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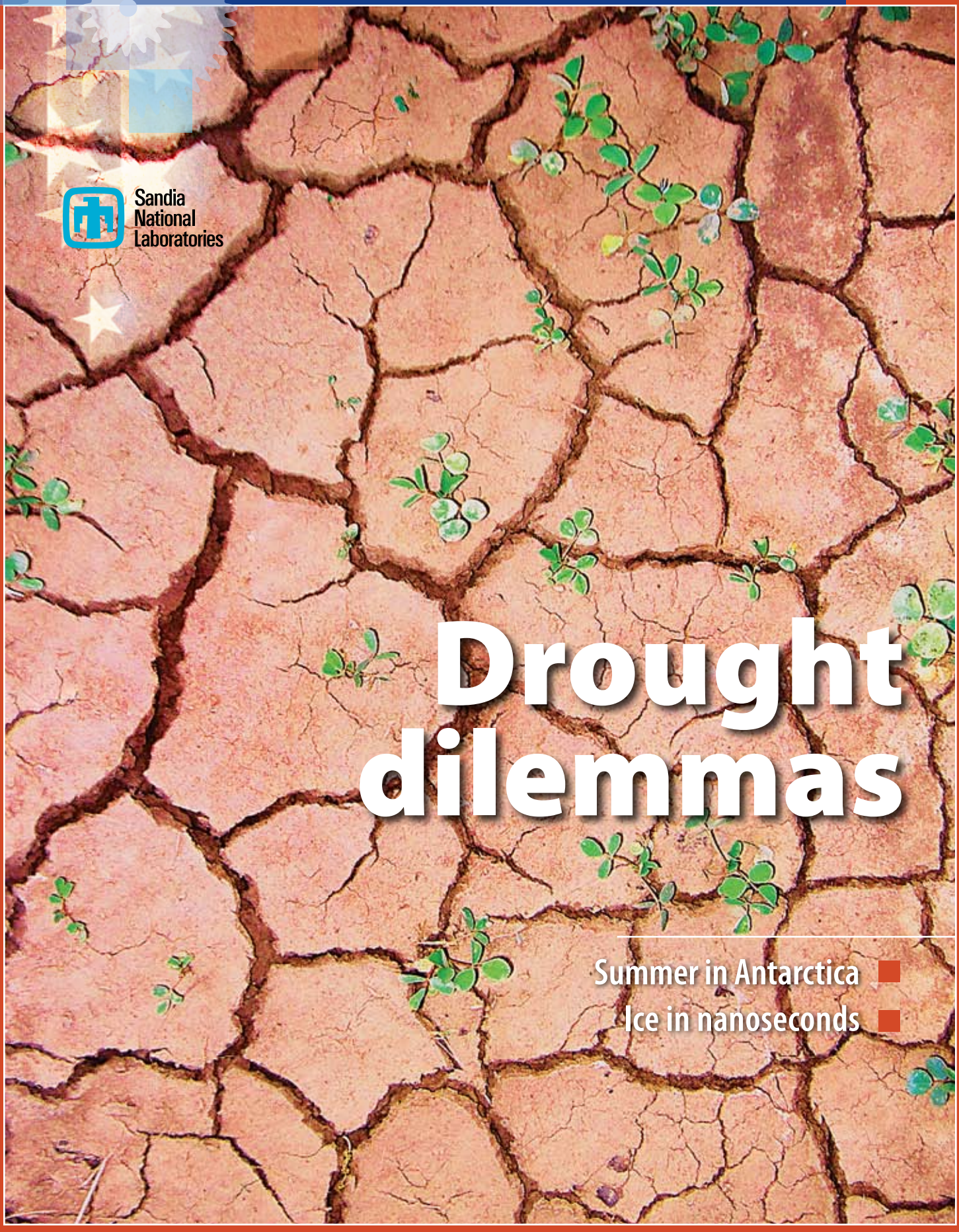

Drought dilemmas

Summer in Antarctica

Ice in nanoseconds

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What is LDRD?

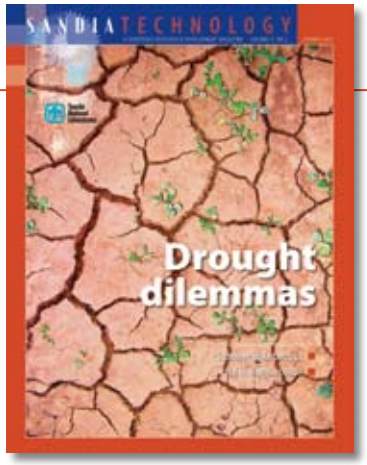
Sandia's world-class science, technology, and engineering work defines the Labs' value to the nation. These capabilities must remain on the cutting edge, because the nation's security depends on them. Sandia's Laboratory Directed Research and Development (LDRD) program provides Sandia the flexibility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

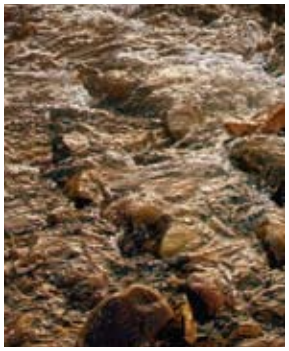
LDRD supports Sandia's four primary strategic business objectives: nuclear weapons; energy, resources, and nonproliferation; defense systems and assessments; and homeland security and defense. LDRD also promotes creative and innovative research and development by funding projects that are short term, discretionary, 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 stage in the history of the technology or program, LDRD funding played a critical role.

On the cover:

In the arid West and elsewhere, disputes over water are being resolved with the help of computer models. (Story on page 12.)





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Dear Readers,

When 12 miners died last January at the Sago Mine in West Virginia, the Mine Safety and Health Administration needed answers. Experiments by a Sandia team confirmed that a lightning strike above the mine could have caused a spark in the mine, a conclusion the MSHA adopted in its final report. The results could lead to life-saving new practices. (Page 2)

In the last issue we followed researchers to chilly northern Alaska on an expedition to understand climate change. In this issue, we go to the other extreme — to Antarctica, where another Sandia team is testing a type of radar that sees through snow. The sensor shows promise for helping pilots detect hidden, snow-covered crevasses that make landing planes there treacherous. (Page 8)

Microfluidics — the art and science of handling minuscule volumes of liquid — has come of age. Research supported by the LDRD program allows scientists to examine individual cells as they are attacked by, and respond to, infectious agents. (Page 6)

Finally, as conflicts over water become commonplace in many parts of the world, new computer tools are encouraging farmers, urban developers, environmentalists, and others to put their heads together, to resolve their differences. (Page 12)

Other highlights:

- Ice hotter than boiling water? In an LDRD-supported project, researchers examine states of water we've never heard of, or imagined. (Page 18)
- Fake-proof U.S. currency is the goal of a National Academies study, and technology is leading the way. (Page 5)
- Decontamination foam developed to dash away bio warfare agents is being sold in stores to combat a more common problem — household mold. (Page 21)

John German
Sandia Technology Editor

Findings of a Sandia research team were part of a recently released report by the U.S. Mine Safety and Health Administration (MSHA) indicating that lightning was a likely cause of the explosion in the Sago Mine on Jan. 2, 2006. The disaster killed 12 coal miners.

Tragedy strikes

Story by Chris Burroughs

What ignited the explosion that killed 12 miners the morning of Jan. 2, 2006, at the Sago Mine in West Virginia? Since the tragedy struck nearly 18 months ago, several theories have been put forward, ranging from a gas-well rupture to a roof fall to a lightning strike.

As part of its official investigation, the MSHA asked Sandia to examine whether energy from a lightning strike could have traveled underground to ignite an explosive mixture of methane gas trapped in a sealed section of the mine.

Smoking gun

Among evidence for the lightning theory were three strikes recorded by national detection networks, along with eyewitness accounts of other strikes near the mine. The bolts struck nearly simultaneously with the explosion, registered by seismographs.

Thirteen miners were in close proximity to the underground blast when it occurred. The force of the explosion killed one, and 12 others retreated behind a curtain at the working face of the mine in an attempt to barricade themselves against the smoke and carbon monoxide. They awaited rescue, which would come too late for all but one of them.

In early November 2006, a Sandia team spent 10 days at the Sago Mine analyzing the likelihood that electric current produced by a lightning strike could transmit effects deep into the coal mine. Their findings became part of the final MSHA accident investigation report delivered to Congress on May 9, 2007.

"We never expected to discover a smoking gun," says Sandia senior manager Larry Schneider. "However, we pursued and characterized a coupling mechanism that the team of accident investigators hadn't previously considered — that current from a surface lightning strike can generate electromagnetic fields that can propagate through the earth, as opposed to current being driven into conductors entering the mine such as metal rails or power lines."

Sandia has studied lightning effects for decades, primarily to understand how it might affect critical nuclear weapons facilities at U.S. Department of Energy facilities such as the Pantex Plant located outside Amarillo and underground facilities at the Nevada Test Site.

"Accident investigators had been suspicious all along that lightning was the cause of the explosion, but there had been no definitive proof one way or the other," says Sandia manager Michele Caldwell.

