LOS ALAMOS NATIONAL LABORATORY ◇ SUMMER 2019

NATIONAL ★ SECURITY SCIENCE

THE EARTH & SPACE ISSUE

Securing our shores: protecting military bases from Mother Nature

Explosion monitoring: a complicated game of telephone

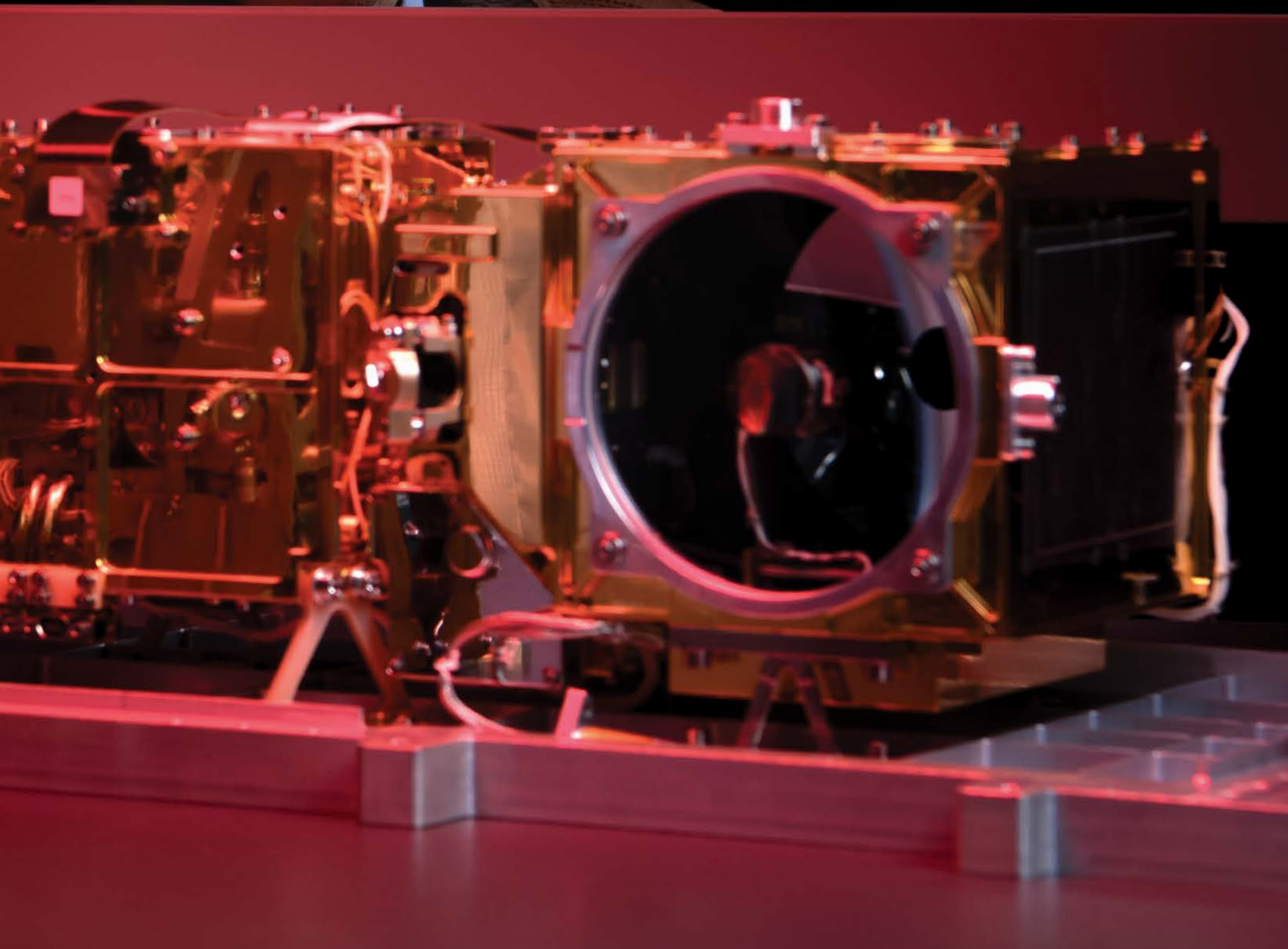
Science turned skyward: how a bomb built the space program

+ PLUS:

Seismic sleuthing in southern California	Could scientists deflect an asteroid?	Q&A with astronaut John Phillips

PHOTOBOMB

Laboratory Fellow Roger Wiens, principal investigator for SuperCam, takes one last look at his invention before sending it to collaborators at Institut de Recherche en Astrophysique et Planétologie in Toulouse, France. Ultimately, SuperCam will make its way to NASA's Jet Propulsion Laboratory for attachment to the Mars 2020 rover. Learn more about SuperCam's capabilities on p. 30.



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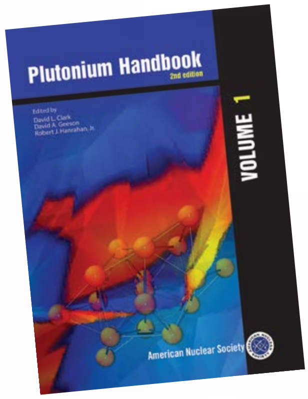

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ABOUT THE COVER: Los Alamos technology enhances America's national security, from the far reaches of space to the geology below Earth's surface.

Photo: Dreamstime.com/Titoonz

IN THIS ISSUE

FEATURES

EARTH & SPACE

UNDERSTANDING OUR PLANET—from its inner core to its surrounding solar system—is essential for maintaining America's national security.

BY BOB WEBSTER
DEPUTY DIRECTOR, WEAPONS

Stretching across 40 square miles, Los Alamos National Laboratory comprises just 0.03287 percent of the state of New Mexico, 0.00105 percent of the United States, and 0.00002 percent of the globe.

And although we sometimes feel physically isolated in our high-desert location (the closest international airport is almost two hours away), our work touches nearly every part of this great big world—and beyond.

That's because our mission is to deliver science and technology to protect our nation and promote world stability. We do this in dozens of very big and very small ways, a handful of which are captured in this issue of *National Security Science* magazine.

For starters, Laboratory scientists develop the tools necessary to monitor for underground explosions. They do this by looking at geology and seismic activity—and now they're adding modern weapons codes to the mix to model what any type of explosion might look like anywhere in the world. Turn to "A complicated game of telephone" (p. 20) to learn more.

On Earth's surface, some of our scientists are concerned with coastline erosion, particularly with how crumbling coastlines, combined with storm surge and sea-level rise, might impact our nation's military bases. Will Naval Station Norfolk be underwater soon? Read "Securing our shores" (p. 12) to find out.

Finally, look up. Los Alamos scientists and engineers have been pioneering space technology since the 1950s, before it was even considered space technology (the original goal was to develop a nuclear rocket to deliver a nuclear weapon to the Soviet Union). In "Science turned skyward" (p. 30), read about the history of Los Alamos' contributions to space and several of the capabilities we're working on now. From license plates for miniature satellites to lasers for the Mars 2020 rover mission, the technologies are really out of this world. ★

▶ Because this is the Earth & Space issue, let's take a moment to celebrate the 50th anniversary of the first manned mission to land on the moon. Here, astronaut Buzz Aldrin, part of the United States' Apollo 11 mission, stands on the moon on July 20, 1969. Today, Los Alamos is helping to develop technology that will take astronauts to Mars. Photo: NASA

MASTHEAD

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National Security Science highlights work in the weapons and other national security programs at Los Alamos National Laboratory. Current and archived issues of the magazine are available at lanl.gov/nss. *NSS* is unclassified and supported by the Lab's Office of Nuclear and Military Affairs. To subscribe, call 505-667-4106, or email magazine@lanl.gov.

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NSS STAFF SPOTLIGHT

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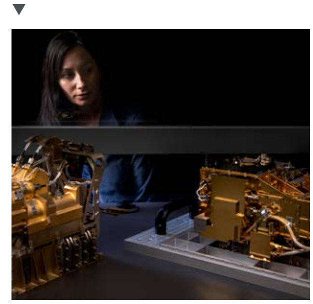


Katharine Coggeshall observes SuperCam, a sophisticated suite of instrumentation for NASA's Mars 2020 rover. To read more about SuperCam and the Laboratory's other contributions to space research, turn to Coggeshall's article on p. 30.

ENVIRONMENTAL STEWARDSHIP

The Laboratory executes its national security mission while monitoring and protecting its air, water, and ecosystem health.

The Laboratory's mission is to solve national security challenges through scientific excellence. Inseparable from the Lab's commitment to excellence in science and technology is its commitment to environmental stewardship and full compliance with environmental regulations.

Every year, the Laboratory produces an Annual Site Environmental Report to communicate the impacts its operations might have on the surrounding environment and the approaches used to mitigate these impacts.

Here are just a few numbers from the 2018 report. ★


JEMEZ MOUNTAINS SALAMANDER


YELLOW-BILLED CUCKOO


SOUTHWESTERN WILLOW FLYCATCHER


NEW MEXICO MEADOW JUMPING MOUSE


MEXICAN SPOTTED OWL

5

ENDANGERED SPECIES that live on or near Lab property and are monitored by Laboratory biologists

17.07

inches of **PRECIPITATION**

1,800

PREHISTORIC AND HISTORICAL SITES identified on Lab property

27

million gallons of **RECLAIMED WASTEWATER** reused in computer cooling towers

785

BIRDS representing 59 species that were recorded during surveys

1,112

Laboratory **PROJECTS REVIEWED** for environmental impacts and National Environmental Policy Act compliance

825

WASTE DRUMS that the Laboratory's Transuranic Waste Facility can store regularly

38 **MONITORING STATIONS** that sample radionuclides in the air

615 **TONS** of mixed paper, cardboard, plastic bottles, and cans **RECYCLED**

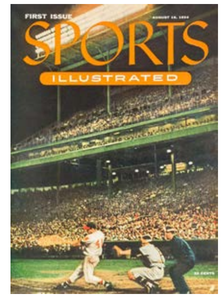
INFOGRAPHIC

THE INTERSECTION

Where science and culture converge in Northern New Mexico—and beyond.

Retired Laboratory weapons designer Blake Wood is recognized in the June 2019 issue of *Trail Runner* magazine for finishing the Hardrock Hundred Mile Endurance Run 22 times.

In 1953, Lou Pierotti, operator of the Los Alamos soda fountain under contract to the Atomic Energy Commission, formed the nation's only five-man fast-pitch softball team. Pierotti's Clowns, as the team was known, was featured in the first issue of *Sports Illustrated* in August 1954.



NATIONAL PARK SERVICE

Most of the Los Alamos portion of Manhattan Project National Historical Park is off-limits to the public—but a special tour on Lab property is happening on October 4. Visit lanl.gov/museum/manhattan-project for details.

Walking around downtown Los Alamos? Check out the "News from Mars" screen, which broadcasts recent images from the Mars Curiosity rover.

On May 2, the League of American Bicyclists recognized the Laboratory with a Bronze Bicycle Friendly Business award, recognizing it as a bicycle-friendly organization.

THE LEAGUE OF AMERICAN BICYCLISTS

CULTURE

SCIENCE

QUOTED

$16.5 BILLION

—The president's 2020 budget request for the National Nuclear Security Administration (NNSA), an 8.3-percent increase from 2019.

"Our ability to maintain a robust national security portfolio hinges on funding from the federal government. The proposed budget would enable our Lab and other NNSA entities to make sustained investments into national security. It provides funding for Directed Stockpile Work, including funding to support the life extension programs, modifications, and a major alteration."

—Laboratory Director Thom Mason ★

HOW TO SPOT A LOS ALAMOS SCIENTIST

POLARIZED SUNGLASSES: New Mexico has more than 300 days of sunshine annually.

BIKE HELMET: Los Alamos County has 58 miles of trails and celebrates "Bike to Work Week" every May.

HAWAIIAN SHIRT: On Fridays, Lab employees wear tropical prints as a nod to the days of nuclear testing in the Pacific.

LOW-TECH WATCH: Many Lab buildings don't allow personal electronics, so low-tech watches help Labbies get places on time.

COFFEE: Solving the world's national security challenges requires a lot of caffeine.

PAJARITO MOUNTAIN SKI PASS: Never mind that it's summer—Labbies always have their fingers crossed for a powder day.

SOCKS AND SANDALS: All-terrain sandals are a must for spontaneous lunchtime hikes. Wool socks prevent tan lines.

"Well, I don't know how well they dress here, but they've got brains."

—During a visit to Los Alamos on December 7, 1962, **President John F. Kennedy** paraphrased remarks by New Mexico Senator Clinton P. Anderson. Learn more about Kennedy's visit on p. 30.

RESEARCH

READ ALL ABOUT IT

New center makes archived classified weapons research more accessible.

Los Alamos has been up and running for more than 75 years, which means the Laboratory has accumulated quite the collection of classified weapons research materials in its vault. Most of these include official documents, drawings, and films produced by the Laboratory and other organizations in the Department of Energy (DOE) and the Department of Defense (DoD). Some of the materials are papers or notebooks from scientists and engineers who've long been retired, and unless they belonged to someone famous (such as Robert Oppenheimer), they've long been forgotten. Until now.

In June, the Laboratory's Weapons Research Services Division opened the National Security Research Center in the National Security Sciences Building. The center has increased access to the archived documents and other media in the vault. "We spruced up the vault to include a nice viewing room so that scientists and engineers can sit for a while and read historical documents," says Program Manager Julie Maze. "We also created an easy-to-use search capability on the classified network so that researchers can look for hard-copy documents in the vault, then make specific requests to see them."

The center is available not just to Los Alamos employees but also to members of the military and employees of other DOE laboratories. "People working to keep our nation safe should be able to build on what's already been learned," Maze says. "Now, more than ever, it's important they have access to that information." ★

"THE BEST COMPUTER IN THE WORLD is of no use if you don't have some kind of experimental validation behind it. WE'RE NOT DOING VIDEO GAMES. We're trying to model complex, real systems, and the way we validate those systems is with a pretty sophisticated suite of experimental tools."

—Laboratory Director Thom Mason during an all-employee meeting on February 5

CAREERS

SUMMER STUDENTS EXPLORE NATIONAL SECURITY SCIENCE

Hands-on projects provide an in-depth understanding of nuclear nonproliferation.

BY ELIZABETH BRUG In the summer of 2018, Jessica Elder, a mechanical engineering undergraduate from Worchester Polytechnic Institute (WPI), took a road trip from her home in upstate New York to New Mexico. She came to Los Alamos to participate in the second G. Robert Keepin Summer Program at Los Alamos National Laboratory, an experience that would challenge and inspire her.

The G. Robert Keepin Summer Program is an eight-week intensive internship that pairs lectures, tours, and training with individual projects for an immersive exploration of nonproliferation. The program is a partnership between Los Alamos and the eight universities that form the Nuclear Science and Security Consortium (NSSC). The partnership aims to create relationships between students and experienced researchers. Program organizer Rian Bahran says that, ultimately, "the program strengthens the pipeline" by bringing new scientists to the Laboratory.

Each year the program accepts 20–30 students. Half of them are NSSC students for whom the program is required. Students in both STEM and policy fields from other schools (such as WPI) compete for the remaining spaces, with about a 30-percent acceptance rate. The selected students attend private activities and lectures as a group, thus developing a real sense of camaraderie by the end of the summer.

Bahran and fellow organizers Chloe Verschuren and James Miller, both of the Nuclear Engineering and Nonproliferation Division, receive weekly feedback from students and continually refine the program, striving to maintain the best parts from past years while letting it evolve with the Laboratory's dynamic environment. Not only do they curate speakers, organize trainings, and find new tours, but they are also matchmakers. With student résumés in hand, they search for mentors and funded projects at the Lab to make the summer meaningful for each participant and the Laboratory.

"It is important to make certain that each student's work is worthwhile," says Travis Grove, who became one of Elder's mentors, along with Jesson Hutchinson. "Students should be learning skills or techniques that will aid them in their future professional or academic careers."

Elder was matched with Grove and Hutchinson in the Nuclear Engineering and Nonproliferation Division's Advanced Nuclear Technology group. Her research focused on developing a theoretical model to predict uncertainties in period measurements and inferred reactivity.

Elder's experience at the Lab was transformative. She sees elements of her summer research in her university classes, and she has shifted away from her initial career path in mechanical engineering to the pursuit of a doctorate in nuclear engineering. Her goal is to work toward a career in global security. "I believe nuclear power is essential for combating climate change in the near future," she says. "By studying nuclear engineering and going into the field of nuclear safeguards—and into the Intelligence Community—I can promote the safe use of nuclear power while also focusing on the nation's safety." ★

WATCH

A plaque commemorates the lives lost during the Burning Ground accident.

BURNING GROUND

A new documentary highlights high-explosives safety.

For more than a decade, Cary Skidmore of the Lab's Detonation Science and Technology group has devoted time and energy to highlighting the importance of safety when working with high explosives (HE). In August 2018, he debuted *Burning Ground*, a documentary he created about an explosives accident that killed four workers at the Laboratory's S-Site on October 14, 1959.

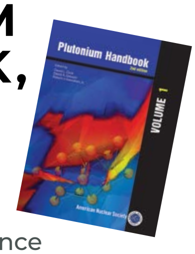
Around the time of the accident—as the U.S. transitioned from World War II technologies to Cold War technologies—more powerful explosives were being developed. The cause of the accident was in the handling of these modern, more volatile materials.

As a result of the accident, Skidmore believes that HE work at the Lab has become safer. "This event indirectly led to the development of 'insensitive' high explosives, which can't be unintentionally detonated," he says. No fatal explosives accidents have happened at Los Alamos in nearly 60 years.

