Sandia RESEARCH

August 2016

People

Explore with us

Sandia National Laboratories

Exceptional service in the national interest

Sandia National Laboratories

Sandia Research is a magazine published by Sandia National Laboratories, a multiprogram engineering and science laboratory operated by Sandia Corporation, a Lockheed Martin company, for the U.S. Department of Energy. With main facilities in Albuquerque, New Mexico, and Livermore, California, Sandia has research and development responsibilities for nuclear weapons, nonproliferation, military technologies, homeland security, energy, the environment, economic competitiveness and other areas of importance to the nation.

Sandia welcomes collaborations with industry, small businesses, universities and government agencies to advance science and bring new technologies to the marketplace. Entities may enter into a variety of partnership agreements with Sandia. For more information email partnerships@sandia.gov or visit http://www.sandia.gov/working_with_sandia/ on the web.

To request additional copies or to subscribe, contact:

CTO Office
Sandia National Laboratories
P.O. Box 5800, MS 0351
Albuquerque, NM 87185-0351
Voice: (505) 284-7761
jchall@sandia.gov

www.sandia.gov

Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2016-7758 O.

Credits:

CTO Office: Robert W. Leland, Andrew McIlroy, Julie Hall

Internal, Digital & Executive
Communications Manager: Valerie Smith

Editor:
Nancy Salem
(505) 844-2739, mnsalem@sandia.gov

Writing:
Stephanie Holinka, Sue Major Holmes, Patti Koning, Mollie Rappe, Nancy Salem, Neal Singer, Rebecca Ullrich

Photography:
Randy J. Montoya

Design:
Michael Vittitow

ON THE COVER

Sandia researcher Charles Reinke works in his lab on a unique phononic/photonic filtering technology that combines light and sound waves on a single chip and is expected to better detect radar and communications frequencies, potentially revolutionizing signal processing systems. Reinke wanted a career with impact, and chose science over medicine.

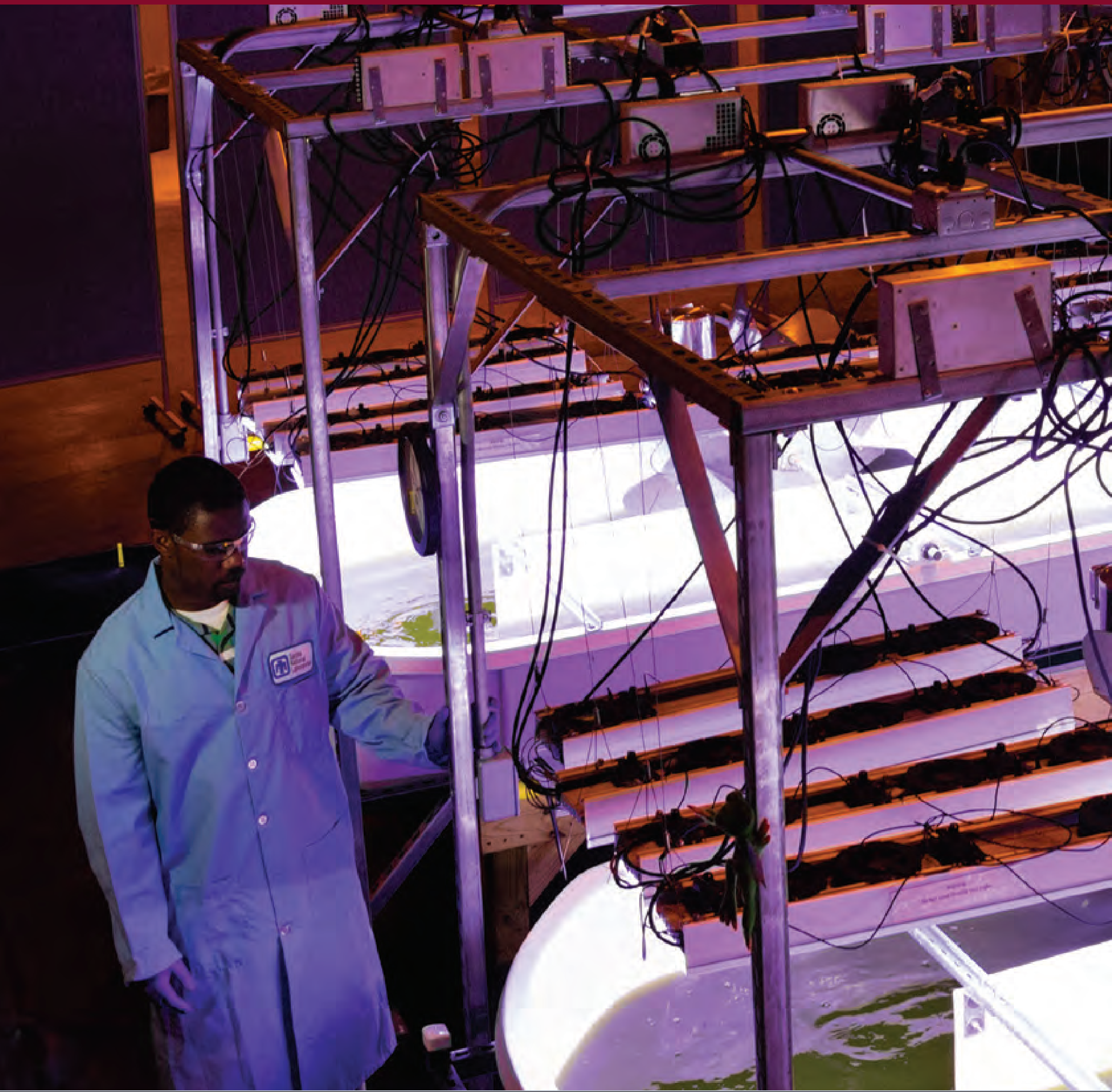
(Photo by Randy Montoya)

CONTENTS

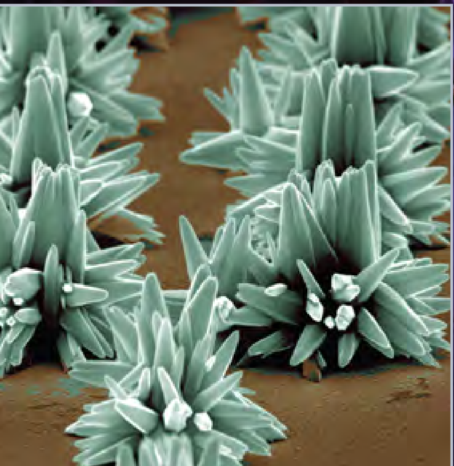
PEOPLE OF LDRD

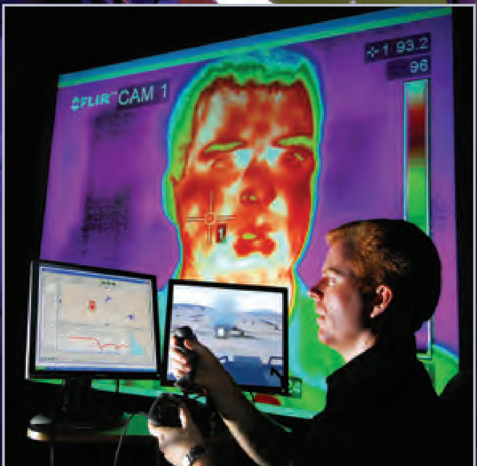
OF THE

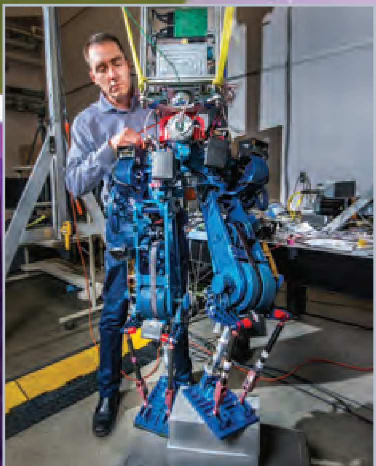
BY NANCY SALEM



CRAZY IDEAS HELP RESEARCHERS GROW. AND THAT'S NOT SO CRAZY.







Jerry Simmons walked into Sandia Labs 26 years ago, hired for a program that didn't exist. His job was to take Sandia into nano-electronics. Searching for a start, he proposed a Laboratory Directed Research and Development (LDRD) project on electronic interactions between closely spaced semiconductor quantum wells. "That work grew into a wide range of activities, from single electron transistors to Coulomb drag to high-mobility molecular beam epitaxy growth," Simmons says.

Sound wild? It is. But that's what LDRD allows scientists to do. "You can take a chance on a crazy idea, which may end up being not so crazy after all," Simmons says. And, along the way, scientists get better.

Simmons is a rock star, one of four active Sandia Fellows whose lists of professional accomplishments fill pages, lifting them into the elite ranks of people who are figuring out how the natural world works. "LDRD has played a crucial role in my career, from day one to the present," Simmons says. "It's no overstatement to say it is the lifeblood of the laboratory."

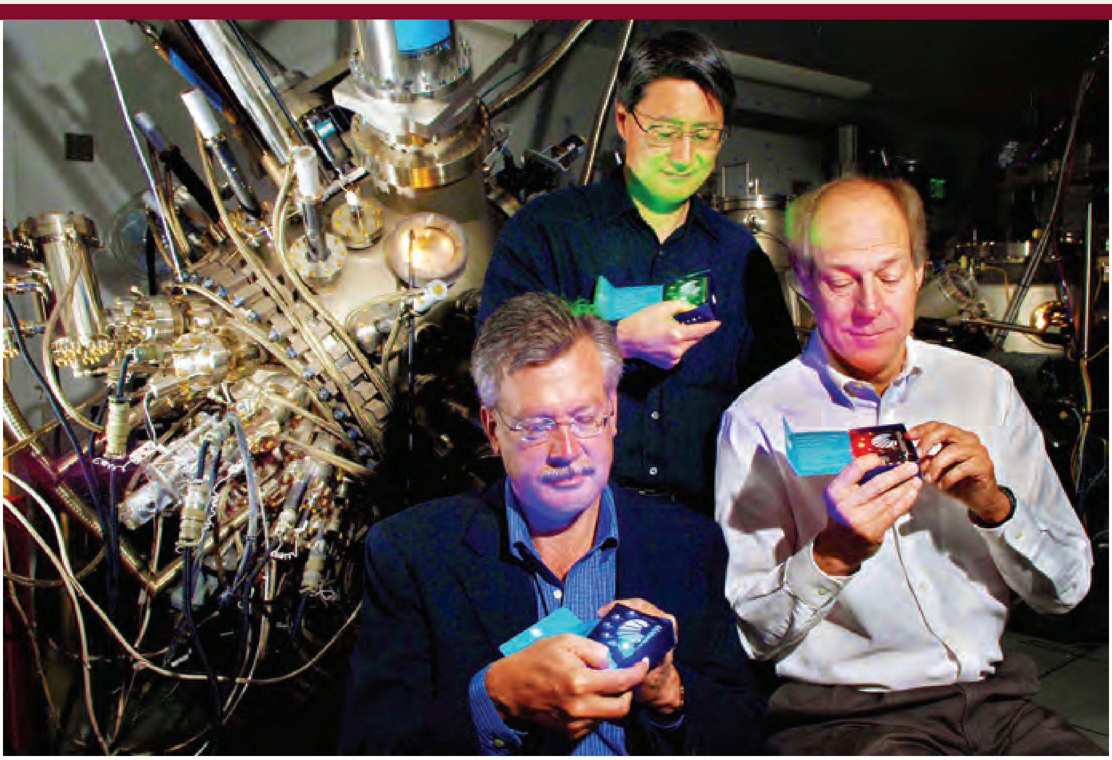
LDRD was established by Congress in 1990 to fund forward-looking, high-risk, potentially high-payoff research at the national laboratories. The goal was to build a vital research environment that rewards innovation, builds skill and produces breakthroughs, pushing the frontiers of science and technology. "LDRD infuses the laboratory culture with a reverence for curiosity and a respect for pioneering discovery," Simmons says. "This is how we take leadership in a field, by being the first to get into something no one else has bought into yet."