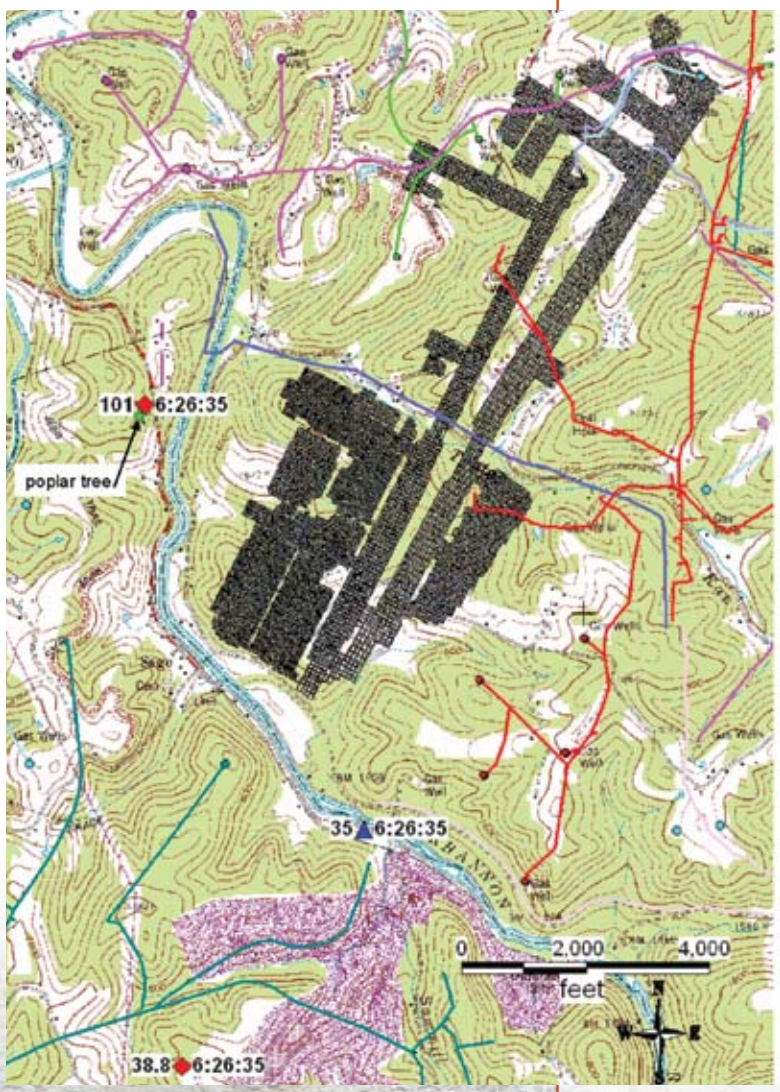
Two scenarios

The Sandia team investigated two modes of transmitting lightning energy into the mine,

Caldwell says. The first mode was direct attachment onto metallic penetrations — such as conveyers used to extract the coal, rails used for transporting people and equipment, or power and communication lines — from the entrance to deep inside the mine. The second mode was energy propagation through the earth's surface from the point of a surface lightning strike or overhead arc channel.

For the metallic penetrations, a small, continuous electrical drive signal was applied at the entrance to the mine, and signals were measured with current and voltage probes at various points in the mine as far as two miles in. The goal was to see how much the signals decreased as a function of the distance from the entrance to the mine.

For measuring propagation of lightning energy from the surface to the mine cavern 300 feet below, the drive signal was applied to a long wire stretched on the surface. Directly below, inside the mine, an antenna was set up to pick up the transmitted signals. Multiple antenna measurements were made inside the mine. The measurements were compared to analytical models simulating lightning field propagation through the earth.



An MSHA map shows the Sago Mine (black) with locations of lightning strikes (red diamonds and blue triangle) recorded at the time of the explosion.

Sandia researcher Dawna Charley, left, and a miner at the Sago Mine's entrance during experiments last November.

Matt Higgins conducts an experiment at the Sago Mine.

The National Lightning Detection Network recorded lightning strikes near the mine area at the time of the accident. One strike may have hit this poplar tree.

The results were combined with a theoretical lightning strike waveform to determine if voltages could get high enough inside the mine to be of concern.

Clear results

The study concluded that it is highly unlikely electromagnetic energy from the strike traveled along conductors through the mine and into the sealed area to ignite the explosion. However, electromagnetic energy from a significant lightning event at the surface, above the sealed area, could have traveled through the ground to create high voltage in the sealed area, subsequently creating a spark that ignited flammable methane mixtures.

"The results of field measurements and analytical modeling were clear — lightning can propagate significant electrical energy into mine systems under the right conditions," says Schneider.

He says mine safety might be improved with a better understanding of this phenomenon in the variety of scenarios seen in the U.S. mining system.

"I can readily envision this leading to additional, reasonable preventive measures to reduce the probability of such a catastrophic event in the future," he says.

MSHA's report on the Sago Mine accident is online at www.msha.gov.

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Discouraging counterfeiters

Tomorrow's U.S. currency may feature 21st-century materials and technology to help deter counterfeiting. A National Academies committee recently recommended several new features — ranging from color-changing inks to nanoengineered materials — that would change the look, feel, and reproducibility of future banknotes. Some of the group's recommendations may show up in a new $100 bill due out in the next few years.

Sandia materials scientist Liz Holm served on the committee, sponsored by the National Research Council's Board on Manufacturing and Engineering Design. Holm works on computer simulations to understand the behavior of materials in a variety of applications. Her time was funded in part by the LDRD program.

The committee submitted several recommendations in two categories to the Department of the Treasury. Features in the first category could be fully developed and ready for use in a banknote within seven years. Because the most common counterfeiting threat today is digital reproduction of paper money using scanners and inkjet printers, the group's proposals focus on features that can't be successfully scanned.

Features in the second category would likely take longer to incorporate, including revolutionary options that would dramatically shift currency away from the ink-on-paper paradigm. The ideas include altering the look and feel of the bill (including analog printed patterns that create visual artifacts when digitally reproduced), adding a see-through registration feature, and incorporating holograms and visual effects.

Patterns using metametric ink could be used to change the color of the money in different lighting conditions. Adding a pattern of small holes in the paper using a laser, a technique called microperforation, also could make reproduction difficult.

Nanotechnology offers some counterfeit-protection concepts that would be difficult for the casual counterfeiter to duplicate, Holm says. For instance, nanocrystal pigments could be used to provide unique color and spectral characteristics in an ink format that could be used to form images on the currency.

Long-term changes include bills created from genetically engineered cotton, or solar chips implanted in bills to power electronic features — like a twinkling eye in a bill's portrait.

"It'll be exciting to see what changes are incorporated in future notes based on the recommendations the committee provided," Holm says.

Hongyou Fan works with nanocrystalline pigments that could be used to print patterns that would fluoresce differently in varying lighting conditions.
Photo by Randy Montoya

Liz Holm served on a National Academies committee that proposed ways to deter counterfeiting of U.S. currency.
Photo by Randy Montoya

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Looking at immune response one cell at a time

Story by Chris Burroughs

A Sandia research team led by Anup Singh is taking a new approach to studying how immune cells respond to infectious agents in the first few minutes or hours of exposure. The team's method looks at cells one at a time as the cells start fighting invading pathogens.

A project, called the Microscale Immune Studies Laboratory (MISL), is investigating early events in immune system response — when pathogens first invade a body. The work is in its second of three years of funding from the LDRD program. Sandia is partnering with the University of Texas Medical Branch at Galveston and the University of California, San Francisco on the project.

Understanding these early steps could lead to better ways to diagnose and stop disease before there are symptoms, and to more effective therapeutics, says Sandia team lead Anup Singh.

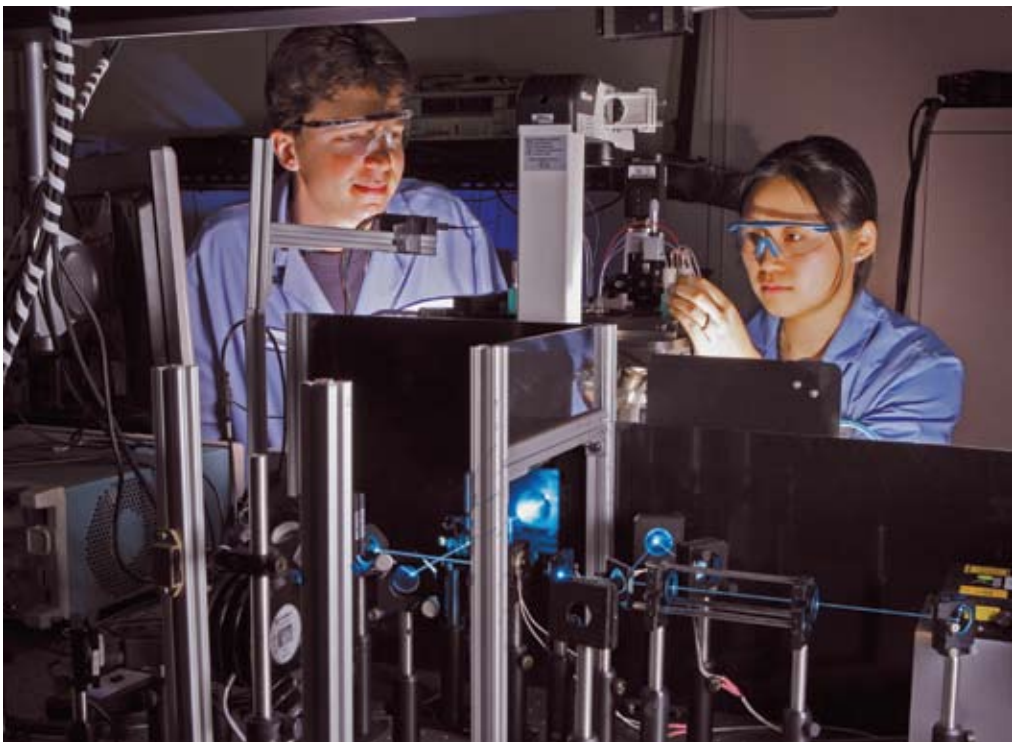
Most existing research into how immune cells respond to pathogens has been done by looking at large cell populations. But information gathered by examining a large population of cells may mask underlying mechanisms at the individual cell level, Singh says.

