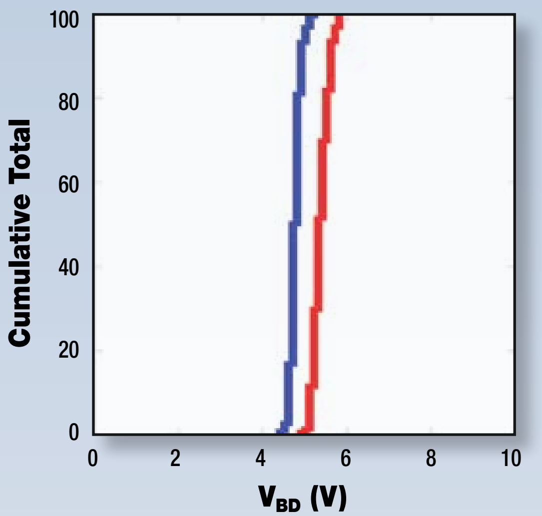
## Moving through traffic

To David Womble, acting director of Computation, Computers, and Math at Sandia, "The question is [similar to] how much traffic can you move how fast through crowded city streets." Red Storm, he says, does so well because it has "a balance that doesn't exist in other machines" between the ability of a processor to get data it needs from anywhere in the machine quickly and how fast each processor can do the additions, multiplications and other operations it needs to do in solving problems.

More technically, Red Storm posted 1.8 trillion bytes per second on the HPCC test to measure the total communication capacity of the internal interconnects. Sandia's achievement in this category represents 40 times more communications power per teraflop (trillion floating point operations) than the result posted by IBM's Blue Gene system, a competing system with 10 times as many processors.

Red Storm is the first computer to surpass the 1 terabyte-per-second performance mark for measuring communications among processors — a measure that indicates the capacity of the network to communicate when dealing with the most complex situations.

# Thin Film Enables IC Antifuses




The narrow distribution of $V_{bd}$ for antifuses made using two different implementations of Sandia's novel dielectric film. This graph was created from 267 individual measurements.

Researchers at Sandia have developed an inexpensive, reliable, and easy-to-manufacture class of dielectric films that have the capability of enabling programmable antifuses on integrated circuits (IC) at less cost and using easier-to-manufacture methods. The new Sandia films enable single-mask level sub 5 Volt write antifuses that are compatible with leading-edge IC specifications.

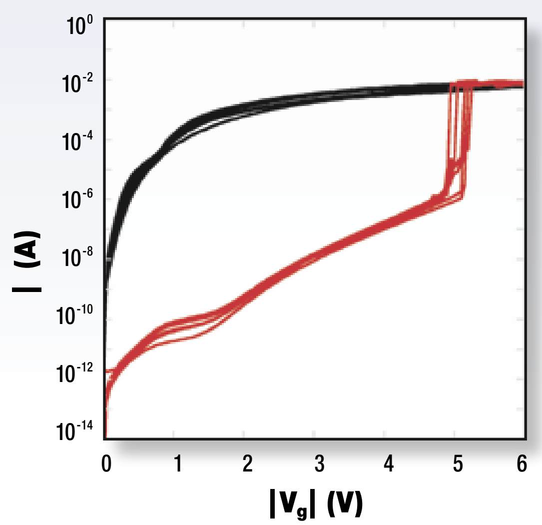
Antifuses are nonvolatile, one-time programmable memories fabricated on ICs that are programmed with applied voltage. People who need specially designed chips that are generally not available can use inexpensive chips made with the Sandia-developed dielectric film and permanently program them after fabrication.

This technology inexpensively enables such activities as post fabrication trimming, ROM programming, on-chip serial number identification, and data and program security. Chips with antifuse devices may also be used in high radiation environments or for long-term storage where flash memory would not be reliable.

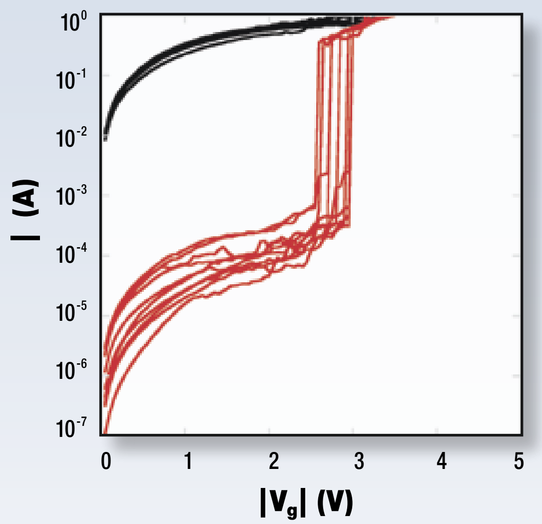
"Antifuses have been around a long time," says Paul Smith, who is involved in technology transfer at Sandia. "The new Sandia-developed film — that ultimately is incorporated into computer chips with antifuses — requires lower voltage and less real estate. This makes them more desirable than existing antifuses."