Skidmore's documentary premiered during the Lab's HE Safety Day, an annual event that emphasizes the vitally important work the Laboratory does with hazardous materials every day. The documentary can now be viewed publicly on the Los Alamos Historical Society's YouTube page (https://youtu.be/DYvfvjcIp68). ★

COMING SOON

THE PLUTONIUM HANDBOOK, SECOND EDITION



After 50 years, the authoritative nuclear science reference has been updated.

Plutonium was first produced and detected in 1940. Twenty-seven years later, in 1967, the *Plutonium Handbook* was published, quickly establishing itself as the authoritative source on plutonium science and technology.

Now, 52 years and scads of research later, the *Plutonium Handbook* is getting an update. The second edition—edited by David Clark, David Geeson, and Robert Hanrahan, Jr.—comprises seven volumes with contributions from 187 authors representing 13 countries. The updates include new topics, such as electronic structure, environmental behavior, power source technologies for space exploration, and microbiology; there's also an entire volume dedicated solely to techniques for working with plutonium.

The second edition was compiled by a team at Los Alamos and will be published in 2019 by the American Nuclear Society. "The 2019 publication of this update is timely because nuclear laboratories around the world are experiencing a significant changeover in personnel," says former Laboratory director Sig Hecker, who wrote the book's foreword. "It is essential to capture and document the science and technology of plutonium to help train a future generation of scientists and engineers." ★

Pictured: David Geeson, of the UK's Atomic Weapons Establishment; Robert Hanrahan, chief science advisor at the National Nuclear Security Administration; and David Clark, director of the National Security Education Center at Los Alamos National Laboratory, are the editors of the second edition of the *Plutonium Handbook*.

▶ Trugman's findings were published in April in the journal *Science*. His work is supported by the Los Alamos Laboratory Directed Research and Development program.
Photo: Dreamstime.com/Mkopka

GEOPHYSICS

SEISMIC SLEUTHING IN SOUTHERN CALIFORNIA

Postdoctoral fellow Daniel Trugman helps identify 1.81 million previously undetected small earthquakes.

Because large earthquakes are so infrequent, scientists don't have a good understanding of what triggers them. But now, thanks to a team that includes Los Alamos postdoctoral fellow Daniel Trugman, scientists may be able to better understand how stress evolves in Earth's crust—and therefore how large earthquakes are triggered.

Trugman and colleagues from the California Institute of Technology and Scripps Institution of Oceanography analyzed nearly two decades of data collected from the 550 seismic monitoring stations in the Southern California Seismic Network (SCSN) that continually monitor movement in Earth's crust.

The SCSN catalog of recorded earthquakes has traditionally been based on visual analysis of seismic signals—an approach that Trugman says misses many weak seismic signals that are indicators of small earthquakes. These weak signals can sometimes get drowned out by background noise—things like traffic or mining, which also create signals.

So, to improve on the catalog, the team started data mining. Trugman likens the data mining process to a giant game of word search. Powerful computers are given a library of waveforms from previously recorded earthquakes. Each of these waveforms is broken down into scalable segments called templates. The computers then scan through continuous seismic network data for small signals that match the basic shape of the templates. "In the word search analogy, the templates are the words you are supposed to find," Trugman explains. "The network data is the letter grid, which is mostly a bunch of junk letters but has real words hidden inside."

After hundreds of thousands of hours, the computers were able to distinguish tiny quakes (less than zero magnitude) from background noise, and the team was able to detect, understand, and locate 1.81 million quakes—10 times more quakes than were previously identified using traditional seismology methods. This translates to an earthquake occurring in southern California every three minutes or so.

The team developed a comprehensive, detailed earthquake library for the entire southern California region, called the Quake Template Matching catalog. The catalog provides a more complete map of California earthquake faults and behavior.

Recently, Trugman and Los Alamos colleagues applied machine learning to study earthquakes created in laboratory quake machines. That work has uncovered important details about earthquake behavior that may ultimately be used to forecast future earthquakes.

"In the laboratory, we see small events as precursors to big slip events, but we don't see this consistently in the real world. This big data template-matching analysis helps bridge the gap," he says. "While the small earthquakes we detected aren't dangerous, they are really important for understanding the physical processes that cause large, damaging earthquakes." ★

FATHER OF THE HEAT PIPE PASSES AWAY

First used to cook a turkey, heat pipes are now used in spacecraft and computers.

In the 1960s, Laboratory scientist George Erickson thought a new device he was working on for the Rover nuclear rocket program could fix the problem his family regularly faced around the holidays: their pre-convection-era oven kept producing a holiday turkey that was browned on the outside, but cold in the middle.

Facing another underdone dinner, Erickson grabbed a basic version of his work project, which resembled a simple metal tube, and jammed it into the turkey before putting the bird back into the oven.

Erickson's tube held liquid and a wick-like material running from top to bottom. As the liquid heated up, it vaporized, condensing at the end of the pipe and releasing heat into the turkey's core before traveling back along the wick to restart the journey. This process efficiently brought consistent heat to the turkey's core, cooking it evenly. Erickson's device—called a heat pipe—had worked.

Today, the heat pipe is one of the Laboratory's most widely used products, with applications on domestic, industrial, and extraterrestrial scales. In fact, if you're reading this on a laptop, you're likely using one—it's dissipating heat from the microchips under your keyboard.

Heat pipes also work well in zero-gravity environments and have been used to manage temperatures inside spacecraft so that heat generated by electronics doesn't damage equipment.

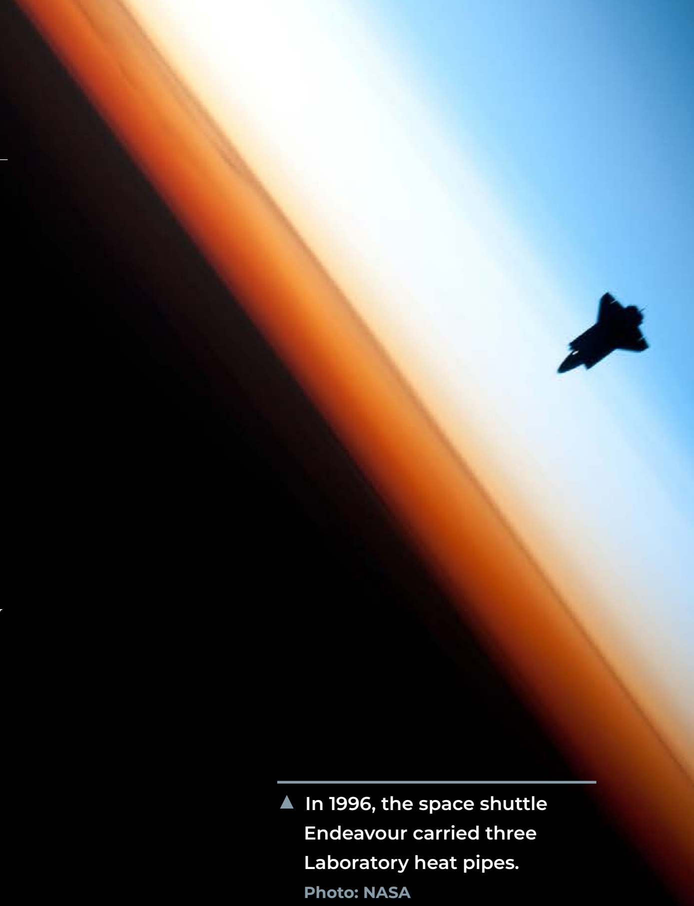
In 1996, the space shuttle Endeavour carried three Laboratory heat pipes that operated at temperatures above 900°F. During the past 20 years, the Laboratory has also worked with NASA's Marshall Space Flight Center in developing heat pipes to generate electricity and propulsion in spacecraft designed to journey to the solar system's outer limits.

Early practical heat pipes used mostly low-temperature working fluids such as water, but water has been replaced by liquid metals in recent practical applications, such as Kilopower, a new reactor that uses liquid sodium in the heat pipes it leverages to create versatile power sources in remote locations, such as Mars.

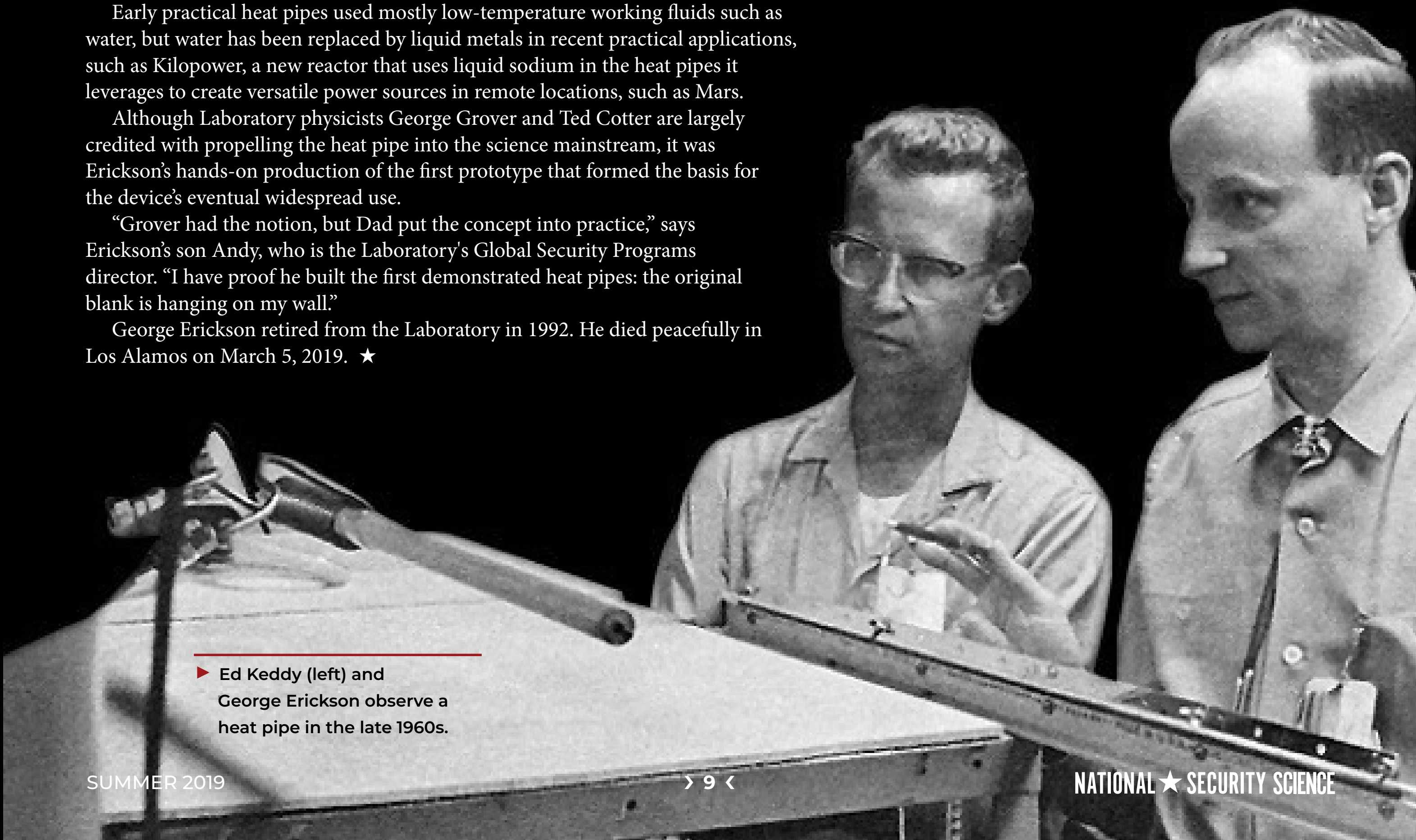
Although Laboratory physicists George Grover and Ted Cotter are largely credited with propelling the heat pipe into the science mainstream, it was Erickson's hands-on production of the first prototype that formed the basis for the device's eventual widespread use.

"Grover had the notion, but Dad put the concept into practice," says Erickson's son Andy, who is the Laboratory's Global Security Programs director. "I have proof he built the first demonstrated heat pipes: the original blank is hanging on my wall."

George Erickson retired from the Laboratory in 1992. He died peacefully in Los Alamos on March 5, 2019. ★



▲ In 1996, the space shuttle Endeavour carried three Laboratory heat pipes. Photo: NASA



► Ed Keddy (left) and George Erickson observe a heat pipe in the late 1960s.

NATIONAL SECURITY FORUM

Civic leaders and senior military officers discuss leadership, strategy, and national security at the 66th annual event.

In May, more than 150 hand-selected civic leaders from across the United States traveled to Montgomery, Alabama, for the 66th annual National Security Forum (NSF) at Maxwell Air Force Base. The three-day event included lectures from senior military officers about the Air Force's current and future objectives and its plans for enhancing national security. NSF was hosted by the Air War College (located at Maxwell) on behalf of Secretary of the Air Force Heather Wilson.

Wilson, whose last day on the job was May 31, was the keynote speaker on the first day of the forum. She shared her vision for tomorrow's Air Force, which includes additional operational squadrons. "The Air Force is too small for what our nation demands," she said. "We have 312 operational squadrons, which are the clenched fist of American air and space power. But we need 386 to meet the requirements of the National Defense Strategy. We must also modernize and grow our support squadrons—a fist is nothing without the power of the body behind it."

On the last day of the forum, Air Force Chief of Staff General David Goldfein delivered the capstone address. He emphasized that civilians can help retain members of the military by advocating for things like better schools around military installations or more seamless procedures for transitioning a spouse into the job market at a new military post.

Better retention means improved military readiness during times of conflict, Goldfein said. "Improving lethality, readiness, and strengthening our team can come only with the speed and innovation gained by the expertise and different perspectives of our engaged civic leaders." ★

Pictured: From left: Brigadier General Jeremy Sloane, Secretary of the Air Force Heather Wilson, and Lieutenant General Anthony Cotton share a laugh during the National Security Forum. Wilson delivered the event's keynote address. Photo: U.S. Air Force/Trey Ward

WEST POINT CADETS VISIT LOS ALAMOS

Two groups of students from the United States Military Academy tour the Laboratory.

On March 11–12, the Laboratory's Office of Nuclear and Military Affairs hosted faculty and cadets from the Physics and Nuclear Engineering Department at the United States Military Academy at West Point. The visitors were briefed on the design and operation of U.S. nuclear weapons and the science and technology used by the Laboratory to sustain the stockpile.

On March 20–22, the Academy's Excel Scholars—high-performing military cadets from underrepresented groups—visited the Lab as part of a program that introduces them to different national laboratories.

Both groups of cadets visited experimental and engineering facilities, including the Los Alamos Neutron Science Center and the Dual-Axis Radiographic Hydrodynamic Test facility, in addition to meeting with Laboratory Director Thom Mason.

Jon Ventura, of the Lab's Office of Nuclear and Military Affairs, helped arrange the tours and says, "These visits allow military and civilian faculty members, along with cadets, the opportunity to better understand the breadth and scope of the Laboratory's capabilities and how those capabilities might be applied to issues and challenges confronting the Army." ★

Pictured: West Point cadets and faculty learn about high-explosives chemistry.

SARA students learn about high explosives from scientist Virginia Manner.

A SUMMER OF SCIENCE

Future military leaders work on innovative projects around the Laboratory.

BY J. WESTON PHIPPEN

Each summer the Laboratory welcomes about 20 cadets and midshipmen from U.S. military academies and students from university Reserve Officer Training Corps (ROTC) programs. Jon Ventura and Jeremy Best, of the Lab's Office of Nuclear and Military Affairs, select these students for the Service Academies Research Associates (SARA) program. Each student will spend four to six weeks working with a Lab mentor on a project. "We believe it's important for these students to understand the science, engineering, and technology available at the Lab," Ventura says, "the tools that can help them deal with problems they'll face as military officers."

Meet four SARA students who are spending their summer at the Laboratory.

To learn more about the SARA program, visit lanl.gov/sara. ★

MATT CRITCHLEY

PHYSICS MAJOR
AT THE U.S. NAVAL ACADEMY

About 16,000 people apply each year to the U.S. Naval Academy; only 1,200 are admitted. Critchley not only got in but also is a Bowman Scholar, meaning he's on a path to become a nuclear submarine officer. As a physics major, he's studying photocathodes, materials that have applications in lasers, but until now he has only conducted theoretical research. "At Los Alamos," Critchley says, "I'm looking at what photocathodes actually do. It's a great opportunity."

JON ZIMAK

CHEMICAL ENGINEERING MAJOR
AT WORCESTER POLYTECHNIC INSTITUTE

Part of uprooting for the summer means adjusting to Northern New Mexico's high-desert environment, which has suited Zimak just fine. "Being able to walk outside and go on a hike is insane," says Zimak, who lives in Massachusetts during the school year. Before he returns to ROTC and his chemical engineering studies, Zimak is developing a Lab database that tracks fire-safety issues.

AUDREY FERNANDEZ

ENGLISH MAJOR
AT THE U.S. NAVAL ACADEMY

"The Lab does a great job of placing us where our interests are and pairing us with mentors," Fernandez says. As an English major who eventually wants to study medicine, Fernandez realizes that being matched with a good placement at the Lab was a little tricky. But the end result was perfect, she says; she's working with stem cells to develop and test how muscle tissue reacts to disease.