LDRD at Sandia draws in thousands of people.

The investment pays off

At Sandia, LDRD is funded as a percentage of all the programs that come into the labs, and is at just under 6 percent, or $155 million a year, for fiscal year 2016. The investment has paid off with important scientific advances across an array of disciplines from bioscience and computing to microsystems and geoscience. LDRD projects, awarded through a rigorous, highly competitive peer-review process, align with the labs' core national security mission while taking science to new and extraordinary places.

LDRD-funded projects have contributed to every facet of Sandia's national security mission, including stockpile stewardship, high-energy-density matter, computing and simulation, materials science, chemistry, biosecurity, cybersecurity and energy. Many Sandia programs, such as radiation-hardened electronics and solid-state lighting, have roots in research that began in LDRD. Projects funded by the program have earned national recognition through awards, including many R&D 100 awards, papers and patents.



Solid-state lighting pioneers, from left, Jerry Simmons, Jeff Tsao and Michael Coltrin have seen their work contribute to the widespread consumer use of light-emitting diodes, or LEDs, an alternative to incandescent bulbs.

Andy McIlroy, deputy chief technology officer and director of Sandia's Research Strategy and Partnerships Center, says LDRD helps Sandia and other national labs attract and keep the best scientists and engineers. "We hire exceptional people and we want to give them the opportunity to use their genius and creativity to find new ways to solve problems," he says. "The research freedom offered by LDRD can launch a scientist to another level of accomplishment."

The National Research Council of the National Academies says LDRD "is critical for attracting and retaining high-quality technical staff and thus for assuring long-term viability of the laboratories and their ability to carry out their mission in the future." The council went on to say that "the novel and innovative approaches supported by LDRD are essential to the nuclear weapons mission."

An early career boost

The LDRD program develops researchers in a variety of ways. From 2009 to 2016, one element invested in early careers and was used to help bring promising young people to the labs. "A manager would meet someone at a conference or hear a great student paper and think that's the kind of person we want," McIlroy says. "But they were looking for jobs right then and the manager didn't have funding for a position. Early Career LDRD gave managers the confidence to bring sharp people in before they took other jobs, and get them started."

More than 200 researchers participated in that program, which is ending in 2016. The overall LDRD program continues to encourage support of early career researchers. "At the start of their professional life, they can have their own LDRD projects," McIlroy says. "And those projects lead to others, building momentum."

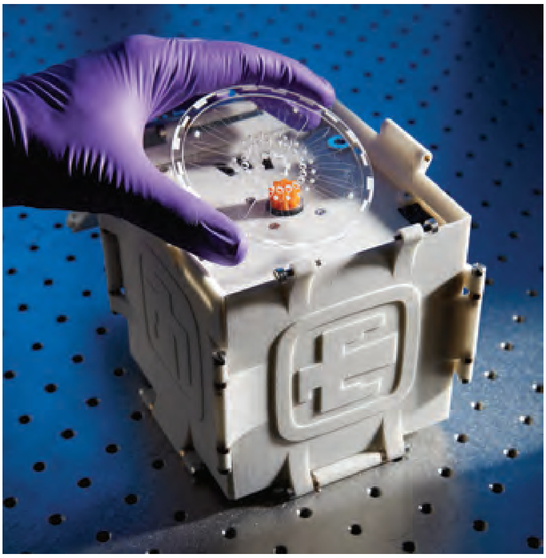
A 2015 report by the Secretary of Energy Task Force on Department of Energy National Laboratories said, "For the NNSA [National Nuclear Security Administration] laboratories in particular, LDRD provides a way to maintain a pool of talented individuals whose work is aligned with the core mission of the laboratories. This finding is supported by evidence of the participation of early career staff and recently recruited staff in LDRD programs."

The program also builds leadership skills. "The principal investigator on an LDRD project must put together a team," McIlroy says. "They have both technical and leadership responsibility. Other people on the team also take on leadership roles." LDRD projects can involve a few people to 20 or more in a Grand Challenge, which is a larger LDRD project that focuses on bold, high-risk ideas with potential for significant national impact.

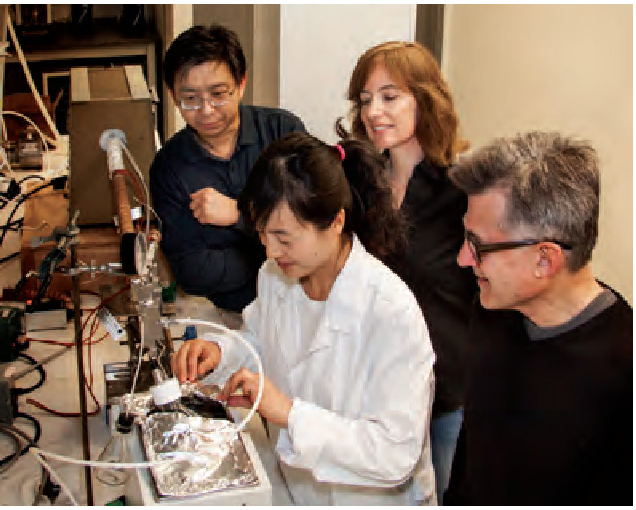
Problems nobody has thought of

"LDRD offers people an opportunity to grow," McIlroy says. "It goes back to creativity and innovation. It gives them another way to contribute to the scientific community and national security. LDRD plays a key role in building and sustaining Sandia's foundation."

Another piece of LDRD is the Truman Fellowship program for distinguished postdocs, named after President Harry S. Truman, who charged Sandia in 1949 with providing "exceptional service in the national interest." Sandia reaches out nationwide for applicants for the three-year fellowship, and extends offers based on mentorship and interviews by senior scientists. "We look for the rising stars,



SpinDx, a lab-on-a-disk that produces medical diagnostic test results in minutes, had its roots in Laboratory Directed Research and Development.



Clockwise from top left, researchers Ying-Bing Jiang, Susan Rempe, Jeff Brinker and Yaqin Fu study the biomimetic CO_2 membrane, a significant advance in the field of membrane technology for reverse-osmosis water filtration.

people who have just earned their doctorates and have the potential to change the world," McIlroy says. "We want to give them the opportunity to reach their potential while serving the nation." Sandia has had 22 Truman Fellows since the program began in 2005, many of whom still work at the labs.

And Sandia's four active Fellows — Jeff Brinker, Ed Cole, John Rowe and Simmons — have LDRD funding they can use for their own research or to fund other people. "As mature and exceptional researchers, they can use these funds to seed critical advances for the labs' future," McIlroy says. "They can identify new researchers, recognize high potential ideas and they can fund their own ideas."

Simmons says his role as a mentor to young researchers through LDRD projects has kept him engaged in the wonder of discovery. "LDRD plays a multitude of roles throughout the career of a scientist," he says. "First it helps new people get a toehold and establish a research program. It's essential for recruiting and retention. Later, LDRD supports our most innovative and revolutionary ideas. And Grand Challenges let Sandia put together large interdisciplinary teams to tackle the biggest problems." Simmons says that in his more than two decades at Sandia he's seen "a lot of really innovative ideas grow from hallucinations to impactful technologies."

"LDRD is important for the long-term health of the institution if we are to transform the products we deliver to our national security customers," he says. "Without it, the labs would be a different place. These crazy ideas don't always pay off, but when they do, it's fantastic — for everyone involved." ■

jerry SIMMONS

was a scrappy kid who searched the world for meaning. He found it in the light of science.

By Neal Singer

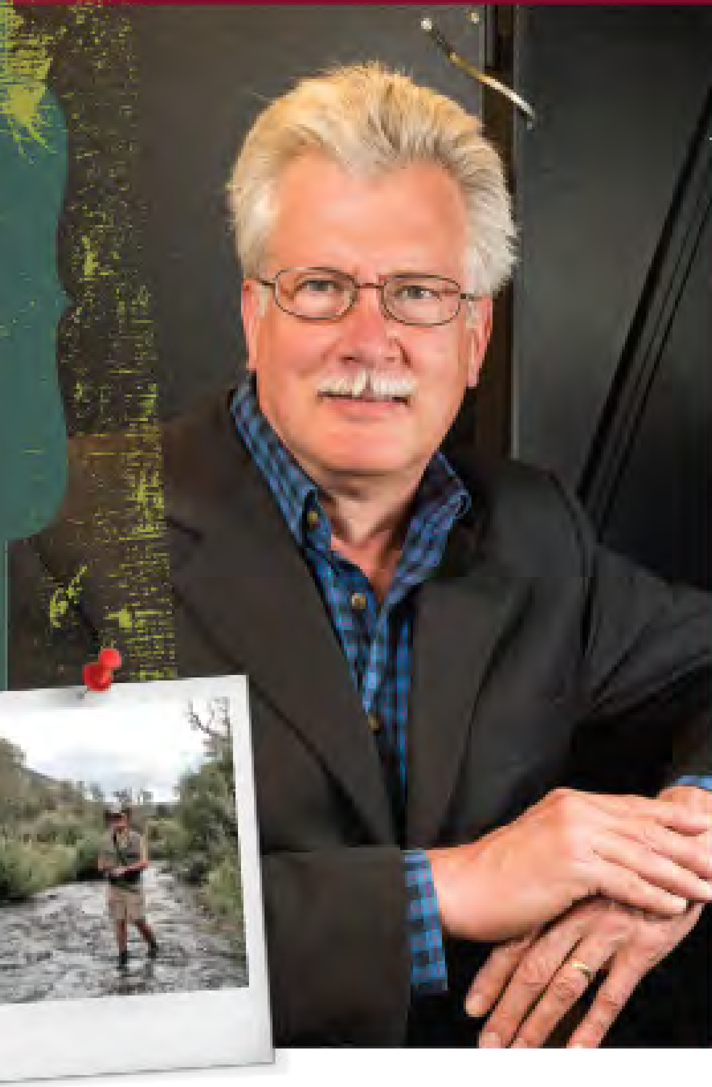
Surfer-dude Attitude

Jerry Simmons holds the title of Sandia Fellow, a rarely bestowed honor, but he never received a high school diploma.

These contradictory facts signal why his story might be less an ordinary narrative than (in lights) "The Jerry Simmons Story": how a neglected waif became — like a galaxy coalescing from thinly dispersed gasses into stars — a Fellow of the American Physical Society and of the American Association for the Advancement of Science, a member of several National Academy of Sciences committees and a main research coordinator for Sandia's Laboratory Directed Research and Development (LDRD) program.

Simmons displayed unusual curiosity as a child. When he was 2½, his mother let him ride his new tricycle out front while she worked in the kitchen. Soon a lady came knocking, Simmons in tow. She found the energetic boy pedaling furiously five blocks away. Asked where he was going, Simmons told her he "wanted to see what was out there." Fortunately, he remembered his address.

He did star-quality math and science his first three years of high school in Santa Barbara, California, surfing when he could and hitchhiking home so his then-divorced mom could pursue her Ph.D. But his rough-hewn travel mode made it impossible to participate in the extracurricular activities essential to winning the National Merit Scholarship for which his test scores made him eligible. He decided high school wasn't for him and left to spend his senior year "out there" in New York City, signing up at the New School for Social Research in a program for kids without high school degrees.



MY SCIENCE

Semiconductors

Semiconductors have revolutionized our lives. The first ones to be well studied were germanium and silicon, and what we learned led to the invention of the transistor at Bell Labs in the 1940s.