Current antifuse technologies rely on complex stacks of ultra-thin films that are foreign to standard Complimentary Metal Oxide Semiconductor (CMOS) processes. These existing multi-stack solutions use write voltages significantly greater than 5 Volts, making existing antifuses incompatible with many leading-edge IC designs. The depositions of these films can also be difficult to control during production, resulting in a potential for poor yield and reliability issues.

"In addition to compatibility with state-of-the-art ICs, Sandia's novel technology offers great flexibility as to where the antifuse can be placed within an IC," says Scott Habermehl, one of the inventors of the dielectric film. "It can readily be integrated into either the front end or the back end wiring." He adds that the new dielectric technology enhances both process margin and device reliability since it allows manufacturers to use thicker films for the antifuse elements.




IV sweeps both before and after breakdown for a 5 Volt write antifuse built with Sandia's novel dielectric technology. At a read voltage of 1.5 V, there are seven orders of magnitude difference between the unwritten and written states. The Figure also shows the narrowness of the $V_{bd}$ distribution.




IV sweeps both before and after breakdown for a 3 Volt write antifuse built with Sandia's novel dielectric technology. At a read voltage of 1.5 V, there are over three orders of magnitude difference between the unwritten and written states. The Figure again highlights the narrowness of the $V_{bd}$ distribution.

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*A group of Sandia scientists and engineers are hard at work on a project this summer to help the DOE make the right choices at the U.S. Strategic Petroleum Reserve. The multidisciplinary group is helping the DOE meet its goal of adding 273 million barrels in capacity to the reserve, which is contained in natural salt domes deep in the Earth's crust, along the U.S. Gulf Coast.*

# Salting away U.S. oil reserves

When the Energy Policy Act of 2005 directed the Secretary of Energy to fill the Strategic Petroleum Reserve to its authorized one billion barrel capacity, a team from Sandia sprang into action. Working with a $2.5 million budget, about a dozen Sandia researchers and a few consultants are providing input on a number of issues connected with selection of new sites for storage caverns and the best way to construct them.

Researchers are studying the geomechanics and engineering integrity of salt domes where the storage caverns would be constructed; access to petroleum infrastructure to distribute the oil; existing or historical problems that would make expansion of the reserve difficult; the geometry of additional salt caverns in presently used domes; and a host of other factors, says David Borns, manager of the Labs' Geomechanics and Engineering department.

Major pipelines from the region head northwest into the Midwest, north to the Great Lakes Seaway and Chicago, and northeast to the Atlantic states, creating the ability to move SPR inventory to most U.S. refineries.

With a typical volume of 10 million barrels per salt cavern, the congressional act means another 27 caverns need to be added to the 62 existing ones, explains project lead Brian Ehgartner. Some caverns will be created within existing domes used by SPR (see page 11), and some will possibly be created at new locations along the coast.

Sandia's Anna Snider Lord and Chris Rautman are combining geologic and other data, such as well logs and oil industry seismic surveys, to map the domes of the Strategic Petroleum Reserve and display them. (Photo by Randy Montoya)

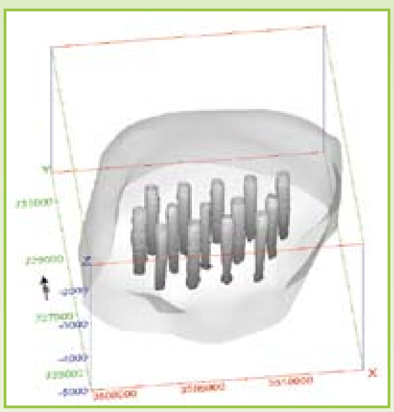
1940

1950

1944: Secretary of the Interior Harold Ickes advocated the stockpiling of emergency crude oil.

1952: President Truman's Minerals Policy Commission proposed a strategic oil supply.