"Cells have different life cycles, just like any living being. And not all cells are exposed to the pathogen at the same time," Singh says. "We wanted to look at cells in the same life cycle and same infectious state. This can only be done cell by cell. We also want to study populations, but one cell at a time."

New tools

The research is possible because of advances in several Sandia-developed technologies, including:

- Microfluidics — tiny valves, pumps, pipes, and other devices — that allow researchers to manipulate single cells
- Advanced imaging to see greater detail than is possible with current commercial imaging technologies
- Computational modeling to help researchers make sense of data obtained from microfluidic analysis and imaging



Designer Thomas Perroud assists biologist Meiye Wu with sorting of macrophage cells in an optical tweezer, using a microfluidic device developed in the Microscale Immune Studies Laboratory. *Photo by Randy Wong*

Real immune cells are short-lived outside of bodies. To do the type of experiments the researchers wanted, they needed cells that can stay alive more than a couple of hours, have the ability to grow, and represent a relevant model of human immune cells. They obtained "immortalized" mouse immune cells from a collaborator at the University of California. These cells have the needed life span and are accepted as a model system by the immunological research community.

"We're starting with robust and well-characterized cells, which simplifies development of our new technologies and methods," Singh says. "We'll soon be working with other cell types, though, like white blood cells isolated from human patients. Our approach is designed to be flexible enough to handle many different cell types, and it also minimizes the number of cells needed for analysis, so it should enable us to do some unique studies on rare cell types."

Proteins in the cells of interest are tagged with fluorescent molecules, essentially colored dyes. The dyes give researchers the opportunity to track proteins and see, for example, the dynamic cellular production of proteins or protein-binding processes inside or on the surfaces of the cells.

The team is developing one platform with two complementary microfluidic modules. One traps and images viable cells during stimulation with pathogens. The other combines cell preparation steps, cell selection, and sorting and analyzes protein content in the selected cell subpopulations.

Compact platform

"In effect, we are taking many workhorse technologies such as confocal microscopy, flow cytometry, and immunoassays and combining them into one compact, miniaturized platform using our unique microfluidic and imaging tools," Singh says.

Hyperspectral fluorescence imaging with multivariate curve resolution is used to image the tagged proteins and provide quantitative measurements on multiple proteins simultaneously. The goal is to analyze as many as 10 to 40 proteins and cellular stains at a time in three dimensions.

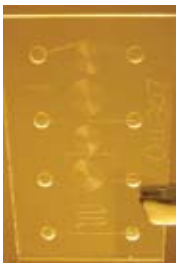
The end result of the imaging and protein analysis is a large amount of data that must be categorized and understood. Computational modeling is then used to develop network models from experimental data, and predictive modeling generates hypotheses to be tested next.

Singh says Sandia researchers have been working in microfluidics — the science of designing, manufacturing, and formulating devices and processes that deal with volumes of fluid on the order of nanoliters — since the 1990s and have a good understanding about how to use microfluidics to analyze cell activity. The microfluidic platform is fast and highly parallel and can perform measurements 50 to 100 times faster than alternate methods.

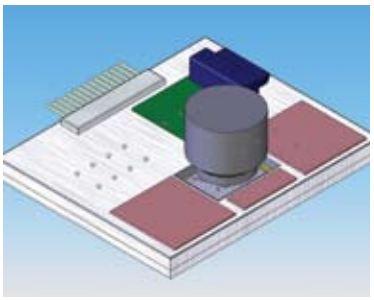
Singh says the goal of the work is to make a benchtop miniaturized system, expected in about two years. It would be placed in highly secure labs to study immune response to pathogenic organisms.

The integrated platform, biological reagents, and computational models developed under this project have applicability beyond infectious disease research, says Singh. These technologies can also be used for studying cellular signaling involved in diseases such as cancer. Pharmaceutical companies might make use of it for biomarker discovery, he says.

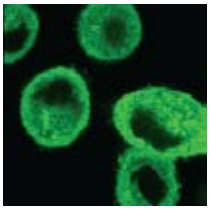
For more information:
http://roswell.ca.sandia.gov/anup.



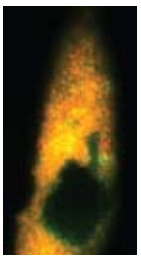
Cell-preparation module that is part of a MISL chip



Top of MISL chip with cell imaging area at right



Macrophage cell carrying green fluorescent-labeled protein



Macrophage cell infected with *Francisella tularensis novicid*, a form of the bacteria that causes tularemia, or rabbit fever

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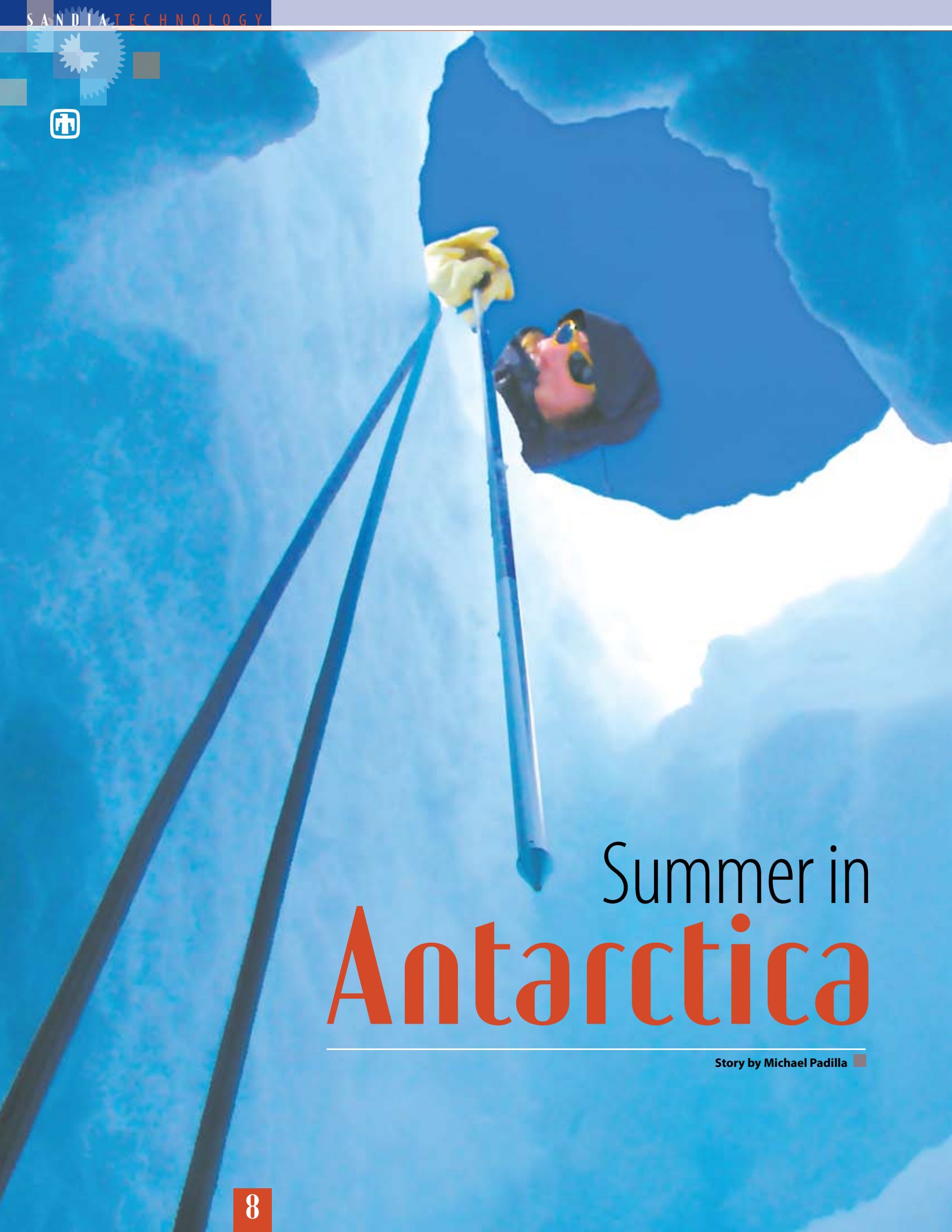


Summer in Antarctica

Story by Michael Padilla

Sandia researchers Jeff Bradley and Jeff Bach unload survey equipment from a snow vehicle.