But silicon was not the end of the story. Researchers moved on to other semiconductor families, and each time they made discoveries that produced new applications. An example is gallium arsenide, which made possible the high-frequency communications that underlie smart phone technologies. Another is gallium nitride, without which today's super-efficient, light-emitting diode (LED)-based, solid-state lighting would not have been possible.

What will be the next family of semiconductors to provide revolutionary technologies for our children? A small community of researchers is looking at extreme-gap semiconductors, or ultra-wide-bandgap materials, which were previously seen as insulators incapable of performing any electrical function. Examples are aluminum nitride, gallium oxide and even diamond. It might be possible to create extreme ultraviolet LEDs and lasers, or develop high-speed power transistors cable of handling 100,000 volts and higher for the nation's electrical grid. But to do this, fundamental questions need answers: How do we grow these extremely hard materials? How do we handle atomic lattice mismatch? How can we "dope" them with impurities to get both negative (electrons) and positive (holes) charge carriers?

He completed the year, which met freshman college requirements, but Simmons never received his high school diploma because of a bureaucratic glitch. Undeterred, the following year found him enrolled in Trinity College in Wales, Great Britain. The college bore no relation to the intellectual meccas of Trinity Cambridge or Trinity Dublin with which the youthful Simmons had associated it. Trinity of Wales was run by an Iowa farm-country college with strict rules about how homework was submitted. Simmons was more concerned with content.

Hells Angels for neighbors

Licking his wounds and no longer sure college was for him, Simmons hitchhiked around Europe then retreated to the New School for another year, renting a small Lower East Side apartment next to the Hells Angels motorcycle club, whose late-night parties made sleep problematic.

His universe began coalescing when he found the New College of Florida, a respected college with few requirements, no grades and a high percentage of students who go on to graduate school. Over three years, Simmons authored two senior theses – the first on linguistic philosophy, the second on solid-state physics.

Regarding philosophy, Simmons says, "The time I spent learning to reason abstractly and express myself in a logical way has been extremely beneficial to my career." He studied how language shapes and is inextricably linked to the structure of ideas — "the sexy philosophy of the 20th century. Maybe if Einstein had spoken Hopi, he would have had an easier time with the concept of time."

The physics thesis, on amorphous silicon semiconductors, resulted from American Physical Society internships at Xerox and the University of Chicago, where he learned about silicon. "I was going to pursue astronomy in grad school, but I was malleable — putty in their [UC's] hands," he jokes. "They probably thought it a victory to rescue me from the clutches of the astronomers."

Simmons was hired as a technician by Bell Labs, where future Nobel laureate Dan Tsui was in the process of moving to Princeton. Simmons went with him, and under Tsui's tutelage, earned his Ph.D. in electrical engineering in 1990, the same year he took a job at Sandia. He quickly rose from researcher to senior manager, doing specialty assignments along the way.

"The reason I went into management is that I'd been building up a team to work on quantum transport and nanoelectronics, but it couldn't get bigger than a two-person staff if led by a single researcher," he says. "There needed to be a manager working to build it as a top priority. I thought I could do that if I took over management of my department. And I did."

An effortless cordiality

"He works very hard," says former Sandia acting VP Julia Phillips. "He's always looking for the best science ideas and the best scientists to bring into a program."

At a celebration for Simmons's 20th year at Sandia, director Charles Barbour mentioned the variety of his work, including quantum computing and solid-state lighting, saying, "He works hard and tirelessly. The [research and financial] trend is always up, thanks to Simmons' work."

A humorous view of Simmons' verbal skills in convincing researchers to work on important projects was expressed by colleague Jeff Tsao, a co-leader with Simmons in Sandia's national solid-state lighting effort, which Simmons helped found: "I tried to remember all the words Simmons used that I didn't know, but because I didn't know them, I realized I couldn't remember them. And when you don't know the word, you just nod your head, not realizing what you've just agreed to."

Simmons projects an effortless cordiality — a "surfer-dude attitude," says his wife Carolyn — but he succeeds because he knows what he wants. "I sit on four LDRD committees, chair two of them and judge Grand Challenge proposals at the same time I help nucleate teams to work on them," he says.

He helped found one of Sandia's 11 long-term Research Challenges. "It's called Power on Demand, and I'm pretty excited about it," he says. It brings together three groups of researchers — in electronics, batteries and photovoltaics — to make lighter and smaller radiation-hard electrical power systems that harvest, store and/or convert electricity for a given mission need.

A key challenge is to get researchers in different fields to talk to each other or, as Simmons puts it, "why would transistor guys talk to battery guys?"

If anyone can encourage them to do so, it's Simmons. The uncertainty of his chaotic early years has faded away; the warmth of his family and plaudits of his colleagues lend him an increased persuasiveness.

And he's persistent.

When he got his engineering Ph.D. from Princeton, for example, he called yet again to see if his high school would see the wisdom of awarding him his diploma. They suggested he take the GED exam.

And he intends one day to return to Wales, site of his nonproductive college year, to hike a thousand miles around that country's border. Asked why, he says, "Well, I like to hike. It'd be pretty. And I want to see what's out there."

yalin HU traveled far in pursuit of science. A desire to solve real-world problems took her even farther.

LEAPS AND BOUNDS

BY PATTI KONING

As a child, Yalin Hu aspired to become a teacher like her parents, who were both university professors. The only question was whose academic path she would follow — become a mathematician like her mother or a computer scientist like her father? "I was always good at math, but my father made computer science seem like more fun," she says. "While my mother's work centered around text-books, my father brought home cool gadgets like a hand-cranked calculator."

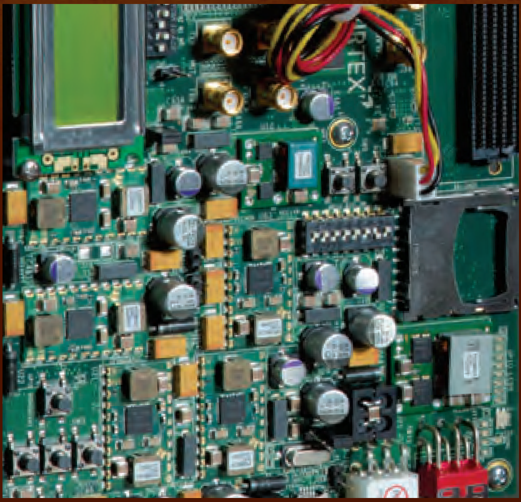
Hu majored in computer science and engineering at Northwestern Polytechnical University in Xi'an, China, her home country. She discovered that she didn't mind the long hours debugging and verify-ing software. Instead, she loved finding and fixing bugs.

After earning a master's degree in computer science and engineering, Hu took a giant leap and moved halfway around the world to attend the University of South Carolina as a doctoral candidate in electri-

MY SCIENCE

Poetry in electronic components

Ubiquitous in modern hardware, field programmable gate arrays (FPGAs) are electronic components that are somewhat like a tabula rasa, a blank page. A better analogy might be a magnetic poetry set – the tiny word magnets used on refrigerators and other magnetic surfaces. A user can reconfigure the words into a variety of meaningful sentences as well as nonsense.



In FPGAs, the words are logic blocks that can be connected in different arrangements to meet specific hardware design requirements. FPGAs derive their power from the first two words of their title – field programmable. Yalin Hu, who works in this field, can arrange and rearrange the logic blocks in contrast to application-specific integrated circuits, or ASICs, which are fixed at the time of manufacture. If an FPGA is magnetic poetry, then an ASIC is a single Shakespearean sonnet.

An advantage of FPGAs over custom hardware like ASICS is that they are harder to attack because the design for a processing functionality is not pre-loaded into the device. Among other uses, FPGA characteristics make them suitable for implementing cryptographic applications.

cal and computer engineering. "While it was tough to leave China, my family was very supportive," she says. "It was an opportunity not available to many students and I worked very hard for it."

Hu had her first encounter with the Department of Energy (DOE) as a graduate student in South Carolina. In a research project for the Savannah River National Laboratory, she explored the use of artificial intelligence in processing nuclear waste. In 1992, Hu won a DOE Excellent Graduate Research Paper Award for "Automated Real Time Neural Computing for Defense Waste Processing." Part of the prize was a trip to tour several DOE facilities and Yellowstone National Park with winners from across the country.

West to Silicon Valley

The trip made a lasting impact. It was her first time traveling outside of South Carolina. The time spent with other graduate students and the DOE mentors left her with exciting new ideas for potential research and career development.

By the time Hu finished her doctorate in 1994, her dreams of becoming a college professor had given way to a desire to work on real-world problems. She wanted to continue with projects like the Savannah River work, but being a Chinese citizen was a significant obstacle to doing meaningful work at a national laboratory. Instead, she did what many new graduates in tech fields do — headed west to Silicon Valley.

She joined Cypress Semiconductor in San Jose as a senior software engineer working on field programmable gate arrays or FPGAs. After four years, she moved to Altera, one of the leaders in the FPGA market.

For 11 years at Altera, Hu led a global development team that generated the simulation models for FPGA development tools for every software release. Over time, the pressure of working in a product-driven environment with new releases every six months and the volatility of the semiconductor industry began to get to her. In 2009, her entire team was laid off due to the company's outsourcing strategy. Hu took a buyout package rather than transfer to another part of the company. "I had become a U.S. citizen by that point, so I returned to my goal of working for a national laboratory," she says. "I enjoyed working in Silicon Valley, but I wanted time to do research, not just development."

Pros and cons of verification models

She came to Sandia in 2010 to work on FPGA firmware development for telemetry. Drawing on her industry experience, Hu was awarded an Early Career Laboratory Directed Research and Development (LDRD) project, "Exploring Formal Verification Methodology for FPGA-based Digital System."

"Having done a lot of simulation and verification model development in industry, I knew the pros and cons of verification methods. Formal verification is very powerful because it tells you that your device will not only do what you want, but also that it will not do what you do not want," she says. "This method was not being investigated enough at Sandia."

As a result of the LDRD project, formal verification became more widely known at Sandia. This led to a follow-on project verifying a key component of the B61-12 nuclear bomb. Hu had two papers published and her work was featured in a tri-lab symposium. In 2011 her team won a National Nuclear Security Administration (NNSA) Defense Programs Award of Excellence.

Now she is the lead of the Project Realization Team for a component in Joint Test Assemblies for the B61-12 and W88 Alt 370, part of the NNSA's Life Extension Program for the nuclear arsenal. Hu feels that her years working in industry set her up to succeed at Sandia. "This is a diverse environment with opportunities to explore new ideas," she says. "I was able to get such strong research results with the LDRD because of the background and expertise I had built up in industry."

In her free time, Hu likes to garden and cook new recipes. Much of her life outside of work is dedicated to her family. And as someone who journeyed over halfway around the world in pursuit of education and professional challenges, travel is naturally important to Hu. Her goal is to travel with her family to all seven continents and all 59 U.S. national parks.

charles REINKE

was home schooled and taken under the wing of college professors. With endless career options, his goal was not to be bored.

He did it His Way

By Neal Singer

Reversing the oft-told story of the recalcitrant South barring people of color from educational institutions, 13-year-old Charles Reinke chose not to enroll when he was invited to attend a top Mississippi private school. “I would have been the only non-white person there,” he says. “I would have essentially been integrating the school.”

Further analysis, this time of a local public high school, indicated that it was, “how shall I say it, not a high-performing school,” Reinke says.

Facing a cost-benefit problem, young Reinke and his parents weighed difficulties in attending against benefits expected to accrue. They concluded that the private school took too great a time and energy investment for the slim intellectual gains expected.

So the family switched its approach. They had moved from Oklahoma to Mississippi because Reinke’s father was promoted to supervisor at the Federal Aviation Administration’s Greenwood Flight Service Station, routing air traffic between Jackson, Mississippi, and Memphis, Tennessee.