# SPR timeline



Visualization of the 14 Big Hill caverns within the salt dome.

## Selection input

With Sandia consultation, the DOE is choosing to add additional storage capacity to its Big Hill, Texas, and Bayou Choctaw and West Hackberry, Louisiana, storage sites, Ehgartner says. This capitalizes on existing infrastructure and operations, shortens development time, and minimizes costs.

Late last year Clovelly, Louisiana, was selected as a candidate site for new SPR caverns. The Clovelly site is a part of the Louisiana Offshore Oil Port (LOOP) system, a deepwater port in the Gulf of Mexico providing tanker offloading for crude oil transported on some of the largest tankers in the world. LOOP handles 13 percent of the nation's imported oil — about 1.2 million barrels a day — and connects by pipeline to 35 percent of U.S. refining capacity.

At Clovelly, the team turned to Sandians Lupe Arguello, Jonathan Rath, and Jim Beam to look at the idea of putting up to 16 SPR caverns deeper in the salt dome, below nine existing caverns used by LOOP. "Salt is notorious for creeping," explains Borns. "So there are questions about the integrity of the existing caverns and subsidence [sinking] at the site. It's really an interesting challenge.

"If the concept proves feasible, it can be applied at existing sites throughout the Gulf Coast for storage of natural gas and other products," says Borns.

Subsidence is critical at most of the SPR sites. Some of the domes are only five or six feet above sea level and researchers must know how they will behave with increased drilling and cavern excavation. This is especially important for the double-tiered cavern concept being considered at Clovelly. Chris Clutz, a mechanical engineer at Sandia, is modeling subsidence for the project.

## Optimal distances

Among the things that will have to be worked out are the optimal shapes and separation distances between caverns in the salt domes. Byoung Yoon, an experienced researcher at the Waste Isolation Pilot Project, is looking at issues related to salt creep and placing new caverns in particularly tight locations at Bayou Choctaw. Steve Sobolik is studying novel cavern shapes, while anticipated changes of shapes during operations are being simulated by Bruce Levin.

Original design life for the caverns was defined as five complete drawdowns (full-empty cycles) of all the oil inside. But future usage may be different. For example there may be partial drawdowns at a more frequent rate. "The question becomes can we design caverns to be less vulnerable to these changes," says Ehgartner.

Chris Rautman and Anna Snider Lord are looking at seismic and well logs to delineate actual boundaries of the salt

(Continued on page 12)

1970

1956: President Eisenhower suggested an oil reserve after the Suez Canal crisis.

1970: A Cabinet Task Force on Oil Import Control recommended a similar reserve.

1973-74: The cutoff of oil flowing into the U.S. from many Arab nations sent economic shockwaves throughout the nation.

1975: President Ford signed the Energy Policy and Conservation Act on December 22, establishing a reserve of up to one billion barrels of petroleum.

# SPR uses natural geologic features


Five new sites are under technical review, following an environmental impact process, for possible inclusion in the Strategic Petroleum Reserve. The new site candidates are Stratton Ridge, Texas, Chacahoula and Clovelly, Louisiana, and Richton and Bruinsburg, Mississippi.

SPR worker checks pumps.

America's emergency crude oil is stored in salt caverns, created deep within the massive salt domes that underlie much of the Texas and Louisiana coastline. These caverns offer a secure and affordable means of storage, costing up to 10 times less than aboveground tanks and 20 times less than hard rock mines.

Storage locations along the Gulf Coast were selected because they provide a flexible means for connecting to the nation's commercial oil transport network. SPR oil can be distributed through interstate pipelines to nearly half of the U.S. oil refineries or loaded into ships or barges for transport to other refineries.

A typical SPR cavern holds 10 million barrels in a cylinder with a diameter of 200 feet and a height of 2,000 feet. One storage cavern is large enough for Chicago's Sears Tower to fit inside with room to spare. The reserve contains 62 huge underground caverns, ranging from six to 35 million barrels capacity.

The federal government acquired previously created salt caverns to store the first 250 million barrels of crude oil in the mid-1970s. This was the most rapid way to secure an emergency supply of crude oil following the oil shocks of the 1970s. To stockpile oil beyond the first 250 million barrels, the DOE created additional caverns, with scientific and engineering assistance from Sandia.

Salt caverns are dissolved out of underground salt domes by drilling a well into a salt formation, then injecting fresh water. The water dissolves the salt and creates the SPR caverns. The dissolved salt is removed and reinjected into disposal wells or piped offshore.