Deep cracks in the antarctic ice have made landing airplanes there difficult and dangerous. The New York Air National Guard needed a way to detect the snow-covered crevasses from the air. Synthetic aperture radar is showing the way.

In one of the coldest parts of the world, four Sandia researchers took advantage of what is considered to be one of the warmest times of the year in Antarctica late last year.

At peak temperatures of 35 degrees outside with the sun shining continuously, the researchers worked diligently on a highly planned project. There was no room for error or equipment failure because there is no overnight express to Antarctica.

The goal of the mission was to test a Sandia-modified miniaturized synthetic aperture radar (MiniSAR) prototype sensor that could detect buried crevasses for the New York Air National Guard. Flying for the National Science Foundation, the Air Guard must land planes safely in remote areas of Antarctica. The use of the Sandia sensor would augment or replace the present method of manually finding the crevasses.

"We were highly successful in demonstrating our ability to detect snow-covered crevasses in Antarctica using Sandia's MiniSAR crevasse detection radar," says Tim Mirabal, project manager. The team left on Thanksgiving Day 2006 and stayed on Planet Earth's southernmost continent for nearly three weeks.

Technical homework

Sandia began working on the crevasse detection radar early in 2006 with funding from the Air National Guard to create a system using Sandia's existing MiniSAR technology.

The first step was to change the normal KU-band frequency to X-band. KU-band frequency is 12 to 18 GHz and X-band frequency is 8 to 12 GHz. The lower frequency was needed to penetrate the snow. Snow in Antarctica is unique in the world as it is very dry; whether the radar would perform as well in other climates would need to be investigated, says Mirabal.

The team built an external X-band converter and changed the front-end components. New

Grant Sander runs the radar during data collection from a de Havilland Twin Otter plane.

engineering had to be done to accommodate the X-band frequency. A gimbal arm and electronics were redesigned to allow free movement and antenna balance. The design had to allow for easy assembly and disassembly, says team leader Grant Sander.

In addition, the team developed specifications for data formats, mechanical and electrical components for installation on the plane (a de Havilland Twin Otter), and software tools to review the data.

The technical design team, composed of more than 30 Sandians, worked for 10 months to meet the objectives of the project. The team built two systems, one serving as a backup. "Being that far away, it was good to have a complete spare in your back pocket," says Sander.

Road to Antarctica

The hidden crevasse problem was first brought to Sandia's attention in 1999, when the Guard needed assistance in locating deep cracks in the ice. The crevasses made it difficult and dangerous to land airplanes. Historically, millions of dollars have been lost due to crevasse-related incidents.

The Air Guard uses the LC-130 aircraft, which has special landing gear, to operate off the snow and ice at McMurdo Station, Antarctica's largest community. McMurdo is built on the bare volcanic rock of Hut Point Peninsula on Ross Island, the farthest south that solid ground is accessible by ship. Established in 1956, McMurdo has grown from an outpost of a few buildings to more than 100 structures, including a harbor, an outlying airport with landing strips on sea ice and shelf ice, and a helicopter pad. There are above-ground water, sewer, telephone, and power lines linking buildings. During the winter 200 to 400 people work at McMurdo, with the population swelling to 1,500 in the summer.

Before arriving at McMurdo, the researchers underwent numerous and extensive physical and dental exams. Each team member had a backup who also went through the rigorous exams as if they were going. At Christchurch, New Zealand, they were fitted for extreme cold-weather gear, and upon arrival at McMurdo they participated in a two-day boot camp where they learned various safety and survival techniques.

The hunt for crevasses

"Most people don't realize how large Antarctica is," says Sander of the continent that is 1.5 times the size of the U.S. "This is the area the Guard is dealing with when it comes to the remote sites that they need to supply."

The crew collected data in several locations. "First we mapped McMurdo, Scott Base, and the nearby pressure ridge. Then we flew to the Pegasus wreck site, where our corner reflector array and junk pile were located," says Jeff Bach, who served as test planner, motion measurement operator while flying on the aircraft, morale officer, and snow shovel operator. Data were sent from the detection radar to an office at McMurdo, where Doug Bickel served as on-ground support analyst.

Bickel then pieced together the data to create coherent maps of the surveyed areas. "Piecing the data together using software was a difficult task," Bickel says. "But the software was able to receive high volumes of data."

On one day the researchers conducted two flights, mapping two 5-by-5-nautical-mile areas. A 5-by-5-mile area was a goal set by the Guard to find a suitable spot to land in the vicinity of a remote camp.

"We saw crevasses from the first patch of radar data onward," Bach says. "The first area was at the shear zone, an area where multiple glaciers come together and flow in parallel. There is a road bladed into it, an attempt to build a road to the South Pole. It has not been maintained this year, but we think we saw it anyway in the radar data. This couldn't be seen by the naked eye."

The Tres Hermanas crevasses, selected by Guard customers, were studied closely. The three crevasses are difficult to see from the air and are located in a fairly flat area that represents a possible location to land LC-130 aircraft. The Tres Hermanas are relatively narrow — around four meters wide — and are covered with snow bridges. Loose snow blows across and camouflages the crevasses, making them look like all the other terrain, especially from the air. The bridges across these crevasses are made up of very loose snow and are only a couple meters thick.

One customer, who is also an LC-130 pilot, "was thrilled that he could detect these crevasses using the radar, especially because of their size and the difficulty of seeing them from the air," says Mirabal.

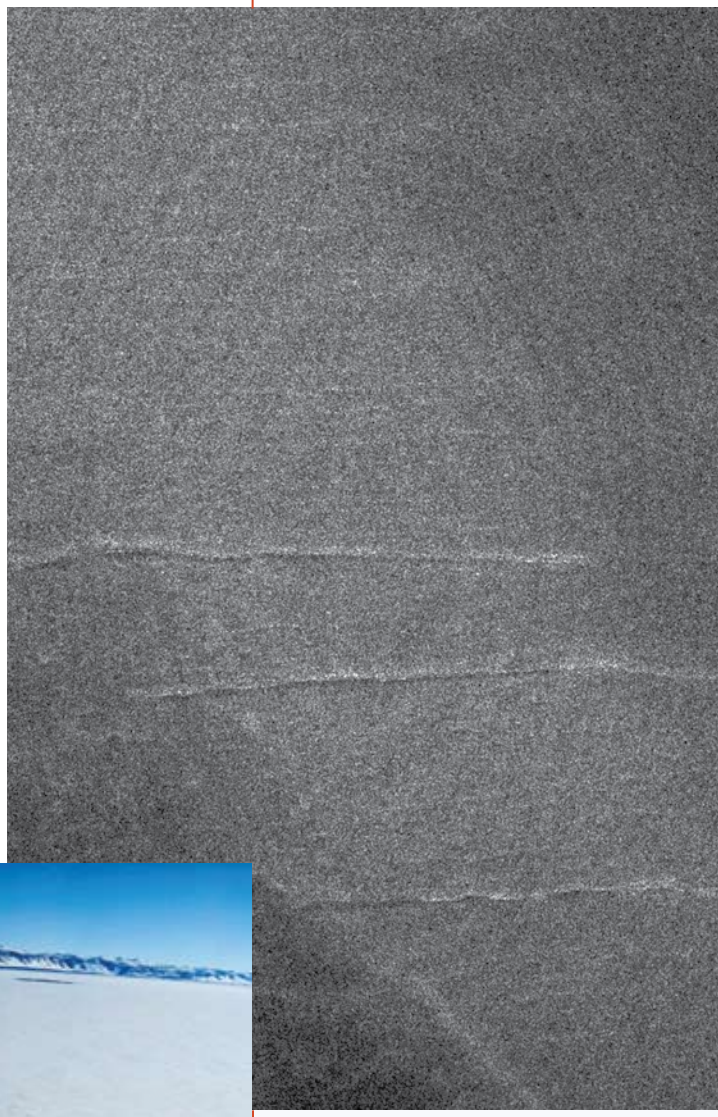
Hidden threats

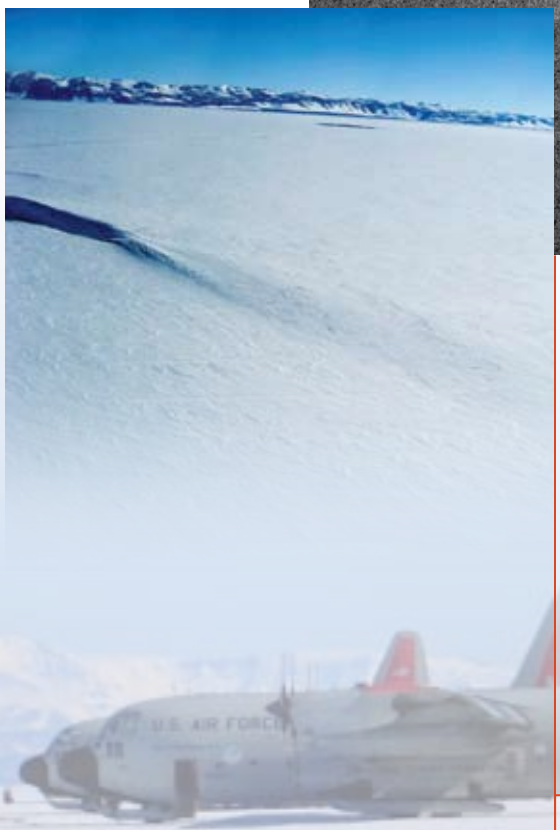
"The Antarctica MiniSAR radar can identify hidden threats and effectively cover large areas," says Mirabal.