CONNOR TRAVIS

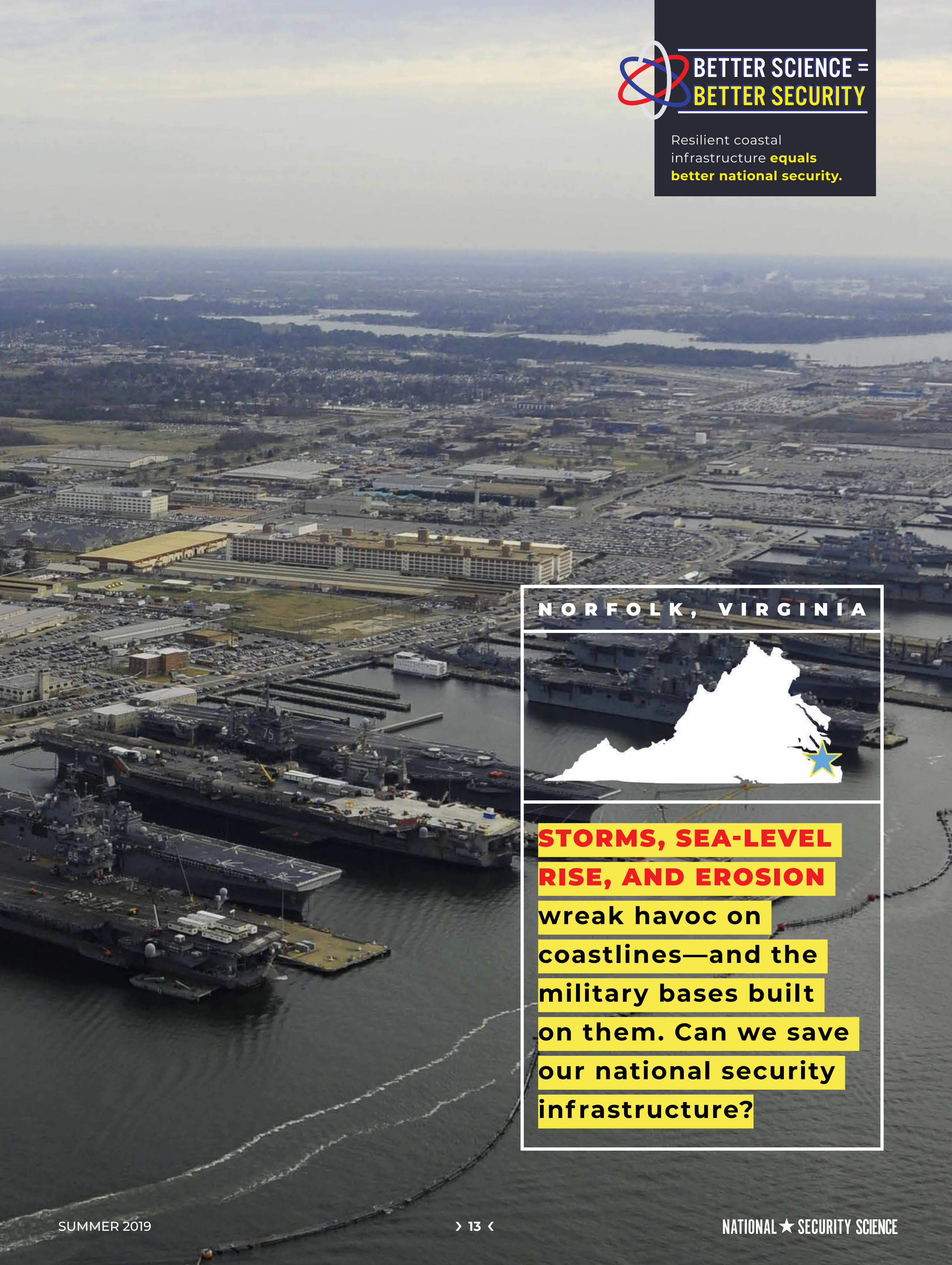
MECHANICAL ENGINEERING MAJOR
AT THE U.S. NAVAL ACADEMY

When Travis heard of the SARA program, he remembered stories his father told him many years before. His father, a Navy captain, had visited Los Alamos and was impressed with its crucial work. "I thought it'd be a great opportunity to see what goes on behind the scenes," Travis says. This summer, the mechanical engineering major is working on a project to develop a handheld device that can detect plutonium and uranium.

BY WHITNEY SPIVEY & J. WESTON PHIPPEN

SECURING OUR SHORES

▶ Five aircraft carriers are in port at Naval Station Norfolk, the world's largest naval station. How will Mother Nature affect Norfolk's infrastructure in the coming years? Lab scientist Donatella Pasqualini aims to find out.
Photo: U.S. Navy/Ernest Scott



BETTER SCIENCE = BETTER SECURITY

Resilient coastal infrastructure **equals better national security.**

NORFOLK, VIRGINIA

STORMS, SEA-LEVEL RISE, AND EROSION wreak havoc on coastlines—and the military bases built on them. Can we save our national security infrastructure?

▼ Major Zachary Nash, a chaplain, helps carry religious items from a church on Tyndall Air Force Base. The base, located near Panama City, Florida, sustained major damage from Hurricane Michael in October 2018.
Photo: U.S. Air Force/Sean Carnes

NAVAL STATION NORFOLK, the largest naval complex in the world, sits at the confluence of the James River and the Chesapeake Bay, just a few miles west of the Atlantic Ocean, in the southeast corner of Virginia.

Norfolk's fleet of 75 ships and 134 aircraft discourages attacks on the station, but all that firepower does not deter, and never will deter, one particular foe: Mother Nature.

Mother Nature is winning her battle against Norfolk and every other coastal military base in the world. Storms and erosion are damaging these facilities—day after day, month after month, and year after year. Rising sea levels also threaten to submerge the base and are projected to reach seven feet in the area around Norfolk by the end of the century, according to a 2016 report by the Union of Concerned Scientists. As a result, a Category 4 storm (the second-highest hurricane classification category) could expose 95 percent of the base to flooding more than 10 feet deep.

The report wraps up by noting that the Navy is responding to these future threats by raising or restoring its piers, but the authors also write that the Navy will need "a more-detailed analysis" of these threats before it can take additional action.

"Our defense leadership has a special responsibility," the report concludes, "to protect the sites that hundreds of thousands of Americans depend on for their livelihoods and millions depend on for national security."

A MORE-DETAILED ANALYSIS

Nearly 1,700 miles from Norfolk, physicist Donatella Pasqualini sits at her desk in the Information Systems and Modeling group of Los Alamos National Laboratory. Her office is remote, perched on a mesa top, and surrounded by towering ponderosa pine trees. In that high-desert New Mexico environment, storm surge and sea-level rise aren't problems that impact Pasqualini personally, yet she has built a career studying these things.

Pasqualini's latest research focuses on the co-evolution of the natural world and the man-

▲ Donatella Pasqualini and her team have developed a capability to understand the co-evolution of coupled natural and engineered systems and aid decision makers in planning adaptation strategies. This work is supported by the Los Alamos Laboratory Directed Research and Development program.

made world, especially on how infrastructure such as electrical power grids and substations interact with weather in coastal zones. "We want to project future evolution of the coastal zones and then quantify the risk that this evolution poses to infrastructure," she explains. "And we want to plan for resilience."

In other words, she's working on the more-detailed analysis the Union of Concerned Scientists pointed to in 2016, one that will help us peer into the future and understand how erosion, storms, and rising sea levels will impact the infrastructure—including military bases—along our nation's coasts.

Pasqualini and her team have developed a computer model they've named New Science for Multisector Adaptation. NeSMA, as it's called, uses complex algorithms to process data about the physical characteristics of coastlines—including soil, vegetation, sensitivity to erosion—and how those characteristics would interact with a hurricane and its water swell.

NeSMA is much more complicated, and much more accurate, than the current method of using past weather events to predict future weather events. "The utilities and the government currently take a very simple approach," Pasqualini explains. "They say, 'OK, Superstorm Sandy came, and my electrical power substation was flooded. I'm going to lift up the substation to prevent it from being flooded in the future.'" But what they don't account for is that—because of things like erosion and sea-level rise—the coastline is always changing.

> **"We want to project future evolution of the coastal zones."**
>
> **—DONATELLA PASQUALINI**

For example, the major utility in the Delaware Bay area, PSE&G, spent billions after Sandy to shore up electrical substations flooded by the storm's water surge. But Pasqualini's model predicts that in the future, some substations the company raised wouldn't have been impacted the same way, meaning PSE&G might have wasted money.

"So maybe the substation that Sandy flooded will not be flooded the next time," Pasqualini says. "Maybe a facility somewhere else on the changed coastline will have a higher probability of flooding. Companies don't always account for that possibility, even though they are investing billions of dollars."

It's not that the utilities and the government aren't aware that coastlines will change. In fact, "they are very, very aware," Pasqualini says. "The problem is that the changes are extremely difficult to model, computationally." This is because the processes that cause coastlines to evolve are interrelated, affecting each other. For example, erosion affects a coastline's vegetation (no soil equals no plants). But vegetation also affects erosion (certain plants might curb erosion or even cause soil to pile up). Throw in additional variables such as sea-level rise, storm surge, and flooding, and the relationship between erosion and vegetation becomes even more complicated. “Feedback—this interrelatedness—makes the problem more complex,” Pasqualini says. “It introduces some nonlinearity, in which cause and effect are not straight forward. Nonlinear problems are very difficult to solve computationally.”

But difficult computations are what Los Alamos scientists do best, and Pasqualini is no exception. First, she has to assign numerical values to everything she wants to compute. So, thank goodness for grad students. Around the Delaware Bay, one of Pasqualini’s focus areas, grad students have been busy testing soil composition for how well or poorly the soils drain water. They have mapped local vegetation and its density and have run experiments on how well the roots hold soil. After testing the soils, the grad students assigned numerical values to the many drainage qualities. These numerical values are then plugged into NeSMA.

Now, say a hurricane is headed toward the Delaware Bay. Pasqualini would download details of the hurricane’s wind speed and rate of travel, getting those numbers from the National Hurricane Center. When she plugged that data into NeSMA, the data would virtually collide with the coastal number set, and what came out on the other end of the computation would be the vulnerability of the Delaware Bay’s critical infrastructure. NeSMA shows the results on a map, with different colors indicating different levels of damage to an area. “For each model, you get approximations of the storm’s impact as seen in water table salinity, storm surge, and erosion,” says Pasqualini, noting that these computations are done on a supercomputer.

But NeSMA doesn’t just model current storms—it also helps predict the future.

ESTIMATING THE DAMAGE

Extreme storms have the most potential for damaging coastlines and infrastructure. In 2005, Hurricane Katrina inflicted an estimated $125 billion in property damage along the Gulf Coast. In 2012, Hurricane Sandy wreaked havoc on the entire Eastern Seaboard of the United States, causing more than $65 billion in damages. In 2017, Hurricane Maria swirled through the Caribbean, leaving more than $91 billion in total losses in its wake.

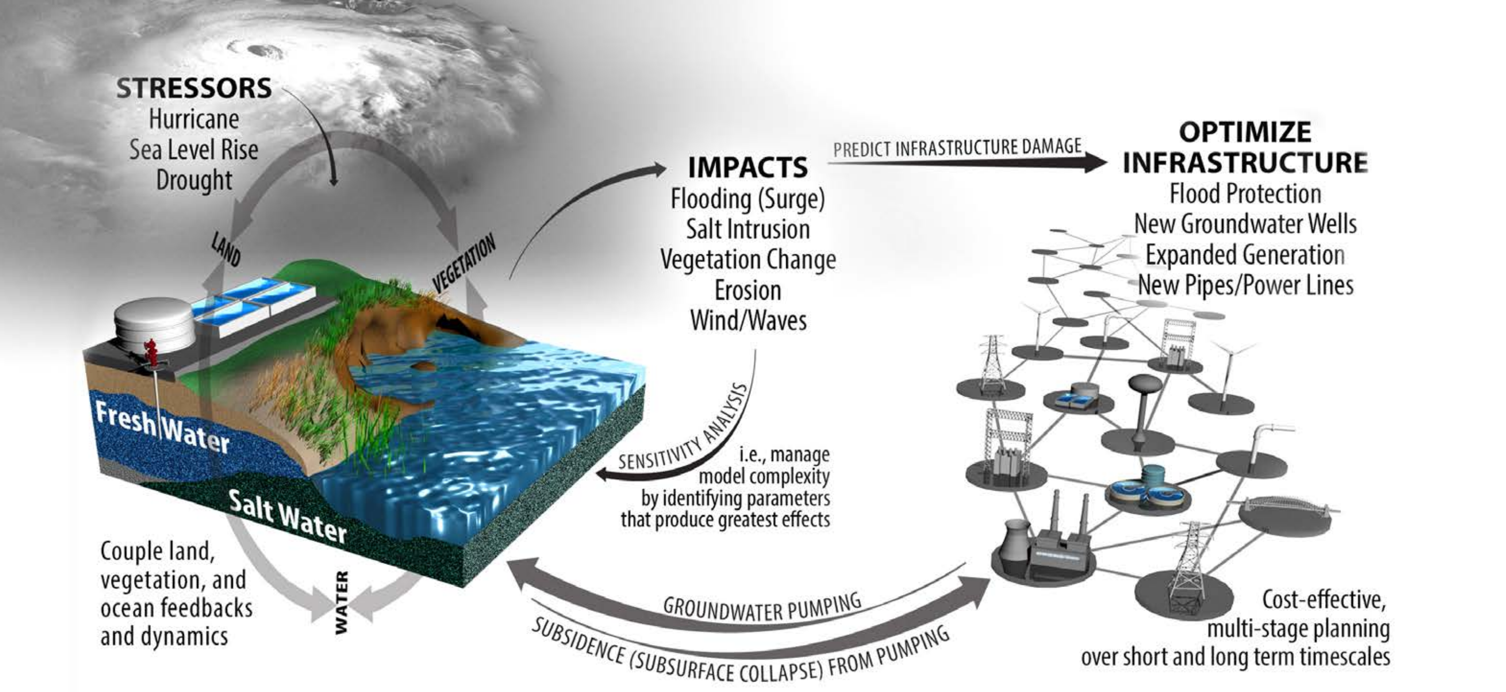
These extreme storms are becoming more common, of that Pasqualini is certain. But what she doesn’t know is how many storms will happen each year and how intense they will be.

In December 2016, Hurricane Matthew damaged or uprooted approximately 300 trees at Shaw Air Force Base in South Carolina. Photo: U.S. Air Force/ Destinee Sweeney

“It is our responsibility to use our scientific knowledge to help make our nation more resilient.”

—DONATELLA PASQUALINI

▶ On October 10, 2018, Hurricane Michael destroyed large portions of Tyndall Air Force Base, near Panama City, Florida. Here, hangers once used to keep aircraft out of the elements lie scattered across the flight line after the storm. Photo: DoD/Alexander Henninger



NeSMA predicts how erosion, storms, and rising sea levels will impact coastal infrastructure.
Graphic: Los Alamos/Anthony Mancino

"No scientist will say, 'You will have 10 Katrinas in the next 10 years.' What they will tell you is that there's a likelihood of 10 Katrinas in the next 10 years."

Because Pasqualini is concerned about the impact of these storms on infrastructure, NeSMA uses a combination of 10,000 possible storms with predicted sea-level values to understand the future risk to our coastal utilities. According to Pasqualini, the model forecasts "every imaginable situation, which helps you understand the things you could do to best prepare."

In addition to demonstrating coastal changes after a storm, NeSMA predicts how many people might be without power after a hurricane. It also shows which substations are likely to be flooded and whether salt water will probably seep into the water table, reducing the supply of drinking water.

The infrastructure piece of the puzzle is complicated because electrical substations and water treatment plants are not isolated. Each is part of a network, "a node" in Pasqualini's terms, that interacts with the network's other nodes. So, for example, if NeSMA predicts a high likelihood of a power substation being flooded, the government may decide to invest in doubling the output of another station nearby.

NeSMA can also help local governments ensure specific outcomes in the aftermath of big storms. For example, perhaps a city wants to ensure that 80 percent of its population has power in the event of a major storm. Or perhaps all hospitals or all of Wall Street needs to have power. Which substations are essential for making those things happen, and what can a city do in advance to make sure those substations can weather the storm? "You can actually explore all scenarios to see where you should invest in infrastructure to keep places safe," she says. Currently, NeSMA is the only model able to not only predict weather's impact on our infrastructure but also recommend solutions.

MILITARY APPLICATIONS

Pasqualini's long-term goal is to be able to assess future risks for any region, anywhere in the world. Although NeSMA is currently parametrized for the Delaware Bay area, the model is "physics-based, and the physics doesn't change, so we can take the model and apply it to different areas," Pasqualini explains. "We just need to change the parameters—the details about the coastline." (To collect these details, you need a lot of grad students taking measurements.)

