LOS ALAMOS NATIONAL LABORATORY
NATIONAL SECURITY SCIENCE
OCTOBER 2018

EXTREME HEAT

WHAT HAPPENS WHEN A B61 GRAVITY BOMB HEATS UP AS A FIGHTER PLANE SITS ON THE TARMAC? SCIENTISTS USE THE WORLD'S FASTEST X-RAY MACHINE TO FIND OUT.

D5 NUCLEAR-ARMED MISSILES

Go on patrol with an Ohio-class submarine that's ready to launch nuclear warheads at a moment's notice.

Manhattan Project physicist Jane Hamilton Hall influenced nuclear policy—AND PAVED THE WAY FOR WOMEN WHO WORK AT LOS ALAMOS TODAY.

PLUS:

The biggest national security challenges of the future

Future military leaders spend a summer at the Lab

Assessing the health of America's nuclear stockpile

A small amount of "edited" PETN explosive undergoes an energetic reaction during an electro static discharge (ESD) safety test.

Explosives need to be safe for handling and storage; they also need to detonate reliably on demand. To better understand explosive sensitivity, Los Alamos scientists replaced an arm of the common initiating explosive pentaerythritol tetranitrate (PETN) with various non-energetic groups to see how those groups could change the sensitivity of the overall molecule. The researchers were able to change the sensitivity of the PETN-type materials, making them both less sensitive and more sensitive. "This is the first time we've taken a fundamental system like this and changed different parts of it to see how it could affect sensitivity," says explosives chemist Virginia Manner.

PHOTO: DANIEL PRESTON

IN THIS ISSUE

FEATURES

ABOUT THE COVER: A pilot climbs into a U.S. Air Force F-15C Eagle fighter aircraft, which can deploy a B61 gravity bomb. To read more about the B61 Life Extension Program and how scientists use the world's fastest X-ray machine to evaluate the safety and reliability of this aging nuclear weapon, turn to page 24.

To successfully deter our adversaries and keep our nation safe, we must maintain a scientific and technical advantage in new arenas of combat.

— Terry Wallace, Laboratory director (pictured here with NNSA Administrator Lisa Gordon-Hagerty and Bob Webster, Principal Associate Director for Weapons Programs)

COMMUNICATING WHAT WE DO

Clear science has value—and national security implications.

BY BOB WEBSTER, PRINCIPAL ASSOCIATE DIRECTOR, WEAPONS PROGRAMS During a recent panel that celebrated women's contributions to Laboratory science and mission, the conversation turned to mentoring. Kathy Prestridge, team leader for the extreme fluids team in the Physics Division, stressed the importance of communication with young staff. She was quick to point out, however, that communication can be really difficult.

"A lot of us who go into science don't usually think: I'm a really good communicator—I think I'll be a physicist," she joked.

Kathy's words resonated with me because they're true. Los Alamos is lucky to have many of the world's brightest scientists and engineers working together on this New Mexico mesa top, but if people outside the Laboratory can't decipher our science and figure out how it might apply to the real world, then they won't understand its value.

Science must be communicated in a way people can understand, which is why the Laboratory publishes *National Security Science* magazine. *NSS* highlights the work of Weapons Programs at Los Alamos—work that is essential to maintaining national and global security.

This issue—our first in more than a year—offers content for every type of reader. History buffs will enjoy "Queen of the Hill" about Jane Hall, the Lab's first female assistant director who worked on Clementine, the world's first fast reactor. Members of our military might relate to "Salt Life" in which a former Navy officer-turned-Lab employee recounts a 70-day patrol onboard an Ohio-class submarine that has the capability to launch the Los Alamos–designed W76 and W88 nuclear warheads. And if the phrase "world's fastest X-ray machine" intrigues you, turn to page 24 to learn about the Lab's DARHT facility and our B61 Life Extension Program.

In addition to translating science into a language we can all understand, these pages show the incredible depth and diversity of the Los Alamos workforce. From the five young staff members profiled on page 6 to Weapons Programs veteran Donald Sandoval (page 46), we have nearly 12,000 intelligent, capable employees dedicated to our national security mission. I hope you enjoy learning about these people and their essential work in this issue of *NSS*.

Lastly, as the Laboratory nears the end of its 75th year of service to the nation, a new contractor will take over management and operations starting November 1. Triad National Security is comprised of Battelle Memorial Institute, the Texas A&M University System, and the University of California—and, like current contractor Los Alamos National Security, is committed to scientific excellence. Although the Laboratory will experience some reorganization and changes as a result of the transition, Weapons Programs will continue to deliver on its mission in a safe, successful, and timely manner. For the next 75 years and beyond, we will continue to solve the most demanding national security challenges using the world's best science and engineering. ★

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STAFF SPOTLIGHT:
Octavio Ramos received a 2017 Distinguished Performance Award for his work since 1995 as the lead writer-editor for R&D 100 Award nominations. Ramos was the principal author of the Laboratory's seven winning entries in 2017. Read his profile of Donald Sandoval on page 46.

National Security Science highlights work in the weapons and other national security programs at Los Alamos National Laboratory. Current and archived issues of *NSS* are available at lanl.gov/NSS. *NSS* is unclassified and is funded by the Weapons Programs directorate.

To subscribe or provide feedback, email magazine@lanl.gov.

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A quick visit to the Laboratory's careers site (lanl.gov/careers) shows many hiring opportunities—and they're not just for scientists with Ph.D.s. Opportunities exist in almost every area of the Laboratory including engineering, technical support, business, and operations.

THE LABORATORY
BY THE NUMBERS

1,780 Summer students

32.8 percent of Laboratory employees are millennials

47 percent of Laboratory employees identify as a minority

45 Average age of employees

392 Postdocs

“Every year we have tens of thousands of people apply for jobs at Los Alamos. In 2017, we took those tens of thousands of people and measured them against the requirements and about 14,000 people actually qualified for a job at Los Alamos. We selected less than 9 percent of those people. That’s on par with the acceptance rate of the most prestigious academic institutions in the world. We really do have not an average workforce but a highly qualified workforce. And that highly qualified workforce—the best workforce—is across all the disciplines.”

–DIRECTOR TERRY WALLACE

64 percent of Laboratory employees have a degree

28 percent bachelor’s
17 percent master’s
19 percent Ph.D.

45 percent of the Laboratory’s summer students are native New Mexicans

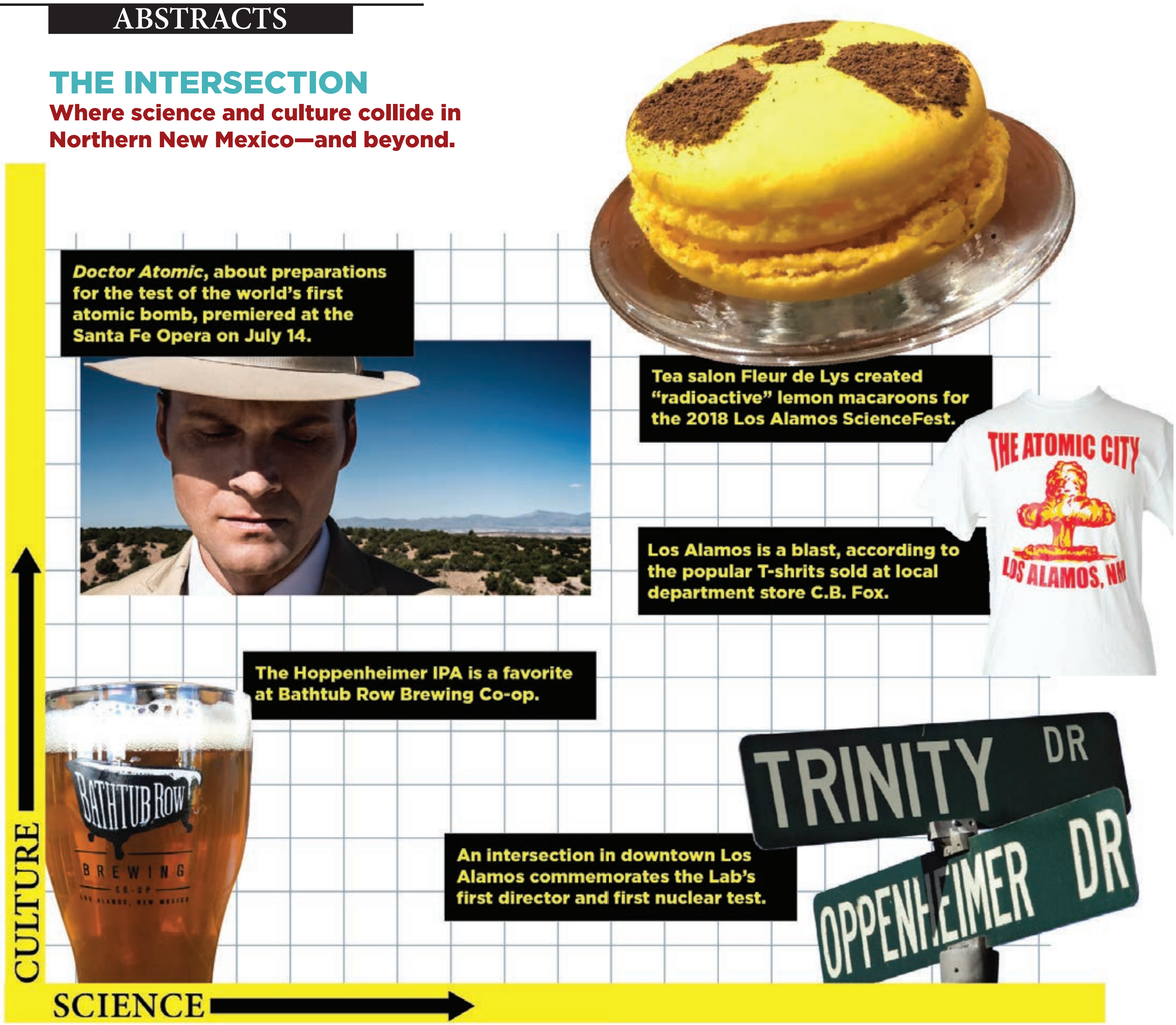
11,738 Total workforce

Laboratory employees

67 33

THE INTERSECTION

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



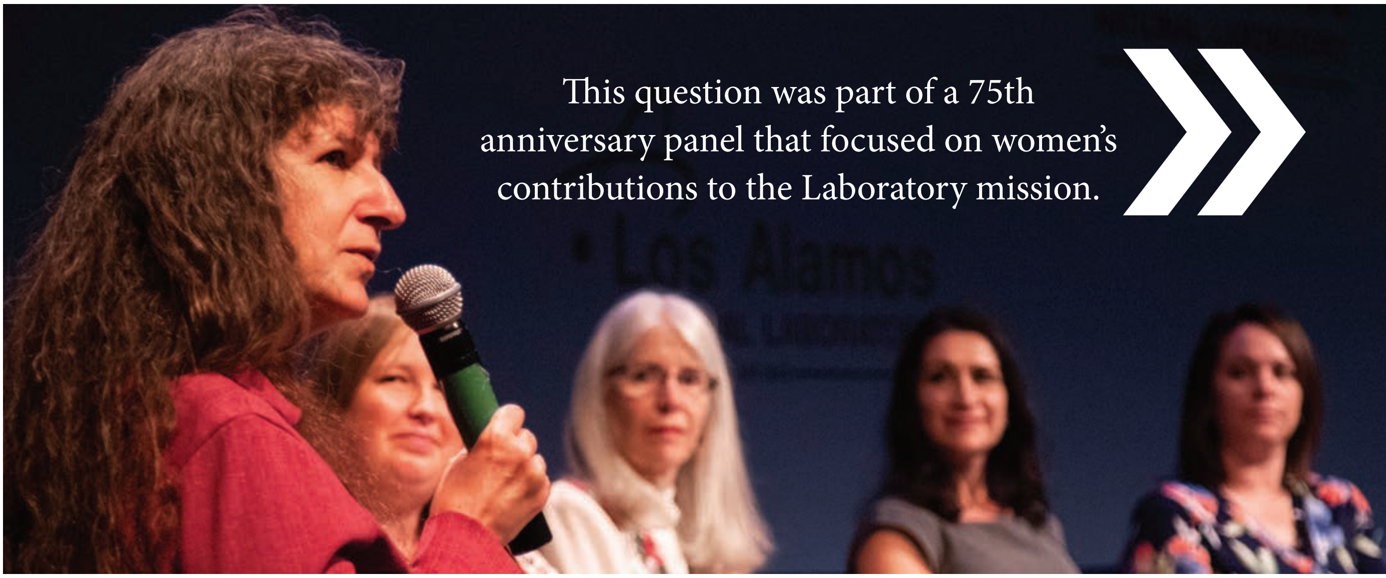
***Doctor Atomic*, about preparations for the test of the world's first atomic bomb, premiered at the Santa Fe Opera on July 14.**

Tea salon Fleur de Lys created "radioactive" lemon macaroons for the 2018 Los Alamos ScienceFest.

Los Alamos is a blast, according to the popular T-shrits sold at local department store C.B. Fox.

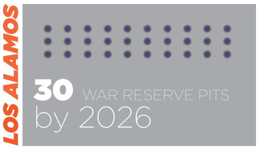
The Hoppenheimer IPA is a favorite at Bathtub Row Brewing Co-op.

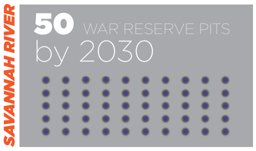
An intersection in downtown Los Alamos commemorates the Lab's first director and first nuclear test.



This question was part of a 75th anniversary panel that focused on women's contributions to the Laboratory mission.

BY THE NUMBERS





Because aging pits pose a risk to national security, in May 2018, the National Nuclear Security Administration reconfirmed that Los Alamos National Laboratory will establish a safe, secure, reliable, and efficient capability to manufacture at least 30 war reserve (WR) plutonium pits per year by 2026. The Savannah River Site in South Carolina will develop the capability to manufacture 50 WR pits per year by 2030.

A war reserve pit is one that meets engineering and physics standards for use in deployed nuclear weapons.

CELEBRATING 60 YEARS OF NUCLEAR WEAPONS COOPERATION

2018 marks the diamond anniversary of the signing of the Mutual Defense Agreement between the United States and the United Kingdom.

Signed on July 3, 1958, the U.S.–U.K. Mutual Defense Agreement (MDA) provides for the exchange of defense information relevant to nuclear weapons, naval nuclear propulsion, and nuclear threat reduction.

Exchanges through the MDA benefit the United States and United Kingdom by advancing each nations' understanding of the safety, security, and effectiveness of their respective nuclear weapon stockpiles.

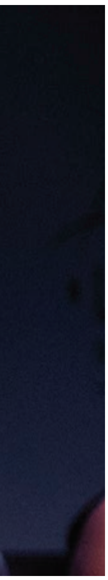
"It has been said many times that the United States and the United Kingdom share a special relationship, and our nuclear defense cooperation is one of the pillars of that relationship," said Secretary of Energy Rick Perry at a commemorative event in June. "The MDA has been central to our shared nuclear security goals, as well as nonproliferation research activities, and we look forward to continuing this vital partnership for decades to come."