"The efficacy of the sensor for this application has now been proven," Bach says. "I hope the project has the opportunity to carry forward to a fully deployable system that the Guard can use to make its job of supplying the remote camps and conducting emergency operations in Antarctica safer and more efficient."

Next steps

Now that Sandia has successfully demonstrated the ability to see buried crevasses, the team will begin to integrate the system with the LC-130 aircraft. "Integration will be a challenge as a lot of work is still necessary to make the system more rugged and user friendly, but we're up to the task," says Mirabal. "The MiniSAR radar has other applications, such as day or night search and rescue, a capability the Guard needs. And we will continue to assist them."





Synthetic aperture radar image of three crevasses, known as the Tres Hermanas, in the shear zone (above). Ground-level photo of one of the crevasses (left).

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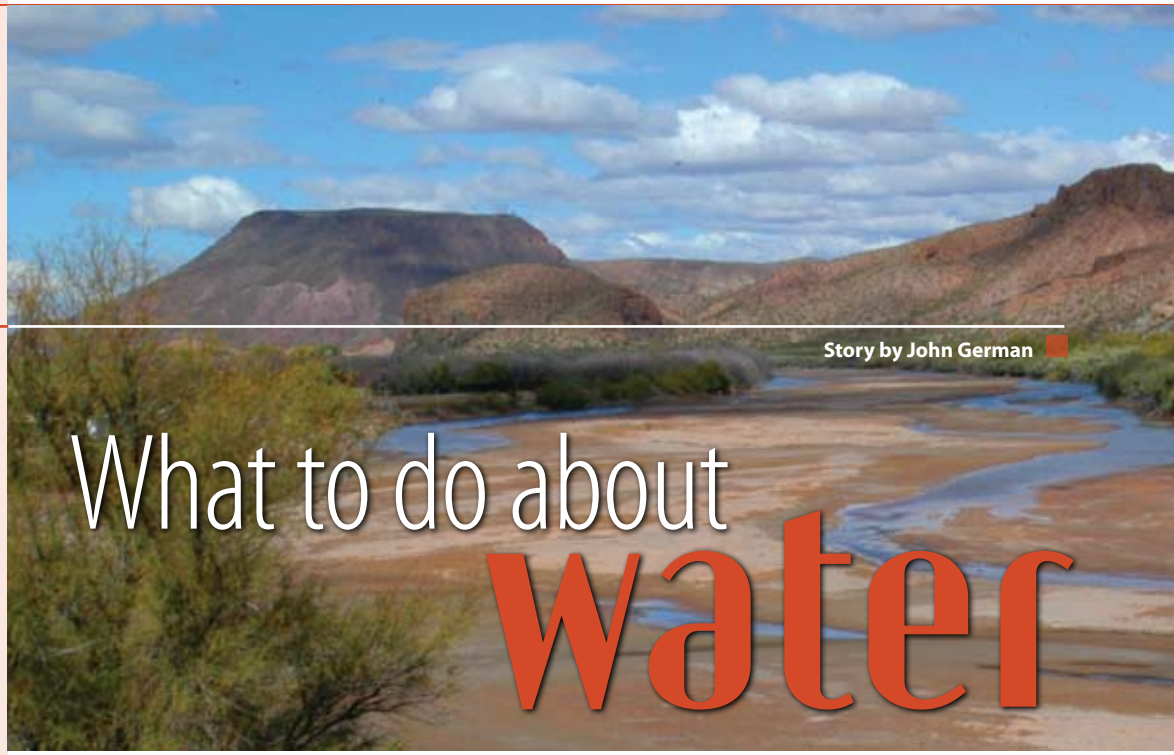


Story by John German

What to do about water

In the American West, developers, farmers, environmentalists, and policy makers are seeking solutions to growing water shortages resulting from agricultural demand, increased development, and drought. New decision tools run on computers are allowing them to explore how choices made today might affect water supplies decades from now.

In southwestern New Mexico, just north of the Mexican border, lies a river basin in limbo. Last June, flows in the Rio Mimbres were insufficient to meet the demands of farmers. It had irrigators — those whose families have farmed the land along the river for centuries — wondering how they could keep their fields green until fall. Then the rains came.

Another couple of dry weeks and the courts would have refereed a water rights dispute whose outcome would satisfy few. The conflict pitted farmers on the "senior ditch" (flanked by senior water rights holders) with upstream farmers and domestic well owners, who would have had to severely curtail their water use to allow the downstream users access to water.

The worst did not come to pass last summer, though all agree that at some point the junior rights holders in the Mimbres river basin will be ordered to cut back.

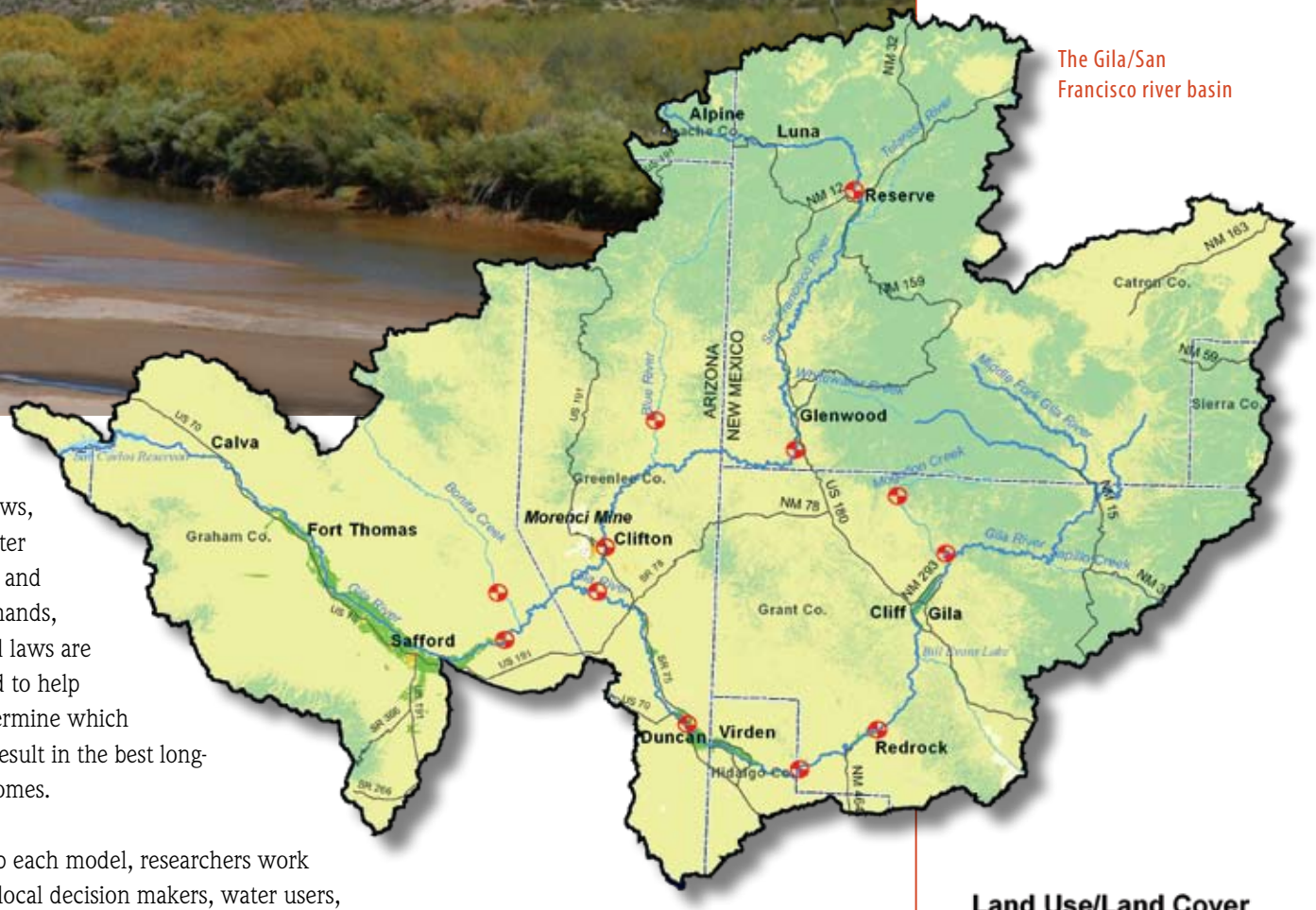
It is a scenario that is playing out across the western United States, portions of which are in an extended drought, says Sandia researcher Vince Tidwell. Surface water and groundwater rights are being contested, suits are being filed to protect aquatic and riparian habitat, and communities and companies are scrambling to assign limited water rights to future demands.