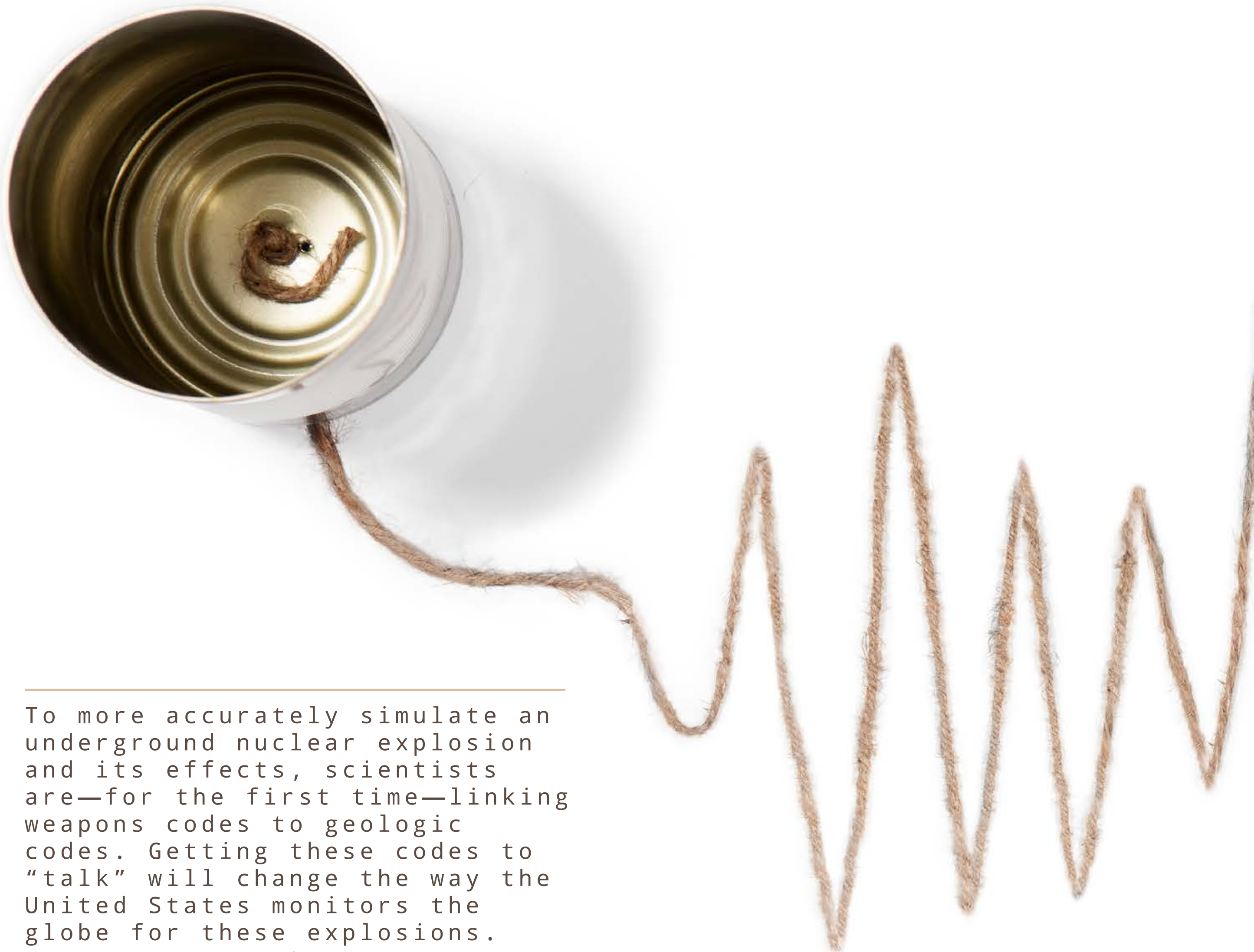
Which brings us back to Naval Station Norfolk—and every other coastal military base that is facing an uncertain future. "We can tell the Department of Defense—with a level of uncertainty—how the future will be for these bases," Pasqualini says. "We can do a risk assessment that is scientifically based."

That means Pasqualini can say with some certainty if, over the course of the next 10, 20, or 30 years, there will be ground below the base, a hurricane and its storm surge will inundate the base, or the base's infrastructure will be impacted by salinity.

"The military needs to know what the impact would be on critical infrastructure so it can plan the best ways to invest in making a base's water supply and electrical power more resistant to damage from hurricanes," she says, noting that things like building sea walls, digging new wells, or even physically moving a base are options.

According to the Union of Concerned Scientists, a three-foot sea-level rise would threaten 128 coastal Department of Defense installations in the United States. For Norfolk, specifically, that means that portions of the station would be flooded with each high tide.

"It's time to respond to such warnings," Pasqualini says. "As a national laboratory, it is our responsibility to use our scientific knowledge to help make our nation more resilient." ★



To more accurately simulate an underground nuclear explosion and its effects, scientists are—for the first time—linking weapons codes to geologic codes. Getting these codes to "talk" will change the way the United States monitors the globe for these explosions.

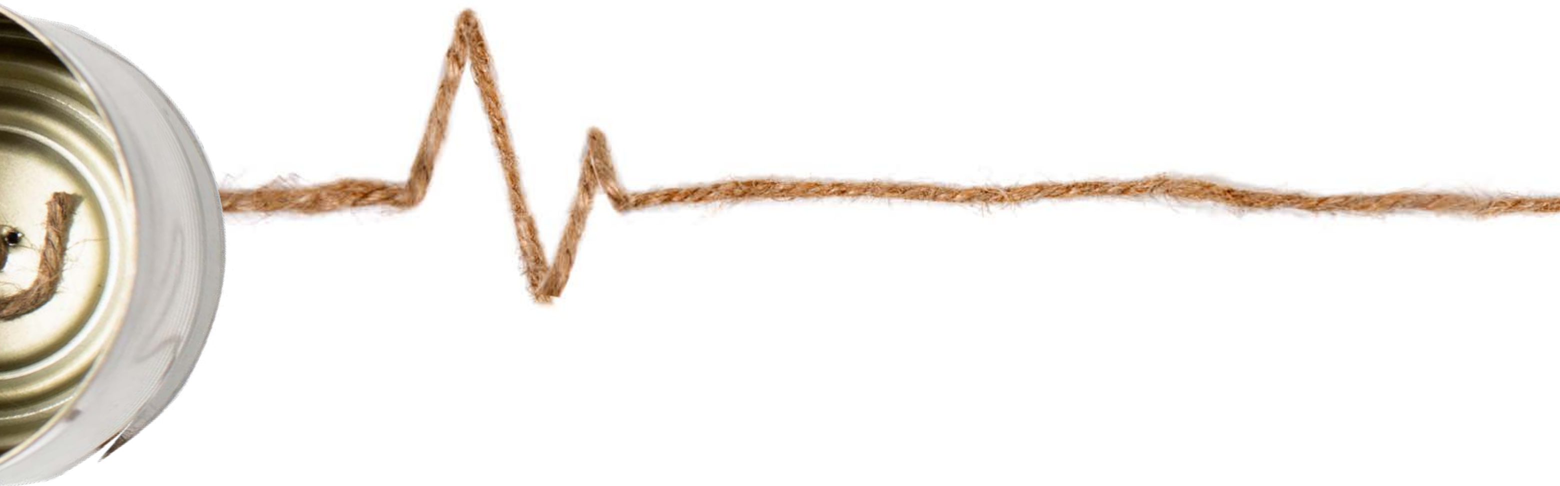
BY WHITNEY SPIVEY

A COMPLICATED GAME OF TELEPH

BETTER SCIENCE =
BETTER SECURITY

Scientists can determine the location and size of an underground nuclear test **conducted anywhere in the world.**

ONE



If Country X tested a nuclear weapon by exploding it deep below the Earth's surface, would we know? Would we care?

"We would absolutely care," says Neill Symons, a seismologist with the Laboratory's Seismoacoustics Team. "Our job is to do research and development to advance the U.S. capability to monitor the globe for underground nuclear tests. We do that in direct support of the Department of Energy's nuclear nonproliferation mission."

The "would we know?" question is a bit more complicated to answer. That's because, at first glance, an underground nuclear test and an earthquake are similar in one very important way: they both release energy in the form of seismic waves.

During an underground nuclear explosion, seismic waves are created as rock is pushed away from the explosion's source and compressed. These compression-caused seismic waves are mostly primary waves (P-waves), which shimmy forward and back like a slinky, along the direction the wave is moving. As they travel through the earth, some P-waves get converted to shear waves (S-waves), which shake up and down perpendicular to the direction the wave is moving (imagine a kid on a pogo stick bouncing down the street).

BY LOOKING AT THOUSANDS OF WAVES, I CAN GET THE BEST GUESS OF WHAT AN AREA LOOKS LIKE GEOLOGICALLY.

SCOTT PHILLIPS — SEISMOLOGIST

During an earthquake, on the other hand, seismic waves are created as two slabs of rock suddenly slide past one another. This motion creates both P-waves and S-waves.

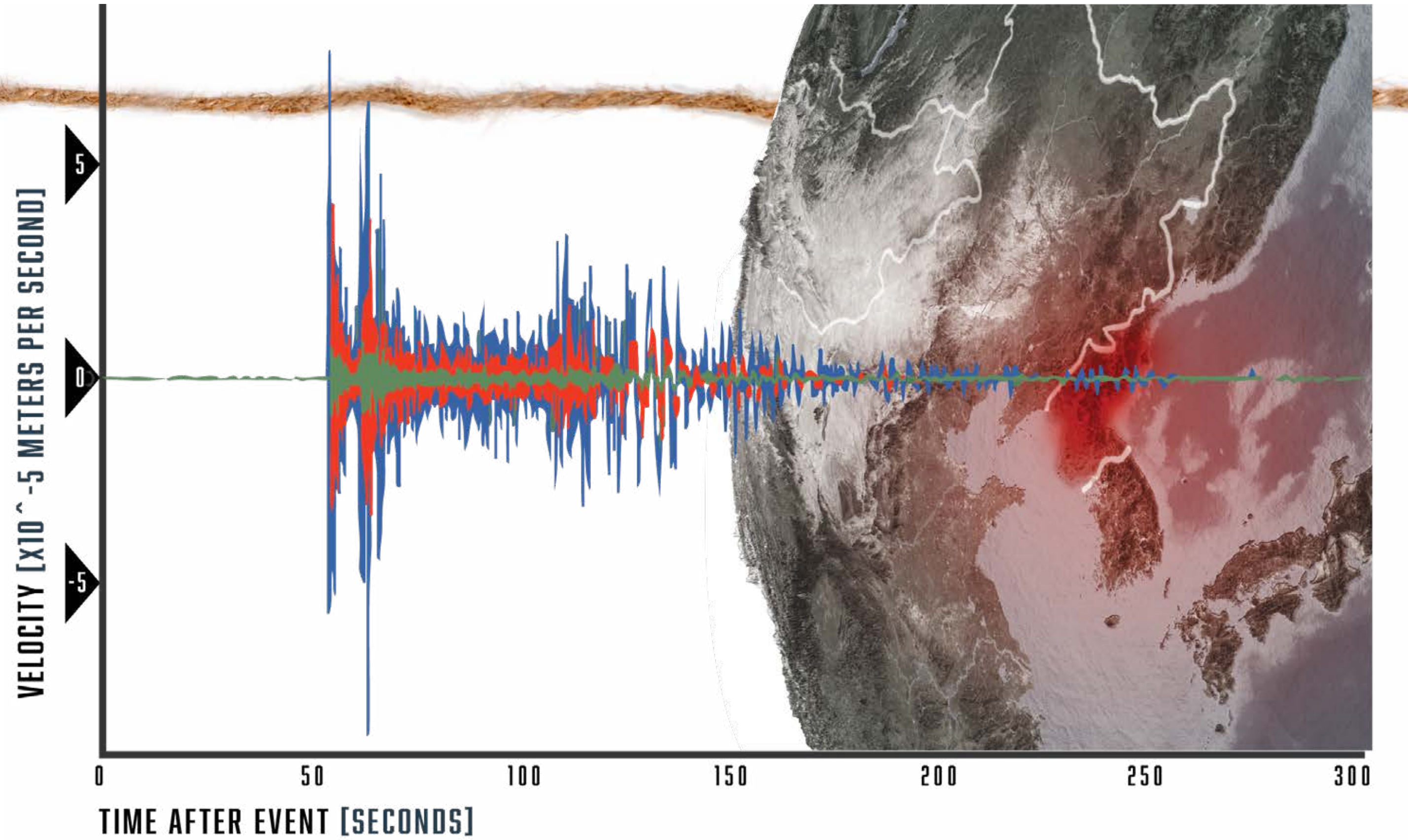
In comparing an earthquake and an explosion with similar P-wave energy, the explosion will generally have less S-wave energy. The technical challenge, however, is doing this comparison correctly, which can be tricky if the geology around and depth of the explosion are not well known.

If they're big enough, waves from seismic events are recorded at seismic stations around the world. With that recorded seismic data in hand, scientists on the Seismoacoustics Team have developed computer codes—complex algorithms that take into consideration things like source, seconds of time, kilometers of distance, and rock properties. They use those codes to simulate the recorded waves. These simulations can reveal whether a seismic event is an earthquake or an explosion. If it's an explosion, the simulation also sheds light on the explosion's depth and yield (explosive power). Yield is important because an explosion surpassing a certain yield is likely to be nuclear.

One challenge, however, is that waves travel differently through different types of rock. For example, waves travel quickly through a hard rock such as granite and tend to move more slowly (but with greater motion and higher energy loss) through soft rock such as tuff.

Laboratory seismologists know a lot about explosions in soft rock because the underground tests the Lab conducted at the Nevada Test Site occurred mostly in soft rock. Lots of seismic data— relating to depth, containment, and yield—were collected from these tests and have been used to develop the codes used for current monitoring techniques.

Scientists also have a pretty good understanding of both the geology and seismic activity in places like the Soviet Union's old Semipalatinsk Test Site and China's Lop Nur Nuclear Test Base. That's because much of the data from the



Three North Korean underground nuclear tests, as recorded at a seismic station in China. Blue is the February 2013 test, red is the May 2009 test, and green is the October 2006 test.

Seismic data: Incorporated Research Institutions for Seismology (IRIS)

hundreds of nuclear tests conducted in these locations is now public.

But what about the geology of places that don't have a lot of seismic activity, natural or otherwise? Much of the rock below Earth's surface remains a mystery, especially in terms of how seismic waves might propagate through it.

Take North Korea, for example. "By looking at topography and old geology maps, we know the Korean test site is in granite," says Laboratory seismologist Scott Phillips. "But beyond that, what's the structure of the granite? Are there layers? Rock is rarely uniform for miles in all directions."

To answer these questions, Phillips looks at every seismic wave that travels through a specific area. The process is rather time-intensive, considering that everything from traffic and construction to landslides creates seismic waves. "Then we feed all of our wave info into a program that's similar to a CAT scan," he says. "Hopefully, we can get a picture of all the 'bones and guts'—where waves do or don't travel well and how fast they are. By looking at thousands of waves, I can get the best guess of what an area looks like geophysically."

COLLABORATION

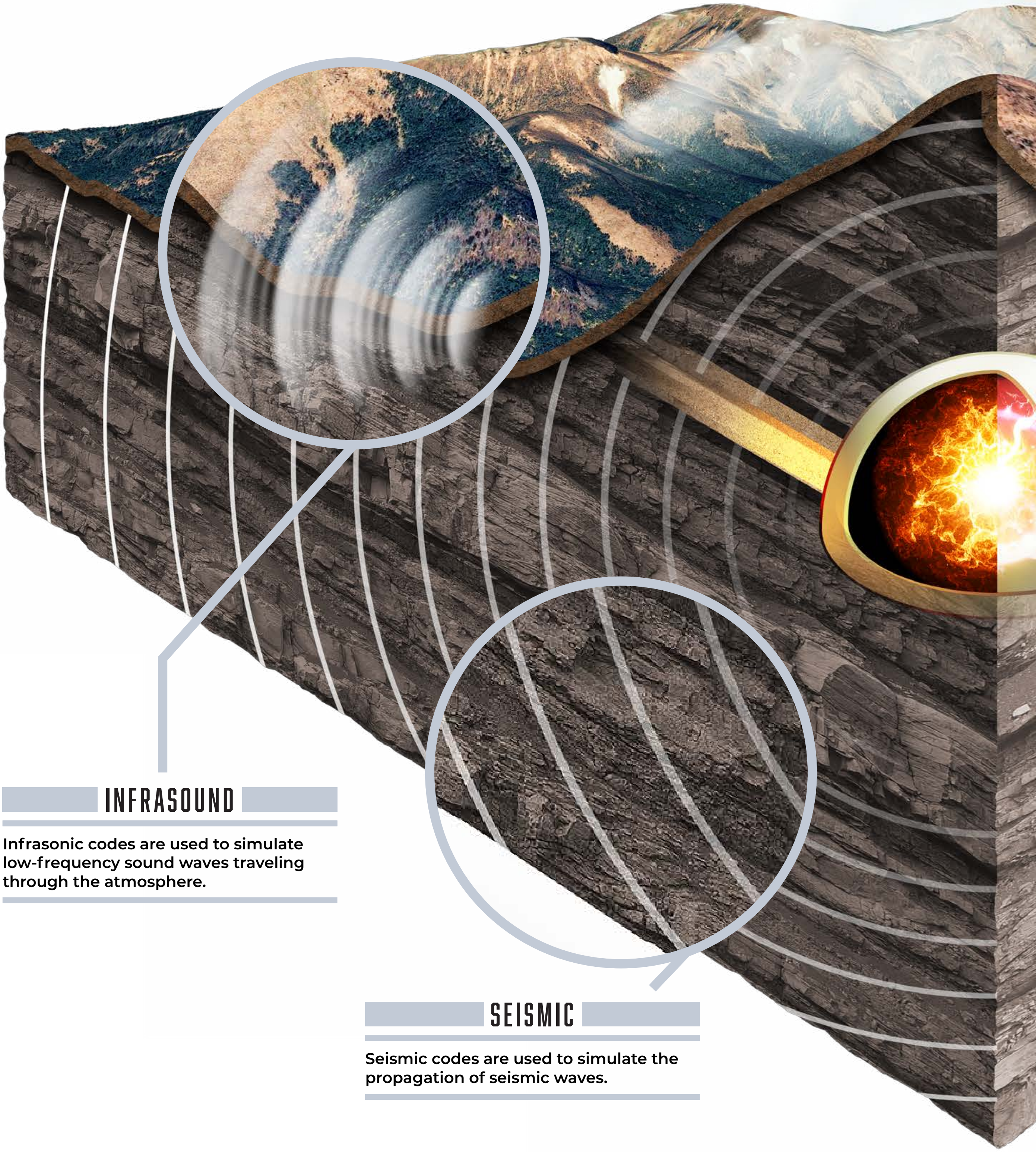
Traditionally, the Seismoacoustics Team has been concerned with big seismic events that create seismic waves traveling thousands of miles around the globe. However, as underground nuclear tests, such as the recent rogue tests by North Korea, have smaller yields than many of the well-studied tests of the 20th century, they produce fewer long-distance seismic waves and are harder to distinguish from earthquakes.