The nature of the salt, a material Sandia engineers are very familiar with, based on decades of research work at the Waste Isolation Pilot Plant, makes the caverns mechanically and environmentally secure. At depths ranging from 2,000 to 4,000 feet, the salt walls of the storage caverns are somewhat plastic and self-healing.

A natural temperature difference between the top of the caverns and the bottom keeps the crude oil continuously circulating in the caverns, maintaining the oil at a consistent quality. As the caverns have aged, the thermal gradient has decreased, resulting in less circulation and in some cases stratification of oil, another topic of research at Sandia.

The fact that oil floats on water is the underlying mechanism used to move oil in and out of the SPR. To withdraw the crude, water is pumped into the bottom of a cavern. The water displaces the crude oil to the surface. Each withdrawal affects the geometry and size of the caverns, enlarging and changing them slightly.

## 1970 cont.

1977: The government acquired several existing caverns in salt domes to serve as the first storage sites. Sandia's involvement in the reserve begins.

1977: On July 21 the first oil — approximately 412,000 barrels of Saudi Arabian light crude — was delivered to the reserve.

## 1990


1991: On January 16, coinciding with the international effort to counter the Iraqi invasion of Kuwait, President George H.W. Bush ordered the first-ever emergency drawdown.

1995: Officials suspended filling the reserve to devote budget resources to refurbishing equipment and extending the life of the complex.

domes and existing caverns. They are using modeling software to construct images of the caverns and better define the real estate, where there is currently a lot of uncertainty.

Allan Sattler is studying the drilling history of the domes to gauge what events may impact future operations. In one case, for example, an oilfield logging tool was lost in a cavern. This kind of information must be folded into the final decision-making.

### Even more to do

Sandia's work at SPR will be far from finished with the current effort. Once the sites are selected, DOE will look to Sandia to be involved in site characterization, drill holes, and the actual leaching and operations of the caverns. But getting to that point has meant a tough, tight schedule.

"We have already provided input for a draft Environmental Impact Statement," says Ehgartner. "Secretary Bodman has already written the president recommending we go ahead. Now we must provide analysis to back that up and help guide the expansion plan, starting with site selection."

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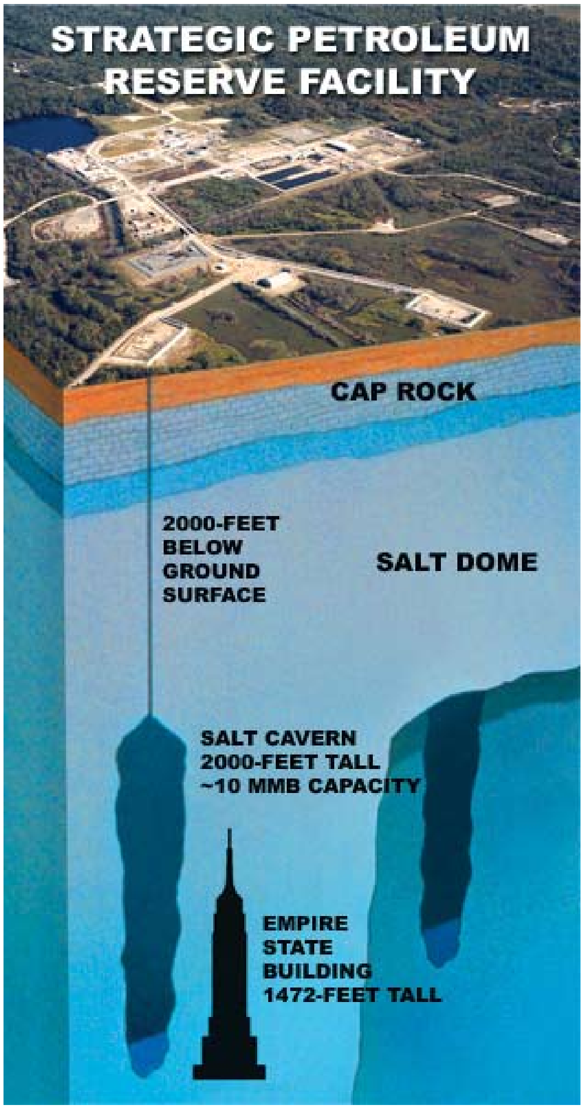
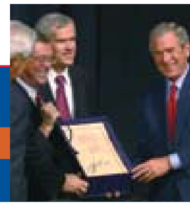



SPR caverns are large enough — as this photo illustration shows — to hold the Empire State Building.