A display in the Laboratory's J. Robert Oppenheimer Study Center highlights historical events and emphasizes the signing of the MDA in 1958.

QUOTED

"MAKE NO MISTAKE, Los Alamos is—and will continue to remain—the nation's plutonium center of excellence. The work that is done here is critical to our nation's nuclear security and central to our stockpile stewardship mission. All of your work contributes mightily to America's security as well as that of our allies and our friends. For all this and more, I am grateful indeed."

—National Nuclear Security Agency (NNSA) Administrator Lisa Gordon-Hagerty, who visited the Lab on April 6, 2018



THE QUESTION: WHAT ATTRACTED YOU TO LOS ALAMOS?

"In 30-plus years across the DOE complex, I've been to many sights, and Los Alamos National Laboratory is the pinnacle. I am honored to enable the mission of this Laboratory in the roll I serve here."

Cheryl Cabbil
ASSOCIATE DIRECTOR, NUCLEAR AND HIGH HAZARD OPERATIONS DIRECTORATE

"Many of us are patriotic and want to have some contribution to national security missions. The national laboratories are one of the few places—maybe the only places—left in the country where you can really do big things."

Dana Dattelbaum
PROGRAM MANAGER, EXPLOSIVES SCIENCE AND SHOCK PHYSICS

"The mission of the Lab is very important, and I wanted to work on something important. There are a huge number of opportunities here. If you're a scientist at Los Alamos, that opens doors."

Joyce Ann Guzik
LABORATORY FELLOW, NUCLEAR THREAT ASSESSMENT
(pictured at left)

"There's such exciting science going on here, and I love the passion that people bring to their jobs. I couldn't get over the passion and dedication every person had in the weapons program. And I think that exists across the Laboratory."

Carolyn Mangeng
LABORATORY DEPUTY DIRECTOR (RETIRED)

"My family has a lot of military history, and if you're way too sarcastic to serve in the military, this is a great place—it's all the service without the boot camp."

Kathy Prestridge
TEAM LEADER, EXTREME FLUIDS TEAM

"I was unsure about coming into the Lab, but there are so many opportunities here. If I feel like I need a challenge in my job, I can call a couple people and go in a completely different direction than what I'm in right now."

Jamie Van Winkle
PROGRAM MANAGER, PLUTONIUM STRATEGY INFRASTRUCTURE

5 UNDER 35

Weapons Programs isn't just for baby boomers.

BY SIERRA SWEENEY Approximately one-third of the Los Alamos workforce are millennials—and that number is growing, according to Laboratory Human Resources. "Millennials bring a new perspective, new ideas, and level of enthusiasm critical to the ongoing and long-term success of the nuclear weapons program," says Jon Ventura, Weapons Programs advisor. "With proper mentoring from experienced designers and engineers, they will ensure the safety, security, and effectiveness of the nation's deterrent for decades to come."

JESSICA ANN BAUMGAERTEL, STAFF SCIENTIST

After studying at the University of Washington and Princeton's Plasma Physics Laboratory, Baumgaertel wanted a career at a national laboratory. "I

graduated in 2012 with my Ph.D. and headed straight to Los Alamos," she says, noting she was hooked by the "breadth of research at the Lab, the opportunities for career growth, the history of the town, and the beautiful mountains." Baumgaertel works in the Primary Physics group in the Theoretical Design division where she underwrites the performance of nuclear weapons through the use of simulations and experiments.

CASEY SPAWN, R&D ENGINEER

After graduating from Montana State University, Spawn was drawn to the Laboratory while completing his capstone project and became hooked after building relationships and discovering opportunities at Los Alamos. "As an early career person, the Lab is a place with many opportunities ranging from continuing education to exposure to some of the world's foremost experts in their fields," Spawn says. "You aren't limited to a single career type here at the Lab. There are 600-plus groups, so there's always another option out there to switch things up!"

ANDREW FORD, PIT PRODUCTION WORKER

"What I do every day has a direct impact on our country's national security," says Ford, who is originally from Tacoma, Washington. Ford was introduced to nuclear weapons in

the Air Force, where he helped maintain them. He was later drawn to Los Alamos by its vital national defense work. "I wanted to work here because I thought it would be important and interesting work, which it very much is," he says. "As long as you're willing to learn, people are willing to teach."

PETER SCHULZE, RESEARCHER

A Los Alamos native, Schulze completed graduate school in Utah and then returned home to focus on the care and performance of the high explosive pentaerythritol tetranitrate (PETN). "I am a firm believer in the effectiveness of the deterrent," Schulze says, "so the fact that my work directly contributes to ensuring the viability of the stockpile is exciting and incredibly motivating." Schulze also states that his enthusiasm has

helped him succeed as a young employee at the Lab, allowing him to participate in various projects and receive funding to lead a research project of his own.

BILL PEACH, FOUNDRY ENGINEER

Born in Rolla, Missouri, Peach attended the University of Missouri and now enjoys the

cross-disciplinary collaboration at the Laboratory. "The exposure and opportunity to try out different tasks are here if you are willing to take them on," he says, noting the keys to success at the Lab are: take ownership, don't wait around, and admit when you are wrong. "It can be intimidating—there are so many great people here with such a vast breadth and depth of knowledge," he says. "It can be like trying to drink from a fire hose!"

BETTER SCIENCE = BETTER SECURITY

THE MANHATTAN PROJECT—DURING WHICH SCIENTISTS BUILT THE WORLD'S FIRST ATOMIC BOMB—LAID THE FOUNDATION FOR THE WORK LOS ALAMOS DOES TODAY.

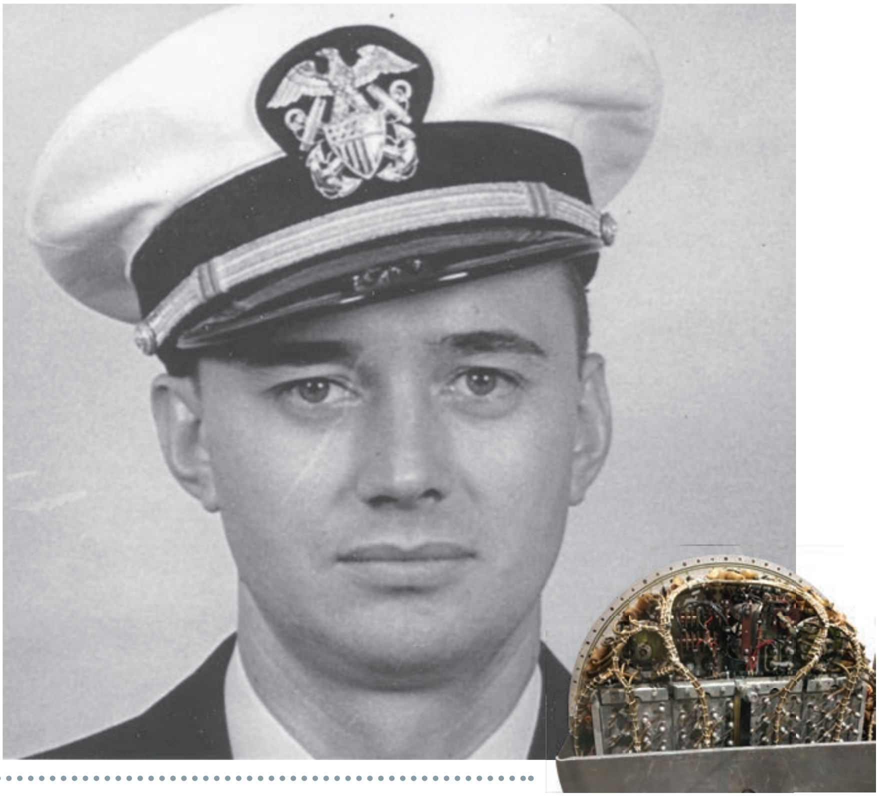
MANHATTAN PROJECT LEGEND TURNS 100

John Tucker celebrates a century.

BY SIERRA SWEENEY Wearing a suit and a bolo tie, John Tucker blew out the candles on his detonator-shaped cake. "You really put the icing on my 100th birthday cake," Tucker said to his audience at the May 8 private celebration at Los Alamos National Laboratory.

The crowd included members of the Detonator Science and Technology group and other Laboratory leadership who reflected on Tucker's 40-plus years of service to the national defense mission and his contributions to detonator science, which continue to support the safety and performance of the United States' nuclear weapons stockpile.

"Since the Manhattan Project, Tucker has made numerous contributions to the Weapons Programs, and his legacy continues to carry the day with two major references he authored," said event organizer Daniel Preston, referring to the *Los Alamos Detonator Catalog* and *Los Alamos Detonator History*, both of which are still in use today. "Our work today parallels those who came before us, and learning about the contributions of one of the founding fathers of detonator science is inspiring and motivating."



Recognized as a key member of the Manhattan Project, Tucker's contributions to detonator science are unparalleled. As a Naval officer during World War II, he served at Los Alamos and on the Pacific Island of Tinian as a member of Project Alberta, which ensured an atomic bomb could be successfully dropped by aircraft. For his part, Tucker designed bomb-handling equipment and wrote disassembly, inspection, testing and assembly check sheets. He personally selected the fireset (pictured) that armed Fat Man, the bomb used over Nagasaki on August 9, 1945.

After the war, Tucker returned to Los Alamos to lead the development of the Laboratory's Detonator Firing site, now known as TA-40. He spent the remainder of his career at the Lab, officially retiring in 1982 but staying active as a consultant for another decade. ★

IN MEMORIAM

One of the last living scientists involved in the Manhattan Project, Nerses "Krik" Krikorian, passed away on April 18, 2018, at the age of 97 at his home in Los Alamos. Krikorian began his career as a uranium chemist at Union Carbide in New York. After the war he made his way to Los Alamos, where he worked first as a scientist and then as an intelligence analyst until his retirement in 1991. He became a Laboratory Fellow in 1985 and was awarded the Los Alamos National Laboratory Medal in 2003.

Robert "Bob" Cowan passed away on July 25, 2018, at the age of 98. Cowan began his career at Los Alamos in 1951 and was a staff member for more than 30 years and then a Senior Laboratory Fellow. Cowan was awarded the Los Alamos Medal in 2008 and was internationally recognized as the "father of atomic structure calculations." He wrote one of the world's first general atomic structure computer codes that was used to understand and diagnose atomic spectra. Today, his codes and algorithms are still used extensively at the Laboratory and throughout the world.

BETTER SCIENCE = BETTER SECURITY

THE SCIENCE DONE AT LOS ALAMOS GIVES THE U.S. MILITARY CONFIDENCE THAT IT CAN RESPOND TO A THREAT WITH RELIABLE AND EFFECTIVE WEAPONS.

Director Terry Wallace (right) greets STRATCOM Commander John E. Hyten upon his arrival in Los Alamos. STRATCOM is one of nine unified commands under the Department of Defense. It is responsible for the global command and control of U.S. strategic forces to meet decisive national security objectives, providing a broad range of strategic capabilities and options for the president and secretary of defense.
*General Selva is pictured on page 1.

GENERALLY SPEAKING

Two of the most senior U.S. generals visited Los Alamos in recent months to speak to employees about how the Laboratory's work is essential to America's national security.

As part of the Laboratory's 75th anniversary activities, Vice Chairman of the Joint Chiefs of Staff General Paul Selva (USAF) visited the Laboratory on March 14. In a speech to employees, he stressed the importance of the strategic nuclear deterrent—and how it wouldn't exist without Los Alamos. The sailors, airmen, technicians, security personnel, and others who are responsible for the nation's nuclear weapons "recognize that they couldn't do what they do without the work you do every day," he said. "We stand on your shoulders."

He told the audience that, as vice chairman of the Joint Chiefs of Staff, he must be able to tell the president with confidence that the nation's nuclear weapons deterrent will perform as expected if ever required. "That confidence comes from meeting you first hand," he said.

In closing, he said the nation will maintain a technical advantage over its adversaries because of the cutting-edge technology that comes from the bright minds at Los Alamos. "I stand here representing two million uniformed personnel in the Department of Defense who know how important you are," he said. "We are keenly aware that the work you do gives us the confidence to say if we are ever threatened, we can respond."

These sentiments were echoed on May 23, when General John Hyten, commander of U.S. Strategic Command (STRATCOM), spoke to Laboratory employees about how critical the work of Los Alamos National Laboratory is to the security of the nation, specifically its role in ensuring the safety, reliability, and effectiveness of the nuclear stockpile. "What you do here is the most important work in the country," he said. "Deterrence starts and ends with nuclear weapons."

General Hyten also stressed the importance of giving scientists and engineers in the nation's nuclear weapons laboratories more freedom to do their work so the nation can be faster and more agile in response to threats. Additionally, he made clear that the Laboratory and STRATCOM must work together as partners to achieve the nation's defense priorities. "We are partners in the nuclear enterprise of the United States," he said. "My command is nothing without you." ★

FUTURE MILITARY LEADERS SPEND A SUMMER AT THE LAB

Service academy students work alongside scientists and engineers to help solve national security challenges.

BY SIERRA SWEENEY Every year, Weapons Programs advisor Jon Ventura travels to the nation's military service academies in Annapolis, Colorado Springs, and West Point to recruit young cadets and midshipmen to spend a summer working at Los Alamos National Laboratory.

"We run a very competitive selection process that brings us the very best students from the nation's service academies," Ventura says of the Laboratory's Service Academies Research Associates (SARA) program, which educates future military leaders about science and national security through hands-on research at the Lab. "The program provides future military officers with their first exposure to leading-edge scientific, engineering, and computational tools—and to the people who allow the Laboratory to answer the most difficult national security problems."

During the summer of 2018, Air Force Academy Cadet Claire Badger focused on computer vision algorithms at the Lab. "My interests in computer science and cyber have been renewed, and it's good to see the applications of computer science in the real world," Badger says. "I'm so thankful to have had this experience and to have had my curiosity ignited thanks to Laboratory staff."

Other cadets and midshipmen have contributed to Dual-Axis Radiographic Hydrodynamic Test (DARHT) experiments, the Shock and Detonation Physics group, and stockpile life-extension programs at the Laboratory.

Army Cadet Mary Clare Cassidy is a junior and an electrical engineering major at West Point who researched atom interferometry at the Lab. "I learned new approaches and techniques and increased my ability to tackle difficult problems," she says. "Solutions to national security challenges need to be functional. It's important that military leaders convey functionality when presenting the Lab with problems. It is equally as important that scientists try to understand that constraint when supporting the military."

Involving young cadets and midshipmen in scientific work to build an understanding and appreciation of the Laboratory's role in national security not only benefits Laboratory relations, but also the future endeavors of all students who participate.