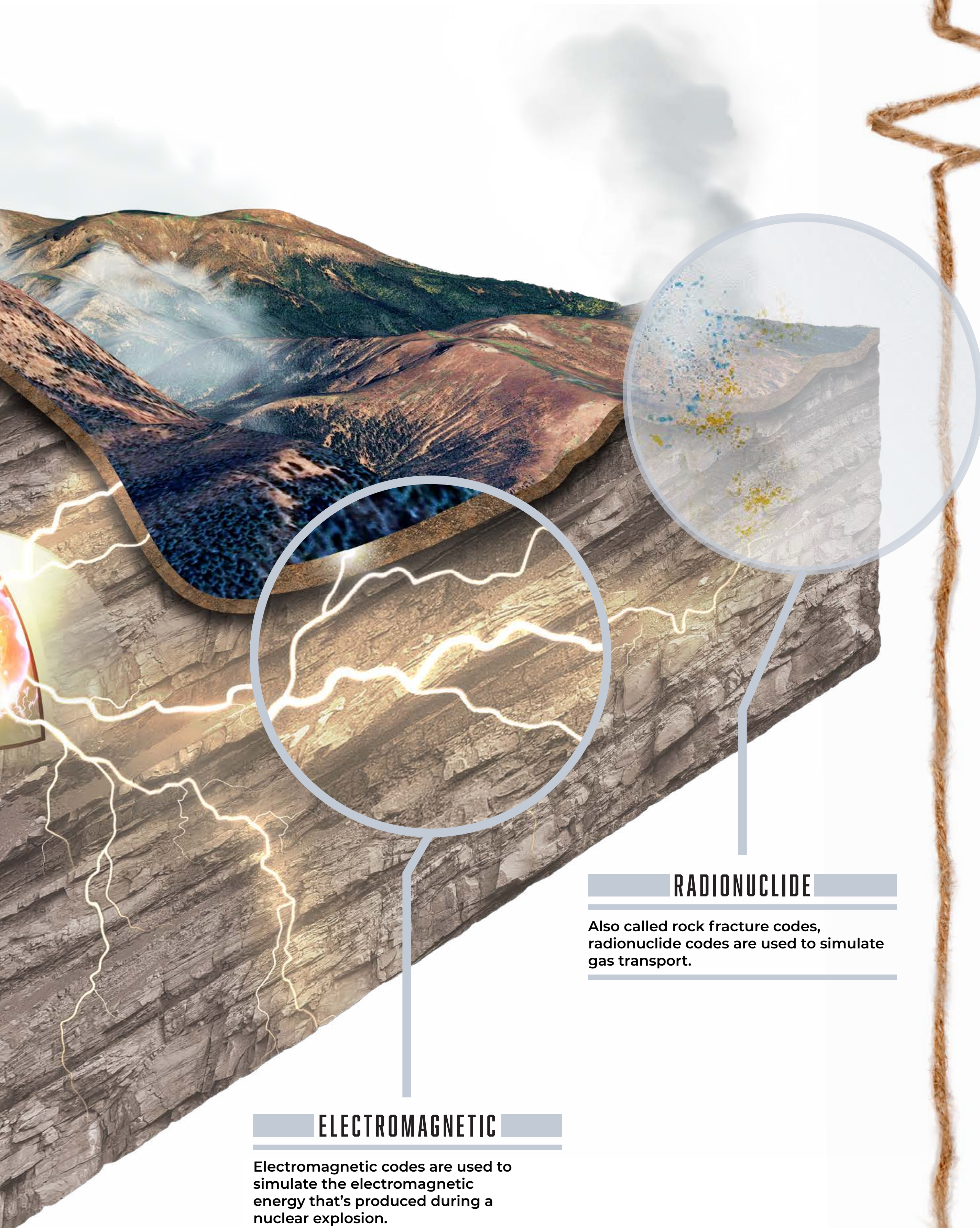
For example, on October 9, 2006, North Korea experienced a magnitude 4.3 seismic event, which is not particularly big except for the fact that seismic events of this size aren't common on the Korean peninsula. The North Korean government claimed the event was caused by a nuclear test—but was it really?

When it comes to modeling how a specific type of explosion might look in a certain type of rock, "Los Alamos has an edge in being able to make a real impact—we can handle the problem from source to sensor," says weapons designer Amy Bauer. In addition to being experts in nuclear weapons, the Laboratory is doing fundamental science in each area necessary to develop this new capability.

Graphic: Low Yield Nuclear Monitoring program at Los Alamos National Laboratory/Dan Judge

Map data: Google, Landsat/Copernicus, CNES/Airbus, Digital Globe





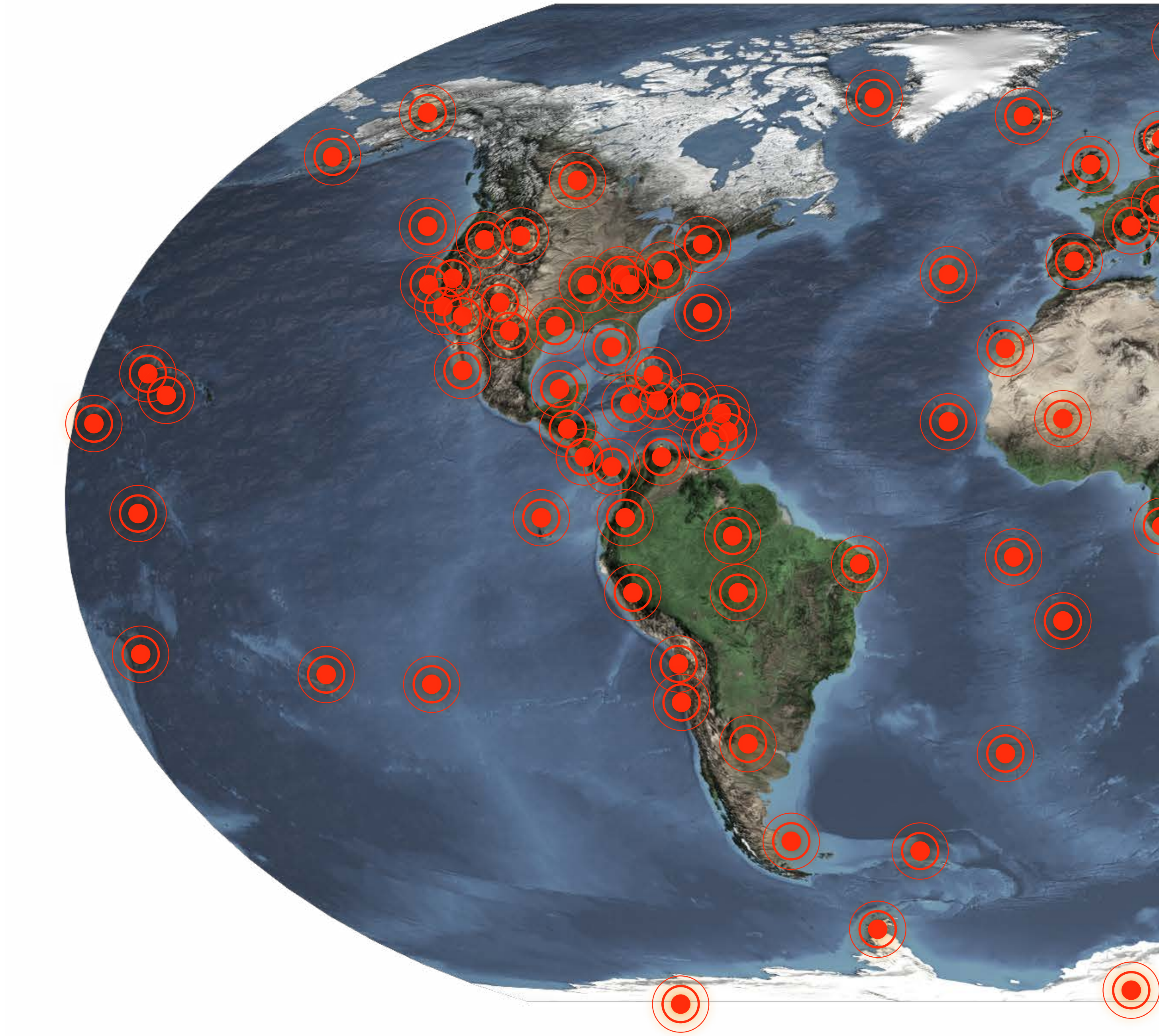
RADIONUCLIDE

Also called rock fracture codes, radionuclide codes are used to simulate gas transport.

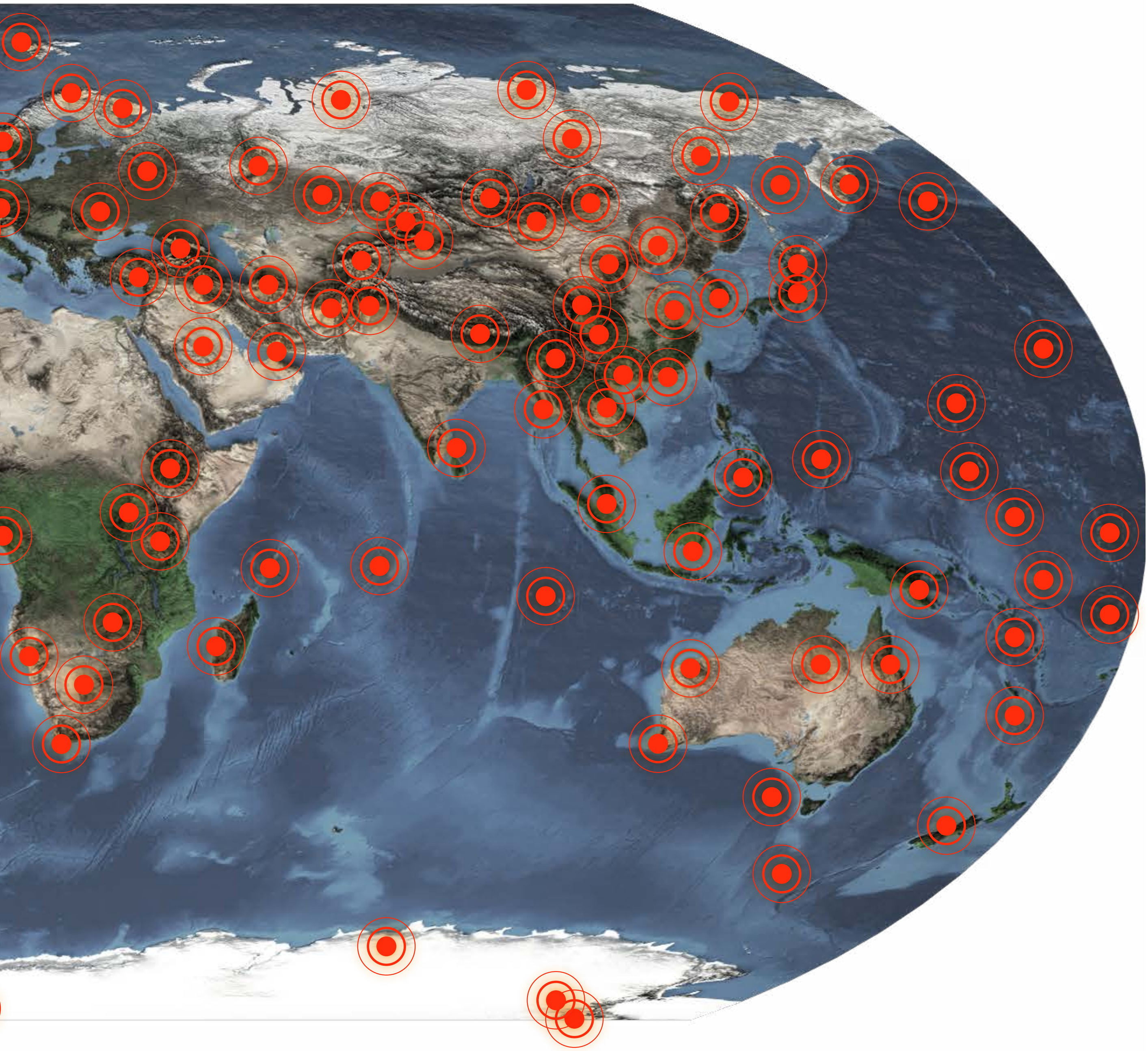
ELECTROMAGNETIC

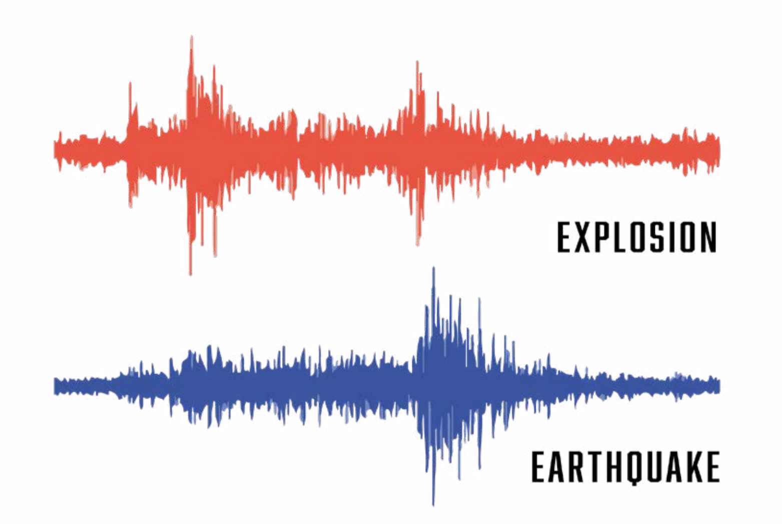
Electromagnetic codes are used to simulate the electromagnetic energy that's produced during a nuclear explosion.

■ Seismic stations around the world gather data that the Seismoacoustics Team uses for its explosion monitoring mission. The Seismoacoustics Team is part of the Laboratory's Earth and Environmental Sciences Division.
Photo: IRIS



> "THESE CODES HAVE NEVER SPOKEN TO EACH OTHER. THEY HAVEN'T EVEN BEEN INTRODUCED."
>
> AMY BAUER — WEAPONS DESIGNER





The Source Physics Experiments series, underway at the NNSS, focuses on identifying the differences between explosions and earthquakes. The seismogram on top is from the fifth test in the series. Photo: NNSS

Using their traditional methods, the Seismoacoustics Team could use codes to simulate waves to characterize this alleged test. "But it would be kind of like looking at a car from 100 yards away," explains Seismoacoustics Team leader Mike Cleveland. "We could see it's a white car, but that's it." The team wanted the 10-yard view. "We want to be able to tell that it is a 2006 white Subaru Outback with tinted windows and a roof rack," Cleveland continues. "In other words, we realized our understanding of an underground nuclear explosion would be much better if we could simulate not just the seismic waves but also the nuclear explosion and other geologic effects of the explosion."

Fortuitously, Los Alamos is one of two national labs that have access to America's nuclear weapons codes, which are the highly specialized and validated codes that are used to simulate the performance of the nuclear weapons in the U.S. stockpile.

And the Laboratory employs a plethora of scientists who develop infrasound, electromagnetic, and radionuclide codes that simulate low-frequency sound waves, electromagnetic energy, and gas transport, respectively.

In the end, all these different scientists were willing to come together in an effort to, for the first time ever, link their respective codes to more accurately simulate an underground nuclear explosion—from the detonation to the resulting geologic effects. (It helped that the NNSA's Office of Defense Nuclear Nonproliferation Research and Development agreed to fund the collaboration.) By being able to simulate, for example, a specific hydrogen bomb explosion in a specific type of granite, scientists will be better able to verify such an event should it ever happen in real life.

LINKING CODES IS HARDER THAN IT SOUNDS

"We already have the many individual codes that have been written for different pieces of the puzzle," explains weapons designer Amy Bauer. "The problem is that these codes have never spoken to each other. They haven't even been introduced."

It's almost like playing a game of telephone with a bunch of people who all speak different languages. "We want them to speak each other's language so the output from one code can be the input for the next code," Bauer continues. "It becomes a computer science problem—writing scripts so the codes can talk to each other."

But it's also more complicated than that because different codes are concerned with different time and length scales. "Nuclear weapons codes are concerned with shakes, each happening in 10 billionths of a second, while other codes are concerned with things happening over minutes or even months," Symons explains. "It's hard to make the handoff from code to code because they're working on different time scales."

For example, a nuclear test detonates in the blink of an eye and causes the rock around it to fracture. The size of the fracture depends on the type of explosion and the type of rock. Very large fractures will reach Earth's surface, which allows gas from the explosion to also reach the surface, but over the course of weeks or months.

"One of the biggest challenges in computational physics is the coupling of physics across disparate time and length scales," Bauer says. For the collaboration to work, many factors—the type of explosion, the type of rock, the size of the fracture, the amount of gas—along with their time frames must be accounted for in the codes. And the codes must be compatible with one another to ensure scientists get a complete picture of an explosion and the resulting geologic effects.

If that sounds complicated, it is. But Bauer stresses that the work is also rewarding. “The physics is fun—there are so many different scientific problems,” she says. “And I get to work with world-class, engaged scientists.”