In Mississippi they encountered nothing but fabled Southern hospitality. But on their 68 acres of forested land, complete with a creek and pond, the family agreed that Reinke would be home-schooled. He had always been self-motivated in exploring how things worked; in Oklahoma he was part of the Young Astronaut Council and participated in science fairs. Now his mom, finishing her bachelor's in business administration at historically black Mississippi Valley State University, volunteered to home-school him and effectively be his high school principal.

A push to medical school

The solution needed adjustments. Since Reinke liked math, his mom found a professor at Valley State to help out when he advanced beyond her level of knowledge. For physics and chemistry, since it would have been hard to build labs at home, she arranged for him to audit 101-level classes at her college, which she applied as high school credit.

His professors noted the unusual abilities of their high school protégé, and not only offered college credits for his audits but recommendations to help him into medical school "if I wanted that path," he says. The offer was tempting because Reinke wanted his career to have an impact. But he felt conflicted. "If I made a wrong decision as a doctor, it would be a huge responsibility. Someone might die," he says. "In a lab, I might ruin a piece of equipment, but no one would get hurt."

For that and other reasons, science became Reinke's first choice. He decided to attend Jackson State University, a nearby, highly rated historically black university. He declared math his major but quickly realized that "math was going to bore me — I found it very theoretical and abstract — so I switched to physics, which to me meant applying math to how the world operates."

The next career choice was engineering, which takes an understanding of the physical world and applies it to real problems. Jackson State didn't offer undergraduate engineering but had a dual degree program with the Georgia Institute of Technology, six hours away. It offered participants a five-year double-bachelor's degree in physics and electrical engineering. Reinke signed up.

"Engineering takes a scientific advance already established and does something with it," he says. "Pure science means coming up with new things that can be used." Reinke liked both. "Even if the science is already established, I want to understand

the underlying physics before I go on to do the engineering I'm paid to do."

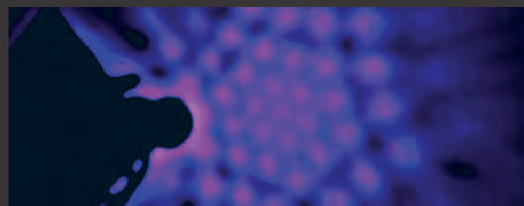
He at first found Georgia Tech's teaching methods remote. "There were 1,500 students in my first computer science class. I could barely see the professor at his lectern," he says. "I think if that had been my first college experience, I would have been overwhelmed." It made him value the nurturing environment at Jackson State even more. He could easily find his professors to question them about fundamental concepts; at Tech, he found it was more about chasing graduate students who offered a less mature level of knowledge.

Still, he found his way. For graduate school, after being wait-listed by Massachusetts Institute of Technology (MIT), he chose to remain at Georgia Tech. He saw articles in science publications about work at Sandia National Laboratories on photonic crystals. These caught his eye because his thesis concerned the simulation and design of nonlinear photonic crystals, and Sandia was making headlines in the field.

At a talk in Sydney, Australia, in 2009 on his graduate work, he was approached by Sandia researcher Ihab El-Kady. "He saw my talk, mentioned that he

MYSCIENCE

Photonic crystals



A photonic crystal is an optical structure made of materials whose refractive indices vary periodically on length scales close to that of the wavelength of light. Such structures are interesting because they can exhibit light propagation behavior that is not normally observed in nature. One example is negative refraction, where light is deflected in the opposite manner as dictated by Snell's law, which describes refraction in "normal" materials. In other examples, the propagation of light pulses at certain frequencies can be completely forbidden, or slowed to a fraction of the speed of light in free space.

Charles Reinke became interested in photonic crystals after a summer research experience involving light transmission in optical fiber networks. Deciding to pursue the topic in graduate school, he studied the coupling of nonlinear optical effects with photonic crystals. One highlight of the work was the creation of an efficient numerical simulation code that is particularly suited for investigating such effects.

Closely related to photonic crystals is the area of phononic crystals, which are the mechanical-wave analogues of their electromagnetic-wave counterparts. It was in support of an Laboratory Directed Research and Development (LDRD) project on phononic crystals that Reinke was hired at Sandia as a postdoctoral appointee. Later he would lead an Early Career LDRD on the topic of engineering thermal conductivity in silicon using photonic crystals. Although his research since grad school has broadened from phononics to optomechanics and other areas, photonic crystals area are still an area of interest.

was doing similar work and that he had a postdoc position open," Reinke says.

An early career LDRD

It was time for the next stage in Reinke's life. He had done an internship at the MIT Lincoln Laboratory near Boston and visited Oak Ridge National Laboratory. "I didn't have any desire to live in California, which is expensive and has earthquakes, and the hustle-bustle of Boston and New York didn't appeal to me either," he says. "Sandia in Albuquerque looked fine. Though it seemed in the middle of the desert, the cost of living and laid-back lifestyle were similar to back home."

At Sandia, he began research on an early career Laboratory Directed Research and Development (LDRD) project that used phononic crystals to improve the usefulness of silicon for thermoelectric applications. "That LDRD definitely gave me the experience of running a small project within Sandia, learning the labs' own culture and way of doing things," he says. A thermoelectrics project that grew out of that, he says, has the promise of closely integrating cooling with microelectronic devices, a commercially important problem.

"We're trying to integrate coolers directly on the active area of the chip, rather than relying on a heat sink placed relatively a long distance away," Reinke says. "Heat is ubiquitous; virtually everything creates heat. So, work in this area could have a wide impact. Experiments using silicon — the overwhelming material of choice for microelectronics manufacturers — suggest a wide range of potential applications."

A paper detailing the work is expected within a year.

"Making the next iPhone is cool," he says introspectively, "but what impact are you really making? At Sandia, we make a difference to our national security. Even when we can't talk about it, we know we're doing it. That's one of the big features of Sandia that draws and keeps top researchers here. You may not become a millionaire or get your face on the cover of Forbes, but your work is gratifying."

When not working, Reinke spends time with his wife of seven years, Lakeisha, and their daughter, Salomé. He can often be found playing the organ in church. "Music is very mathematical," he says. "It's no wonder you see many scientists and engineers who play musical instruments." ♫

tina NENOFF

tailored molecular sponges to pull radioactive ions from nuclear waste.

CAPTURING THE IMAGINATION

By Mollie Rappe

Tina Nenoff learned to ski when she was about 10 while visiting relatives in Quebec. Despite the unrelenting cold and icy snow, she fell in love with the thrill and challenge. Similarly, a fantastic high school teacher sparked her interest in chemistry. Mrs. Tomcufcik was excited about the science and zestfully spread her enthusiasm.

Working in Sandia's Physical, Chemical and Nano Sciences Center, Nenoff creates and tests molecular sponges specially tailored to capture various chemicals. Her Sandia career began with optimizing porous clay-like zeolites to absorb radioactive ions from legacy nuclear waste. Her work has expanded far beyond that in both the sponge-like materials in her arsenal and their applications.

Notably, she worked on crystalline silicotitanates used to clean up contaminated seawater after the Fukushima Daiichi nuclear disaster in March 2011. "I think that being at Sandia enables my work to have a much broader effect than if I worked anywhere else," says Nenoff.

Diverse and dynamic people

Spurred by her high school teacher, Nenoff studied chemistry at the University of Pennsylvania. Her original intention was to go to medical school afterward, but the combined experiences of doing research in a dynamic chemistry lab and spending a lot of time in the hospital with a sick friend made her re-evaluate that decision.

Her undergraduate research was in the lab of Alan MacDiarmid on conducting polymers, the work for which he won a chemistry Nobel Prize in 2000. She enjoyed the cutting-edge multidisciplinary research, the diverse and dynamic group of people and the general creativity and excitement. It was such a heady and invigorating environment Nenoff has looked to recreate the nature of that team throughout her career.

After deciding not to go to medical school, she worked for a year and a half at Ciba-Geigy Chemicals just outside New York City. Nenoff liked the city, but realized that to be "the boss," she would have to go back to school for a doctorate.

It was in graduate school at the University of California, Santa Barbara, that Nenoff learned zeolite synthesis and characterization, skills that formed the foundation of her career. Near the end of her doctoral work, Nenoff thought she was going to continue her fundamental research on zeolites in academia or industry, but Sandia came knocking.

Drawn to innovative research on nuclear waste cleanup — and the good local skiing — Nenoff joined Sandia in 1993.

"I'm a firm believer that to be successful at Sandia you need to have a core program, a mission-area driven program that gives you the continuity and the reason you're here. But LDRD [Laboratory Directed Research and Development] lets me dive into

different ideas and leverage off of these baseline programs I have and take them in different directions, build new customers, build new teams. It's a really valuable program," says Nenoff.

She was able to reconstruct at Sandia the multidisciplinary, creative environment of her undergraduate lab. The funding from LDRD projects lets her bring in vibrant, young postdocs such as Dorina Sava Gallis, Summer Ferreira and Koroush Sasan, many of whom have made the transition to staff.

There's no I in team

In her core research and LDRD projects, Nenoff works closely with experts in many fields across the labs. Geoscientists and computer modeling people help design the molecular sponges. Folks in materials science determine the structure and characteristics of the resulting porous materials. Researchers take experimental results and analyze them in the context of real-world models.

And Nenoff, who was included in a book highlighting the careers of 100 women in ceramic and glass science and engineering by Lynnette Madsen of the National Science Foundation, has fruitful collaborations with researchers at other national labs and in academia. She works closely with Karena Chapman and Peter Chupas at the Advanced Photon Source at Argonne National Laboratory on the structural determination of the zeolites, metal organic frameworks and other nanoporous materials. She has a long-running collaboration with University of California, Davis, physical chemist Alexandra Navrotsky, who provides technical expertise in calorimetry, a method for characterizing how well the sponges absorb their target chemicals.

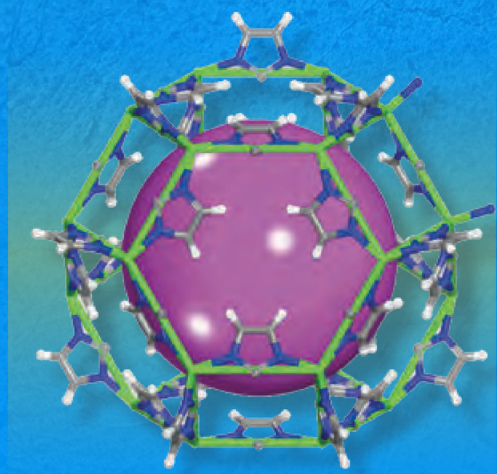
"I have a great team of people I work with. We can be efficient and we can be creative. When you're in an environment like that, lots of people like to join because it's a fun environment. It's easy to get stuff going and get going quickly. It's also important to recharge, so when I leave work, I leave work. For the most part I can clear my head and enjoy the rest of the day," says Nenoff.

That's when Nenoff turns to travel and the outdoors, particularly skiing in Taos, road biking and rock climbing. She spent a summer scuba diving in Fiji and has biked through France several times. Her idea of a great vacation is one that takes her out of work so thoroughly, she forgets all of her passwords.

MY SCIENCE

Separating oxygen from air

Tina Nenoff recently completed a Laboratory Directed Research and Development project in which she and colleagues designed and tuned porous materials, in this case metal organic frameworks, to selectively remove oxygen from air.



The work was important because the traditional way of doing that, for the most purified air, is cryogenic. Air is frozen to very cold temperatures, which separates oxygen from other components like nitrogen and argon. But it is energy-intensive. Other porous materials work, but are selective for nitrogen, and oxygen still has to be purified and carbon dioxide pulled out.

The Sandia method pulls out oxygen only. The project was basic research with a real-world application, specifically oxy-fuel combustion using oxygen for higher efficiency furnaces. Using oxygen versus air is more energy efficient. Sandia secured a few patents from the research and is talking to industry, particularly in glass melting, about licensing the materials.

patrick FENG

Hawaii? Microbrewery? Grad school? Germany?
He picked his way to acclaim in radiation detection.