Air Force Lieutenant Colonel Erik Johnson worked as a SARA student in 1999 and attributes much of his military success to the experience he gained through the program. "The perspective I gained as a LANL student helped guide my actions as a B-52 weapons squadron commander in 2015." He also notes that the program is valuable for helping "military members see the patriotism of the DOE members who sustain our nuclear capability." ★

Success of the SARA program is largely due to the mentors across the Laboratory, including: Greg Archbold, Jessica Baumgaertel, Jeremy Best (far right), Millicent Firestone, Tim Goorley, Jennifer Harris, Juston Moore, Robert Reid, Chris Scully, Avneet Sood, Bryce Tappan, Laurie Triplett, and many others.

To apply to SARA, visit lanl.gov/sara

To be a SARA mentor, email jonathan_v@lanl.gov

The Laboratory remembers Army Captain Daniel Lehman, who was a SARA student in 2011. Captain Lehman double majored in nuclear physics and philosophy at West Point. He died unexpectedly in Colorado Springs on September 15, 2018.

DEVELOPING THE ANNUAL ASSESSMENT

Though penned in the director's office, the annual weapons assessment letter is the result of an entire Laboratory workforce.

Laboratory Director Terry Wallace at his desk in the National Security Sciences Building (pictured at right).

BY TERRY WALLACE, LABORATORY DIRECTOR

On September 23, 1992, the United States conducted Divider, an underground test at the Nevada Test Site. The Los Alamos–designed test was the nation's 1,030th—and final—nuclear weapons test, marking the end of an era that began with the Trinity test 47 years prior.

In 1995, President Clinton announced the intent to sign the Comprehensive Test Ban Treaty (CTBT), which would permanently eliminate testing, with a caveat: The United States reserved the right to withdraw from the CTBT for reasons of supreme national interest.

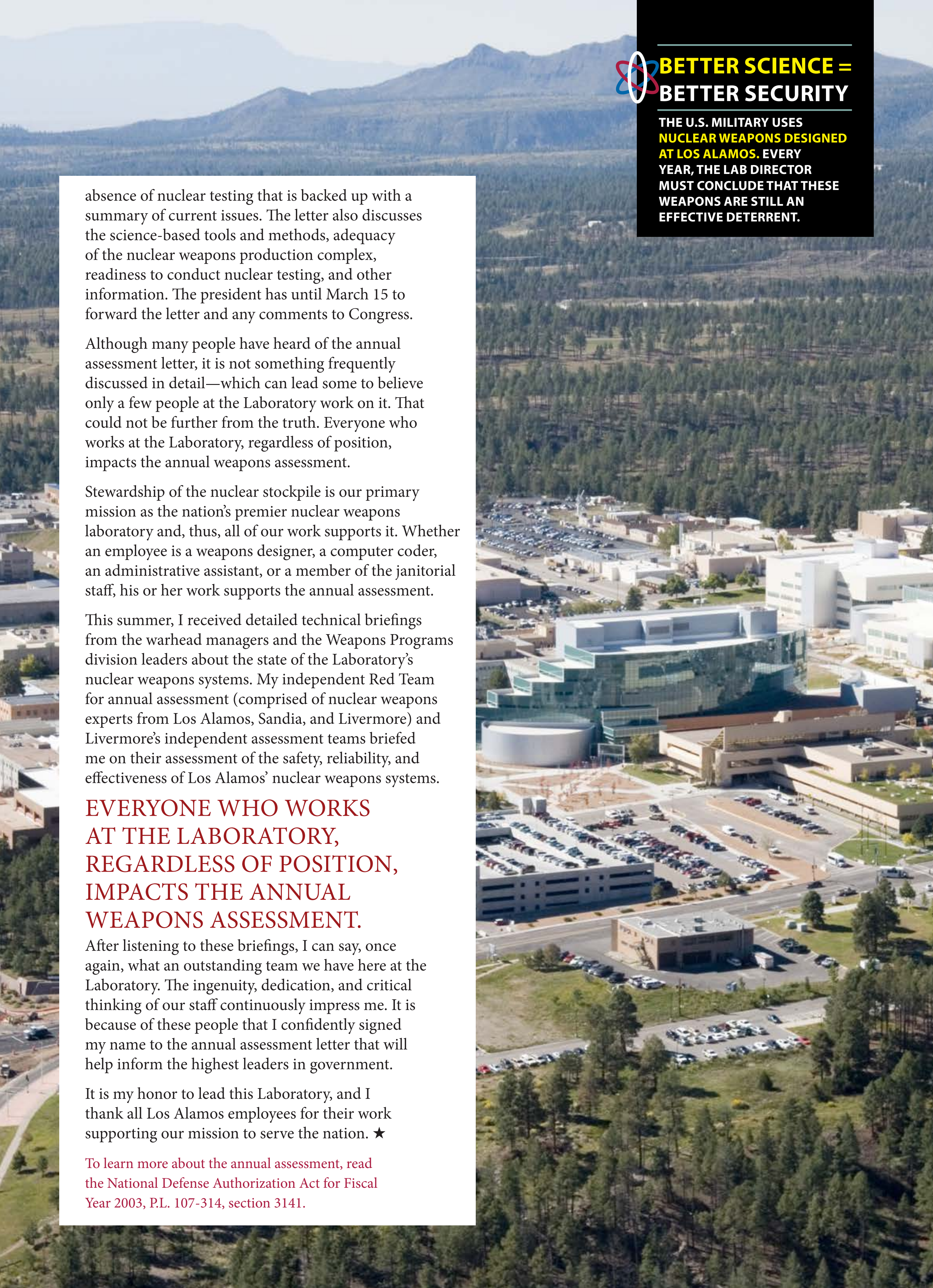
The cessation of nuclear testing presented an extraordinary challenge: With no full-scale nuclear testing, how could the nation know that our nuclear weapons would work?

As stockpile stewardship—a science-based program of experiment and simulation to replace actual testing—developed, so did an annual assessment process that requires the Laboratory directors at Los Alamos, Livermore, and Sandia to complete an assessment of the safety, reliability, and effectiveness of each nuclear weapon type in the active stockpile. Los Alamos and Sandia jointly develop and issue annual assessment reports on each warhead and bomb for which they are responsible—the B61, W76, W78, and W88. These warheads, however, are decades old. How can we be confident that an aging warhead will still deliver the expected results?

The answer lies in the Laboratory's extensive expertise in modeling and simulation, physics, chemistry, and a whole host of other scientific and technological capabilities. Los Alamos has spent the 26 years since the end of nuclear testing developing the tools required to understand at the subatomic level what happens to materials and components as they age. It is this information that feeds into the annual assessment and allows me to conclude, with confidence, that the nation's strategic nuclear deterrent is reliable.

One of my most important jobs as director of Los Alamos National Laboratory is to provide this assessment, which comes in the form of letter to the president (via the secretaries of Energy and Defense) every September. The specifics in the letter cannot be changed by anyone once it is issued from Los Alamos.

The letter contains a statement regarding the ability to maintain warhead and bomb certification in the



BETTER SCIENCE = BETTER SECURITY

THE U.S. MILITARY USES NUCLEAR WEAPONS DESIGNED AT LOS ALAMOS. EVERY YEAR, THE LAB DIRECTOR MUST CONCLUDE THAT THESE WEAPONS ARE STILL AN EFFECTIVE DETERRENT.

absence of nuclear testing that is backed up with a summary of current issues. The letter also discusses the science-based tools and methods, adequacy of the nuclear weapons production complex, readiness to conduct nuclear testing, and other information. The president has until March 15 to forward the letter and any comments to Congress.

Although many people have heard of the annual assessment letter, it is not something frequently discussed in detail—which can lead some to believe only a few people at the Laboratory work on it. That could not be further from the truth. Everyone who works at the Laboratory, regardless of position, impacts the annual weapons assessment.

Stewardship of the nuclear stockpile is our primary mission as the nation's premier nuclear weapons laboratory and, thus, all of our work supports it. Whether an employee is a weapons designer, a computer coder, an administrative assistant, or a member of the janitorial staff, his or her work supports the annual assessment.

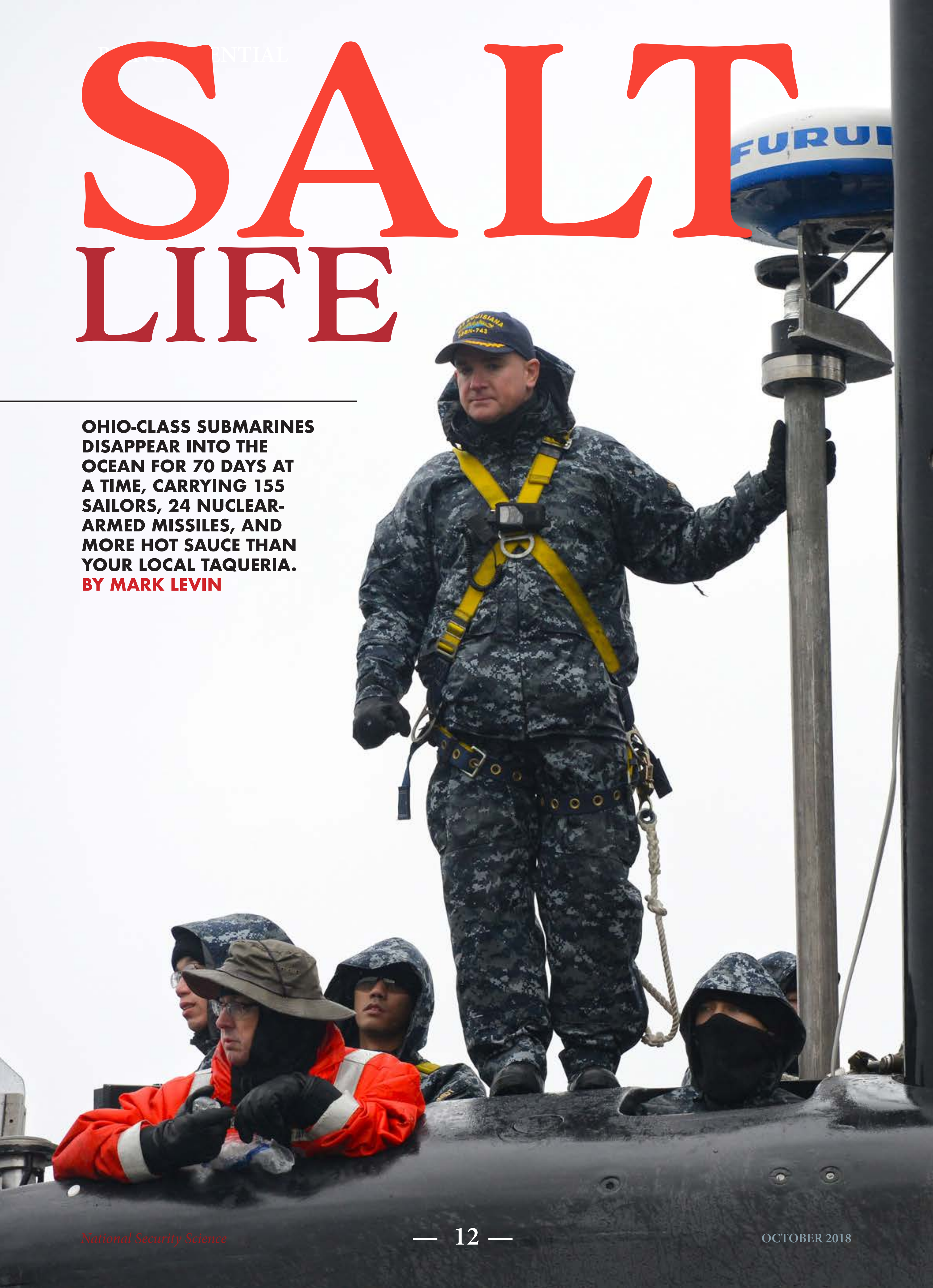
This summer, I received detailed technical briefings from the warhead managers and the Weapons Programs division leaders about the state of the Laboratory's nuclear weapons systems. My independent Red Team for annual assessment (comprised of nuclear weapons experts from Los Alamos, Sandia, and Livermore) and Livermore's independent assessment teams briefed me on their assessment of the safety, reliability, and effectiveness of Los Alamos' nuclear weapons systems.

EVERYONE WHO WORKS AT THE LABORATORY, REGARDLESS OF POSITION, IMPACTS THE ANNUAL WEAPONS ASSESSMENT.

After listening to these briefings, I can say, once again, what an outstanding team we have here at the Laboratory. The ingenuity, dedication, and critical thinking of our staff continuously impress me. It is because of these people that I confidently signed my name to the annual assessment letter that will help inform the highest leaders in government.

It is my honor to lead this Laboratory, and I thank all Los Alamos employees for their work supporting our mission to serve the nation. ★

To learn more about the annual assessment, read the National Defense Authorization Act for Fiscal Year 2003, P.L. 107-314, section 3141.



SALT LIFE

OHIO-CLASS SUBMARINES DISAPPEAR INTO THE OCEAN FOR 70 DAYS AT A TIME, CARRYING 155 SAILORS, 24 NUCLEAR-ARMED MISSILES, AND MORE HOT SAUCE THAN YOUR LOCAL TAQUERIA.