GAINING CONFIDENCE

Up until 1992, if scientists wanted to better understand a certain type of nuclear explosion and the resulting seismic behavior, they would simply attach sensors to a test device and blow it up. Testing has since been replaced with the Stockpile Stewardship Program—nonnuclear experiments that provide data for the codes and the resulting computer simulations that give scientists the confidence they need to ensure the safety, security, and effectiveness of the nuclear weapons in the U.S. stockpile.

“We rely on the work in the Stockpile Stewardship Program to give us confidence that the weapons codes are extremely accurate,” Symons says.

To gain confidence in the rest of the codes, particularly those that involve geology, the Lab is conducting several experiments.

The Source Physics Experiments (SPE) series is currently underway at the Nevada National Security Site (NNSS). Ten different-sized tests will be detonated at different depths in different rock types. These tests, which are chemical (nonnuclear), can be used to validate codes in places with known geology.

“The data collected from the SPE trials strengthen our national security by advancing technical solutions for treaty monitoring and improving computer simulation methods used to evaluate potential explosions anywhere in the world,” says Brent Park, the NNSA’s deputy administrator for the Office of Defense Nuclear Nonproliferation.

In 2022, Physics Experiment 1 (PE1) will take place at NNSS, generating data on how rock changes as energy is released during an explosion. The $70-million experiment comprises three chemical explosions underground in a tunnel and will validate weapons and geologic code calculations.

In the meantime, scientists can create simulations of known (historical) tests to see how their simulations compare with real data. If the simulations and the data match, the new monitoring technique is working.

THE END PRODUCT

Let’s circle back to a seismic event occurring in Country X. “We want to be ready,” Phillips says. “We want to be able to tell if it is a nuclear explosion.”

Being ready involves having a solid idea of what that explosion would look like, despite possibly never having seen any seismic activity in that location before.

“It’s a totally new way of doing monitoring,” Symons says. “It lets us go beyond just looking at places we know about to imagining what the signals are going to look like in places we can think about; it lets us overcome data limitations.”

Bauer agrees. “This is a great example of a program that only succeeds by doing top science to solve big problems,” she says. “Having passionate scientists available to work on something like this is why Los Alamos is one of our nation’s gems—nobody does it better than we do.” ★

“

IT’S HARD TO MAKE THE HANDOFF FROM CODE TO CODE BECAUSE THEY’RE WORKING ON DIFFERENT TIME SCALES.

NEILL SYMONS SEISMOLOGIST

BETTER SCIENCE =
BETTER SECURITY

Los Alamos started the U.S. space program in the 1950s and continues to deliver the technology that keeps the program innovative.

SCIENCE TURNED SKYWARD

SPACE

BY KATHARINE COGGESHALL

HOW A BOMB BUILT THE SPACE PROGRAM

The Rover Program—Los Alamos' solution to delivering an H-bomb around the world—was the United States' first foray into nuclear rockets.

"America has a 40,000-pound hydrogen bomb that needs to be transported 5,700 miles to Moscow," says Laboratory historian Alan Carr. "How do we do it?"

What sounds like a junior-high math problem is actually the question that spurred Los Alamos to delve into nuclear rockets in the 1950s. With national security as the catalyst, the Laboratory began a space program that continues to this day.

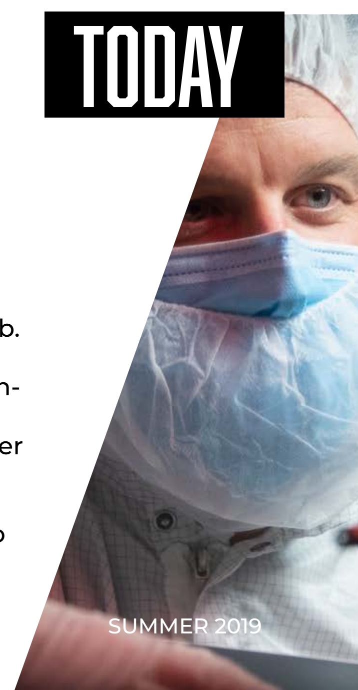
Hydrogen bombs were first built in the throes of the Cold War, when tensions were escalating between the United States and the Soviet Union, as each country developed increasingly powerful nuclear weapons. Although Los Alamos scientists constructed a new behemoth bomb—nearly four times heavier than the first wartime atomic bomb, "Little Boy"—they were unsure how to deliver it. Carr jokes that scientists "just hoped the plane would stay together," but that's not far from the truth. A bomb weighing nearly five tons needed a more reliable and efficient way to travel halfway around the world.

Enter Project Rover—Los Alamos' first foray into space technology. As a part of the Nuclear Rocket Propulsion Division, Rover's mission was to build a new kind of rocket, one that was nuclear powered, to rapidly and safely deliver a heavy-weight hydrogen bomb to Moscow.

ROVER'S MISSION WAS TO BUILD A NEW KIND OF ROCKET, ONE THAT WAS NUCLEAR POWERED, TO RAPIDLY AND SAFELY DELIVER A HEAVY-WEIGHT HYDROGEN BOMB TO MOSCOW.

Before Project Rover, chemical rockets were the standard for space. But the speed, power, and fuel economy that a nuclear-powered thermal rocket could offer were undeniable—nuclear rockets are three times as efficient as chemical rockets, and they significantly cut travel time in space. With a nuclear rocket, a trip to Mars could be accomplished in as little as four months, and the delivery of a hydrogen bomb to Moscow could be accomplished in 30 minutes.

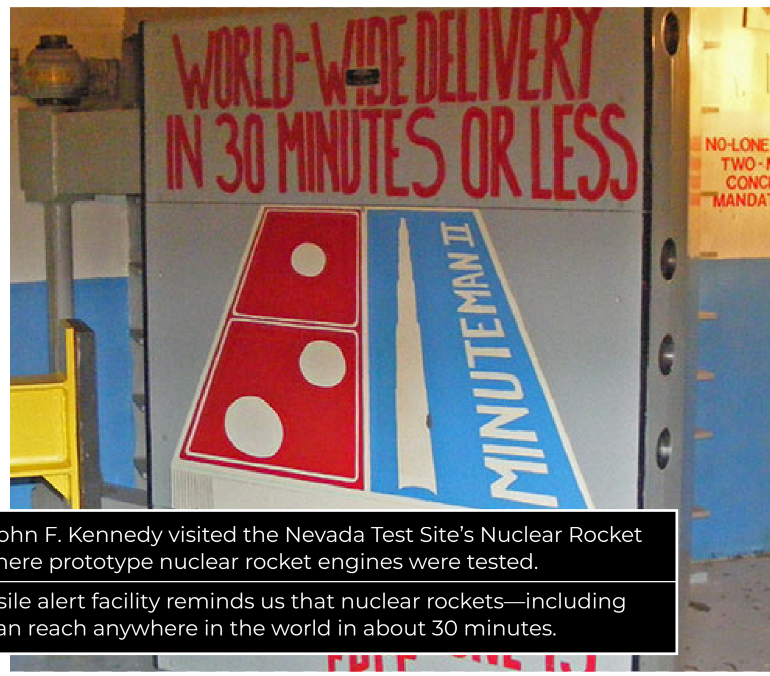
When it began in 1955, Project Rover was one element of Los Alamos research that acted as a metronome for keeping pace in the Cold War. Los Alamos scientists were simultaneously working to miniaturize atomic bombs, and by 1956, the problem was solved with a design for a lighter bomb. This second-generation hydrogen bomb was tested during Operation Redwing and offered a 5-megaton-yield nuclear explosion (equivalent to 5 million tons of TNT) at half the weapon weight. This newer, lighter bomb was transportable by conventional rockets, so building a nuclear rocket for bomb delivery was no longer necessary. It was time for Project Rover to abide by the rules of evolution—adapt or die.



1950s

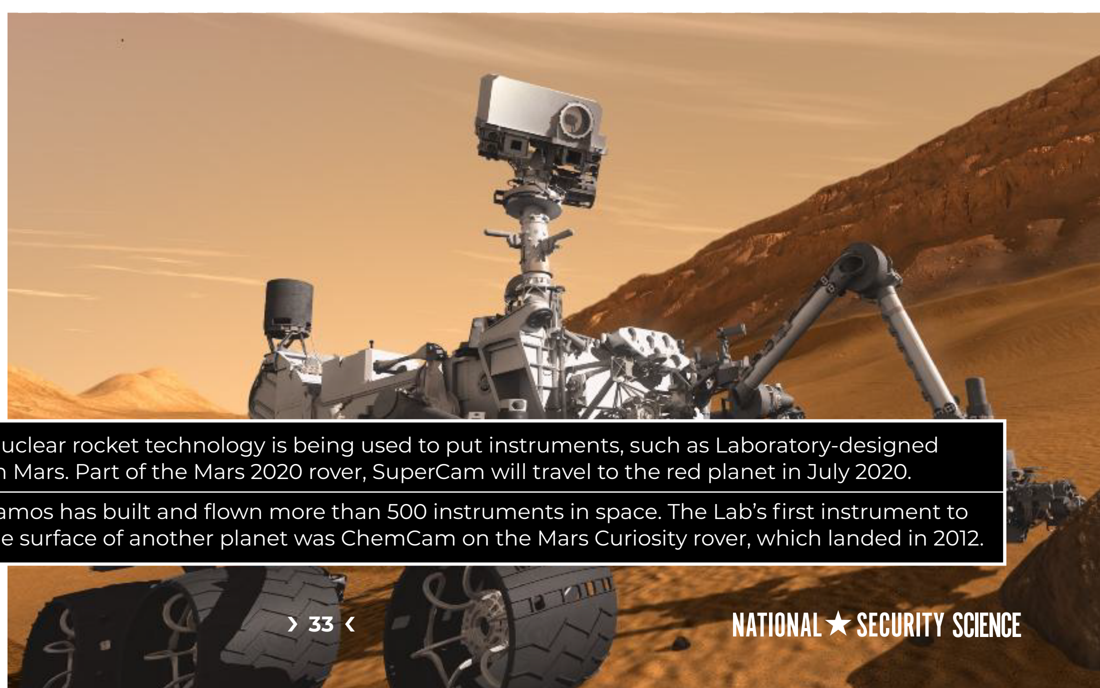
Left: A Phoebus rocket test at the Nevada Test Site.

Right: In the 1950s, the most powerful nuclear weapons were too heavy for an airplane to carry halfway around the world. So Los Alamos began designing nuclear-powered rockets to do the job.



Left: In 1962, President John F. Kennedy visited the Nevada Test Site's Nuclear Rocket Development Station, where prototype nuclear rocket engines were tested.

Right: The door at a missile alert facility reminds us that nuclear rockets—including Minuteman III ICBMs—can reach anywhere in the world in about 30 minutes.



Left: Today, nuclear rocket technology is being used to put instruments, such as Laboratory-designed SuperCam, on Mars. Part of the Mars 2020 rover, SuperCam will travel to the red planet in July 2020.

Right: Los Alamos has built and flown more than 500 instruments in space. The Lab's first instrument to operate on the surface of another planet was ChemCam on the Mars Curiosity rover, which landed in 2012.

COLLISION COURSE

Could scientists deflect an asteroid headed toward Earth?

An asteroid crashing into Earth is extremely unlikely—but not unprecedented. Sixty-five million years ago, such an event occurred and caused the dinosaurs to go extinct.

Today, to prevent humans from experiencing the same fate, scientists use sophisticated telescopes to monitor the nearly 20,000 asteroids and other near-Earth objects (NEOs) that are on a possible trajectory to collide with our planet.

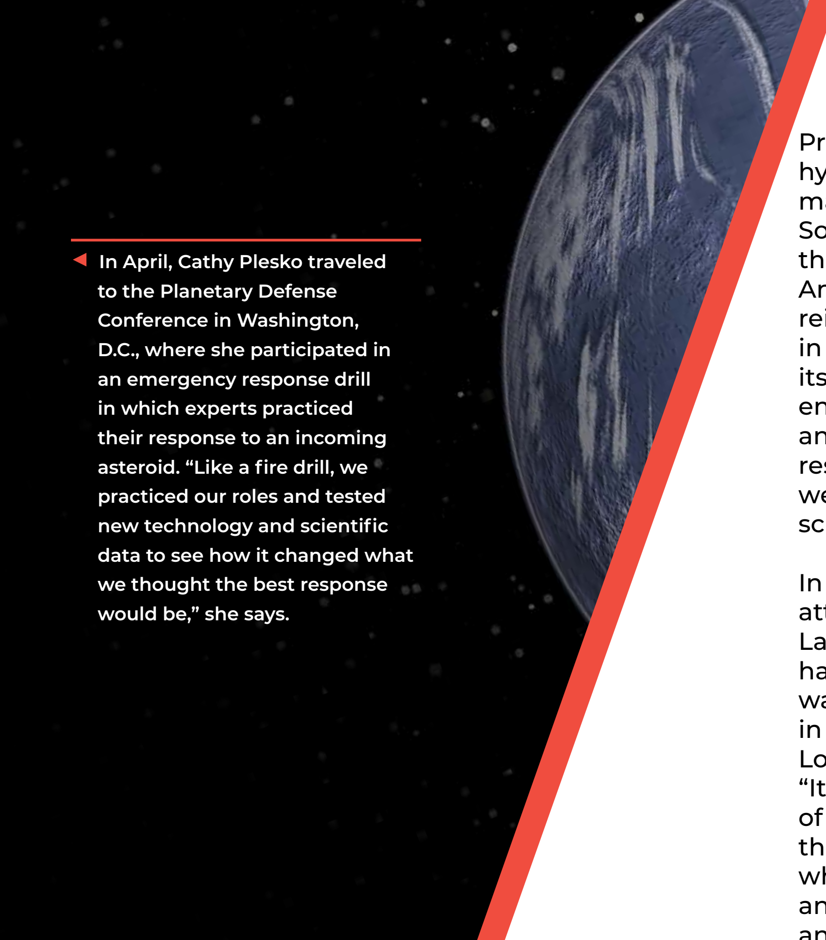
But what good is monitoring without a plan?

Enter planetary defender Cathy Plesko, a computational physicist at Los Alamos who studies ways to alter an NEO's flight path. Recently, Plesko studied an asteroid named Bennu, which is as wide as the Empire State Building is tall and weighs as much as 800 aircraft carriers. Bennu approaches Earth once every six years, making it a perfect test case (even though it has only a 1 in 2,700 chance of hitting Earth, about 100 years from now).

"We used computer models to study two ways of pushing Bennu off course: smashing a spacecraft into the asteroid or detonating a nuclear device from several hundred yards away," Plesko says. "We fed the best estimates of Bennu's shape, composition, mass, and strength into our computer models and predicted what would happen in each scenario."

Smashing a spacecraft into Bennu seemed like the best bet, even though it would mean launching a spacecraft 10–25 years before the predicted impact. To further test this concept, NASA—working with Plesko—has designed the Double Asteroid Redirection Test (DART) spacecraft, which will launch in 2020. In 2022, DART is expected to crash into an asteroid called Didymos B at the speed of 6 kilometers per second—enough to shift the asteroid's orbital path a fraction of 1 percent (but not enough to knock Didymos B onto a collision course with Earth).

"I'm glad we're doing this research now while we can take the time to carefully study the problem and triple-check our models without the pressure of a specific, potentially hazardous object coming at us," Plesko says. "If we prepare well, then for the first time, our species could prevent a major natural disaster. We can't yet push a hurricane off course, cork a volcano, or lock an earthquake-prone fault, but in a few years, we could be ready to stop an asteroid in its tracks." ★



In April, Cathy Plesko traveled to the Planetary Defense Conference in Washington, D.C., where she participated in an emergency response drill in which experts practiced their response to an incoming asteroid. "Like a fire drill, we practiced our roles and tested new technology and scientific data to see how it changed what we thought the best response would be," she says.

Project Rover was on the brink of extinction when hysteria was unleashed by news of Sputnik, the first man-made satellite, which was launched by the Soviet Union. The pressure to beat the Soviets in both the arms race and the space race ballooned across America, and all eyes were back on Rover. Instantly reinvented as the solution to the Soviet's sudden lead in space, Project Rover surged on, leaving behind its original mission of bomb delivery and focusing entirely on space travel. "Sputnik was a pivotal piece and the best thing that ever happened to space research at Los Alamos," Carr reflects. Americans were thirsty for space research, and the Rover scientists intended to deliver.

In 1962, President John F. Kennedy brought national attention to Project Rover when he visited the Laboratory. Dressed in suit and tie, Kennedy was hands-on with the cutting-edge technology that was changing the world. Kennedy's visit culminated in a speech to the townspeople in which he praised Los Alamos' contributions to the nation. He said, "It's not merely what was done during the days of the second war, but what has been done since then, not only in developing weapons of destruction which, by an irony of fate, help maintain the peace and freedom, but also in medicine and in space, and all the other related fields which can mean so much to mankind if we can maintain the peace and protect our freedom."

Kennedy's support of space research at Los Alamos was echoed by his successor, President Lyndon Johnson, but budgets fell short with President Nixon in 1973, and the project was canceled.

Though the history of why the Laboratory's science turned skyward is unexpected, the resulting technical contributions that came out of Los Alamos space research are invaluable.

THE SENSOR TECHNOLOGY DEPLOYED ON VELA SATELLITES AS THE EYES AND EARS OF THE NATION IS STILL IN USE TODAY.

COUNTERPROLIFERATION TECHNOLOGY

One of the most important contributions to space research was the Los Alamos–developed suite of satellites called Vela, which launched in 1963 and could detect nuclear detonations in space (even at clandestine test sites, such as behind the moon) as well as on the Earth's surface and under water. The Velas used special sensors for x-rays, gamma rays, neutrons, and the natural background of radiation in space.