2000



1999: Filling resumed with royalty oil from federal offshore tracts.

2001: In November, President Bush ordered the SPR to be filled to approximately 700 million barrels by producers, who operate leases on the federally owned outer continental shelf.

2005: On August 8, President Bush signed the Energy Policy Act of 2005 directing the Secretary of Energy to fill the reserve to its authorized one billion barrel capacity.

2005: In late August, the SPR's second emergency drawdown occurred after Hurricane Katrina caused massive damage to the oil production facilities, terminals, pipelines, and refineries along the Gulf regions of Mississippi and Louisiana.

# A drop in the bucket?

*...there is a greater than 90 percent chance over the next decade that an event will occur somewhere in the world that will cost the U.S. up to five million barrels per day of production.*

Why is the SPR expanding? Is it worth a $30 billion investment that includes $3 billion in infrastructure and $27 billion in oil? At 5.5 million barrels a day, can SPR production really help the U.S. in a crisis?

Economic and strategic experts say it can help and it's worth the effort.

Brian Ehgartner, Sandia project lead for the SPR work, notes that an economic study from Oak Ridge National Laboratory showed that there is a greater than 90 percent chance over the next decade that an event will occur somewhere in the world that will cost the U.S. up to five million barrels per day of production. "The reserve is now being sized to make up that difference," he says.

Although the U.S. daily consumption of 20.7 million barrels is much higher, the critical difference is typically in product at risk, Ehgartner explains. About 12 million barrels a day is imported to the U.S., with about five million of that coming from relatively stable resources in Canada and Mexico.

The SPR is designed to cover the balance of higher-risk sources, says David Borns. "The probabalistic situation is that you will lose production from the Persian Gulf, or Venezuela, or some other area for a certain amount of time. SPR is designed to absorb the difference." Last year, this concept was illustrated when SPR production allowed a number of critical refineries to stay in normal operation until supply disruptions from Hurricane Katrina could be repaired.

Given the potential for terrorist disruption, increased global competition for oil, and dwindling supplies, reserves are much more valuable today, says Daniel Yergin, American author and economic researcher. While the standard way of thinking about economic security has been in terms of diversity of supply, Yergin now suggests the concept of "resilience of supply" as a new factor, which includes adequate storage.