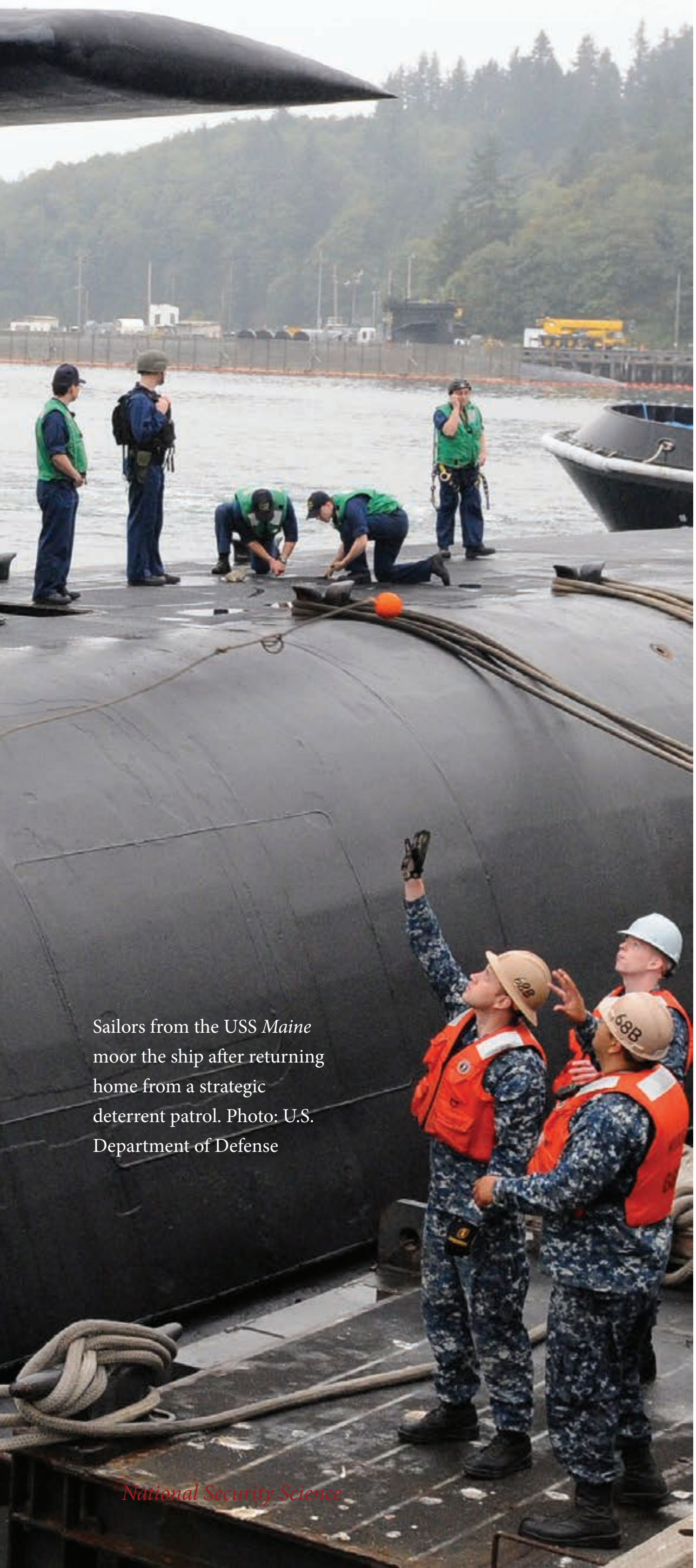
BY MARK LEVIN

BETTER SCIENCE = BETTER SECURITY

CARRYING 24 MISSILES ARMED WITH LOS ALAMOS–DESIGNED NUCLEAR WARHEADS, OHIO-CLASS SUBMARINES DEMONSTRATE THAT THE U.S. HAS AN ASSURED SECOND-STRIKE CAPABILITY—A SURVIVABLE SYSTEM FOR CARRYING OUT RETALIATORY NUCLEAR ATTACK.

The USS *Louisiana*, an Ohio-class ballistic missile submarine, returns to Naval Base Kitsap after a strategic deterrent patrol. Photo: U.S. Navy

KEY WORDS: D5 missiles, Nuclear Posture Review, strategic deterrence, nuclear warheads



Sailors from the USS *Maine* moor the ship after returning home from a strategic deterrent patrol. Photo: U.S. Department of Defense

8 a.m.

HOOD CANAL, PUGET SOUND, WASHINGTON

When the weather is cooperating, officer of the deck is the best job on the planet, and that is my assignment today onboard the USS *Nebraska* nuclear-powered, nuclear-armed Ohio-class submarine (SSBN).

Standing exposed on the bridge at the very top of the submarine's giant tower, my job is to "drive" the submarine out of our homeport, Naval Base Kitsap, through the watery network west of Seattle that empties into the Strait of Juan de Fuca, and then into the Pacific Ocean, where the boat will slip underwater. I feel an underlying excitement that is rivaled only by the feeling returning home will give me, 70 days from now. I feel alive.

Driving the submarine means I am responsible for the safe navigation of the ship; I "steer" the ship by giving rudder orders to the helm (the person who turns a wheel to position the rudder). Because the helm sits below deck and I am on the bridge above deck, the experience of driving the submarine is often compared to blindfolding the driver of a car while a passenger stands through the sunroof and instructs the blindfolded driver how fast to go and which direction to turn.

I order one prolonged blast on the ship's whistle and we are underway, embarking on a 10-week strategic deterrence mission. Carrying 24 Trident II D5 submarine-launched ballistic missiles (SLBMs) armed with Los Alamos–designed nuclear warheads, the *Nebraska* will prowl the depths of the ocean, its exact location unknown to everyone but its crew. Our mission is to remain hidden at sea with our SLBMs, so as to deter a nuclear attack on the United States by demonstrating to other countries that the United States has an assured second-strike capability—a survivable system for carrying out a retaliatory nuclear attack.

Looking down, the top of the submarine's black steel hull stretches ahead of and behind me, totaling nearly two football fields in length. We approach our dive location—the point at which we'll submerge—on time. To dive the ship, crewmembers must rig the submarine for dive, which means each component that is exposed to water must be positioned and sealed correctly, checked by an enlisted person, and checked again by an officer. Because this task is so huge, the *Nebraska* started its rig yesterday.

I begin rigging the bridge for dive with an enlisted lookout. We have done this task many times together, sometimes even in the dark, so we move quickly. As I climb down the long, vertical ladder from the bridge into the belly of the submarine, I check the bottom hatch and announce, "Last man down, hatch secure!"

ADDING HOT SAUCE MAKES ANYTHING EDIBLE. HOT SAUCE IS RELIGION ONBOARD A SUBMARINE.

As the submarine descends slowly below the surface, the crew shifts quietly into its new normal: the underway routine.

As we descend, I feel the boat rolling gently in the surface waves and know the slight rocking will dissipate as we lower to patrol depth. But even deep underwater, a submarine moves more than most people think, and I can recall multiple times an entire crew has been seasick—but thankfully today is not that type of day.

My next stop is the "sonar shack," a tiny room with no lights. Behind the closed door, five watchmen monitor for slight changes on sonar displays. These glowing electronic screens graphically display underwater sounds that are picked up by the boat's sensors (sonar technicians can also use headphones to listen to the raw sounds). The crew relies on these displays to provide clues about the surrounding aquatic environment—sonar (short for SOund NAvigation and Ranging) is essentially the eyes and ears of the submerged boat. I have spent years developing my skills at reading sonar displays, but our sonar technicians have far superior abilities. Despite today's modern

navigation equipment, one of the best direction-finding instruments onboard is the experienced sonar technician's ear.

Before departure, the officers and navigation team have a good idea of where the patrol is headed. The mission is not necessarily to lurk ominously offshore of other countries but rather to remain undetected in the depths of the ocean.

The navigation team updates the number of miles traveled every day. There's not much interest from the rest of the crew in total miles traveled or our location. Most crewmembers are content to know we are somewhere, undetected, in the 64-million-square-mile Pacific Ocean. (By contrast, subs that depart from the base in Kings Bay, Georgia, patrol the smaller, 41-million-square-mile Atlantic Ocean.)

Of course, no matter our location, one crucial part of our mission always remains the same: to launch nuclear missiles only when authorized by the president. If ordered, the 24 Trident II D5 missiles onboard this sub are launched underwater and, after breaking the surface, travel at 15,000 miles per hour to reach nearly anywhere in the world. We have the power to destroy an adversary's military, infrastructure, and everything in between. As the sea-based delivery system of America's nuclear triad, Ohio-class subs also have a greater chance of survival from a first strike. Once an SSBN goes to sea, it is a high-priority target for other nations, so staying undercover is crucial for our safety.

I've always felt everyone onboard understood the gravity of the mission and accepted responsibility for his or her part of the mission. I came to terms with my role before my first patrol nearly a decade ago, and I am ready to play my part in launching a nuclear weapon if asked.

Authorization to launch would come in an Emergency Action Message from the president

that two junior officers would decode. (Junior officers have just completed the Navy Nuclear Training pipeline and Submarine School and are reporting to their first submarine.) In order to launch, the two junior officers, an executive officer, and the commanding officer (CO) must agree that the message is authentic. The CO would then authorize the launch, and the weapons officer would pull the trigger that launches the missile.

Only some of the nation's nuclear-armed submarines are on alert (ready to launch nuclear missiles) at any given time. However, those not on alert are still fulfilling a vital mission because they can transition to alert status within 24 hours.

ALTERNATE REALITY

Submarines don't have windows, so crewmembers have no sense of time of day (not that windows would help tell time in the dark depths of the ocean). Instead, our day is illuminated by fluorescent lights and structured by eight-hour rotations punctuated by meals. For example, I'm on watch for eight hours, I perform routine maintenance or have free time for eight hours, and I sleep for eight hours.

The meals are the biggest clue to the time of day. We eat breakfast, lunch, dinner, and—everyone's favorite—midrats. Midrats, short for "midnight rations" is the midnight meal and consists mostly of leftovers from lunch and dinner. Corn dogs are universally accepted as the ideal midrats treat, and morale peaks when corn dogs are served. If the word spreads quickly enough, some crewmembers will wake up in the middle of the night just to eat corn dogs.

Our submarine's half-dozen cooks prepare these four meals in a broom-closet-sized galley (kitchen) using only a grill, two ovens, two fryers, and four steam kettles. The cooks serve food cafeteria-style to the 140 members of the enlisted crew, who must eat quickly because the seating area has only a 36-person capacity. The 15 officers eat in the 10-person wardroom, where food is served family style with dishes passed around the table. Although the locations are separate, the food is the same for all crewmembers.

The food taken onboard before we are underway is all that's available for 70 days (to remain undetected, the submarine isn't restocked at any point during patrol). Fresh fruits, vegetables, and milk last about seven days. Eggs are wax coated, stored in a frigid room with ventilation fans and cooling coils, and supposedly last 45 days. In my opinion, you are rolling the dice if you choose the egg selection at breakfast after day 14.

After all the fresh food has been consumed, the frozen and canned stash is opened—at which point food becomes known only by its color.

NO MATTER OUR LOCATION, ONE CRUCIAL PART OF OUR MISSION ALWAYS REMAINS THE SAME: TO LAUNCH NUCLEAR MISSILES ONLY WHEN AUTHORIZED BY THE PRESIDENT.

Question: "What vegetable is that?"

Answer: "That is the green option."

The green option is most likely broccoli, asparagus, or spinach, but it doesn't matter because all green vegetables are boiled into the same tasteless slime. Fortunately, adding hot sauce makes anything edible. Hot sauce is religion onboard a submarine.

Procuring hot sauce for the officers is entrusted to the newest officer and is a very important duty. Before departure, the new officer must figure out what flavors and levels of hotness will ensure the morale of the other officers remains high. A smart procuring officer asks what everyone prefers; a cocky one may assume he knows best. If the officer chooses poorly, he will be endlessly hassled until he turns the job over to the next new guy. It's a learning experience.

Thankfully, on this patrol, we are fully stocked with sriracha and my favorite, Frank's Red Hot Original Cayenne Pepper Sauce.

SSBN is the Navy hull classification symbol for a nuclear-powered, ballistic-missile-carrying submarine. The SS denotes "submarine," the B denotes "ballistic missile," and the N denotes "nuclear powered." Here, the USS *Maine* returns to Naval Base Kitsap. Photo: U.S. Department of Defense

SSBNs of the future

The 2018 Nuclear Posture Review outlines a path forward for America's sea-based deterrent.

BY JUSTIN WARNER Ohio-class ballistic missile submarines (SSBNs) form the undersea component of the strategic nuclear triad, complemented by air-based gravity bombs and cruise missiles and land-based intercontinental ballistic missiles (ICBMs). The triad is at the heart of American nuclear strategy and is meant to ensure a diverse and flexible nuclear deterrent amidst evolving global threat conditions.

The 2018 Nuclear Posture Review (NPR), a policy document released by the Department of Defense, outlines the United States' nuclear outlook and enumerates related strategic concerns. The 2018 NPR notes that much of today's nuclear triad was deployed in the 1980s or earlier and recommends that the United States modernize its arsenal to accommodate a tailored nuclear deterrence strategy. To this end, the document envisions a path forward for the SSBN fleet.

The United States currently operates 18 Ohio-class submarines, 14 of which are designated as nuclear-capable SSBNs. These submarines range in age from the USS Jackson, commissioned in 1984, to the USS Louisiana, commissioned in 1997. The 2018 NPR ensures Ohio-class SSBNs will remain "operationally effective and survivable" until they can be replaced, one per year, once the next generation of SSBNs—Columbia-class submarines—can assume its deterrence role in 2031. The Columbia-class submarine is still in development but is expected to deploy a host of advanced technologies and cost-saving measures, such as a "life-of-the-ship" nuclear fuel core requiring no mid-life nuclear refueling.

Through the 2020s, Ohio-class SSBNs will serve to assure allies and deter potential adversaries with a powerful arsenal of submarine launched ballistic missiles (SLBMs). Each Ohio-class submarine can carry up to 24 Trident II D5 missiles, with each missile capable of delivering up to 12 independently targetable thermonuclear warheads. The missiles carry two types of warheads, both designed by Los Alamos National Laboratory: the W76 and the W88. Trident D5 missiles have a range between 4,500 and 7,500 miles. The missiles will accompany SSBNs until 2042, which is the end of service life for both the missiles and Ohio-class SSBNs.

Apart from the Trident D5, the 2018 NPR describes plans to introduce new armament to patrolling SSBNs in the near and long term. In the near term, the United States plans to modify existing SLBM warheads to provide a low-yield nuclear option. A low-yield option, according to the 2018 NPR, will "raise the nuclear threshold and help ensure that potential adversaries perceive no possible advantage in limited nuclear escalation, making nuclear employment less likely." In the longer term, the United States plans to develop a modern nuclear-armed sea-launched cruise missile (SLCM). The NPR explains that "a low-yield SLBM warhead and SLCM will not require or rely on host nation support to provide deterrent effect" and will provide "additional diversity in platforms, range, and survivability, and a valuable hedge against future nuclear 'break out' scenarios."

SSBN's constant readiness, mobility, and global range make them invaluable assets to the deterrence strategy of the United States. There are no known, near-term credible threats to the survivability to the SSBN force, so one can expect SSBN crews to be patrolling the oceans for decades to come. ★

OHIO-CLASS SUBMARINE STATS

Built by: General Dynamics Electric Boat Division

Date deployed: 1981

Length: 560 feet

Beam: 42 feet

Displacement: 18,750 tons submerged

Speed: more than 20 knots (23 miles per hour)

Armament: 24 tubes for Trident II D5 missiles, four torpedo tubes

Inventory: 18 (14 are nuclear-capable)

Crew: 155 officers and enlisted personnel

TRIDENT II D5 MISSILE STATS

Built by: Lockheed Missile and Space Company

Length: 44 feet

Weight: 130,000 pounds

Diameter: 83 inches

Range: More than 4,600 miles

Speed: 15,000 miles per hour

Ceiling: 700 miles

Armament: Multiple independently targeted reentry vehicles with W76 or W88 warheads

Date deployed: 1990

COLUMBIA-CLASS SUBMARINE STATS

Building begins: 2021

Expected deployment: 2031

Length: 560 feet

Beam: 43 feet

Displacement: 21,000 tons submerged

Armament: 16 tubes and Trident II D5 missiles

Inventory: 12

Crew: 155 officers and enlisted personnel

In November 2015, the USS Kentucky launched an unarmed D5 missile in the Pacific Test Range off the coast of southern California that was visible from San Francisco. Photo: Abe Blair

LAW OF FINITE HAPPINESS

Today—and every day—I wear the uniform set by the CO: navy blue, U.S. Navy-issued coveralls. My Asics running shoes are the only optional part of the uniform (along with the University of Illinois T-shirt underneath my coveralls, but no one can see that). Shoe choice is based on comfort, durability, and style. Above all, the shoe must be able to survive the patrol, which means surviving oil, water, and solvents that might leak from equipment.