Multiple CHOICE

By Patti Koning

Patrick Feng can map his professional success to a series of decisions that led him to Sandia. That path began as a high school student in Hawaii.

Until his senior year, Feng had planned to study electrical engineering in college. "I was involved in extracurricular activities like circuit design competitions and electronics club, but then I discovered synthetic chemistry," he says. "The idea that you could create something wholly new, that would not otherwise exist in nature — that was fascinating."

His high school chemistry teacher taught labs like sol-gel growth of large organometallic crystals, which exposed Feng to the possibilities of chemistry. When it came time to fill out his college applications, Feng had decided to major in chemistry.

Growing up on the island of Hawaii, Feng said he wanted to go anyplace else for college. "I really took for granted the natural beauty and wonders of Hawaii," he says. "Now I appreciate what a special place it is." He chose Colorado State University without ever setting foot in the state.

Research tipped the scales

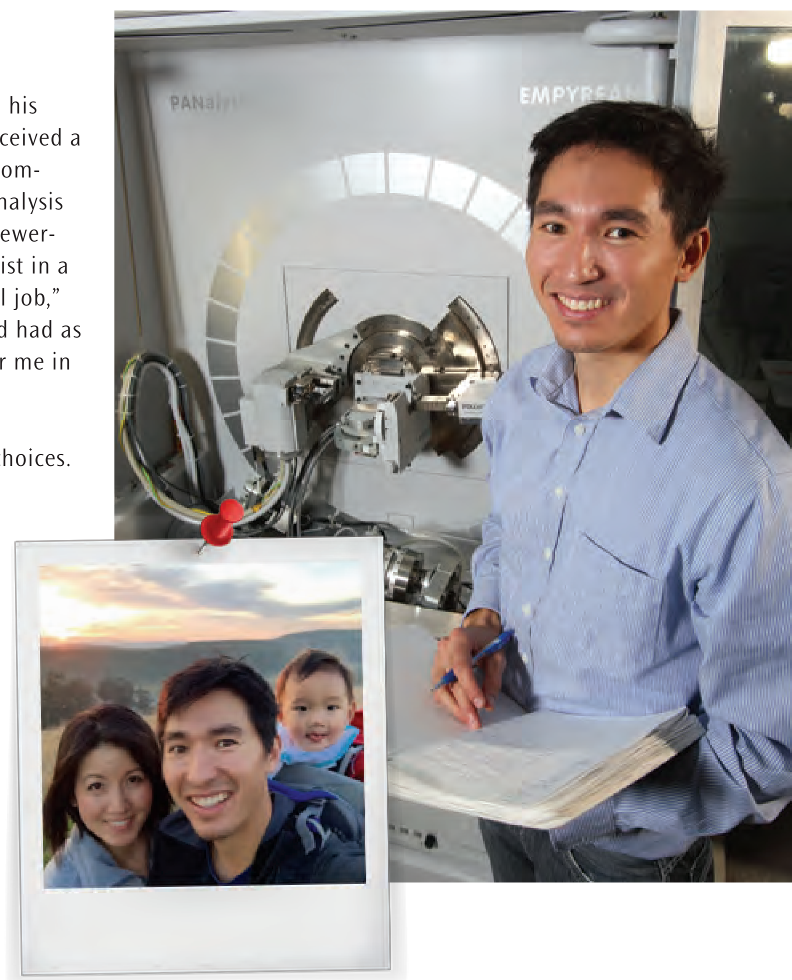
Another key decision came when he finished his undergraduate degree. As a student, Feng received a partial research scholarship from the Hach Company, a manufacturer of water testing and analysis equipment used in Colorado's many microbreweries. "I had an opportunity to work as a chemist in a microbrewery, which would have been a cool job," says Feng. "But the research opportunities I'd had as an undergraduate really tipped the scales for me in favor of graduate school."

Feng was then faced with two more critical choices. He decided to attend graduate school at the University of California at San Diego, turning down offers from Stanford and the University of Washington. He and his college girlfriend, who remained in Colorado, chose to give a long-distance relationship a try. "We married in 2014 after she moved to Livermore. Her finance job in Colorado was downsized, which was the perfect opportunity for us to finally live in the same city again," says Feng. He and Sophia now have a 2-year-old son, Kai.

Just two years into graduate school, Feng's adviser left for a position in Germany. With the alternatives of following the professor to Germany or restarting his research, Feng opted to remain in San Diego. He began a new research project on molecular magnetism under a different professor.

"What at first appeared to be a major setback, I now think set me up for later success," says Feng. He quickly became passionate about molecular magnetism and matured both academically and professionally through the experience of working under two very distinct advisers. "My advisers had very different styles. One was very hands-on and another one hands-off. I learned to appreciate the pros and cons of academic freedom, particularly during those formative years, " he says.

After completing his doctorate, Feng sought out opportunities for work that would have practical applications. He landed at Sandia in 2009 as a postdoctoral student working under Mark Allendorf. "Mark ran his projects in an academic style," says Feng. "His style fell right between that of my two



graduate advisers. He gave me just enough structure while still keeping research open-ended."

Most Promising Engineer

What came next for Feng was a series of high-profile projects. As a postdoc, he worked on Patrick Doty's project, "Use of Metal Organic Fluors for Spectral Discrimination of Neutrons and Gammas." The Laboratory Directed Research and Development (LDRD) project looked at organic scintillators in different testbeds including plastics, oils and a relatively new class of materials, metal organic frameworks, or MOFs.

After becoming a member of the technical staff at Sandia, Feng was made the principal investigator on a National Nuclear Security Administration-funded project to further develop plastic scintillators. That technology, Triplet-Harvesting Plastic Scintillators, went on to win an R&D 100 award in 2014. That year Feng also won an Asian American Engineer of the Year award, Most Promising Engineer.

He's now leading a project, which began as an Early Career LDRD and has follow-on funding, examining how to modify crystalline materials to achieve a given goal. "It's a first-principles approach to solving technological problems," says Feng. "Usually this is done with a physics approach." The goal is to develop a class of materials that can be used for radiation detection in the field. "I find this work extremely satisfying because it is basic research with an eye to a path to commercialization and large-scale impact," says Feng. "I think we will achieve success during my tenure at Sandia."

Despite his busy career at Sandia, Feng finds plenty of time for mentoring. He has one postdoc and two year-round undergraduate students. He has mentored seven undergraduate students during the past six years. "Mentoring reenergizes my outlook on science. Young scientists still have the excitement of discovery that is sometimes tempered in those of us who have been doing research longer," Feng says.

He also finds satisfaction in making a tangible impact on the future of young researchers. "This is particularly true when I hear about the success that some of my interns have in their academic and professional careers. I enjoy being able to see the development of these individuals as scientists, even over relatively short timescales such as an academic year or even a summer."

MY SCIENCE

Symmetry

Symmetry, the correspondence in size, form and arrangement of parts on opposite sides of a plane, line or point, is also defined as "excellence in proportion" in creating beauty. In nature, symmetry does more than make features pleasing to the eye – it also impacts many phenomena encountered in everyday life. It is remarkable how many diverse properties are defined simply by the arrangement of things in space.

For example, fundamental material properties such as thermal and electrical conductivity, magnetic permeability and nonlinear optical effects are intimately associated with the geometric arrangement of constituent atoms or molecules in a material.

These relationships between structure and property have factored into several of Patrick Feng's research projects. In one project to improve the efficacy of radiation detection materials, his team prepared rotational threefold symmetric versions of fluorescent organic molecular crystals used in such an application to improve their radiation-induced luminescence signature. In other words, the highly symmetric crystalline lattices were found to provide improved discrimination of threat materials against benign background radiation. In this case, the symmetry of the lattice controls the physics of light production and the mechanical strength of the material, in ways that improve the radiation detection performance of preceding materials.

susan REMPE walks a winding road with eyes set squarely on the mountain.

It ain't over till it's over

By Nancy Salem

Yogi Berra once said, "You've got to be very careful if you don't know where you're going, because you might not get there." Susan Rempe loves the quote because her path in work and life has been anything but direct.

"Even if you take the circuitous route, it can be valuable and rewarding," says Rempe, a theoretical chemist and computational biophysicist who joined Sandia Labs in 2001. "But know which mountain you will go after." Spoken like a true outdoorswoman, which Rempe is.

Growing up in Montana, Rempe considered lots of options, from writing to being a physician, veterinarian or astronaut. She was serious about music. "I was curious about all kinds of things," she says. But science was her strength. As a high school senior, she used ultraviolet spectroscopy to assess the water quality in Flathead Lake near her home. She graduated first in her class of about 500 students.

Rempe majored in pre-medical sciences with concentrations in history and German literature at Columbia University in New York City, but ruled out medicine when she had to assist in brain surgery on a dog with no preparation. "It worked out fine, but the stakes were too high," she says. "It helped me decide what I didn't want to do."

All her questions explained

Rempe married and started a family, and she and her husband returned to Montana. She went back to school and earned a bachelor's degree in chemistry from the University of Montana and a master's and doctorate in physical chemistry from the University of Washington. "Physical chemistry explained all my questions in the world," she says.

She planned to become a high school chemistry teacher until she ran into Sandia's Jim Martin, who was recruiting at Washington. "He told me Sandia is about science and solving fundamental problems, and about national security," she says. "I could do what I wanted science-wise. He said I could find colleagues with any expertise I needed. It sounded like a place I would like to work."

Rempe's field is molecular modeling, and she has led three major Laboratory Directed Research and Development (LDRD) projects at Sandia. One is a technology developed in partnership with the University of New Mexico (UNM) that helps regulate carbon dioxide emissions from electricity-generating plants and other industrial activities. Her team's nano-stabilized enzymatic membranes for CO_2 capture provide a simpler, more energy-efficient approach than conventional methods. The recently patented CO_2 Memzyme won a national Federal Laboratory Consortium (FLC) award and two awards at the 2015 R&D 100 ceremony, including the Gold Award for green technology.

Rempe also led the development of biomimetic membranes, a revolutionary advance in the field of membrane technology for water filtration. The biomimetic membrane is inspired by the way the human body filters water and is designed for water purification using reverse osmosis, which removes impurities with applied pressure powered by electrical energy. The technology, also developed with UNM, received R&D 100 and FLC awards.

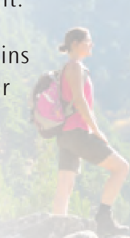
And she has worked with the MD Anderson Cancer Center in Houston on a problem involving an enzyme used to treat childhood leukemia that causes serious side effects. Rempe's team showed how to potentially control the side effects by eliminating a side-reaction catalyzed by the enzyme. She and her colleagues are studying ways to use the enzyme in different cancer treatments.

Rempe has published extensively in scientific journals and was invited for the prestigious Wilsmore Fellowship at the University of Melbourne, Australia. She is an adjunct professor of biology and research professor in chemical and biological engineering at UNM and has spoken internationally at scientific meetings including Gordon conferences and Telluride Science Research Center workshops.

A career mainstay

Funding from the LDRD program was critical to Rempe early in her career as she pursued research into biomimetic membranes. Later, an LDRD-funded project led her to the MD Anderson collaboration. And recently LDRD funding has allowed her to further expand research into anti-microbial compounds in collaboration with the University of Illinois at Urbana-Champaign. "LDRD has been a mainstay of my scientific career," she says. "I don't know that I could have accomplished what I have without it."

Ever the Montanan, Rempe is drawn to mountains and rivers, where she and her husband and four kids do white-water kayaking and back-country telemark skiing. In quieter moments, Rempe is



MY SCIENCE

Carbon dioxide

Carbon dioxide (CO_2) has gained notoriety as a greenhouse gas that traps heat and warms the Earth when it hits the atmosphere. It makes up 80 percent of all human-caused greenhouse gases and is a long-lived molecule. In the atmosphere, CO_2 can exert its warming effect for centuries, far longer than a greenhouse gas like methane, which decays within 10 years. Warming of the Earth is linked to climate change, and the Pentagon has designated climate change a threat to national security. Governments around the world have pledged to reduce CO_2 emissions to counter the threat.