Before Vela (meaning "the watchman" in Spanish), the United States lacked the technology to know whether a nuclear treaty was being followed, so we had to resort to informal agreements that relied on trust. But trust is fleeting in times of war, even in cold war, and the security Vela offered calmed the nation. "Vela changed history," Carr notes as he explains that this new counterproliferation technology played a role in securing the 1963 Limited Nuclear Test Ban Treaty with the Soviets.

The development of Vela sensors and satellites required extreme engineering, and it was accomplished at a breakneck pace. "We built the sensors in about one year," says Los Alamos Intelligence and Space Research Division Leader Herb Funsten. But quality was not compromised for speed: the sensor technology deployed on Vela satellites as the eyes and ears of the nation is still in use today.

In the 56 years since Vela launched, Los Alamos has flown 400 instruments carrying more than 1,400 sensors on more than 200 total launches. These five decades of space research built upon Vela's foundation, adding monumental advances in satellites—GPS, broader nuclear weapon detection, multispectral thermal imaging, and miniaturization (see "Electronic license plates for space," below). While Vela could detect a nuclear explosion, current satellites can detect facilities on Earth that conceal nuclear weapons (preventing an explosion in the first place).

THE SCIENCE WAS NOVEL AND INCREDIBLY COMPLEX —LITERALLY ROCKET SCIENCE.

NUCLEAR-POWERED SPACE TRAVEL

The other important Los Alamos contribution to space research evolved on the ground through Project Rover. Three nuclear rocket designs, done in series—Kiwi (1955 to 1964), Phoebus (1964 to 1969), and Peewee (1969 to 1972)—brought about the knowledge required to achieve space travel powered by a nuclear rocket. All of these designs rely on nuclear fission (the splitting of a nucleus into smaller particles) to heat a propellant gas, in this case, hydrogen. The hydrogen expands as it reaches higher and higher temperatures, causing pressure to build inside the rocket. The pressurized gas can be funneled through a rocket nozzle to create thrust.

Kiwi (named for the flightless bird) was the first nuclear rocket series built at Los Alamos. Tested at the Nevada Test Site, it was never intended for flight; instead, Kiwi was a practice design that defined basic nuclear rocket technology.

Scientist David Palmer holds an experimental ELROI model (left) and the final, much smaller, technology (right).

ELECTRONIC LICENSE PLATES FOR SPACE

Identification for satellites solves growing space-traffic problems.

A success in its own right, the Kiwi series led to the development of the Phoebus series. Phoebus focused on copious power, with the goal of an interplanetary voyage—such as a voyage to put a man on Mars, which was one of Kennedy's intentions. Phoebus led to the Peewee series, which focused on a more compact nuclear rocket design, ideal for unmanned missions to space.

This science was novel and incredibly complex—literally rocket science. It demanded numerous inventions in materials and engineering to overcome the extraterrestrial challenges these rockets would face. For example, special uranium-loaded graphite fuel and stable internal engine components were designed at the Laboratory's Sigma Complex; heat pipes (see p. 9) were created as a cooling system solution (because nuclear cores get incredibly hot); and new techniques for advanced understanding of graphite and carbon were developed. With every barrier to rocket science success came an even greater scientific invention. More than 100 technical papers were published as a result of Project Rover.

▲ ELROI, which uses a laser diode to communicate a unique serial code that identifies a CubeSat, is the same size as a Scrabble tile.

In the silent vacuum of space, an anonymous CubeSat (miniature satellite) crashes into a U.S. national security satellite, rendering the nation vulnerable and without the ability to identify the responsible party. This type of hit-and-run space traffic scenario is one the nation's military and intelligence communities fear for the near future, as more private companies commission thousands of CubeSats—4-inch cubes, shorter than an average smartphone.

"CubeSats give the common man access to space; you don't need a billion dollars to get to space anymore," explains Los Alamos mechanical engineer Dan Seitz. At a reasonable price of $40,000 or less to launch, these 3-pound satellites allow anyone in the world to purchase his or her own CubeSat and send it to space aboard a large rocket.

The exponential boom in demand for commercial CubeSats comes from these satellites' ability to gather data needed for important predictions and studies. For example, CubeSats can track port traffic and agricultural patterns for predictions of economic growth, or they can gather environmental data for studies of global warming. Commercial CubeSats can also offer services, such as internet and radio. There is great economic opportunity for companies that take to the sky, but as more and more companies do just that, the skies become overcrowded, which is why traffic congestion in space is now a hot-button issue.

"To maintain U.S. leadership in space, we must develop a new approach to space traffic management," the National Space Council states in its Space Policy Directive-3, issued June 18, 2018. David Palmer, a Los Alamos space and remote-sensing scientist, has designed that new approach. It's an extremely low-resource optical identifier (ELROI)—an electronic license plate technology for space.

ELROI uses a laser diode to communicate a unique serial code that identifies a CubeSat, attributing a name to who is responsible for each satellite in space. The laser on a CubeSat blinks 1,000 times each second, with each blink lasting only a millionth of a second. The blink-nonblink pattern is like a binary code of ones and zeros that translates to a serial code. Back on Earth, that code is detected by a corresponding telescope filtered to the laser's specific wavelength, and the CubeSat is identified by name and position.

Currently, larger satellites use radio waves powered by many watts of electricity to communicate their name and position back to Earth. But this technology performs only if the satellite is working and can afford to use that much power for communication. "There are 5,000 space objects with payloads in space, but a mere 2,000 are working and able to identify themselves," Palmer explains. Because the number of space objects is expected to more than quadruple in the next few years, this issue of unidentified space objects cluttering the skies must be addressed.

The benefit of ELROI is that it can identify a satellite whether the satellite is working or not because each ELROI is powered by its own rechargeable solar cell. The wattage used for ELROI is about that of a refrigerator light when ELROI is on, which is only 1/1000th of the time, thanks to its blinking on and off. Overall, it consumes about as much power as a laser pointer (when averaged over a second or longer) and costs the satellite nothing to operate, in terms of power.

The ultimate plan for ELROI, which initially rode to space in December 2018 and will be part of two more launches in 2020, is to enforce space safety. "The vision is to have an ELROI license plate on every object that gets registered for space launch," Palmer says. At an expected cost of less than $1,000 per unit, the tiny ELROI (no larger than a Scrabble game tile) will be a simple solution for a growing problem. ★

Fifty years later, the technology from Project Rover has evolved at the Lab into the development of highly compact nuclear reactors. “These compact reactors can be safely deployed in space, providing unprecedented power—both heat and electricity,” Funsten explains.

FROM ROVER TO ROVER

Each of the Project Rover nuclear rocket series proved successful, but none has launched explorers on long-range space missions—yet. Space travel is expensive, but no one is questioning whether Americans will eventually land on Mars. “By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth,” said President Barack Obama in 2010. “And a landing on Mars will follow. And I expect to be around to see it.”

On March 11, 2019, NASA Administrator Jim Bridenstine formally announced the “Moon to Mars” initiative, financially backed by the Trump administration. Bridenstine explained, “We will go to the Moon in the next decade with innovative, new technologies and systems to explore more locations across the lunar surface than ever before. This time, when we go to the Moon, we will stay. We will use what we learn as we move forward to the Moon to take the next giant leap—sending astronauts to Mars.” The NASA timeline has the manned Mars mission slated for the 2030s, just as Obama predicted.

A NUCLEAR ROCKET IS EXPECTED TO CUT TRAVEL TIME TO MARS IN HALF, MAKING A HUMAN JOURNEY TO MARS FEASIBLE AND CERTAINLY IN OUR NEAR FUTURE.

But before Americans can set foot on Mars, exploratory missions offering look-before-you-leap information about the planet must take place. Once again, Los Alamos is taking center stage. Laboratory space researchers are developing the power supply and two new space instruments—SuperCam and SHERLOC—for NASA’s 2020 Mars rover. “The goal is to better understand Mars, our sister planet,” explains Laboratory Fellow Roger Wiens. Wiens is not only the principal investigator for the two new instruments, he was also the mind behind the successful ChemCam instrument currently aboard NASA’s Curiosity Mars rover.

Powered by 10 pounds of non-fissionable plutonium fabricated by Los Alamos, Curiosity’s goal is to study Mars’ past habitability and characterize the planet’s hazards to humans: Can we have a sustained human presence on Mars? ChemCam is the Los Alamos–developed instrument aboard Curiosity that is currently helping to answer that question. This instrument uses a laser to identify molecules such as water and organics on Mars. Thus far, the data from ChemCam and the other rover instruments are promising; NASA will land another rover on Mars in 2020 to gather even more data.

The new rover will boast a souped-up version of ChemCam, called SuperCam, which is a suite of instrumentation: laser-induced breakdown spectroscopy, Raman and time-resolved fluorescence, color micro-imaging, and VISIR spectroscopy. Another fascinating addition is a microphone. “For the first time,” Wiens explains, “we will be able to listen to Mars!”

SuperCam’s job is to blast Martian rocks with its laser to investigate chemical and mineral compositions from a distance. In addition to SuperCam, there will be six other new instruments on the 2020 rover. SHERLOC (Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals) is the second Los Alamos contribution, which will reside on the rover’s robotic arm. SHERLOC is equipped with an ultraviolet spectrometer and camera for studying organics. The 2020 rover will answer the question: Which resources will humans be able to use on Mars?

But one remaining concern about sending Americans to Mars is radiation. As Funsten explains, “Traveling beyond the protective magnetic cocoon of Earth’s space environment and into interplanetary space, where cosmic rays continuously bathe spacecraft and solar storms can unleash high-energy particles, is our biggest challenge. Radiation from these sources can cause permanent damage to our bodies.” The current solution to this problem is the same solution we turned to for fast, efficient bomb delivery in the 1950s—nuclear rockets.

COSMIC COLLABORATION

Lisa Danielson sparks Lab-wide collaboration to advance Los Alamos planetary science.

▼ Lisa Danielson brings expertise and new energy to planetary science.

"Does life exist beyond Earth?" That's the question Lisa Danielson has wondered about since the age of five, when she first became interested in space. Four decades, three degrees, and one stint at NASA later, she is now equipped to find the answer as the new lead for planetary science in the Space and Remote Sensing Group at Los Alamos.

Danielson started her position on April 15. She moved to Los Alamos from Houston, where she was the manager of Basic and Applied Research for Jacobs, a contractor of NASA's Johnson Space Center. But this isn't her first taste of New Mexico. In her early 20s, Danielson visited the Earth and Planetary Sciences building at the University of New Mexico, where she encountered the space rocks that sparked her career. "I stepped inside and saw meteorites, and I was instantly hooked," Danielson says.

In a sea of scientists, Danielson stands out, and not just because of her pink hair and 1,000-watt smile. Like a beacon, she radiates excitement over her new role at the Laboratory—officially, planetary science expert, but unofficially, scientist herder. "There are tons of experts at the Lab who do unique and exciting work, but they need someone who can pull those experts together to grow the field of planetary science," Danielson says.

"Lisa is that someone," explains Reiner Friedel, director of the Center for Earth and Space Science and manager of NASA programs at the Lab. "Lisa will help write strategy proposals, bring experts into Los Alamos and together at the Lab, and be an ambassador for the center."

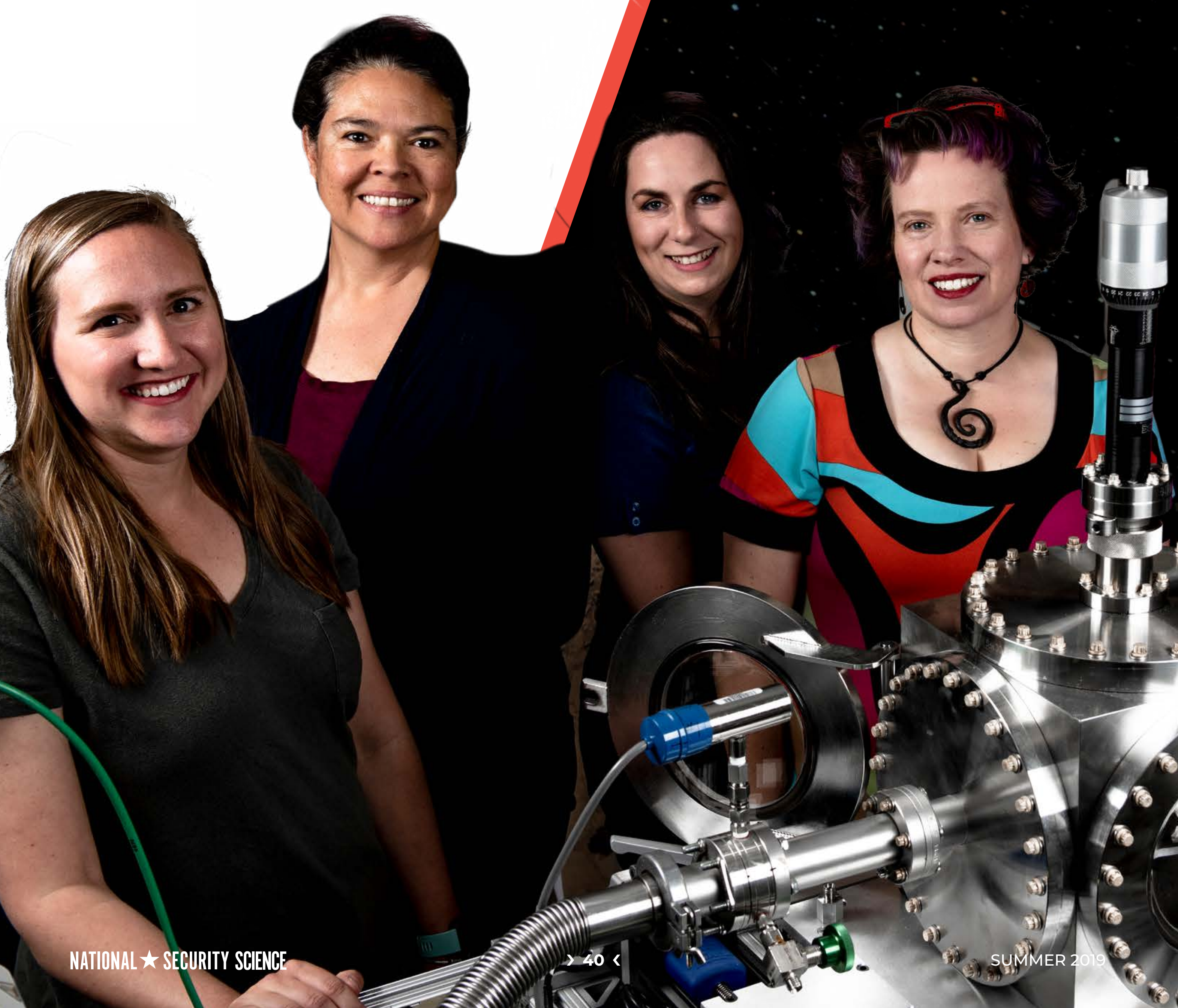
Planetary science (the study of the composition and formation of planets, moons, and planetary systems) is a broad field, and Danielson intends to make it broader, encouraging collaboration among Lab experts working in disparate fields, such as shock physics, that were traditionally far removed from space research. Space is complex, and to tackle future challenges in planetary science, the Lab needs experts from a diversity of fields working together.

Danielson's umbrella will encompass everything planetary, from new instruments for the Mars 2020 rover (see "How a bomb built the space program," p. 32) to the miniaturization of satellites (see "Electronic license plates for space," p. 36). With every step forward in planetary science, there is a speed bump to overcome with new technology. "People always think of the amazing space pictures that are taken once we reach a planetary destination, but it is the journey to that destination that matters most—contributing technological improvements that benefit the public and national security." ★

Given that total radiation exposure is a function of radiation flux and time, getting humans to Mars faster will be one way to minimize exposure. To that end, NASA is once again looking to Project Rover's nuclear rocket technology. A nuclear rocket is expected to cut travel time to Mars in half, making a human journey to Mars feasible and certainly in our near future.

What started with a 40,000-pound bomb and a question of transport launched the field of space exploration. Coming full circle from past to present, the technology that came out of Project Rover is now leading America's way to Mars. ★

▼ The women of the ChemCam Engineering Operations team (from left): Suzi Montano, Adriana Reyes-Newell, Roberta Beal, Lisa Danielson, Nina Lanza, and Cindy Little.



THE WOMEN POWERING THE MARS ROVER LASER

The brains behind the Curiosity rover's rock-penetrating laser, which last year enabled the discovery of an ancient Martian lake bed.

The laser that zaps rocks on Mars is commanded by a talented group of engineers and scientists at Los Alamos National Laboratory—a team that also happens to be made completely of women, a rarity in the engineering field.

"It's unusual, simply because engineering still tends to be male dominated," says Nina Lanza, a planetary scientist in the group who helped recruit other members. "Typically on teams like this, you'll have a few women, but a majority are men. I don't know of any other instruments on the Mars Curiosity rover that have an all-female engineering team."

The women are responsible for sending commands to the ChemCam instrument, which shoots Martian rocks with a laser to determine their chemical make-up. The laser was developed at Los Alamos in conjunction with the French space agency and played a key role in the discovery of the existence of an ancient lake on the Red Planet.

The team meets daily with planetary scientists from around the world, who identify which rocks on the surface of Mars to zap and analyze. The engineering team then figures out what commands to send to the ChemCam instrument to make that possible.

"This job requires a lot of long hours and dedication," says Lisa Danielson, the ChemCam operations manager. "And there's a high intensity that requires excellent communication and teamwork. We work really well together and are very supportive of each other. We create a very positive environment and know that we can depend on each other."

It wasn't intentional to create the all-woman team, Lanza says. They were just looking for the best people for the job. "What matters is that they have the right set of skills and the right personality." But as more women fill leadership roles, Lanza says, teams like this are bound to become more common.