Hats are not required, but we are allowed to wear them. Most crewmembers wear ball caps of their favorite sports team, which says a lot about people and where they're from. The submarine receives limited radio messages; the messages that do come sometimes include sports scores. The folks relaying the scores do not always share our enthusiasm for this "holy grail" of message traffic and frequently cause undue heartache when scores are incorrectly reported.

Ball caps can also invoke the Law of Finite Happiness during playoff seasons. The Law of Finite Happiness is a fact of human interaction and occurs on all submarines only after all watertight hatches have been closed. The law dictates that only a finite amount of happiness is stored inside each person onboard a submarine. When one submariner "steals" happiness from another, he becomes stronger and the other person becomes weaker.

> **I AM READY TO PLAY MY PART IN LAUNCHING A NUCLEAR WEAPON IF ASKED.**

The law commands that submariners have a thick skin and not show emotion. For example, if one submariner mocks another about his hat choice, the submariner being pestered cannot show any signs of it bothering him, or the tormenting will continue, and the person doing the mocking will tell everyone else so they can join in.

Thankfully, I am a St. Louis Cardinals fan and have enjoyed many a successful baseball season and therefore plenty of happiness.

SEMPER GUMBY

Living quarters onboard an Ohio-class sub are the largest the submarine fleet has to offer, but they are still small. Enlisted quarters are located in the submarine's missile compartment, almost as if crew berthing was an afterthought in submarine design. Three racks (beds) are stacked on top of one another, and nine racks are nestled between large metal missile-launch tubes. Rack curtains, which are pulled across the length of the rack, provide some privacy although they do not block sound.

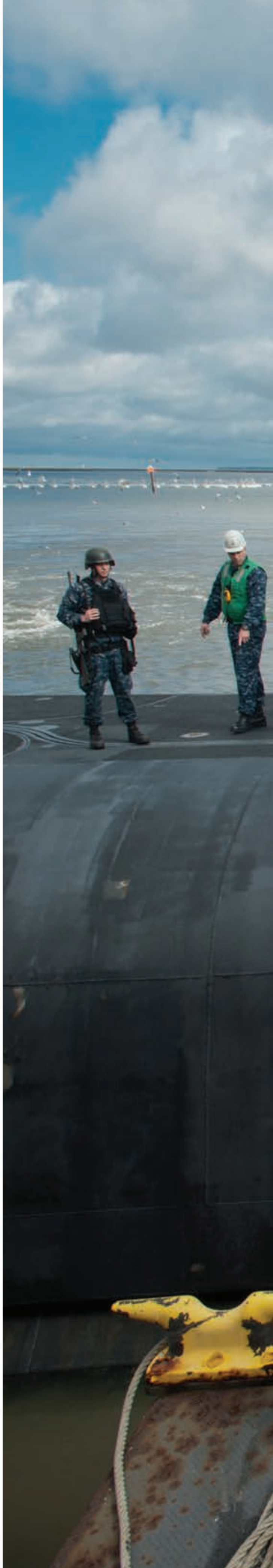
Everything a crewmember needs for an underway, including toiletries, clothing, and uniforms, must fit in a rack pan underneath the mattress. Careful planning is required to fit everything you could potentially need for 70 days. There is no convenience store underway, so whatever you forgot, you have to live without or get from someone else.

Officer quarters—aka staterooms, although that word makes them sound more glamorous than they are—are located in front of the crew quarters. Although I am fortunate to have more space than the enlisted men, I still share a cramped room with two other officers.

Although the *Nebraska* does have a large movie and library collection, many sailors bring their own entertainment. My rack pan is filled with music and books. To save space, I've opted for digital media, listening to songs on my iPod and reading my favorite Joseph Conrad novels on a tablet. I've seen crewmembers install an Xbox and television in their cramped sleeping area. They'd rather have their own video games, even though it means sleeping curled up in a small ball on one end of the bed.

Sleep is the most precious commodity onboard the submarine, and submarine culture is steeped in sleep lore. Some legendary junior officers have somehow managed to write themselves off the watch bill (not when they are really needed, of course) and claim to have spent 24 hours in the rack on a submarine. I have never experienced that bliss.

The flip side is hot racking—when two enlisted crewmembers have to share a bed, but not at the same time. When one person is on watch, the other person is sleeping in the bed, and then they switch. Imagine doing that for two months at a time, not to mention also having to share a rack pan. Hot racking is definitely not the norm, but depending on the mission, more crew might



After a long deployment, the USS *Tennessee* returns to its homeport at Naval Base Kings Bay. Photo: U.S. Navy

IF NO ONE EVER KNEW WHAT WE DID, IT WAS A SUCCESSFUL PATROL.

be required for training reasons or for support operations.

Sleep is sometimes interrupted when something breaks on the ship, and the crew has to perform repairs. There is not a deep-sea tow truck to bring a submarine back to port, so it's all hands on deck when something goes wrong. Problems can range from a light that's stopped working to a complete loss of communications.

"Semper Gumby" is a phrase commonly heard around the submarine. Loosely translated, it means, "always be flexible." In the more than three years (total amount of undersea time) I have spent underway, something has always broken—but I have never once thought the crew couldn't fix it. Each crew onboard a submarine has specialists, such as sonar technicians, radiomen, and nuclear mechanics, who can solve just about any problem imaginable.

HOMECOMING

We begin counting down the days left on patrol when we have 24 days to go. Some of the guys have fashioned a model of our boat out of discarded parts and duct tape. We hang the unwieldy reproduction on missile tube 24. The next day, the model moves to tube 23, and so on.

The anticipation is really apparent about a week before our return to port. As an officer, I worry about keeping the guys on task so we can get safely home, but the last week always seems to fly by, and finally it is homecoming day. We surface a few hours from Bangor, and every crewmember is assigned a specific job until we dock. The crew is in high spirits because pulling into the pier with family waiting is the best feeling. Unfortunately, that is not the case today. The boat has some maintenance issues that crewmembers must fix, and families have been asked not to wait on the pier.

I am one of the last to leave the sub, but my wife is waiting when the bus drops me off in

The USS *Wyoming* at sea. Photo: U.S. Navy

the same desolate parking lot where this whole adventure started at 2 a.m., 70 days ago. I feel satisfied with my last patrol and what I have accomplished during this three-year tour: I am fully qualified and fairly proficient as an officer of the deck, I am a qualified nuclear engineer, and I have successfully trained my replacement. My job is complete, and I am ready to begin my next assignment: shift engineer at the Nuclear Training Unit in Charleston, South Carolina.

As my wife drives me home, she talks about everything that has happened in her world during the past 10 weeks, and I feel myself slipping back into a "normal" life. We don't talk much about my patrol, which is fine by me. I always thought that if no one ever knew where we were or what we did, it was a successful patrol. I don't need praise from the public or from politicians—our admirals always provide all the praise we need. The submarine community is closed to the outside, and I like it that way. Most of the crew also feel this way. Maybe submariners are a strange breed, but it works for our mission.

On the highway, we pass a pick-up truck with a "Salt Life" window sticker, and I laugh. If submarines had windows, that sticker would be perfect. ★

An unarmed Trident II D5 missile launches from the Ohio-class ballistic missile submarine USS *Nebraska* off the coast of California. Photo: U.S. Navy

ABOUT THE AUTHOR

MARK LEVIN served in the U.S. Navy for 20 years. He enlisted as a submarine electrician after his junior year of college. "By sheer chance or fate, I bumped into a Navy recruiter, and he convinced me that seeing the world from a submarine was the next logical step," remembers Levin, noting that he did not join the Navy to go on an Ohio-class submarine. "I joined to go on a fast-attack submarine, cruising the world and pulling into foreign ports, which I did do much later in my career."

Since April 2016, Levin has worked at Los Alamos National Laboratory, where he leads the team that operates and repairs the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility accelerators.

Turn the page to learn more about DARHT.

A DAY AT

TO EVALUATE HOW A B61 GRAVITY BOMB MIGHT PERFORM AT HIGH TEMPERATURES, SCIENTISTS USE DARHT, THE WORLD'S FASTEST X-RAY MACHINE, TO TAKE RADIOGRAPHS OF A MOCK-NUCLEAR WEAPON IMPLOSION. THE RADIOGRAPHS TAKE ONLY A FEW MICROSECONDS, BUT SHOT DAY IS A LONG, TEDIOUS CULMINATION OF MORE THAN 18 MONTHS OF HARD WORK.

BY WHITNEY SPIVEY

BETTER SCIENCE = BETTER SECURITY

SCIENCE-BASED STOCKPILE STEWARDSHIP COMBINES SCIENTIFIC AND EXPERIMENTAL CAPABILITIES (SUCH AS THOSE AT DARHT) WITH HIGH-PERFORMANCE SUPERCOMPUTING SIMULATIONS TO ENSURE THE WEAPONS IN AMERICA'S NUCLEAR STOCKPILE WILL WORK.

ARHT

DARHT's two accelerators (Axis 1 is pictured here) produce intense, high-energy electron beams that generate X-rays.

KEY WORDS: B61 Life Extension Program, hydro tests, radiographs, stockpile stewardship

On the afternoon of Monday, May 21, the skies opened up and nearly an inch of rain—and in some places, hail—pounded the dry and dusty Pajarito Plateau. Amid thunderclaps and lightning strikes, the parched earth soaked up the first precipitation in 55 days, the first of the summer monsoons that might curb the chronic drought conditions plaguing Northern New Mexico.

In the middle of the plateau, on a narrow mesa pinched between Water Canyon and Cañon de Valle, operations at Los Alamos National Laboratory's Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility ground to a halt. After a productive day and a half of setting up an experiment—during which time a crane lowered a high-explosive test device into a spherical confinement vessel on an exposed concrete pad—the facility operations manager deemed the weather too dangerous to continue preparations.

And so the roughly $7.5 million experiment was postponed until Thursday, May 24.

At 8 a.m. on that Thursday, 58 people—50 men and 8 women—gathered in the DARHT accelerator control room for roll call. Nearly all of them wore jeans with sneakers or hiking boots. A few wore tropical-print Hawaiian shirts, and a few more wore suspenders—the unofficial dress code for the day. Some stood and sipped coffee while others sat in rolling office chairs and ate breakfast burritos. Along the room's perimeter, 73 screens lit up with numbers and graphs and live feeds of the facility's firing point.

Terry Priestley, the operations manager, stood in the south corner and called each person's name before explaining that from this point forward, no one would be allowed to leave the building. Then he turned to Omar Wooten, a short bespectacled physicist who looks like he graduated college much more recently than 2000.

"Omar," Priestley said, "Can you please tell us why we are here today?"

THE B61 BACKSTORY

Wooten's answer—to take radiographs of a hot B61—has a complicated backstory that most people in the room already knew.

In 1963, Los Alamos designed and engineered the B61, a thermonuclear gravity bomb that can be dropped by a plane at high speeds from as low as 50 feet. Most B61s were produced in the 1970s with a life expectancy of 10 years. Decades later, however, the B61 is still part of America's nuclear weapons stockpile.

The B61 is currently undergoing a life-extension program (LEP) at Los Alamos in partnership with other nuclear weapons laboratories to convert four versions of the bomb (models B61-3, -4, -7, and -10) into a single, updated version: the B61-12. By refurbishing key components through a combination of reuse, redesign, and remanufacturing, the LEP will help ensure that the B61 remains a safe, secure, and effective part of the stockpile until at least 2040.

To explain why the LEP is necessary, Wooten, the lead physicist on this particular DARHT experiment, compares the B61 to a 1964 Ford Mustang. "If you were to go to Ford to get new parts for your antique car, you'd have a problem," Wooten says. "Those parts don't exist anymore. Materials have changed. Rules about emissions and safety have also changed—what was OK in the '60s isn't up to current standards."

The same is true for the B61. Like parts of an antique car, weapons components degrade with age. Metals corrode and fatigue, plastics become brittle and crack, rubber dries out and crumbles, and adhesives no longer bond. But these weapons are still expected to work, and it's the job of Los Alamos scientists to make sure each part of the weapon functions appropriately. "If we are going to change something about the B61, we need to make sure it performs correctly," Wooten explains. "We are trying to characterize how the system performs as we introduce these new components."

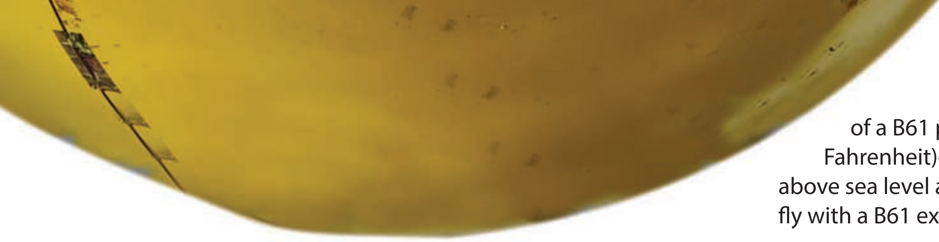
But how can scientists be certain that a refurbished weapon works as well as the original?

The obvious answer is by testing the weapon, but the Comprehensive Nuclear Test-Ban Treaty has prohibited nuclear testing since 1992. (Although the United States did not ratify the treaty, President Bill Clinton signed the treaty, and America has not tested a nuclear weapon for more than 26 years.)

In lieu of testing, Los Alamos and other nuclear weapons laboratories developed the science-based Stockpile Stewardship Program, which combines scientific and experimental capabilities with high-performance supercomputing simulations. These simulations, however, are only as good as the data that go into them. These data come from a variety of experiments, including the experiments performed at DARHT.

SOME LIKE IT HOT

DARHT is only a seven-mile drive from the Laboratory's main technical area, but those seven miles encompass two security checkpoints, an elk-filled ponderosa pine forest, and a view from the DARHT parking lot that stretches east across



the entire Rio Grande Valley to the peaks of the Sangre de Cristo mountains some 30 miles away. In other words, the facility feels quite remote.

That feeling doesn't go away inside DARHT. The building itself is an explosives bunker: thick walls, no windows, no personal cell phones. On the day of an experiment, once you're in, you're in. Most of the people who arrived there early on the morning of May 24 were there for more than 10 hours.

Which is why there was so much food. Chips, salsa, hummus, popcorn, cheesecake, and cupcakes covered three folding tables pushed together in the kitchenette area. Well before noon, someone started passing around Spam sushi, and by 2 p.m. a couple mechanical engineers were chopping ingredients for their much-anticipated mango guacamole.