Electricity generated by power plants that burn fossil fuels like coal or natural gas accounts for almost half the CO_2 emitted in the U.S. Despite investments in renewable and low-carbon fuels for electricity, domestic and global CO_2 emissions are expected to increase over the next quarter century. Other ways to reduce and reuse CO_2 include planting trees, but the scope

is overwhelming. Each coal-fired power plant emits about 3 million tons of CO_2 yearly. Planting 63 million trees and letting them grow for 10 years could achieve the annual emission target of 90 percent reduction set by the Department of Energy – for a single power plant over a single year.

Susan Rempe and colleagues at Sandia and the University of New Mexico have developed an advanced membrane, called the CO_2 Memzyme, that shows promise as a cost-effective and environmentally friendly way to capture and separate CO_2 molecules from emitted gases. The CO_2 Memzyme could play a critical role in the capture and purification of CO_2 for industrial reuse. ■

an accomplished pianist who has performed with the Symphony Orchestra of Albuquerque.

Rempe returns to Yogi Berra often for inspiration. Another beloved quote is, “When you come to a fork in the road, take it.” And then there’s, “It ain’t over till it’s over.” Or don’t call it quits until you’re done. “For me, there are lots and lots of ideas for advancing my research and lots of important projects still to pursue,” she says. “I keep moving forward and I enjoy the journey.”

julia

CRAVEN

got her first taste of scientific R&D as a high school intern.
Now the world is her stage.

big picture bigger risks

By Stephanie Holinka

Julia Craven has come full circle at Sandia Labs, from summer intern to accomplished optical engineer and remote sensing scientist. “The positive experience I had as an intern was a primary motivator that led me to pursue a STEM [science, technology, engineering and mathematics] discipline in college,” she says.

Craven works in an area of the laboratory that provides technical capabilities to detect, monitor and assess targets relevant to nuclear nonproliferation, treaty verification and other national and global security missions. She is also the principal investigator on a Laboratory Directed Research and Development (LDRD) project using optical remote sensing tools and techniques to solve problems in the nuclear nonproliferation and treaty verification mission spaces.

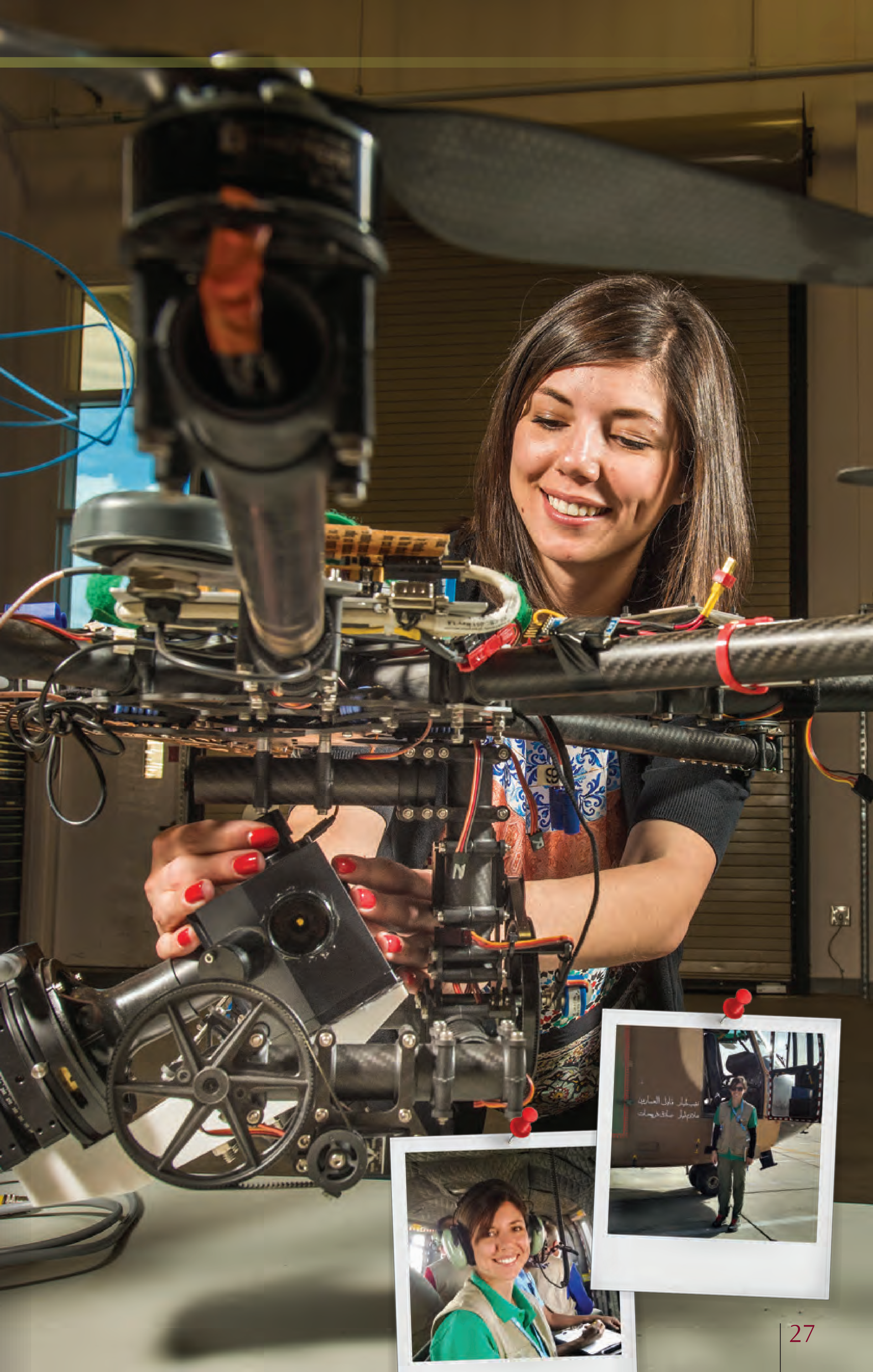
Craven has been a member of technical staff at Sandia since 2011, but first came to the labs as a high school summer intern in the Advanced Materials Lab. “My experience there was my first exposure to what a career at a national lab could look like,” she says.

NNSA funded doctoral research

In 2006, Craven received a bachelor’s degree in physics from San Diego State University. She followed that with a master’s in 2008 and doctorate in 2011 in optical sciences from the University of Arizona. Craven’s doctoral research was funded through a grant from the National Nuclear Security Administration’s (NNSA) Defense Nuclear Nonproliferation Research and Development office, which continues to fund her work at Sandia.

“As a part of my university grant, I presented my work annually at reviews by national lab researchers, including several staff members from Sandia,” Craven says. Those reviews renewed her interest in working in the national lab community.

Craven’s current LDRD project investigates the use of optical imaging polarimetry for current and future remote sensing missions for national security applications. “Optical polarization describes the amplitude and phase of the electric field component of a light



field," she says. "Although substantial investments have been made by multiple agencies to produce polarization-sensitive optical sensors, the equivalent utility for polarization data for remote sensing missions has not been definitively established."

So Craven's work is focused on quantifying how, and perhaps if, the addition of polarimetric data products to conventional detection and discrimination capabilities can provide for overall enhanced sensing for national and global security applications. "On any given day, I could be in the lab testing sensors, in the field deploying systems and taking measurements or I could be meeting with other scientists and engineers to collaborate and share results," Craven says. "I work with an amazing team of people both inside and outside Sandia."

Nuclear Test Ban Treaty exercise

Craven was the only U.S. member of the 12-person External Evaluation Team for the Integrated Field Exercise 2014, the largest and most technologically advanced Comprehensive Nuclear Test Ban Treaty on-site inspection exercise completed to date. Her job was to examine the use of several optical remote sensing technologies used to inform the inspection team's search activities. Craven won the NNSA Administrator's Silver Medal for her work on the exercise, which was conducted in Vienna, Austria, and the Dead Sea region of Jordan.

Craven says her externally funded research focuses on the application of optical polarization to solve specific detection or identification problems, so the tie between her LDRD project and other work is very strong. But the LDRD focuses on characterizing fundamental phenomenology and exploitation approaches that ultimately could be applicable to a variety of mission spaces.

"LDRD lets researchers like me solve big-picture problems that external projects often don't have the bandwidth for," says Craven, who is a volunteer at the National Museum of Nuclear Science and History and in her free time enjoys cross country skiing and hiking with her dogs.

It also lets her take bigger risks than are possible in external projects. "Choosing to pursue a high-risk approach or solution when an external deliverable is on the line can be difficult, but with LDRD I feel I have more flexibility to take those risks — and that can lead to big rewards not just for Sandia but also the broader research community."

MY SCIENCE

Optical polarization

Optical polarization describes the amplitude and phase of the electric field component of a light field. Some light we can see, and is referred to as visible light, while other light is invisible, like infrared or ultraviolet. However, all light is a type of electromagnetic (EM) radiation.

Other types include X-rays, microwaves and radio waves. For many applications, EM radiation can be treated as a wave consisting of two perpendicular field components: an electric field and a magnetic field. Each field component is a transverse oscillating wave that has amplitude and phase, but out of convention polarization is used to describe the electric field exclusively.

An optical polarimeter is a sensor that can be used to characterize the polarization state of a light field. When light interacts with a material or a surface, that material can alter the polarization state of the light field. Consequently, remote sensing scientists like Julia Craven often measure the polarization state of light to gather information on the surface properties of an object, like the roughness or structure, the light interacted with before reaching the observer.

dan

SINARS

was 15 when an elite school beckoned. He left home and, after shedding some tears, never looked back.

Out of the nest

By Neal Singer

Dan Sinars' science career began on an odd note when his junior high school wanted to place him in remedial education. His family had moved from Chicago to the suburbs, and admission papers listed him as having hearing loss. "Lots of people with hearing loss fall behind in school," Sinars says. "But not everyone."

Apparently not. Sinars is now senior manager at Sandia's Z facility, which creates several times the entire world's electrical power output in the nanoseconds when it fires.

Back then it took determined intervention by a gifted-class teacher to rescue Sinars. She worked out a deal with the remedialists: The school put Sinars in gifted classes on a trial basis and watched him closely. Sinars didn't realize he was getting unusual scrutiny but was happy after four weeks to be formally invited to the gifted program. Once ensconced, he had permission to take an SAT exam that qualified him to spend three high school years in the elite Illinois Math and Science Academy in Aurora, Illinois. "That's what really launched me into science and engineering," he says. "More than half of my teachers had Ph.D.'s."

But while a teacher launched him into more complex courses and high SAT scores into a science high school, he realized after his parents dropped him off at IMSA that he overlooked something big. Students were expected to live in dormitories; travel home was permitted only on weekends.

"I met my roommate, my parents left and I thought I was fine," Sinars says. "I called my mom that night to check in and the enormity of what I had done — leaving home at the age of 15 — overwhelmed me. I broke down completely. My mom said, 'You can always come home, but this is a great opportunity.' That was all I needed to hear, and I never looked back."

He took numerous physics and chemistry classes and three years of German, combined with liberal arts courses he enjoyed for their mind-expanding content and because he would not have to take them again in college.

A prestigious offer from Cornell

Still, Sinars wasn't locked into a research career. "I wasn't sure what I wanted to do," he says. "I never gave it serious thought."

An IMSA guidance counselor suggested that people with his interests often chose electrical engineering. The University of Oklahoma was among the schools he applied to. "They called me every other week, flew me out before the fall semester for a look-see and offered me a full ride." They also had more National Merit Scholars than any other engineering school. So Sinars went.