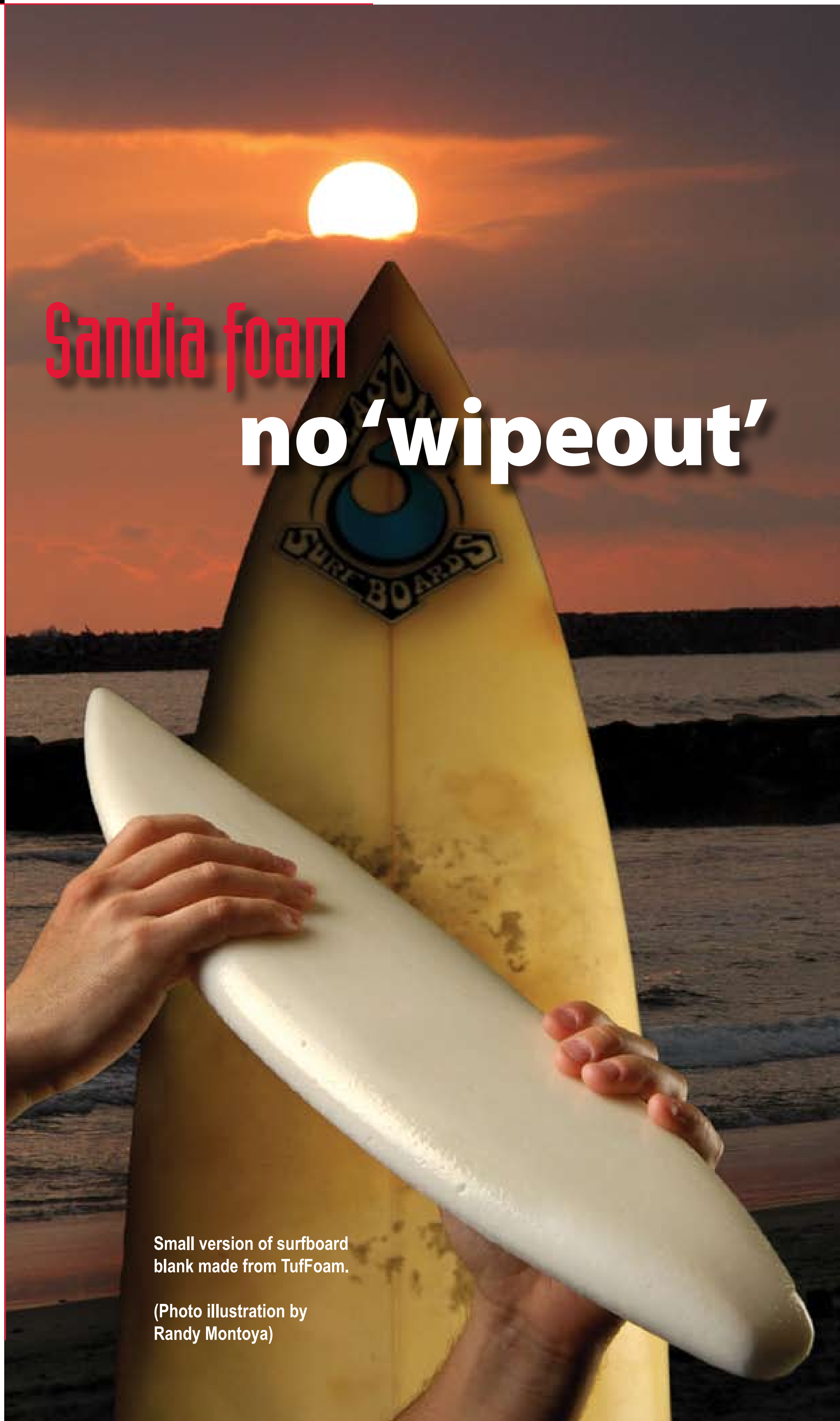
In the future, the integration of infrastructure will play an increasing role, says Borns. Researchers at Sandia are examining these issues from a national security viewpoint.

## SPR in Numbers

| | |
|---|---|
| Current storage capacity | 727 million barrels |
| Average price paid for oil in the reserve | $27.73 per barrel |
| Maximum drawdown capability | 4.4 million barrels per day |
| Time for oil to enter U.S. market | 13 days from presidential decision |
| | |
| Past Emergency Sales | |
| - 2005 Hurricane Katrina sale | 11 million barrels |
| - 1991 Desert Shield | 17 million barrels |
| | |
| Investment to date | $22 billion |
| Number of people employed by SPR | About 1,050 including contractors |
| Number of years of Sandia involvement | 29 |

# Sandia foam no 'wipeout'

*Sandia researchers have developed a low-density, environmentally friendly foam that may be the answer to a surfboard industry critical material supply problem. Originally created to protect sensitive electronic and mechanical structures from harsh environments, the foam's properties may be ideally suited for surfboard blanks — not to mention other applications, such as car bumpers and airplane wings.*




**Small version of surfboard blank made from TufFoam.**

**(Photo illustration by Randy Montoya)**

*Two licensees have begun evaluating a Sandia-developed foam for use as surf-board blanks. Scores of other inquiries have been received for other potential uses.*

Researchers at Sandia in Livermore, California, have developed a low-density, energy-absorbing foam that — among other potential applications — could help avoid a complete wipeout for the nation's $200 million surfboard manufacturing market. TufFoam™ was originally conceived by Sandia materials scientists as an encapsulant material to protect sensitive electronic and mechanical structures from harsh weapons environments. But beyond its use as a structural material, the foam likely has other applications.

The material is unique in its ability to withstand high-rate impact without fracture or loss of structural integrity. Largely because of its low density — two pounds per cubic foot — Sandia's TufFoam™ might very well fit the bill as a drop-in replacement material.

"It can be used for thermal and electrical insulation, and as a core material for the automobile and aerospace industries," says Jim Wilhelm, a business associate at Sandia, which is actively pursuing licensing and commercialization partners. "TufFoam™ might not only be ideal for surfboards, but also for car bumpers and airplane wings. The potential market could be staggering."