The food was a necessary distraction from the holding pattern everyone at DARHT was caught in that day. This particular test was a "hot shot," meaning that the test device was heated at three degrees a minute to 74 degrees Celsius (165 degrees Fahrenheit). That temperature then had to be maintained for 24 hours, which meant the experiment (aka the shot) wouldn't happen until after 4:30 p.m. During a brief update that afternoon, Priestley reminded the crowd that this experiment had been in the works for 18 long months; a few more hours of waiting was nothing in the grand scheme of things.

While folks dove into the guacamole, Wooten explained the reasoning behind a hot shot. "Have you ever been on an airplane, sitting on the runway, during the summer?" he asked, alluding to the fact that the bombers and fighter planes that could deploy a B61 might stew on the tarmac in places such as Guam or Saudi Arabia. "This test is designed to measure any potential changes to the primary implosion resulting from LEP-designed components at the upper temperature extremes at which the B61 is required to perform."

Scientists must also consider how heat might affect the weapon as its temperature increases—will it twist? Expand? To make sure the final radiographs account for any physical changes to the weapon's shape and capture exactly what the scientists want them to capture, several dry runs—radiographs taken without an explosion—were performed as the team waited for the actual detonation.

"We have to guarantee performance across the temperature range," says Wooten, noting that back in August 2017, a "cold shot" was performed at DARHT to assess how components of a B61 perform at minus 54 degrees Celsius (minus 65 Fahrenheit)—the approximate temperature at 30,000 feet above sea level and the height at which a B-52 bomber might fly with a B61 exposed on an underwing pylon.

HYDRO TEST 3682

By 4:30 p.m., the vessel had been "soaked" at the appropriate temperature for 24 hours and people began making final preparations for the experiment—and the radiographs and other data that would accompany it.

In a DARHT experiment, scientists detonate a mock nuclear weapon—essentially a weapon that, instead of having a (nuclear) plutonium pit at its core, contains a non-nuclear metal. The explosion that follows is not nuclear but can be used to understand how that weapon would work if armed with a real pit.

The heat and pressure created by the implosion cause the weapon's mock non-nuclear pit to melt and flow like water. This change from solid metal to liquid is why the experiment is considered "hydrodynamic" and often called a "hydro test," or more simply, a "hydro." Each hydro is given a number; this hot shot of a mock B61 was hydro 3682.

At DARHT, multiple suites of diagnostic cables are attached to a weapon to gather data as it explodes, but the most important data come in the form of five radiographic (X-ray) images that are taken as the weapon detonates. The radiographs are used to better understand the implosion—specifically the implosion symmetry—and this understanding, in turn, influences the computer simulations that predict how well a real nuclear weapon will perform.

"Image quality at DARHT is amazing in terms of contrast and resolution," Wooten says. "Without underground testing, our codes need to be predictive, and experiments like 3682 help us continually improve our understanding and modeling of multiphysics phenomena."

Turns out, taking radiographs during a detonation is a lot more complicated than taking radiographs at, say, the dentist's office. For starters, the button at the dentist's office isn't labeled "fire," and you don't have to have a security clearance to see the images. And, rather than providing one image of a fixed target, DARHT must produce five high-resolution images of phenomena moving thousands of miles per hour.

DARHT is the only facility in the world that can do this; in fact, DARHT is the world's fastest and most powerful X-ray machine. To acquire high-resolution images of some of the densest metals known to humankind (that are even more compressed during an implosion) requires X-rays that are about 20,000 times more intense than a medical X-ray.

The DARHT facility comprises two perpendicular wings: Axis 1 and Axis 2. The wings stop just short of meeting one another at a right angle; at the would-be intersection, called the firing point, a six-foot spherical confinement vessel contains the mock nuclear weapon.

Each axis contains a massive linear accelerator that is focused on a tantalum target outside the confinement vessel. Each accelerator generates an intense high-energy beam of electrons that hits this target at nearly the speed of light. The electrons are yanked off course by the strong electrostatic pull of the positively charged nuclei in the tantalum atoms. Their sudden change in direction causes them to give off high-energy X-rays. The X-ray beams penetrate the confinement vessel, which holds the weapon.

AXIS 1

Axis 1 takes one radiograph per hydro test by producing one short electron pulse (60 nanoseconds, or billionths of a second) of extreme intensity (1.9 kiloamperes) with an energy of 19.5 megaelectronvolts. The beam is focused to a 1.3-millimeter-diameter spot on the 1-millimeter-thick tantalum target—which, at the time of Axis 1's construction in 1999, was the smallest spot size and shortest pulse length achieved at that intensity. As a result (and also because new electronic detector technology developed at Los Alamos replaced film), the image quality was much higher than that at any other hydro test facility, providing the clearest single views ever made of the inside of a hydro test object. The views helped validate new descriptions of implosion physics used in computer simulations of a weapon's performance.

"WE HAVE TO GUARANTEE PERFORMANCE ACROSS THE TEMPERATURE RANGE."

AXIS 2

Initially, Axis 2 was to be an exact replica of Axis 1, but when the moratorium on nuclear testing began in 1992, scientists realized the need for more images—more data—from each experiment. Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories collaborated on a design that produces four images, making Axis 2 the only accelerator of its type in the world.

Fully assembled in 2008, Axis 2 produces four short electron pulses sliced from a 1,600-nanosecond-long beam of extreme intensity (2.1 kiloamperes) with an energy of 16.5 megaelectronvolts. The beam is focused to a 1.3-millimeter-diameter spot on the tantalum target to produce four X-ray pulses. The tantalum target for Axis 2 is thicker than that of Axis 1 because it has to withstand four pulses without debris and particles from the target upsetting the incoming beam and without being significantly eroded from pulse to pulse.

Depending on when scientists want to take radiographs, the four pulses are independently adjusted from 35 nanoseconds to more than 100 nanoseconds in duration. Information on the symmetry of the implosion is obtained when a pulse from Axis 2 is simultaneous with the pulse from Axis 1.

IMAGE CONTROL

To produce the highest-quality images, recorded X-rays must originate at the target X-ray spot and not come from other sources, such as scattered X-rays from the beam stop (which absorbs spent electrons after they exit the target). DARHT reduces these unwanted X-rays by using metal collimators that focus the X-ray beam between the target and the weapon.

Another type of collimator, called a Potter-Bucky grid, sits on the other side of the weapon, between the weapon and the detector (camera) system. Los Alamos pioneered these grids, which use 137,000 thin tubular lines of sight in a 40-centimeter-thick block of X-ray-absorbing material. These tubular lines point back to the X-ray target spot so that only rays from the target spot pass through. By rejecting 99 percent of scattered X-rays, the grid has significantly improved the contrast of DARHT radiographs.

After passing through the target, X-rays are converted into visible light with a scintillator. The light is recorded on the most sensitive optical recording devices available: astronomy-grade charge-coupled devices that are cooled to reduce electronic noise. The DARHT camera systems are more than 100 times more sensitive than film and 40 times more efficient at absorbing X-rays.

On Axis 2, four images are recorded at a rate of 2 million frames per second. Because data cannot be transferred off the chip at this high rate, the information for each frame must be stored locally on each pixel and slowly read off after the experiment ends.

CONFINEMENT VESSEL

When DARHT was first built in 1999, test devices were detonated outside the bunker, producing fiery explosions that took weeks to clean up. In the early 2000s, growing concerns about environmental a

As the lead physicist on hydro test 3682, Omar Wooten develops a pre-shot prediction of what he expects the results to be and a post-shot analysis of what the experiment actually showed. "Facilities like DARHT that allow us to acquire data that are very closely related to the ultimate performance in which we are interested, are invaluable," he says. Wooten is pictured here in the accelerator control room at DARHT.

contamination and the health impacts of materials such as beryllium and depleted uranium prompted scientists to consider enclosing explosions in confinement vessels. The first fully contained hydro was executed in 2007. More than 50 hydros have been executed in confinement vessels since then (DARHT averages six to eight hydro tests per year).

Today, all tests occur inside two-layer confinement vessels, which not only contain all hazardous waste but also reduce cleanup time at the firing site. The cylindrical outer vessel provides mechanical support to the spherical inner vessel, which is six-feet wide and made from 6.25-centimeter-thick steel. The inner vessel, which contains overlapping aluminum shielding plates around the device to protect the vessel from shrapnel damage, can handle up to 18 kilograms of explosives and can be cleaned up and reused for other hydro tests.

THE COUNTDOWN

As 4:30 approached, people gathered in the accelerator control room, huddled around monitors showing the live feed of the confinement vessel. "5, 4, 3, 2, 1," said a voice on the loudspeaker. In the adjacent test control room, Trevor Sanders, the DARHT Detection Chamber Operator, pressed the "fire" button. On the monitors, nothing happened—a sign of a well-contained explosion.

Wooten and his colleagues examined the radiographs on screens in the test control room, and word began to spread around the facility that the test was a success.

Scientists and analysts shook hands and patted one another on the back, saying "Congratulations, we nailed it!"

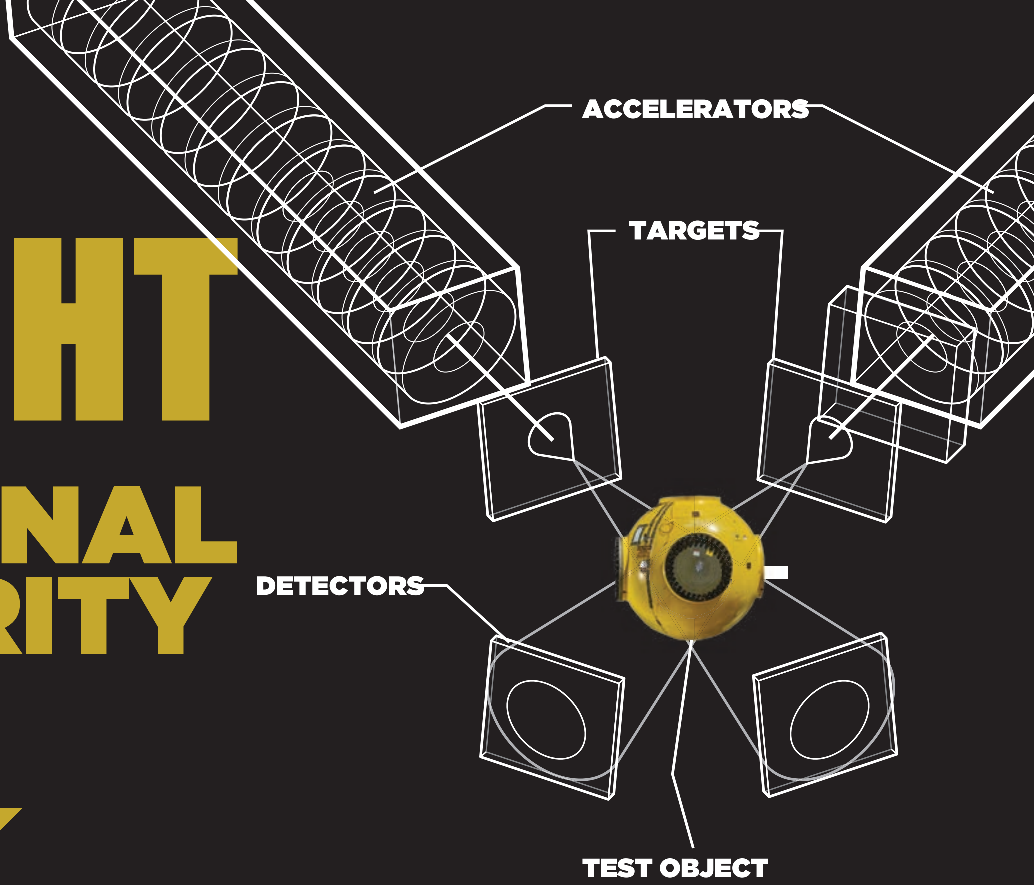
Less than an hour later, people were allowed to leave the building, and a line of cars slowly moved west toward the Jemez Mountains and back to civilization.

A few days after the test, Wooten confirmed that he was "very pleased" with the images and the 100 percent data return from all the diagnostics. Next steps involve looking for differences between images from this hydro and images from prior related shots. "More quantitative detailed analyses will follow in the future," he says, noting that the data from this hydro will help validate codes used for computer simulations and also provide feedback on his pre-shot prediction and the choices he made as he developed the model for this experiment.

Wooten also confirmed that he "slept hard" in the nights following the test, which was the culmination of years of work. "This being my first hydro test, the stress was largely self-imposed," he laughs. "As a new designer, being responsible for an experiment that is so expensive and that so many people across the Lab have worked on is daunting."

"It's also one of the most significant privileges one can have at this Laboratory, and I'm humbled to be able to play a role," he continues. "To get to work on something that will enter the stockpile, thereby helping to further continue the security of this great country—it's really beyond words." ★

WHY DARHT FOR NATIONAL SECURITY



Scientists' understanding of **PHYSICS** + Real data from **DARHT**

Simulations from
SUPER COMPUTERS

+

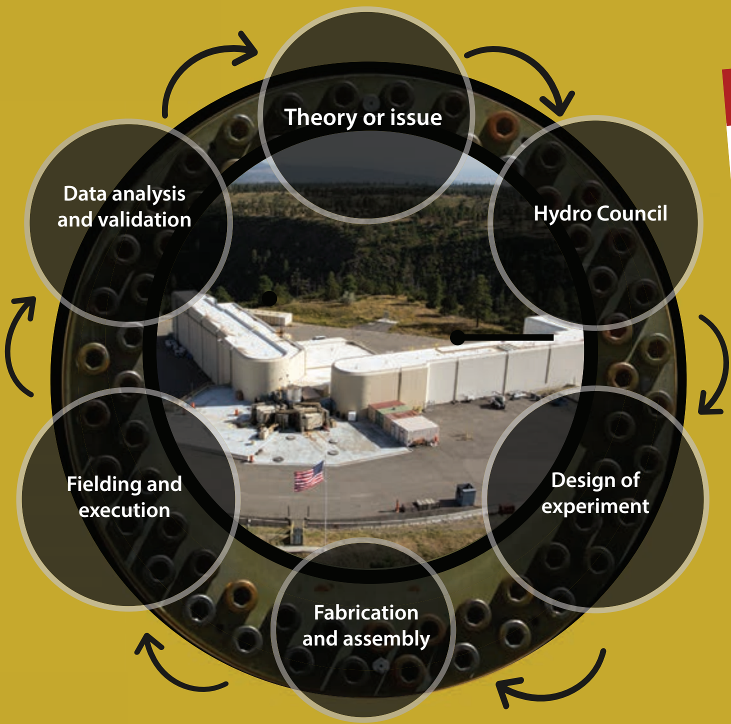
Safe, secure, and effective
STOCKPILE

Experiments at DARHT ENSURE THE SAFETY & RELIABILITY OF OUR NUCLEAR WEAPONS

DARHT's firing site is currently a concrete pad where the confinement vessel sits, exposed to the elements, between Axis 1 and Axis 2. In May 2019, a building will be constructed at the firing site to enclose the area. Although lightning could still halt work on an experiment, the building will allow preparations and experiments to continue in more varied weather; workers won't have to be directly exposed to the hot New Mexican summer sun, and snow removal won't be an issue in the winter.