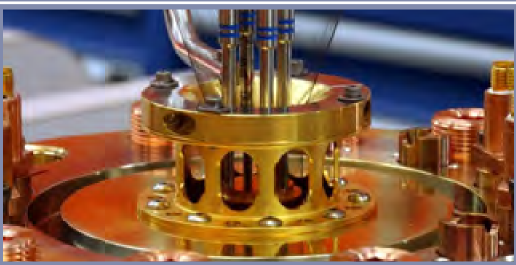
There he met and married his wife, a chemistry student, and applied in physics to seven graduate schools "so we had a high probability of both getting into the same school." One day a call came from the renowned

MYSCIENCE

Z-pinch

A z-pinch is a plasma cylinder with a large current running along its axis – the z-axis. The axial current generates its own magnetic field around the circumference of the cylinder. The axial current and its magnetic field result in a radially inward force directed toward the axis of the cylinder. If the current is large enough, the magnetic pressure can squeeze or "pinch" the plasma, much like a person crushes an empty soda can with a hand.

Z-pinches are used as radiation and fusion sources. In the 1950s, people tried to see if gas puffs made of fusion fuel could pinch hard enough to ignite. Since then, a wide variety of different pinches has been studied. Today the Z machine at Sandia Labs is being used to create the most powerful z-pinches in the world. It allows scientists to study materials under conditions similar to those produced by the detonation of a nuclear weapon and produces key data used to validate physics models in computer simulations.



Dan Sinars has long been fascinated by the pinching process. As a graduate student he tried to understand whether a Z-pinch plasma known as an X-pinch underwent a radiation-driven collapse to very high density due to such pinching. He subsequently created hot (millions of degrees), short-lived (tens of picoseconds), small (1 micron) plasmas.

Sinars has led two Laboratory Directed Research and Development projects on pinching. In one, Sandia's SATURN pulsed power facility was used to demonstrate that much brighter, albeit bigger (5 micron), X-pinch plasmas could be created. The other two explored whether the implosion of cylindrical metal tubes, or liners, for inertial confinement fusion or dynamic materials research can be stably controlled.

Cornell physicist David Hammer. "He said he thought I'd make a wonderful addition to his research group, and that was enough for me," Sinars says.

"I hope you see a trend here," he says. "One thing leads to another. I follow the path of least resistance. I've succeeded by doing what people asked me to do." Though, he adds, "there's a lot of hard work involved." The work involves extensive analysis before Sinars follows what he terms the path of least resistance.

"Cornell had CHESS (Cornell High Energy Synchrotron Source), great physics and particle physics, and my wife used X-ray sources from the synchrotron to study 3-D structures of proteins, so the school was appealing to us both," he says.

He caught "the plasma fusion bug" from summer internships and didn't want to do physics as a theorist, sitting in front of a computer. "I wanted to get my hands dirty."

Since a number of his graduate projects were paid for by Sandia and a Department of Energy research grant, Sinars was open to working at the labs when several researchers gave him the hard sell about the Z machine.

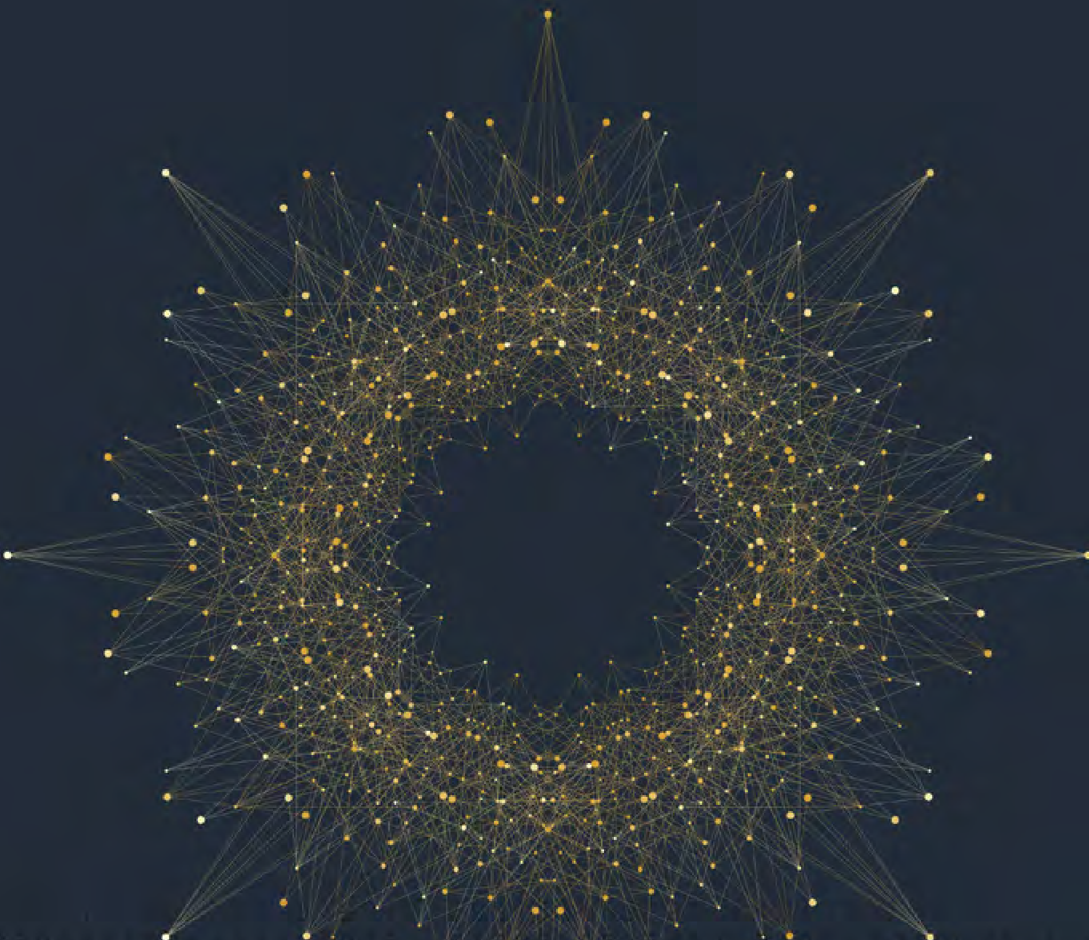
Leadership in LDRD

At Z, he says, "I've had a ton of Laboratory Directed Research and Development [LDRD] projects. In 2006, after being here only five years, I was principal investigator on a $5 million Grand Challenge LDRD project looking at advanced targets for Z, among other things. Later, LDRD gave me an opportunity to do a science project on SATURN, a sister facility to Z, to help balance my workload at the time. LDRD was the only means of getting funding for that project.

"I've had other awards — the DOE Early Career Award, and ARPA-E [Advanced Research Projects Agency-Energy] money — but that's all work for others. LDRD is so much nicer because Sandia researchers get to define what we think is important. The Grand Challenge LDRD is a great way, because of its size, to achieve cross-fertilization of ideas and learning. That's what you want for young staff. And LDRD offers small leadership opportunities. The principal investigator is given an opportunity to lead, to influence the direction of themselves and others and make mistakes and learn from them."

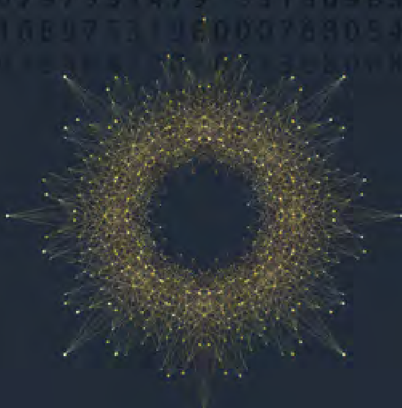
Sinars sees himself as an institution builder. "In physics, we build this edifice. Every one of us adds a brick or some mortar, or makes some other small contribution to this grand thing we call physics."

cindy PHILLIPS zooms in on impact in the fast-moving world of computing.



SQUISHY SCIENCE

By Sue Major Holmes



Computer scientist Cindy Phillips knew by junior high her career would be something technical, and like many science-minded kids, she decided to become a veterinarian. But she realized it wasn't a good fit when she developed terrible allergies to animals. So she switched her goal to math professor. Her conclusion in college that applied math was more fun than pure math led her to computer science. "From there it was, 'Programming is awesome!'" she says.

She studied computer science in grad school, still with the thought of academia. Then her physician husband's career brought the couple to Albuquerque for his residency at the University of New Mexico, their No. 1 choice for its combination of a good radiology program, quality of life — and the possibility she could get a job. She finished her dissertation on *Theoretical and Experimental Analyses of Parallel Combinatorial Algorithms*, and joined Sandia.

Phillips intended to remain for only the four years of her husband's residency. "But we stayed. He was offered a faculty position and I wanted to stay here," Phillips says.

That's common for Sandians of her generation. "There are a bunch of us who started around 1990 thinking we'd have a taste of the Southwest and a taste of the national labs, and we just never left," she says. "We loved who we were working with, the interdisciplinary nature of the work and the fact that interesting problems come to you; you don't have to dream them up."

Multidisciplinary, team-oriented research

Much of her research has been supported by the Department of Energy's Office of Science and Sandia's Laboratory Directed Research and Development (LDRD) program, directed at forward-looking research. Phillips gives a nonstop recounting of LDRD projects she's been part of, leaning forward, often using the word "we" in acknowledgement of Sandia's multidisciplinary, team-oriented nature.

A senior scientist, she works largely on shorter-term projects in specialized areas as a member of Sandia's Center for Computing Research. "We are people who do mathematical optimization, an area that can be applied in so many practical problems, but if you really want to solve them effectively you have to know something about the application," she says. "So we have to learn something about water distribution networks or wireless networks and communication. We're also usually trying to learn computer and math sub-disciplines like statistics, data mining or machine learning."

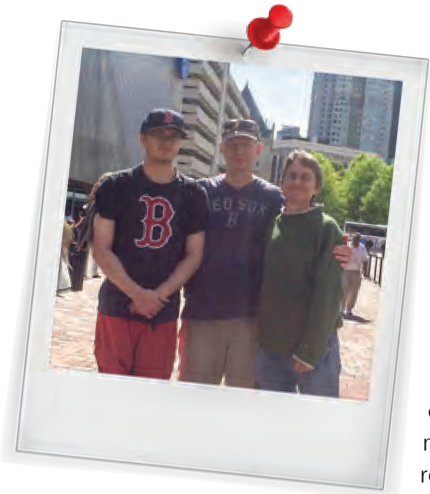
Learning is great, but "the real fun part is actually working on the problems with other people," Phillips says. "I think the lab can be the best of academia and the best of industry, where you make sure what you're working on is important, that it's going to have impact."

Rather than focus on narrow applications of particular problems, "we can think more generally and look to solve classes of problems and from there meta-classes of problems. After solving several specific problems you can have the luxury of stepping back and asking what the general lesson was and really making breakthroughs," she says.

Early in her career, she led an LDRD project on network interdiction, looking at how someone could use limited resources to damage networks such as an enemy supply line. Next she headed a three-year bioscience project on multiple sequence alignment and phylogenies, or evolutionary trees, to predict protein properties. She also led an early project to create a massively parallel integer programming code, a complicated concept she explains with a simple example of building factories, represented as an optimization problem to minimize costs. Without so-called integer constraints, the program suggests an eighth of a factory in one location, a sixteenth somewhere else, a smaller piece in a third place and half a factory somewhere else. "Your math problem assumes you're getting this fractional benefit. Of course you're not going to get an eighth of the benefit from building an eighth of a factory; you're going to get no benefit," she says. Instead, an intelligent search procedure using the structure of the problem leads to solutions "that tell you exactly where to build your factories."