Along the Middle Rio Grande Valley in central New Mexico, for example, state, county, and municipal governments are grappling with the competing water demands of sprawling residential development, agricultural irrigation, and the needs of an endangered fish called the silvery minnow.

Just north of the Mimbres basin, in the Gila/San Francisco basin that stretches into Arizona, authorities are deciding what to do with an extra 14,000 acre-feet of water per year awarded to New Mexico as part of federal legislation known as the 2004 Arizona Water Settlements Act. New Mexico wants to put the water windfall, along with the federal funding that came with it, to the best possible long-term use while preserving environmental resources in the region.

Farther away, on the Willamette River in western Oregon, authorities, users, and environmentalists are devising a system of barter for "thermal credits" whereby heating of river water by communities and pulp and paper mills who use the water is traded for restoration projects that cool water elsewhere along the river, all to improve salmon habitat.

In each case, Sandia computer models that simulate the complex interrelationships among



The Gila/San Francisco river basin

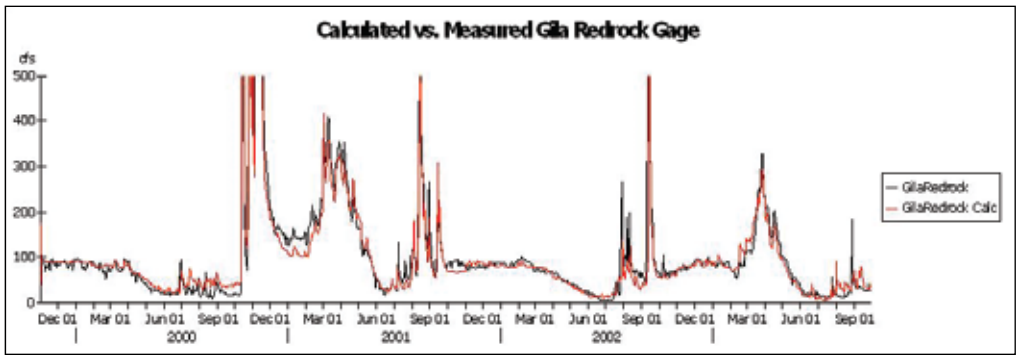
surface flows, groundwater dynamics, and water demands, rights, and laws are being used to help locals determine which tradeoffs result in the best long-term outcomes.

To develop each model, researchers work alongside local decision makers, water users, and others as part of a process known as computer-aided dispute resolution (CADRe). The project is a joint effort of Sandia, the U.S. Army Corps of Engineers' Institute for Water Resources, and several universities. The work is done in part with funding arranged by Sen. Pete Domenici (R-N.M.).

Tidwell says the models allow decision makers to run hundreds of versions of the future and see the effects of their choices decades away. The models can be run on a PC. A simulation takes 10-15 seconds to run after the inputs are set.

In 2001 Tidwell and Sandia researcher Howard Passell began working with the Middle Rio Grande Water Assembly — representing agricultural, urban, and environmental interests in a three-county region in central New Mexico — to develop an integrated surface water and groundwater model. The water plan that resulted from the project was accepted by the state engineer's office in late 2003 as part of statewide water planning, says Tidwell.

More recently the Middle Rio Grande model was expanded to include 17 river reaches stretching from the Colorado state line to Elephant Butte Dam in south-central New Mexico, plus six reservoirs and three integrated groundwater basins. The model is available to city, county, and state water managers as a rapid analysis tool to help them home in on regional water solutions. Partners in the project include the New Mexico Interstate Stream Commission, the U.S. Bureau of Reclamation



Calculated water flows versus measured water flows on the Gila River

(USBR), the U.S. Army Corps of Engineers, and the U.S. Geological Survey (USGS).

The bigger value of the computer models might be in the collaborative process itself, Tidwell says. Local stakeholders are involved in building each model from the ground up for the specific water resource in question.

"We meet regularly with the stakeholders to discuss what's important for the area, how decisions are made, and what the alternatives are," he says. "When people see how the whole thing is built and how it works, they are more likely to accept its results."

Helping develop the models forces many collaborators to confront inaccurate assumptions about water, says Tidwell. Some believe, for example, that use of low-flow appliances will save a lot of water. In reality most indoor water used is restored in a municipal treatment facility and returned to the environment. Thus, very little water is saved by low-flow appliances.

With a healthy level of disagreement at the table, participants often begin to understand the perspectives of those they are competing with for water. "It forces them to look at water as a system and to deal with its physics," he says. "Without somebody cramming it down their throats, they come to understand the complexities and the need for a multidisciplinary approach."

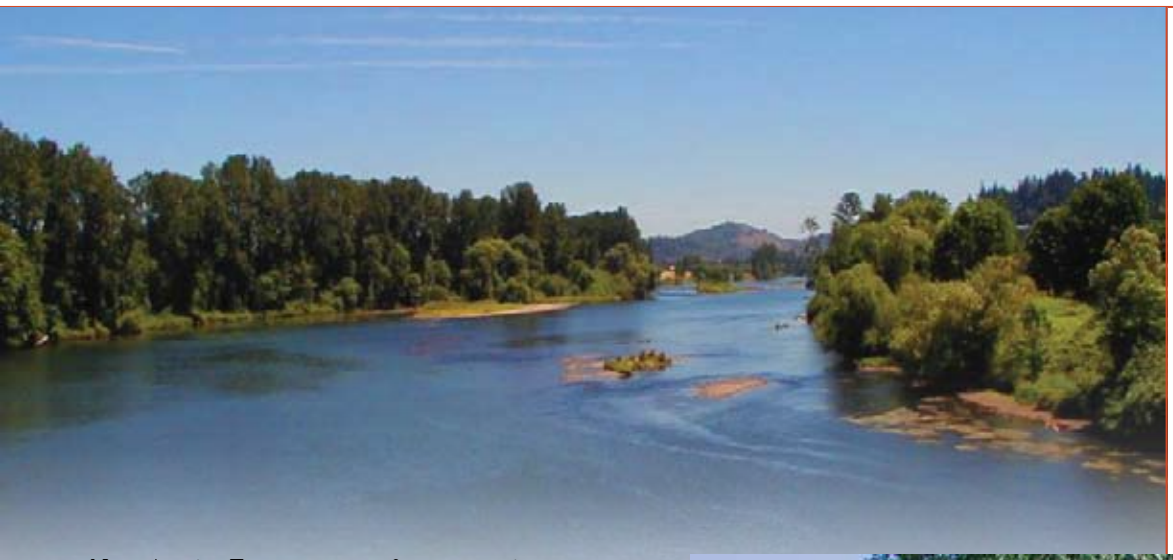
On the Gila River, as part of a project that began in October 2005 to allocate water awarded to New Mexico in the Arizona Water Settlements Act, Sandia worked with the New Mexico Interstate Stream Commission, USBR, U.S. Fish and Wildlife Service, environmental organizations, and the Southwestern New Mexico Water Planning Group to develop and test a computer-aided decision tool. The efforts have generated interest in expanding the model to address water issues in southwestern New Mexico more broadly.

In the Mimbres River basin, authorities are using a model devised by Sandia and the University of New Mexico to set up and test a water resources market, called a "water bank," whereby irrigators trade water credits with other users, not only within the same ditch but across ditches and with domestic well owners.

The model incorporates a four-mile stretch of the Rio Mimbres, the associated groundwater system, nine acequias, a reservoir, and adjudicated water rights for the basin. In times of drought, the Mimbres water bank would allow users to trade credits equitably by a set of defined rules and, thus, with minimal conflict, says Tidwell.

"It has allowed people to play a water trading game in a virtual environment to find out what will work and what won't work without losing any real water," he says.

Partners in the project include the New Mexico Office of the State Engineer, Mimbres Water Users Group, and the University of New Mexico.



On the Willamette River in western Oregon, locals are devising a system to limit industrial heating of surface water.

Near Austin, Texas, as part of a cooperative project with the University of Texas funded by the LDRD program, Sandia researchers helped couple system-level models, which allow for rapid analysis, with a spatially detailed USGS MODFLOW groundwater model to study part of a major aquifer. Joining the modeling platforms allowed for greater flexibility in the simulations performed and helped engage stakeholders in the decision process, says Tidwell.

The water modeling work has an international component to it as well. Howard Passell and a team of Sandia researchers are using common water concerns to foster cooperation among governments at international borders, particularly in the Middle East.

Acequia, or ditch, on the lower Rio Mimbres

Gila River basin (red) and Rio Mimbres basin (blue)

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Water resources decision making often results in a protracted, inefficient, litigious decision process that takes too long, costs too much, and leaves us without broad consensus on the decisions.

When water disputes boil over

By Hal Cardwell
U.S. Army Corps of Engineers
Institute for Water Resources

Persistent conflict among competing interests and needs is increasingly common in water resources management. Too frequently, conflicts bubble outside the control of water managers, as individuals illegally open irrigation gates, groups organize mass demonstrations to reject privatization of water services, and states sue each other over water withdrawals.