## Strength to weight

Clark Foam, the leading manufacturer of foam for surfboard construction, unexpectedly closed its doors late last year because of the impact of ever-tightening environmental regulations on the manufacturing of their polyurethane surfboard blanks. The move led to near-panic, particularly in California, by manufacturers and sellers of surfboards, who feared they would not be able to find the high strength-to-weight ratio surfboard blanks necessary to make the boards. Surf historian Matt Warshaw, in an article in the *Santa Barbara NewsPress*, described the loss as "the equivalent of removing lumber from the housing industry."

Sandia materials researcher LeRoy Whinnery with two TufFoam™ samples. (Photo by Bud Pelletier)

A key feature of TufFoam™ is that it does not contain toluene diisocyanate (TDI). A toxic chemical used in the production of the polyurethane foam surfboard blanks, TDI use is being restricted by increasingly stringent interpretation of environmental regulations.

Another attractive feature of the Sandia product is that all of the chemicals used to make TufFoam™ are commercially available in commodity quantities. The material is currently formulated to be processed in a batch mode, but the processing schedule can be modified for machine mixing or injection molding.

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# Showing what experiments miss

Simulations of the nanoscale provide researchers more detailed results — not less — than experiments alone. That was the message delivered by Sandia researcher Eliot Fang to members of the Materials Research Society at its semiannual general meeting in April.

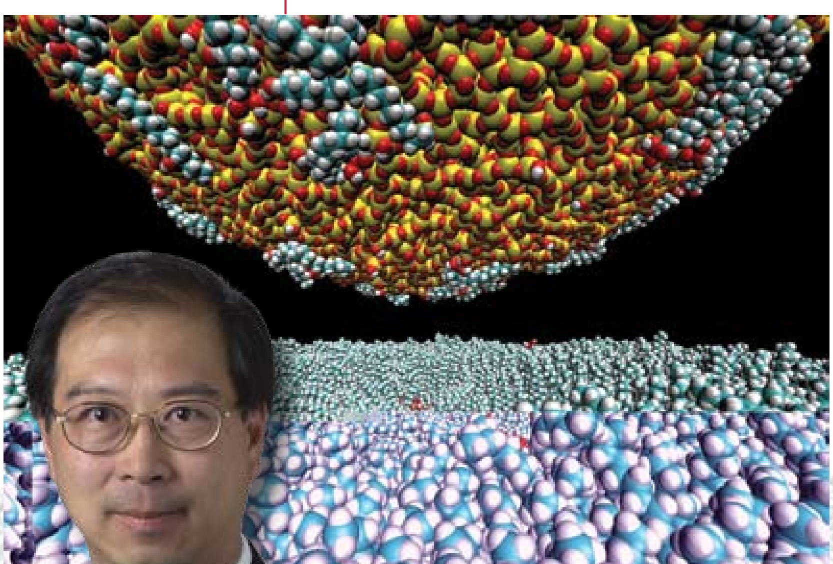
Fang disputed the conventional belief that inputs for computer simulations are so generic that outcomes fail to generate the unexpected details found only by actual experiment. In fact, he reversed the truism. "There's another, prettier world beyond what the SEM [scanning electron microscope] shows, and it's called simulation," he told his audience. "When you look through a microscope, you don't see some things that modeling and simulation show."

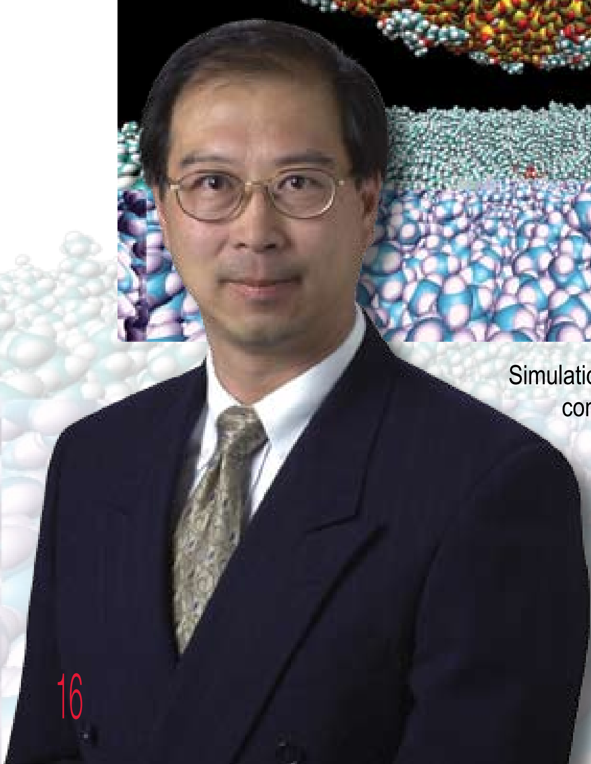
This upgrade of the position of simulations in science is a natural outcome of improvements in computing, Fang said. "Fifteen years ago, the Cray YMP [supercomputer] was the crown jewel; it's now equivalent to a PDA we have in our pocket."