Hard-to-define problems

Phillips, named Fellow of the Society of Industrial and Applied Mathematics and a distinguished member of the Association of Computing Machinery, now heads an LDRD project on advanced data structures, useful for cybersecurity, which allow large streams of information to be rapidly accepted and saved for later searching.



She says working on specific projects with concrete goals prepared her for the "much more squishy and challenging problems that are coming now, where you kind of know what the problem is, but how you exactly define it, how to make progress on it, can really be hard."

Some of her off-hours time is still work-related, such as duties as vice president of the Society of Industrial Applied Mathematics or helping collaborators outside Sandia publish research on projects that have ended. She skis and likes to bike to work when she can. She's a trustee for Albuquerque's Manzano Day School — her Sandia badge dangles from a red school lanyard — although her children have long since left the private elementary school. A New England native, she says her addiction to the Red Sox devours free time from April to September, "sometimes a little longer if they make the post-season."

MYSCIENCE

Connecting data

Finding ways to connect data can be challenging when you have a huge amount of information. For computer scientist Cindy Phillips it's also fascinating research.

Let's say Counterterrorism Agency A and Law Enforcement Agency B each store data about the relationships between people, but they're forbidden to share that data. Agency A wishes to understand the connection between two people. How can the agencies pool their information to connect the dots without revealing sensitive information?

The solution could lie in "geographically distributed graph algorithms." Graphs are a common way to show how people or objects relate to each other. Here, people are the objects (nodes) in each agency's graph, and the edges of the graphs connect two people known to have a relationship. The goal is to design ways to answer the question without combining the graphs.

Finding a connection between two nodes in a graph is like finding a route between two places in a road map. In this case, two entities have different overlapping parts of the map and must determine if there is a connection without revealing the route.

Sandia researchers and academic colleagues correctly and securely determined if two nodes are connected using "secret sharing" during communication. Although the conversation must find a route — connections between two people using intermediary people — it reveals no other names. Thus, Agency B learns the question (the connection between people) and both learn the answer.

laura BIEDERMANN

wanted to be an astronaut. She also wanted to try new things and make science fun. Physics led her there.

YOU MIGHT AS WELL AIM HIGH

By Sue Major Holmes

Sandia physicist Laura Biedermann was out running with scientifically astute but non-physicist friends who asked about news that the Laser Interferometer Gravitational-Wave Observatory had detected such ripples in space. "They're asking what are gravity waves and interferometers, and so I'm explaining, 'You've got these two optical paths'" — she stretches out her arms — "and acting out an interferometer while we're running."

Biedermann likes explaining science. "You've got to start off with what you're doing and why. It's fun trying to explain things when you don't have a white board or anything around you because you've got to figure out how to give people the correct mental image. If you can get people to have the correct mental image without anything tangible in front of them, you've succeeded at communicating."

She got into physics because that's where she found answers, literally. When she asked her high school biology teacher about concepts, the teacher told her not to worry; she'd learn it next year in chemistry. The next year, Biedermann was equally frustrated by the chemistry teacher telling her she'd get the answers next year in physics. The physics teacher didn't tell her she'd learn it later, "so I majored in physics."

Originally, she thought that would help her become an astronaut. "If you fail at that, you still have options," she reasoned. "You might as well aim high."

The Vomit Comet

In college, a fluid flow project took her to the Johnson Space Center for two weeks as part of NASA's Reduced Gravity Student Flight Opportunity program. Students propose, design and fly experiments aboard a KC-135, known as the Vomit Comet because of the stomach-turning effects of flying parabolic arcs. The program was fascinating, but Biedermann realized even mission scientists "can't really do research on the Space Station, that everything's really prescribed and there's no option to try new things, to change things. You don't get to have the experimental freedom that makes science fun because of all the necessary constraints."

She continued in physics without being sure how she'd use it. Early on, she decided against a career in academia because "I noticed my professor looked like a kid in the candy shop on the rare Friday afternoons he actually got into the lab to see the experiments real time and test out the new equipment. I just figured I wasn't going to go to school for eight or nine years to not touch equipment anymore."

MYSCIENCE

Desalinization

Physicist Laura Biedermann points out a photo of a membrane being developed for desalinization "This is what they look like; kind of beautiful," she says, then, "It's in the lab right now; want to go take a look?"

Sandia is interested in how desalinization could reduce the water demands of energy production for the electric power industry and others. Biedermann is in the first year of a three-year Laboratory Directed Research and Development (LDRD) project, studying laminar graphene oxide/polymer structures for a new chlorine-tolerant low-energy desalinization membrane. It's a fundamental science effort to explore how to optimize the graphene oxide assembly for high water permeability while rejecting salt from brackish water and improving the tolerance to the chlorine used for disinfection during water treatment.

The intrinsic structure of graphene oxide nanosheets makes them ideal layered materials for desalinization membranes, Biedermann says. "Nature is very kind to us — when we assemble laminar graphene oxide structures, the oxygen functional groups act as nanopillars, defining a slit about one nanometer wide through which the water permeates, around the graphene oxide nanosheets. This width is ideal to prevent salts in water from permeating. With graphene oxide/polymer membranes, we have nanoscale-structured materials that eventually can treat water on the municipal scale."

As a senior at the University of Illinois, she took a nanotechnology survey course and loved it. That gave her a path for graduate school at Purdue, studying condensed matter. In her fourth year at Purdue, Biedermann presented a talk at Sandia under the Campus Executive Graduate Research program. A month later, she attended a Materials Research Society meeting, where Sandia staff members recognized her as the grad student speaker and approached her to say hello. She was impressed, and came to Sandia in 2009 as a postdoctoral appointee. In 2010, she joined the Electronic, Optical and Nanomaterials department in the labs' Materials Science and Engineering Center.

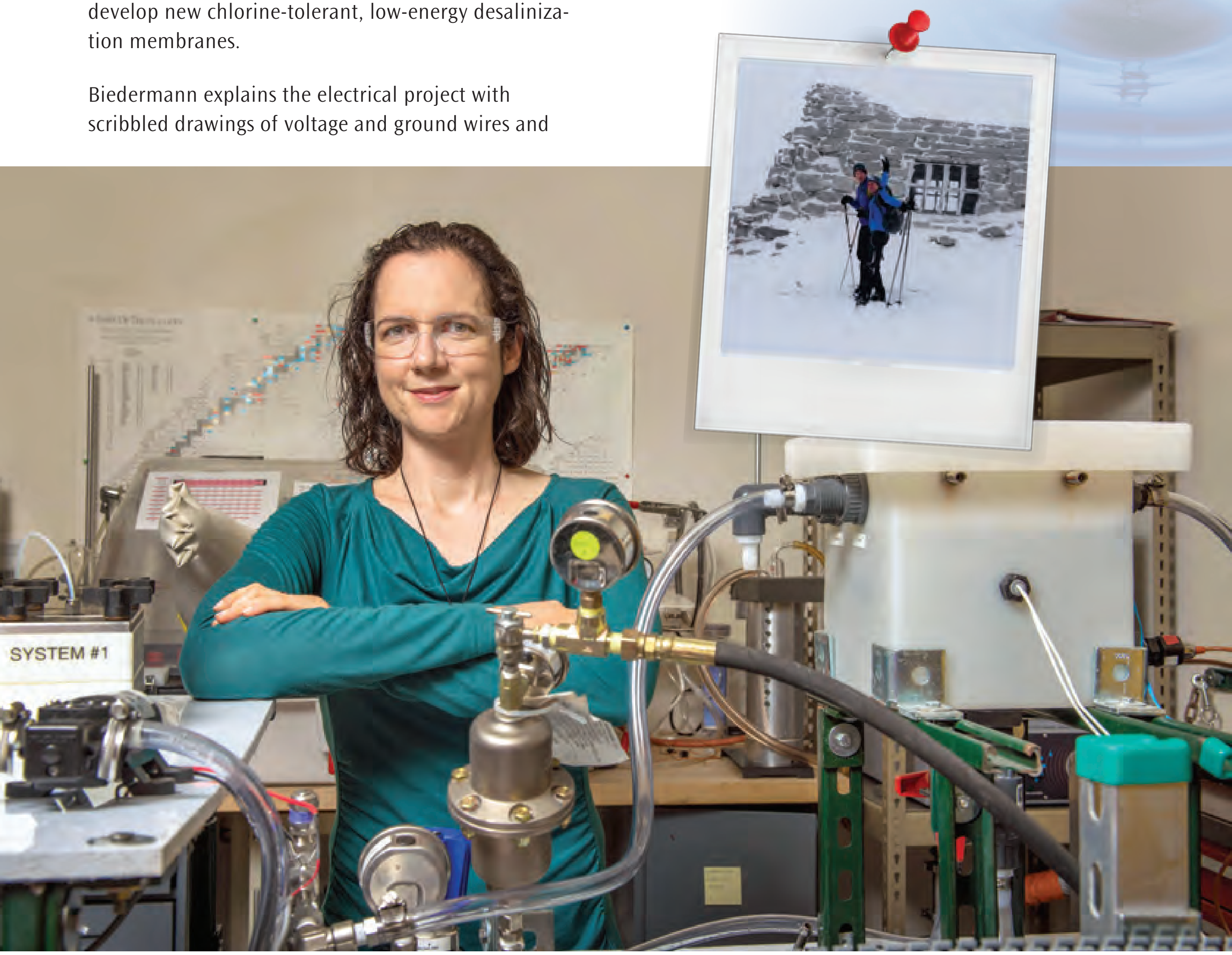
Scribbled drawings on scrap paper

Working on diverse projects in grad school "stirred my bifurcated research nature because I've never been able to stick to one topic since," she says. Sandia gives her freedom to pursue vastly different research, illustrated by two key projects: one on high-voltage electricity and plasma physics and the other a Laboratory Directed Research and Development (LDRD) project to develop new chlorine-tolerant, low-energy desalinization membranes.

Biedermann explains the electrical project with scribbled drawings of voltage and ground wires and a ceramic insulator on a piece of scrap paper, and bends her arms, demonstrating how she tells friends about shaping an electrical field. It's exciting research "because you've got materials, you've got experiments, you've got modeling, and atmospheric chemistry and the plasma processes," she says. "There are just a lot of really fun questions and really good people I get to work with."

She opens a presentation she gave the previous day on the desalinization research, pointing out details, remarking on questions to be solved. There's even a joke slide: the edible salinity scale, ranking salt concentration according to a scale consisting of V8 juice and soy sauces. Laughing, she notes: "Low-sodium soy sauce has the same sodium concentration as the concentration of salt in seawater."

But even without visual aids, desalinization work is easier to explain because people relate to water. "With water projects you get to say exactly what you're doing and why," Biedermann says.



Sandia RESEARCH

Sandia National Laboratories
P.O. Box 5800, MS 0359
Albuquerque, NM 87185-0359

LOOKING BACK

DAWN OF LDRD

When Al Narath stepped into the role of Sandia director on April 1, 1989, fundamental research was long-established at the national laboratory. Narath himself embodied the origins of that expertise, having arrived in 1959 as part of a cohort of Ph.D. scientists hired to deepen the labs' research base.

The first labs director selected from Sandia's ranks, Narath had a strong commitment to maintaining a vibrant research program. He pushed Sandia to define its core competencies and build its research foundations on them.

The labs' future was uncertain in the early 1990s in the midst of political changes and budget cuts that came with the end of the Cold War. Narath and his management team shaped Sandia's strengths into forward-looking research programs, including Laboratory Directed Research and Development (LDRD) established by Congress in 1990.

Narath's focus on the program transformed LDRD from an ad hoc endeavor operated by volunteers into a permanent office with a dedicated manager overseeing a single process. LDRD was an explicit commitment to the exploration of new ideas based on the early Sandia belief in the need to pursue basic questions in support of creative solutions.

— *Rebecca Ullrich*