These conflicts occur in arid regions such as New Mexico (think silvery minnow and U.S.-Mexico relations around the Rio Grande), and humid ones such as Virginia (think trans-basin diversion for Virginia Beach's water supply, or the ongoing battle over King William reservoir). They occur in highly developed economies like ours, and in countries such as Bolivia where the median income is well below our poverty line.

By its very nature, solving water problems requires technical information to identify and evaluate solutions. But too often the information is not presented well, decision makers or other stakeholders don't understand the information that is presented, or important players don't trust the technical analysis. This means that the decision on how to use this public resource is made without a full understanding of the choices.

Thankfully, water managers in the U.S. and around the world are becoming increasingly aware not only of the need to do solid technical analyses, but also of the need to engage a broad range of stakeholders and decision makers to collaboratively identify and judge potential solutions.

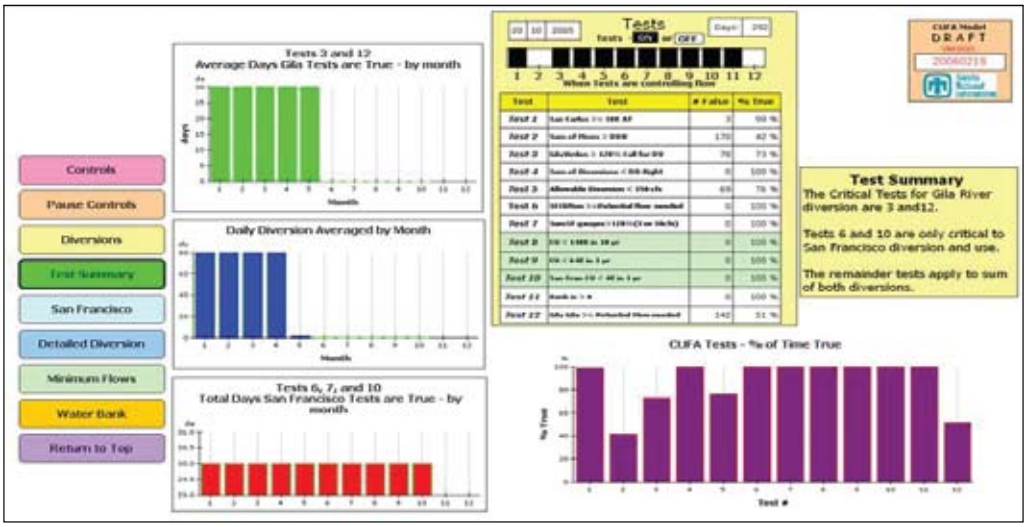
This new way of doing business is driving demand for new tools, or combinations of tools, that merge multi-stakeholder public decision processes with computer tools. Water resource practitioners need to work with modelers to modify existing technical tools to make them transparent and relevant. They need to work with facilitators and mediators to craft ideas about how these technical tools can support greater public involvement.

Previous efforts around Lake Ontario, the Rio Grande, the Roanoke River, and many other places demonstrate the value of open, collaborative analysis supported by transparent computer models. Presently, small communities of practitioners from national labs, the private and nongovernmental organization sector, academia, and government are working to develop such technical tools and methods, often independent of each other and with limited sharing of knowledge and techniques.

To help water managers at all levels integrate technical issues within a collaborative planning framework, the National Science and Technology Council's Subcommittee on Water Availability and Quality has proposed an initiative to develop and advance the integration of computer-based modeling tools within multi-stakeholder public decision processes for U.S. water solutions.

Researchers from Sandia are teaming with the U.S. Army Corps of Engineers, the U.S. Geological Survey, and other federal organizations to develop and implement this initiative. The proposal includes a review of current collaborative modeling processes, development of an evaluation framework for these collaborative processes, targeted demonstration projects to develop recommended approaches and methodologies, and development of a focal point or center to facilitate coordinated federal research.

Water management today is an exciting and important place to be – economies, the environment, and our livelihoods depend on this increasingly valuable resource. Together, federal partners can combine the best of our technical talents with our knowledge of the social and behavioral sciences to support those in state and local government and the private sector to develop more sustainable solutions to water problems.



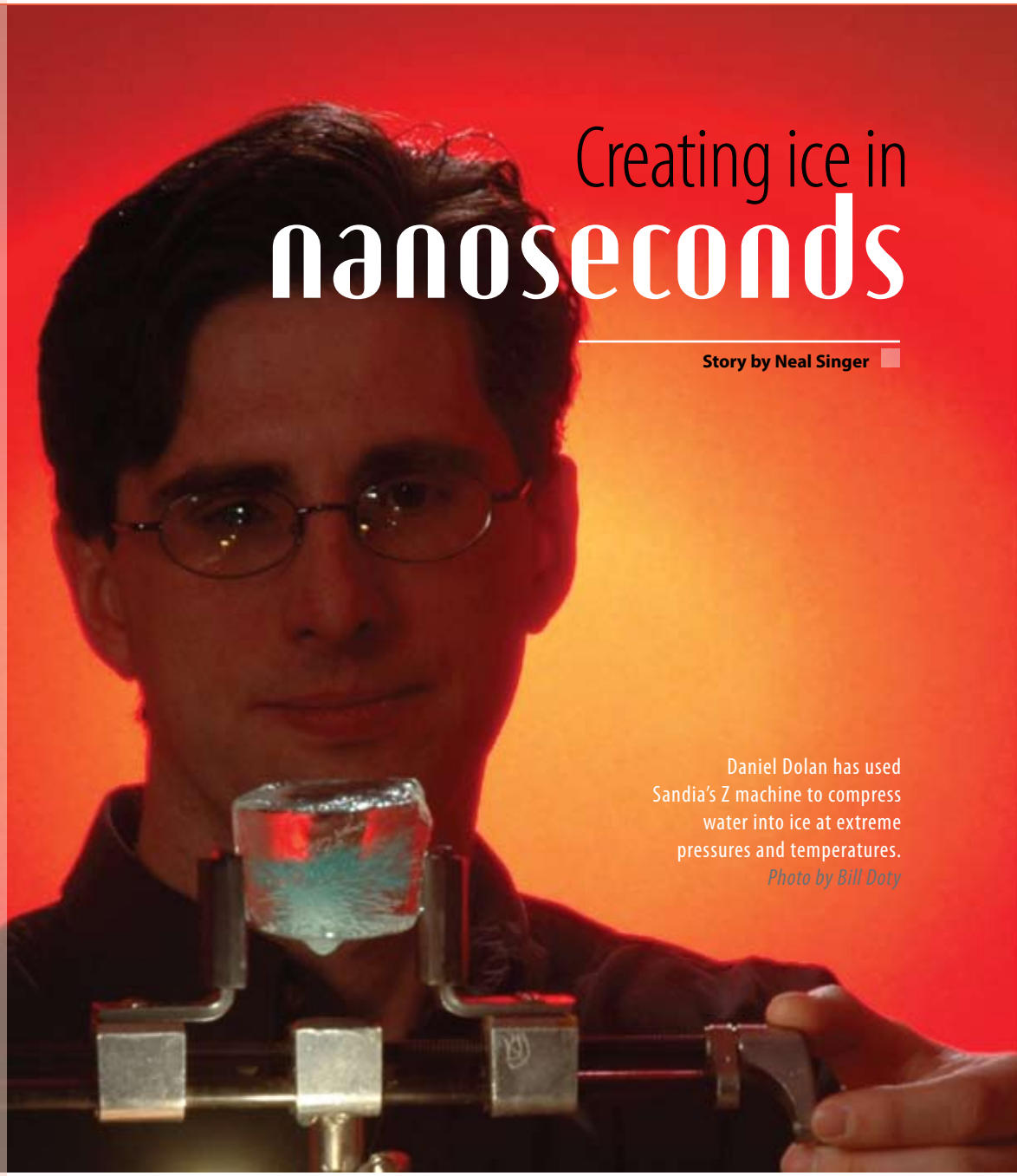
Hal Cardwell leads a national interagency program on collaborative modeling for water conflict resolution. He has nearly two decades of experience in government and nongovernmental organizations, both in the U.S. and overseas, leading and supporting projects associated with integrated water resources management, environmental impact and sustainability, climate change, transboundary issues, public policy, strategic planning, and public involvement. He holds a Ph.D. in water resources systems from Johns Hopkins University and is an active member of the American Society of Civil Engineers.

Computer models are helping authorities, users, and environmentalists make tough choices.

Creating ice in nanoseconds

Story by Neal Singer

Sandia's huge Z machine has transformed water to ice in nanoseconds — ice that is hotter than the boiling point of water. It turns out that the three phases of water that most of us are familiar with are among a host of possible phases in more extreme conditions.



Daniel Dolan has used Sandia's Z machine to compress water into ice at extreme pressures and temperatures. *Photo by Bill Doty*

"The three phases of water as we know them — cold ice, room temperature liquid, and hot vapor — are actually only a small part of water's repertory of states," says Sandia researcher Daniel Dolan. "Compressing water customarily heats it. But under extreme compression, it is easier for dense water to enter its solid phase [ice] than maintain the more energetic liquid phase [water]."