THE HYDRO LIFECYCLE

One DARHT experiment demands a fully integrated Laboratory: collaboration across seven Laboratory divisions for more than 18 months. "Coordination of the various organizations is a big challenge," Priestley says. "Everyone has a role in our success, no matter how many years of education you have. This is a very physical set of activities that requires full participation."



Theory or issue

- Scientists ask a question that can be answered by a DARHT experiment.
- Divisions involved: X Theoretical Design (XTD), Weapon Systems Engineering (W), Weapon Stockpile Modernization (Q), Integrated Weapons Experiments (J), Sigma, Prototype Fabrication (PF)

Hydro Council

- This group of senior managers and analysts throughout the Lab's nuclear weapons community allocates funding—sometimes as much as $7.5 million—approximately 18–24 months before the test actually happens.
- Divisions involved: XTD, W, Q, J, Sigma, PF

Design of experiment

- Scientists and engineers design an experiment to test the question they want answered. "Defining an experiment means determining the initial device geometry that will produce a desired configuration at a specific time," Wooten explains.
- Divisions involved: XTD, W, Q, J

Fielding and execution

- This step includes post-shot cleanup, waste generation, and sanitation.
- Divisions involved: J, Q, W, WFO

Fabrication and assembly

- The weapons detonated at DARHT aren't taken out of the stockpile; all weapons are fabricated and assembled at Los Alamos.
- Divisions involved: PF, Sigma, W, J, Weapons Facilities Operations (WFO)

Data analysis and validation

- "My goal was to lead the physics portion of the experiment in a manner that respects the tremendous efforts that everyone else involved with the experiment has put forth," Wooten says. "Seeing the final images means that everything worked as expected."
- Divisions involved: XTD, W, Q, J

The Laboratory owns seven confinement vessels that are used at DARHT; each fully outfitted vessel costs approximately $2 million and can be cleaned and reused after an experiment.

DARHT is also used to evaluate the health of the W88 warhead used on D5 missiles on Ohio-class submarines. Meet Donald Sandoval, the leader of the primary physics effort to rebuild the primary in the W88 Alt 370 program.

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BETTER SCIENCE = BETTER SECURITY

JANE HALL'S SERVICE TO THE NATION INCLUDED 25 YEARS AT LOS ALAMOS, WHERE SHE PIONEERED NEW PHYSICS CAPABILITIES, INFLUENCED POLICY, AND INSPIRED WOMEN TO FOLLOW IN HER FOOTSTEPS.

JANE

QUEEN OF THE HILL

BY WHITNEY SPIVEY

HALL

The Laboratory's first female assistant director brought smarts, style, and a steady hand to Los Alamos.

KEY WORDS: Manhattan Project, Atomic Energy Commission, women in science, fast reactors

Manhattan Project

ATOMIC ENERGY COMMISSION • UNITED STATES OF AMERICA •

WOMEN IN SCIENCE

FAST REACTORS

On October 6, 1970, a small but notable crowd gathered at Los Alamos Scientific Laboratory to watch Glenn Seaborg, chairman of the Atomic Energy Commission, award the AEC citation for outstanding service to the nation to Jane Hamilton Hall, the recently retired assistant director of the Laboratory.

"As many of you know, the Commission has not acquired a reputation for making hasty decisions on any question, but, I must say, there wasn't a moment of hesitation in the Commission's selection of Jane Hall for this citation," Seaborg told the crowd, citing Jane's "out-of-the-ordinary and impressive resume" that included a quarter-century of employment at Los Alamos and a commitment to the U.S. atomic energy program that started during the Manhattan Project. "It is well known that she has fulfilled a significantly greater commitment to job and country than is normally expected," he said. "We find too few and need many more Jane Halls in our society today."

Jane was the first woman to receive the citation since the award was first given in 1960. The citation, however, wasn't the first time she had broken the glass ceiling for women in science.

CATCHING THE SCIENCE BUG

Born on June 23, 1915, Jane Elizabeth Hamilton grew up in Denver, Colorado, where her father was a pharmacist. While attending South High School from 1929 to 1932, "she got a spark that she never talked about," remembers her daughter, Linda Hall. "Maybe it was in high school, learning science, where she said 'this is something that I can do.'"

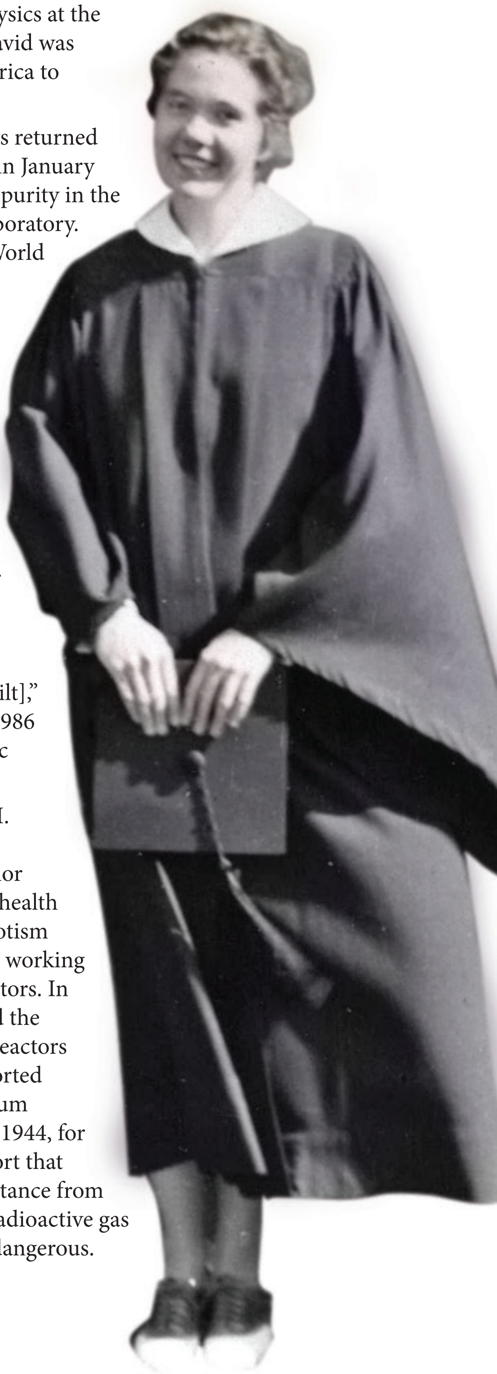
Jane decided to study physics at the University of Denver before transferring to the University of Chicago in 1935. There, she began ticking off degrees: a bachelor's in 1937, a master's in 1938, and a doctorate in 1942. Along the way, she saw a handsome young man "walking up or down some staircase," Linda recalls. "He had on a beautiful vest—a knitted red jumper—and she thought, 'he's for me!'"

That young man was David B. Hall, a New Jersey native and the son of a chemist married to a mathematician. After earning his bachelor's degree at Rutgers University, he'd enrolled at Chicago to pursue a master's and Ph.D. in physics.

"They were unique," Linda says, "a husband and wife team earning their doctorates simultaneously." Jane's thesis work was in crystallography; David's was in cosmic rays. The couple married in December 1939 and completed their doctoral theses while still enrolled at Chicago but working as graduate assistants in the physics department at the University of Denver.

There, the Halls taught a student named Harold Agnew, who would go on to become director of Los Alamos in 1970. According to the March 1979 issue of *The Atom*, the Halls "gave straight As to Harold" and also purchased his Ford Phaeton four-door convertible so that Agnew would have enough money to buy an engagement ring for his girlfriend. "He had just gotten a job with the Manhattan District in Chicago, and we told him he wouldn't need a car in the city, anyway," Jane told the magazine. "Of course, he was somewhat chagrined when we went to Chicago a year later—driving a red Ford Phaeton around the city."

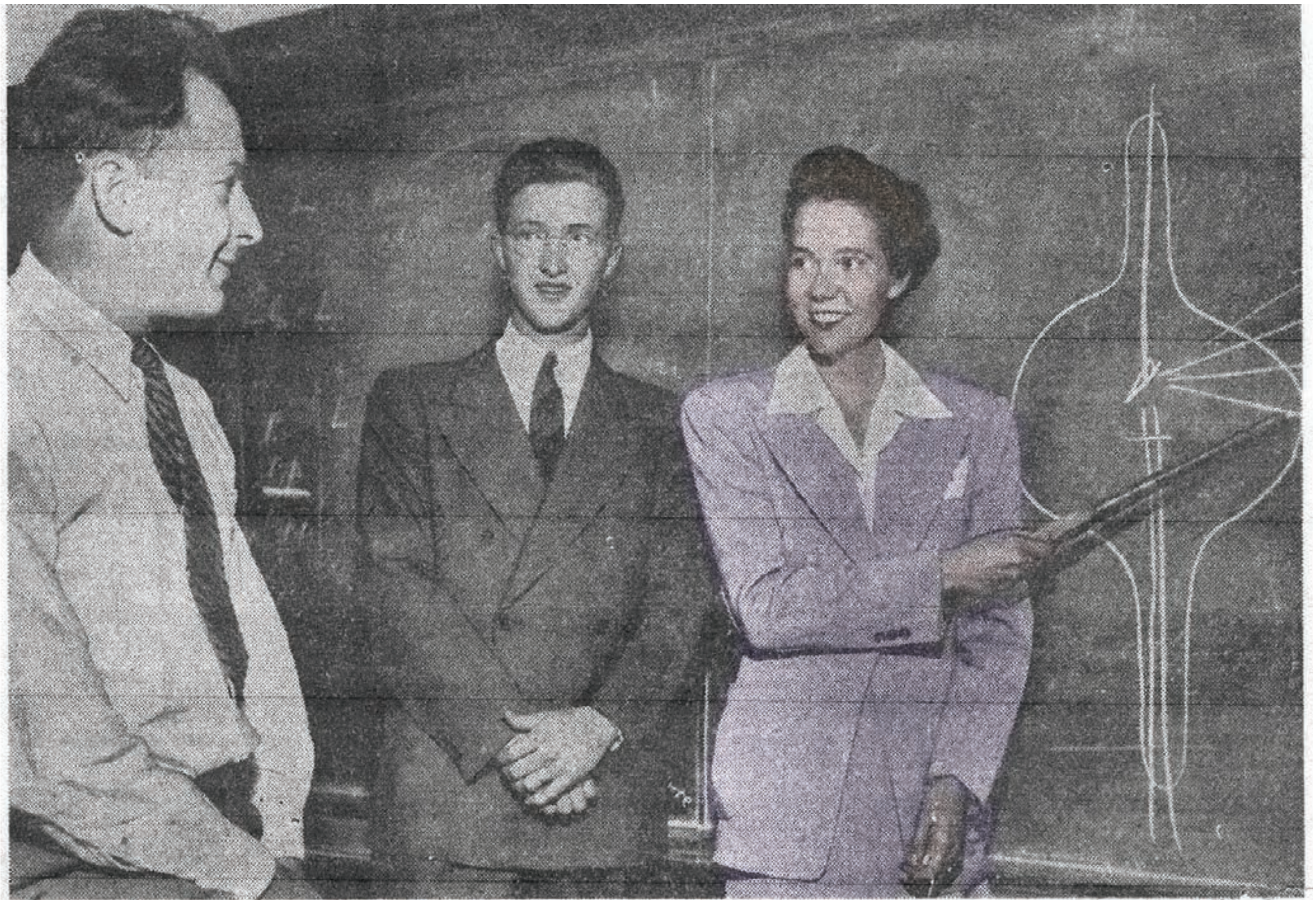
Jane's thesis, published in 1942, was titled "The Temperature Diffuse Scattering of X-Rays by Potassium Chloride and Potassium Bromide Crystals." That year, Jane was one of 461 women to earn a doctorate in the United States—and the only woman to earn one in physics at the University of Chicago. David was one of 3,036 men in America to earn a doctorate.



Degrees in hand, the Halls returned to Chicago from Denver in January 1943 to research graphite purity in the school's Metallurgical Laboratory. But by then the Second World War was raging, and the Halls felt compelled to contribute to the war effort. Hardly a year after establishing themselves in the Windy City, the couple moved 2,000 miles northwest to Washington state to become part of the top-secret Manhattan Project.

"We were asked to go out to Hanford to babysit the construction [of the nuclear reactors being built]," remembered David in a 1986 interview with the Atomic Heritage Foundation.

Officially employed by E.I. DuPont de Nemours and Company, Jane was a senior supervisor of research in health physics because anti-nepotism rules prohibited her from working with her husband on reactors. In this position, she assessed the safety of the production reactors and investigated and reported on the hazards of plutonium inhalation. In September 1944, for example, she wrote a report that discussed the size and distance from a person that a cloud of radioactive gas from a reactor might be dangerous.



FIRST COUPLE to come up as candidates for Ph. D. degrees at the same time at the University of Chicago is David B. Hall (center) and Mrs. Jane Hamilton Hall, shown with Samuel K. Allison, physics professor. CHICAGO SUN STAFF PHOTO.

The Halls lived in a two-story house on Goethals Drive in Richland—one of many homes constructed hastily on government-sequestered farmland in anticipation of the 51,000-plus Manhattan Project workers at Hanford. "Our front lawn…had asparagus coming up," David said. Another "remarkable thing was that the contractor was not able to get bathtubs for the place, and so the bathtubs were poured concrete, which were kind of gritty on your bottom."

"Los Alamos was considered to be the fountainhead of the pure science ..." —David Hall

By the time the Halls helped get the reactors up and running in the spring of 1945, it was apparent that "there was no real science [at Hanford]," according to David. And so the couple went back to Chicago, where Jane served as assistant to the acting director of the Metallurgical Project at the University of Chicago. On July 16 of that year, scientists from Project Y (the Los Alamos branch of the Manhattan Project) detonated Trinity—the world's first atomic bomb—using plutonium produced at Hanford.

"Los Alamos was considered to be the fountainhead of the pure science and the good ideas [about nuclear physics]," David said. And so perhaps it's no surprise that Los Alamos is where the Halls ended up in November 1945. Jane was 30 years old.

BECOMING ESSENTIAL

The Halls, now with newborn son, Malcolm, arrived in Los Alamos at a pivotal time for the Laboratory: the bombs had been dropped, the war had finally ended, and many scientists were leaving the small New Mexico town. But the couple felt strongly that the United States' national security policy depended on the weapons being developed at Los Alamos. "We went [to Los Alamos] because we believed firmly that the work on nuclear weapons had to continue," Jane told the Associated Press in 1970. "Building nuclear weapons had to be done, there was no doubt about it."