"Women in the sciences know other women in the sciences," Lanza says. "That's why a diverse workforce is so important. If you have a diverse team, the members will likely have a network of talented people—so you find people you might have never found otherwise." ★

FROM LOS ALAMOS TO OUTER SPACE

On the 50th anniversary of the Apollo 11 mission, former scientist and astronaut John Phillips talks about his time at Los Alamos and NASA.

BY J. WESTON PHIPPEN

▲ In addition to authoring more than 150 scientific publications, John Phillips was the principal investigator for a plasma experiment on the Ulysses spacecraft as it flew over the poles of the sun. In 1996, Phillips was selected by NASA as an astronaut; he has flown into space three times. Photo: NASA

On July 20, 1969, John Phillips, an 18-year-old midshipman at the U.S. Naval Academy, was in a bar in Tijuana, Mexico. The next day, he would be shipping out for six weeks. So of course, before that next assignment, he and some friends headed for Tijuana to celebrate.

There, on a small, roundish TV screen, he watched Neil Armstrong touch the moon's surface, a moment that cemented his desire to go to space, he says. "The entire Apollo program, not just Apollo 11, was a profound experience for me." It would take nearly three more decades before Phillips got his own chance in a rocket. And a major part of accomplishing that goal, he says, was the time he spent at the Laboratory.

Starting in 1987, Phillips worked at Los Alamos, first as a J. Robert Oppenheimer Fellow and then as a staff scientist until 1996. "Coming to the Lab was a fortuitous stepping stone," Phillips says of his journey to NASA. "It definitely helped me get in."

Today Phillips lives in Sandpoint, Idaho, about 50 miles from the Canadian border. The town of 8,000 people is just north of the Coeur d'Alene National Forest, and Phillips can almost make out the ski slopes from his window.

Now 68 years old and retired, he says he spends most of his time "skiing and kayaking the great West." In fact, when *National Security Science* caught up to Phillips, he'd just returned home from a weeklong trip rafting the Green River in Utah.

"I achieved all of my work goals, and now I'm achieving all my life-balance goals," he says. "You probably won't see my picture on the front of a scientific journal anytime soon."

NSS spoke to Phillips recently about his time at Los Alamos—how it prepared him for becoming an astronaut and what he believes the U.S. should have done after the Apollo landing.

Why were you drawn to Los Alamos?

Primarily, it was because I met some LANL people when I was a grad student at the University of California at Los Angeles. They really talked the place up. They talked about the work, but they also talked a lot about the lifestyle. I like to ski and climb mountains, so it really appealed to me. But at that time, I wasn't even sure where Los Alamos was. I think I thought it was in southern New Mexico or something. Ultimately, the Lab made me a very nice postdoc offer.

Tell us about your early work at the Lab and how that prepared you for a job with NASA.

At first, I worked on existing Lab projects in spacecraft instrumentation. And when I say instrumentation, it wasn't testing and building, it was analyzing the observations. I was more of a data guy than a hardware guy.

So, I was working on all these varying projects when I got involved with the Ulysses mission—a partnership with NASA on the first space probe to study the north and south poles of the sun. Then I kind of inherited the role of principal investigator.

As it turned out, the bulk of my work at the Lab was on the Ulysses project. That helped me the most in my NASA career. Unlike a lot of people at LANL, I did mostly unclassified work. And almost all the reports I published were public, so I was able to work with scientists in Japan, Russia . . . all over the world. That kind of international exposure helped later on when I was applying to NASA.

Exploration and adventure are often associated with astronauts. But did you also

experience those feelings with your work at the Lab?

A bit, yes. There was nothing I did at Los Alamos that was physically risky or demanding in the sense of being an explorer. But I will say that when I was principal investigator for the Ulysses spacecraft, I was the first person to see the measurements we received—and this was from a place no human had ever seen before. I would sit behind my keyboard, looking at the data as it came back, and in a way, it was kind of like being in the Amazon jungle, exploring. Being the first person to see this part of space was similar to being the first person to paddle around the bend of an unexplored river. I mean, I was always going home at night to eat dinner with my family, but the experiences share something wild in common.

Had you always planned on becoming an astronaut?

I don't know if it was a plan. It was always a dream. But I never had much of a career plan. I'd thought about being an astronaut since I was 10 years old, when Russian cosmonaut Yuri Gagarin became the first person to fly in space. I first put in to be an astronaut when I was a 25-year-old Navy pilot, although they didn't hire me for another 20 years. I always followed my nose.

Did you take the job at Los Alamos thinking it would help you reach that goal?

I made the decision to come to LANL because of the work I could do at the Lab and because of even more mundane things—it was a good place to raise a family, and the pay was good . . . that kind of stuff.

I will say, though, a lot of my time at NASA was much more like being in the Navy. The Lab always valued creativity and intellectual achievement. NASA valued attention to detail and teamwork. So, the experiences were kind of opposite. The job of an astronaut is to operate a spacecraft. You don't need to be a physicist; you don't need to have a long list of published work. A lot of my research with NASA didn't correlate at all with my previous work at the Lab.

What were some of the experiments you conducted in space?

The primary mission for my first flight was to deliver a robotic arm to the International Space Station and install it. The arm helps astronauts move equipment around and maintain the craft. On my third flight, the mission was to deliver and install big solar panels.

Scientific experiments were never my primary mission, and of the ones I did, at least half had a medical purpose. We learned how to do ultrasounds in space. We did an experiment that looked at wear and tear on the lower body while living in space—how to avoid kidney stones. The experiments were almost all biological in nature, and I have no biology background.

You had three missions to space. What was the most memorable moment?

I think my second flight. I was training on Russian rockets in Kazakhstan, and I'd been speaking Russian for half a year, training as if I were a Russian cosmonaut. For me, that was the most challenging thing I've done. Not everyone makes it through that training, and there are times when you feel completely overwhelmed. That was the most accomplished I've ever felt.

That's maybe not the response most people expect—they'd expect it to be something like looking back on Earth, or at least something about space.

Well, of course. My first spacewalk was certainly cool. And so was the first time the rocket engines cut off, and we were floating. But I think as far as personal satisfaction, launching with the Russian flight is one of the things I'll remember most.

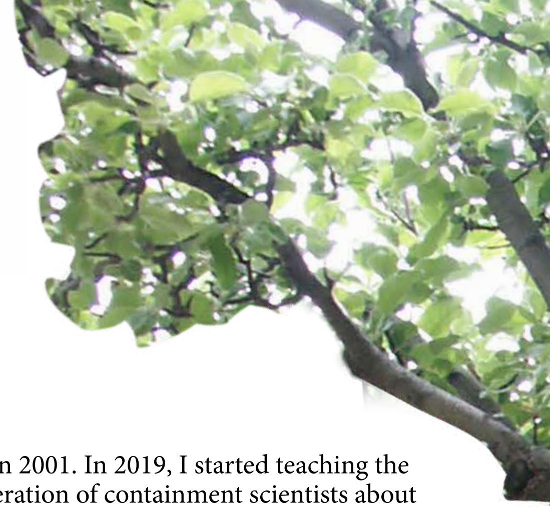
The Lab is currently doing a lot of work to get to Mars. Given your science and space experiences, what do you think of that goal?

I've thought a lot about the years that followed the Apollo program, almost 50 years ago now. Instead of focusing on Mars, I thought we should have established a semi-permanent base on the moon. But over the past 30 years, our emphasis has bounced back and forth between Mars and the moon. We're a long way from putting people on Mars—decades probably. I'd really love to see Los Alamos become a major player in researching and developing science for a moon base. That would be wonderful.

What advice do you have for LANL people interested in a career path similar to yours?

First off, the Lab is a wonderful place to achieve your scientific goals. When I was there, it always had huge resources, and you could find an expert on anything and everything you wanted. Specifically, for Lab folks interested in NASA, I'd say gain some expertise in what I'd call expeditionary projects, in places that are far off and hard to reach and that require teamwork, toughness, and an element of survival. You need to show you can work on deadline with a team, in demanding circumstances. ★

▼ The space shuttle Discovery sits atop a launch pad at the Kennedy Space Center in Cape Canaveral, Florida, on March 11, 2009. The Discovery would fly to the International Space Station, where astronaut—and former Laboratory staff member—John Phillips would deploy a robotic arm to install the S6 truss, part of the station's "backbone." Photo: NASA



BUSY BEE

BY OCTAVIO RAMOS As a containment scientist at the Laboratory and as a beekeeper at home, Chris Bradley cultivates a broad-minded outlook on life that enables him to find solutions to challenging problems.

Dressed in a cotton suit and a hat with a wire-reinforced veil, Christopher Bradley of the Laboratory's Geophysics group kneels before a wooden box, opens its lid, and carefully extracts a frame, sending hundreds of bees into the air. Most of the buzzing insects pay no mind to Bradley, who inspects the honeycombed frame for brood (the eggs, larvae, and pupae of honeybees) and then slides the frame back into place.

Bradley is an amateur beekeeper, his hives located in the backyard of his home in Chimayo, New Mexico. Like other beekeepers, Bradley has experienced his ups and downs with the hobby, but it's the importance of bees in nature, particularly their pollination of plants, that keeps him in the game.

"I am not a professional beekeeper by any means," Bradley notes. "But there've been years when the bees have delivered good crops of honey, which my wife and I have used as Christmas presents for our friends and family."

FROM GEOLOGIST TO CONTAINMENT SCIENTIST

After graduating from Los Alamos High School, Bradley attended the University of New Mexico, where he earned a geology degree. After a short stint with the United States Geological Survey, Bradley secured a Laboratory summer student position, where he worked on the Hot Dry Rock project. It was this project that sparked Bradley's interest in physics, so he returned to college and earned a doctorate in geophysics.

"Although I had a few job offers, the Laboratory's offer once again won out," Bradley says. "Coming back to the mountains was the best draw—I missed the hiking and the skiing here."

For the past 19 years, Bradley has been a containment scientist for subcritical testing. Subcritical testing plays a significant role in safeguarding the nation's nuclear stockpile.

"These tests form no critical mass, so there is no self-sustaining chain reaction like in a nuclear explosion," Bradley explains. "However, these tests provide data that scientists can use to create computer simulations that help ensure the safety and reliability of our nuclear stockpile."

Despite being subcritical, these tests consist of explosives coming into contact with special nuclear material, such as plutonium and uranium. It's up to containment scientists to ensure that these materials are not released into the uncontrolled environment outside the experiment chamber, which is located in an underground complex at the Nevada National Security Site (NNSS).

"Geophysics, mechanical engineering, and knowledge of explosives and nuclear safety—you mix all these broad subject areas and you have a containment guy," Bradley notes. "My first subcritical test was in 2001. In 2019, I started teaching the next generation of containment scientists about subcritical tests, such as 'Vega,' which took place earlier this year at the NNSS."

CULTIVATING APPLES AND HONEY

Bradley met his wife, Nancy, while he was a postdoc and she was working on a graduate degree. "We bought this house in Chimayo—it was a real fixer-upper," he says with a laugh. "The electricity consisted of a power cord nailed to the ceiling vigas and the plumbing was a piece of PVC pipe that had been pounded through an adobe wall."

The home's backyard was a different matter. "The house also came with its own apple orchard," Bradley says. "If you know anything about Chimayo, you know the place is all about apples. As we learned more about apples, we also hit upon the idea of keeping bees. My wife—who is a geologist and an organic farmer—and I have been beekeepers for about 19 years."

CULTIVATING A PROBLEM-SOLVING OUTLOOK

Originally trained as a theoretical and computational scientist, Bradley found that he had to think broadly rather than specifically when he began working as a containment scientist. "Instead of focusing just on writing code to solve a specific problem, I found that I needed to think in broad terms to address unexpected problems like penetrating welds on a barrier, gas blocks on a cable, and what explosives might do when they contact aged metal."

Over time, Bradley found that such broad thinking influenced his beekeeping hobby. "Rather than focus on observing a bee's particular characteristics, I like to sit back and watch bees just to see what happens," Bradley says. "Such observations have enabled me, for example, to identify what pollen is coming back to the hive just by examining the residue on a bee's legs. It's fascinating what bees have taught me . . . and continue to teach me." ★

▶ A swarm of bees in Chris Bradley's backyard in Chimayo, New Mexico.

"I like being diverse in my thinking. Thinking in broad terms—it really makes life much more interesting.

THE DISTINGUISHED ACHIEVEMENTS OF LOS ALAMOS EMPLOYEES

BETTER SCIENCE = BETTER SECURITY

Hardworking people—the Laboratory's most important asset—**enable Los Alamos to perform its national security mission.**

Malcolm Boshier and **Dana Berkeland** were awarded the 2019 Science and Technology Best Paper in the *Journal of Intelligence Community Research and Development*. The paper, "A Survey of Environmental Magnetic Field Noise and Mitigation Techniques," summarizes the measurements of background magnetic fields in a variety of environments and frequencies.

Young Jin Kim was recognized with a 2019 Outstanding Young Researcher Award from the Association of Korean Physicists in America. Kim was recognized for her efforts in precision magnetic measurements for fundamental and applied sciences based on highly sensitive state-of-the-art detectors, including superconducting quantum interference devices (SQUIDs), atomic magnetometers, and high-resolution conventional systems.

The New Mexico Technology Council recognized two Laboratory researchers with 2019 Women in Technology Awards. **Janette Frigo**, an electrical engineer with the Intelligence and Space Research Division, and **Laura Monroe**, a mathematician with the Laboratory's High-Performance Computing Division, were recognized for their exceptional work in the STEM fields and their commitment to community and mentoring of other women.

Ricardo Lebensohn is the recipient of the 2019 Distinguished Scientist/Engineer Award from the Minerals, Metals, and Materials Society's Structural Materials division. Lebensohn pioneered work in the field of multiscale modeling of materials and its connection with the characterization of microstructure by x-ray diffraction.

Procurement team leader **Maureen Armijo** was awarded the NNSA's first Strategic Sourcing MVP Award. During fiscal year 2018 and under Armijo's leadership, the Laboratory delivered $46.6 million in strategic savings, resulting in an impressive overall savings rate of 5.78 percent. These savings free up dollars that allow for reinvestment in other programmatic areas at the Laboratory.

Mary Anne With, of the Office of Partnerships and Pipeline, is the recipient of the National Postdoctoral Association's 2019 Distinguished Service Award. With, who has influenced the careers of more than 10,000 postdocs, is being honored for the many opportunities she has helped create for postdoc research and career advancement.

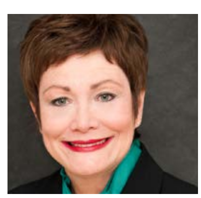
In a ceremony on May 7, the Global Security Red Room, an SCI-level exhibit suite in the Laboratory's National Security Science Building, was named in honor of **Terry C. Wallace, Jr.**, the 11th director of Los Alamos National Laboratory and now director emeritus. While principal associate director for Global Security from 2011 to 2017, Wallace envisioned a secure space where special visitors could learn about some of the dynamic work the Laboratory does to support the Intelligence Community, DoD, DHS, and other sensitive sponsors. "The vision for the Red Room became a reality during his tenure," says Laboratory Director Thom Mason. "It is fitting that we are dedicating this suite in honor of Terry Wallace, who had the vision, the commitment, and the perseverance to bring it to fruition." ★

IN MEMORIAM

MILES BARON

Miles Baron came to Los Alamos to complete his doctoral research and remained at the Laboratory for the rest of his career, working as a nuclear weapons designer and an intelligence analyst. Highlights of his 30 years at the Lab include being appointed Joint Test Assemblies flight test coordinator in 1999, earning both individual and small team Distinguished Performance Awards in 2007, leading a Reliable Replacement Warhead design team, acting as the special adviser to the deputy director of the Laboratory, and serving on the Science Council for the assistant secretary for Defense Programs in the Department of Energy. Baron also chaired the Laboratory's Native American Working Group in the late 1990s. In 2011, Baron was awarded the National Intelligence Medallion for his exceptional analytical contributions to the Intelligence Community. Baron passed away on March 13. ★

ELLEN TAUSCHER



The Honorable Ellen Tauscher, chair of Triad National Security's Board of Directors and a former Congresswoman from California, died of complications from pneumonia on April 29. As a politician, Tauscher was known for negotiating with Russia on the international nuclear arms treaty New START and for representing the United States at the Non-Proliferation Treaty Review Conference at the United Nations in 2010. In 2012, she began serving on the board that operates Los Alamos National Laboratory. She also chaired the Regents' Committee on Oversight of the DOE Laboratories for Los Alamos, Lawrence Livermore, and the Lawrence Berkeley National Laboratories. ★

8 YEARS AGO

On June 27, 2011, a crew member aboard the International Space Station captured this image of the Las Conchas wildfire, which burned more than 150,000 acres just southwest of Los Alamos National Laboratory. ★ **Photo: NASA**

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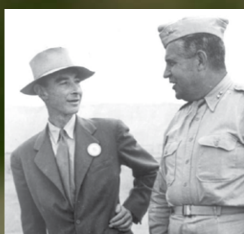

ON THE MORNING OF JULY 16, 1945, Manhattan Project scientists conducted a test that proved the feasibility of weaponizing energy from the atom. Trinity, as the test was known, was the detonation of the "Gadget"—the world's first atomic device—near Alamogordo, New Mexico. Above, Laboratory Director Robert Oppenheimer and Manhattan Project Director General Leslie Groves stand at ground zero of the Trinity site in September 1945.

In May 2011, Oppenheimer and Groves became permanent fixtures in downtown Los Alamos. Created by Santa Fe artist Susanne Vertel, the life-size bronze statues are popular among locals and tourists alike. ★