No one denies that experiments are as important as simulation — equal partners, in fact. But for predicting the reliability of materials that coat surfaces, Fang said, "We find that when we compare our simulation models with data from the experiments, we get a more complete understanding."

There is also the matter of cost, he said. "With smart people developing numerical methods, models, and algorithms to use computers to study real cases, we find we can rerun calculations merely by changing computer parameters. Thus the cost to push science forward is much cheaper than running experiments — particularly in nanoscience, where the realm is so small that experiments are difficult to perform, testing devices are not available, and data acquisition is a challenge.

"We need to sit back and put our mindset in a different mode," Fang told his audience. "We're all too busy doing [laboratory] research [instead of considering] how we can leverage resources to push our science to the next level."





Simulation of an Atomic Force Microscope tip contacting an anti-friction coating used in micro-electromechanical systems demonstrates that contact with the sample leads to material being transferred to the probe tip.

(Simulation by Sandia researcher Michael Chandross)

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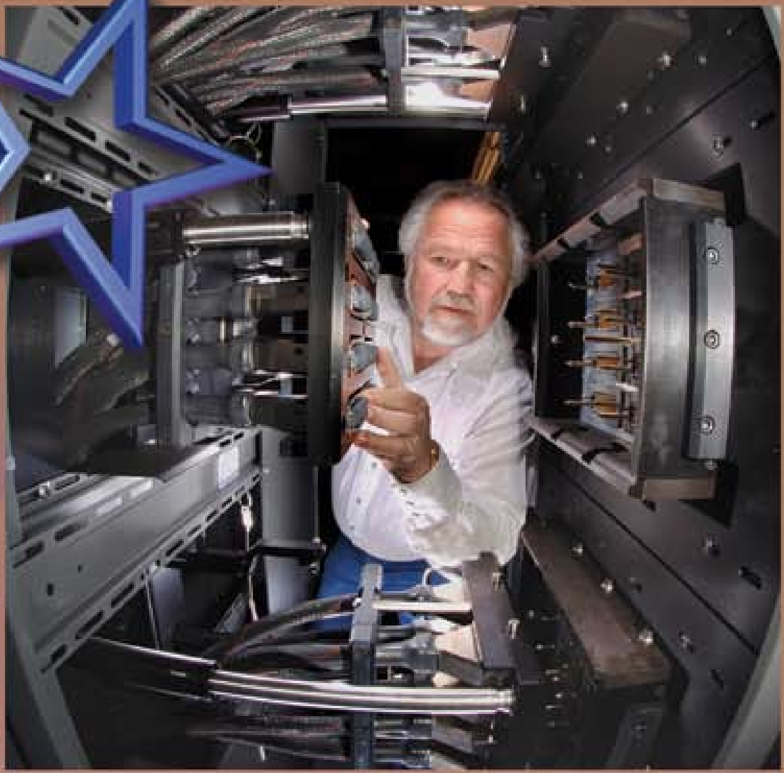

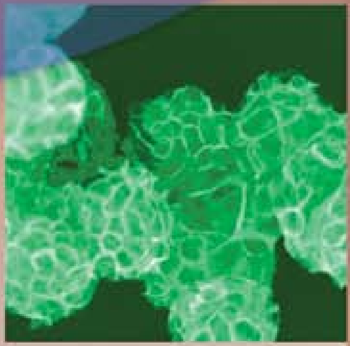

*"There's another, prettier world beyond what the SEM [scanning electron microscope] shows, and it's called simulation. When you look through a microscope, you don't see some things that modeling and simulation show. With smart people developing numerical methods, models, and algorithms to use computers to study real cases, we find we can rerun calculations merely by changing computer parameters. Thus the cost to push science forward is much cheaper than running experiments — particularly in nanoscience, where the realm is so small that experiments are difficult to perform, testing devices are not available, and data acquisition is a challenge."*

**Eliot Fang**
*Sandia researcher*

Sandia National Laboratories

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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

NNSA National Nuclear Security Administration

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