In a recent Z machine experiment, the volume of water shrank abruptly and discontinuously, consistent with the formation of almost every known form of ice.* "This work," says Dolan, "is a basic science study that helps us understand materials at extreme conditions."

But the experiment also has potential practical value. The work, published in the May issue of *Nature Physics* [1], was undertaken partly because phase diagrams that predict water's state at different temperatures and pressures are not always correct. This fact is worrisome to experimentalists working at extreme conditions and those having to work at distances, where direct measurement is impractical.

For example, work reported some months ago at the Z machine demonstrated that

* One might wonder — given the common experience of frozen water expanding to wreck garden hoses left outside over winter — why this ice shrank instead of expanding. The answer is that only "ordinary" ice expands when water freezes. There are at least 11 other known forms of ice occurring at a variety of temperatures and pressures.

[1] Dolan, D.H., Knudson, M.D., Hall, C.A., and Deeney, C., "A metastable limit for compressed liquid water," *Nature Physics*, May 2007, pp. 339-342.

astronomers' ideas about the state of water on the planet Neptune were probably incorrect. (*Sandia Technology,* Vol. 8, No. 4, Winter 2006/2007.) Closer at hand, water in a glass can be cooled below freezing and remain a liquid, in what is called a supercooled state.

Avoiding failures

Accurate knowledge of water's behavior is potentially important for the Z machine's operation because its water acts as an insulator and switch. Now that the machine has been newly refurbished with more modern and thus more powerful equipment, questions about water's behavior at extreme conditions are of increasing interest to help avoid equipment failure — for the new machine or even more powerful successors, should those be built.

One unforeseen result of Dolan's test was that the water froze so rapidly. The freezing process as it is customarily observed requires many seconds at the least.

It's the very fast compression that causes the very fast freezing, says Dolan. At both the Z machine and at Sandia's nearby Shock Thermodynamic Applied Research (STAR) gas gun, thin water samples were compressed to pressures of 50,000-120,000 atmospheres in less than 100 nanoseconds. Under such pressures, water appears to transform to "ice VII," a phase of water first discovered by Nobel laureate Percy Bridgman in the 1930s. The compressed water appeared to solidify into ice within a few nanoseconds.

Nucleating agents are often used to hasten sluggish chemical processes, such as when clouds are "seeded" with silver iodide to induce rain. Dolan already had demonstrated, as a graduate physics student at Washington State University, that water can freeze on nanosecond time scales in the presence of a nucleating agent. However, the behavior of pure water under high pressure remained a mystery.

Sandia instruments observed the unnucleated water becoming rapidly opaque — a sign of ice formation in which water and ice coexist — as pressure increased. At the 70,000 atmosphere mark and thereafter, the water became clear, a sign that the container now held entirely ice.

70,000 atmospheres

"Apparently it's virtually impossible to keep water from freezing at pressures beyond 70,000 atmospheres," Dolan says. For the tests, Z machine experimentalists created the proper conditions by magnetic compression. Twenty million amperes of electricity passed through a small aluminum chamber, creating a magnetic field that compressed aluminum plates roughly 5.5 by 2 inches in cross section. This created a shockless but rapidly increasing compression across a 25-micron-deep packet of water.

The multipurpose Z machine, whose main use is to produce data to improve the safety and reliability of U.S. nuclear stockpile systems, has compressed spherical capsules of hydrogen isotopes to release neutrons — the prerequisite for controlled nuclear fusion and essentially unlimited energy for humanity.

A series of gas gun projectile experiments at Sandia's STAR facility complemented experiments at the Z machine. The gun experiments subjected water samples to multiple shocks at increasing pressures.

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NEWSNOTE

Here comes the sun

The world's largest parabolic trough farms, located in the Mojave Desert, Calif., comprise nine plants producing 354 megawatts of power at peak output.

An approach to aligning the parabolic mirrors of solar trough-type power plants is drawing interest from the solar power industry because of its simplicity, affordability, and energy efficiency.

The new alignment system, called theoretical overlay photographic (TOP) alignment, uses a pole outfitted with precisely placed cameras to evaluate the existing alignment of parabolic mirrors and prescribe adjustments.

"TOP alignment could cure a significant problem with trough systems — inaccurate mirror alignment that prevents sunlight from precisely focusing on solar receivers," says Sandia researcher Rich Diver. "Improperly aligned mirrors result in lost and wasted energy."

The curved mirrors of parabolic troughs direct sunlight onto a receiver tube running the length of the trough along the parabolic focal line. Oil flowing through the tube is heated by the focused sunlight to high temperatures and routed through a heat exchanger to generate steam. The steam runs a conventional power turbine to generate electricity.

Previous methods for aligning mirrors in parabolic modules have been cumbersome. Diver, working with Tim Moss, came up with TOP alignment using a 20-year-old parabolic mirror system located at the National Solar Thermal Test Facility at Sandia in Albuquerque.

Four of the five cameras on a TOP fixture take digital images of the four rows of mirrors on the parabolic module. The fifth camera photographs the module's center, where a boresight gauge is attached to vertically center the pole to the trough module.

Computer algorithms calculate the best possible mirror alignment. The calculated image is overlaid onto the photographs showing the actual mirror alignment. The mirrors can then be adjusted to match the ideal alignment.

The method could be used during trough-plant construction, to improve the performance of existing power plants, or for routine maintenance, Diver says.

Diver and Moss tested TOP at a trough plant outside Tucson, Ariz., last year. They plan to test the system again at Kramer Junction, Calif., later this year. The ultimate goal is to license the technology to solar power plant operators and project developers.

"This whole process is very simple," Diver says. "Once the mirrors are aligned, the energy savings start. It's like picking money off the ground. And the mirrors are aligned for the life of the plant."

Rich Diver examines a parabolic trough module at Sandia's National Solar Thermal Test Facility in Albuquerque. *Photo by Randy Montoya*

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A box of Scott's Liquid Gold Mold Control sits on the shelf at a Home Depot store in Albuquerque, N.M.
Photo by Randy Montoya

Stopping household mold

A formulation developed for emergency cleanup following a terrorist attack involving chemical or biological warfare agents is now available on the shelves of hardware stores across the country to address a more common problem — mold and mildew around the house. The product is Mold Control 500, distributed by Scott's Liquid Gold of Denver.

MC 500 is based on Sandia's decontamination formulation (a.k.a. decon foam), which renders harmless a wide variety of both chemical and biological agents. Scott's Liquid Gold has an arrangement with Modec, Inc., of Denver to sell Mold Control 500 in retail markets. Modec is one of two companies holding Sandia licenses to market and distribute products based on the formulation.

"This is pretty exciting," says researcher Mark Tucker, who leads the Sandia team that developed and tested the formulation. "Mold remediation wasn't what we set out to do, but the formulation is effective at killing most microorganisms, so it is good to find uses beyond our original intent — especially uses that may improve public health."

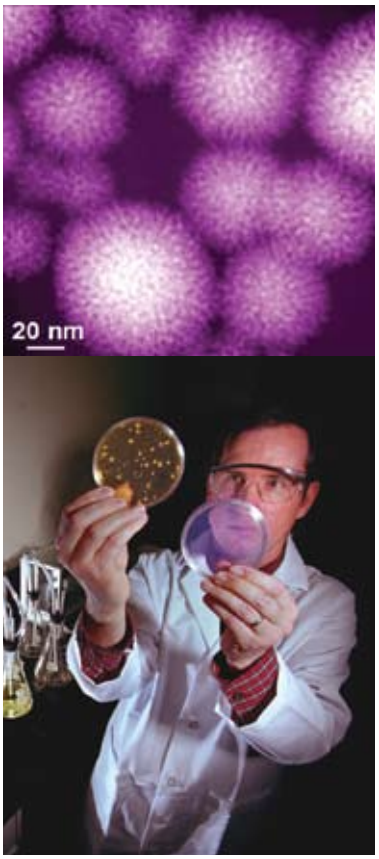
Development of the formulation began at Sandia in 1997, funded initially by the Department of Energy's Chemical and Biological National Security Program. Other sponsors have included the U.S. military and the LDRD program.

The foam helped clean up buildings contaminated with anthrax powder in 2001 in Washington, D.C., New York, and Florida, and it was staged in the Middle East in 2003 for helping clean up hazardous chemical sites. Sandia's two licensees have sold the formulation to municipal and state governments, the first responder community, and the U.S. military, among other users.

Tests at Sandia and Kansas State University in 2004 demonstrated the formulation's effectiveness for killing the virus that causes severe acute respiratory syndrome (SARS), suggesting its use also might blunt the spread of other viruses such as the Norwalk (cruise ship) virus, avian influenza (bird flu), and the common flu.

The formulation now is being discussed as a potential solution to other problems, including hospital sanitization, meth lab cleanup, mold remediation in commercial buildings, and cleaning out agricultural pesticide sprayers in an environmentally benign way.

Mold spores



Mark Tucker examines two petri dishes: one with a simulant of anthrax growing in it (left), the other treated with the decontaminating formulation (right).

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U.S. Army Corps of Engineers
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Sandia National Laboratories

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