Jane immediately went to work in the Laboratory's weapons research division, which was primarily concerned with the mechanics and dynamics of nuclear energy release. She earned $373 a month—a wage that her division leader didn't think was fair. "Mrs. Hall was offered a salary which was too low on the basis of her training and experience," wrote Alvin Graves in Jane's 1946 performance review. "Although Mrs. Hall is one of the newer members of the group, her understanding of the work and her training makes her one of the most valuable members of the group…This recommendation [of $430 a month] is intended to bring her salary in line with those of comparable physicists on the project."

MY DARLING CLEMENTINE

Meanwhile, the world's first fast reactor was proposed and approved. Construction began in August 1946 in Los Alamos Canyon, a deep ravine in the Pajarito Plateau just south of the Laboratory. Under the direction of physicist Phillip Morrison, the new reactor was named Clementine after the song "My Darling Clementine," which begins "in a cavern, in a canyon…" and is about the legendary 49ers. Morrison likened the reactor personnel to modern-day 49ers because 49 was the codename for plutonium (Clementine was the first reactor fueled with plutonium—and the first to employ a liquid metal coolant, mercury; read more on page 42).

When Morrison accepted an offer to join the physics faculty at Cornell University, Jane (now part of the experimental physics division) and David Hall were asked to take his place as co-group leaders on the project. The duo's duties included planning the type and schedule of construction, testing at various stages of completion, planning experiments, taking responsibility for worker safety, writing reports, and interpreting data.

"This is a position of extraordinarily grave responsibility since on [Jane's] judgment and skill and care…will devolve not only the success or failure of [an] extremely important and expensive enterprise, but also the safety and lives of quite a large number of people," wrote physics division leader J.M.B. Kellogg in November 1946. "She has been extremely diligent and enterprising in her work and has made marked contributions to the program."

After core criticality (the point at which a nuclear reaction is self-sustaining) was achieved in 1946, completion of the reactor took 27 more months, and Kellogg's praise of Jane continued in subsequent performance reviews. In 1947, he wrote, "Since no such [reactor] has been built before, and since it is known that this reactor is more dangerous than other [reactors], the utmost responsibility is required of the Hall husband and wife. Dr. Jane Hall is not of secondary importance in the exercise of this responsibility." And in 1948, he said, "It is well known that this responsibility is no light one. Jane Hall's contributions to the development have been considerable, and her work has been excellent."

Steve Lawroski, director of the chemical engineering division at Argonne National Laboratory, and Harvard professor Norman Ramsey (who would go on to win the Nobel Prize in Physics in 1989) were among the men who served alongside Jane Hall on the General Advisory Committee of the Atomic Energy Commission. Photo courtesy of Linda Hall

That year, Jane's contributions included researching and writing a report titled *Effect of Temperature and Reactivity Changes in Operation of the Los Alamos Plutonium Reactor*. "We have, in this discussion, tried to examine all dangerous conditions which might arise during operation [of the reactor] and where definite information was not available have over-estimated the expected trouble," she wrote. "It is believed that all dangerous conditions have been considered and the probability of occurrence minimized through the safety circuits, warning indicators, and the plans of operation."

Clemy (as Jane referred to the reactor in a 1946 letter to a colleague) operated through 1952, and most of its original objectives were realized: important nuclear weapon data were acquired and invaluable experience was gained in the design and control of fast reactors. Clementine was "another step toward finding the best type of chain reactor for the production of useful power," according to a September 8, 1947, article in *Newsweek* magazine.

PIONEERING POISE

Jane continued to flourish in the Laboratory's physics and weapons divisions, conducting research on reactors, X-ray crystallography, neutron physics, and cosmic radiation. "Education, career, and the latter-day duties of a wife and mother have cast no hue of sobriety on the personality of this young woman scientist," reported the *Los Alamos Times*. "She retains a youthful vivacity that shows itself in a frequent carefree smile and the impression she gives of abundant energy."

By 1950, shortly after the birth of her daughter, Linda, Jane was promoted to assistant technical associate director of the Laboratory, a position that allowed her to continue her research on nuclear weapons technology. Although she was prohibited from attending nuclear tests on Eniwetok Atoll because she was a woman, she was allowed at the Nevada Test Site (NTS) and often camped in the desert with her husband while setting up an experiment.

"One day, during [Operation Ranger in 1951] in the desert at NTS, I am told another scientist, male of course, saw a woman walking on the desert all alone," Seaborg remembered. "Naturally, he assumed this was a woman in distress and rushed up to ask if he could be of assistance. Of course, it was Jane, and she quickly assumed her womanly pioneering poise and promptly offered her assistance *to him*."

MAKING THE MOST OF MANAGEMENT

That poise and confidence were among the reasons Laboratory Director Norris Bradbury promoted Jane to assistant director of the Laboratory in 1955.

"Technically, Jane was the Lab's only female assistant director," says Laboratory historian Alan Carr, noting that Jane was likely the only person—male or female—to ever hold that exact position. "The assistant director back in those days was the rough equivalent of deputy director today."

Despite the 1950s being a time of frequent discrimination against women, when Bradbury named Jane assistant director, "there was no reaction" remembers physicist John Hopkins, then a summer student who would later become the associate director for the nuclear weapons program. "She was no-nonsense but easy to talk to; she was just one of the boys."

A letter to the editor in the February 1994 issue of *Physics Today* agrees. "Hall commanded respect and was seen as discharging her responsibilities with strength and careful judgment," wrote reader James McNally. "Looking back, I wonder if she would have been as professionally respected had she been seen as a 'first woman' rather than being recognized for her abilities."

Even as a child, Malcolm Hall recognized that his mother was "an outstanding manager" who was "a little rueful about leaving scientific work for administration, but she acknowledged this was where she could make her most significant contributions."

Well liked for her "cultured and slightly demure manner" (as described in a 1947 *Los Alamos Times* article), as assistant director, Jane was often tasked with hosting visiting scientists. "She was well known for throwing fabulous parties when luminaries such as [physicist and Nobel laureate] I.I. Rabi were in town," Malcolm says. "She was also a good sport for squiring VIPs around; once she escorted philanthropist and socialite Catherine Hearst, then a regent of the University of California [which operated the Lab], to watch an H-bomb test in the Pacific."

On one occasion First Lady Ladybird Johnson telephoned to personally invite Jane to an event at the White House. "Malcolm left a note on the kitchen blackboard that 'Ladybird called,'" Linda remembers. "And it was consternation because Mom felt she had to have a hat to wear to the luncheon; she never wore hats, but she knew the importance of her appearance."

Thankfully, Jane still had ties to her hometown of Denver. "It was the May Company and Denver Dry Goods that drew her to Denver—and a stay at the Brown Palace," says Linda, noting that her mother would travel to Denver twice a year to update her wardrobe with the most current fashions. "She always did everything first class," Linda continues. "It must have had something to do with how she wanted to be in the world that included the best."

INFLUENCING THE NUCLEAR WEAPONS DEBATE

But Jane's tenure as assistant director certainly wasn't all entertaining and high fashion. "She really was a remarkable scientist," Carr says. "And to have such a senior management position so early in her career and for so long was almost unheard of in those days for a woman."

As a manager, Jane's responsibilities included briefing policymakers in Washington, such as New Mexico Senator Clinton P. Anderson and members of the AEC. When nuclear engineer Manson Benedict, chairman of the AEC's General Advisory Committee (GAC), heard that the Laboratory was "losing its enthusiasm for weapons research and would be happier if its primary role were that of a multipurpose research laboratory," Jane was among the "Los Alamos people" he talked to about the Lab's "role in the Commission's program," according to a 1963 letter he wrote to Seaborg.

"If a scientist has technical knowledge that is going to influence the debate [about nuclear weapons], then he must participate," Jane once told a reporter. Perhaps that's why, in 1965, Seaborg recommended to President Lyndon Johnson that Jane be appointed an AEC commissioner.

"She has been with the atomic energy program essentially since the date of its inception," Seaborg wrote to Johnson. "I have known her personally for the last twenty-two years and have been in a position to follow her work quite closely during that entire period. Her performance in the atomic energy field has been outstanding."

Seaborg, a chemist and Nobel Prize winner himself, went on to tout Jane's experience in the development of nuclear reactors and nuclear weapons. He also complimented her character: "Jane Hall, in my opinion, has, in addition to her scientific ability, an unusually large proportion of the other qualities that are required in a good Commissioner…she gets along well with people and would, I believe, perform well in the complex labyrinth of human relations in Washington."

In 1966, Johnson took Seaborg's advice and appointed Jane to a six-year term on the GAC of the AEC. The GAC was established by the Atomic Energy Act of 1946 to advise the AEC on scientific and technical matters relating to atomic energy.

"The GAC was the real group of experts," Carr explains. "If you were [one of the nine people] on the GAC, you were advising the people who were advising the president on very serious matters. The head of the AEC was the very rough equivalent of today's Secretary of Energy—it was a very big deal."

Jane, the first woman appointed to the GAC, previously served as technical secretary of that committee from 1956 to 1959. As a commissioner, she served on the GAC's committee on Nuclear Materials Safeguards, which was established "to assist the Atomic Energy Commission in carrying out more effectively its responsibilities for

In September 1958, Jane Hall attended the second United Nations International Conference on the Peaceful Uses of Atomic Energy in Geneva, Switzerland. At this time, Jane was not only the assistant director at Los Alamos but also the technical secretary of the General Advisory Committee of the Atomic Energy Commission. Photo courtesy of Linda Hall

safeguarding special nuclear materials under the Atomic Energy Act," according to a press release. "Safeguards are measures designed to prevent the unauthorized diversion of enriched uranium and plutonium employed in peaceful nuclear programs to military applications."

Jane later declined an invitation by President Richard Nixon to chair the AEC. "I think it would have meant moving to Washington," Linda speculates.

Regardless, upon her retirement from Los Alamos in 1970, Jane received the AEC citation award for her outstanding service to the nation's atomic energy program.

"The men and women who receive this award all have certain key characteristics in common: they are men and women who, in addition to their outstanding skill and experience, generate confidence and provide inspiring leadership," Seaborg said of the 32 award recipients.

An Associated Press article took a different angle: "A woman physicist who helped pioneer the development of America's nuclear weapons, and whose hobbies include growing lilacs, iris, and tulips, was named to receive one of the nation's highest awards in atomic energy."

In 1971, *Ladies Home Journal* named Jane one of the 75 "most important" women in the country for her work on the AEC. The article, sandwiched between the "keep-your-husband" diet and advice on how to wear pants, celebrated Jane alongside other notable women, including Joan Baez, Katherine Graham, Coretta Scott King, Jacqueline Kennedy Onassis, and others who "had made the greatest impact on our civilization within the last five years and who would continue to affect us significantly for the next five years."

THE LEGACY CONTINUES

Jane's legacy has far surpassed that five-year benchmark. "She has inspired many a young woman to take special note of science and its unique opportunities," Seaborg remarked in 1970. "If there are some women who still can't find a good example of woman's liberation in the field of science, don't put the blame on Jane."

Today, 33 percent of the Laboratory workforce is women, and many of those women gathered on October 4, 2016, for the dedication of the Jane Hall Conference Center at Technical Area 55—the center of plutonium research at Los Alamos. "It was beautiful," Linda says of the dedication ceremony, which occurred nearly 35 years after Jane's death in 1981. "She never talked much about work—and as a kid, I never thought to ask—so I was pleased and proud to see her accomplishments recognized so publicly at the Laboratory that meant so much to her." ★

JANE HALL

CULTIVATING CLEMENTINE
The world's first fast reactor had a short but significant life at Los Alamos.

A nuclear reactor initiates and controls a self-sustained nuclear chain reaction. A nuclear chain reaction is a series of nuclear fissions—the splitting of atomic nuclei (typically heavier nuclei of uranium or plutonium) into two smaller fragments. These fragments are in excited states and emit neutrons, which, in turn, cause new fissions to emit more neutrons, and so on. The extreme energy created in this process can be used for a variety of purposes, including electricity, ship propulsion, producing weapons-grade plutonium, or simply research.

In 1945, Los Alamos scientists proposed the construction of the world's first fast reactor—a small nuclear reactor in which most of the fissions would be produced by fast (high-energy) neutrons. This particular reactor, named Clementine, would operate on the fission of plutonium (^{239}Pu). "The chain reaction proceeds by the high energy or fast neutrons from the plutonium fissions, producing further fissions," explains a 1954 report titled *The Los Alamos Fast Plutonium Reactor.* "The plutonium is in the form of small rods, canned in steel jackets, around which mercury coolant flows at the rate of approximately nine liters per minute. The plutonium rods are held vertically in a lattice arrangement at the bottom of a cylinder… surrounding this active material region is a … reflector of natural uranium, most of which is silver-plated."

The Manhattan Engineer District approved the reactor in December 1945 on the grounds that it would be a means of exploring the adaptability of plutonium as a reactor fuel. Completed in March 1949, "Clementine was a prototype in the field of atomic energy development; it was a source of high-energy neutrons for nuclear physics investigations and was a pilot plant to investigate the possibilities of future high-power atomic energy installations," according to a Laboratory document.

During its first year, Clementine maintained a full schedule that included several important weapons experiments that "made good use of the reactor as a neutron source," according to the 1954 report.

Clementine operated for the last time on December 24, 1952; the reactor was shut down after the discovery that plutonium had contaminated the reactor's mercury coolant (a coolant is necessary to remove

Left: Clementine, the world's first fast reactor.

Below: Jane and David Hall worked together on Clementine. "The utmost responsibility is required of the Hall husband and wife," wrote physics division leader J.M.B. Kellogg in 1947. "Dr. Jane Hall is not of secondary importance in the exercise of this responsibility." Photo: Los Alamos

the heat generated by fission). "The hazard created by this situation and indications of serious abnormal behavior of the reflector material prevented further operation of the reactor and prompted the decision to proceed with a complete disassembly," wrote the report authors.

Despite Clementine's premature demise, most of its original objectives were realized. Researchers acquired valuable weapons data and gained experience in the production and care of fast neutron reactors. ★

JANE HALL AWARD FOR SAFETY IMPROVEMENT

New award honors former Laboratory assistant director

BY SIERRA SWEENEY "Jane Hall was an innovator who ensured all of the innovative work she conducted and led was done safely," says the Laboratory's Voluntary Protection Program (VPP) leader Vanessa De La Cruz. "She didn't compromise safety for innovation."

So it's fitting that VPP and the Worker Safety and Security Team (WSST) teamed up to create the Jane Hall Award for Safety Improvement, which recognizes significant improvements in safety and security processes or performance at the Laboratory.

"We wanted a new award that recognizes workers who doing the right thing," De La Cruz explains. "Usually, only the things that go wrong get publicity, but a lot of things go right. We wanted to recognize that by creating a new award."

The Lab's Radiation Generating Device (RGD) Team received the first Jane Hall Award in July 2018 for its adherence to government radiation policies. The team also implemented a successful reuse and recycle program for radiological materials that saved the Laboratory more than $1 million.

And like Jane Hall, who was always planning for the future of the Laboratory, the RGD team is also working toward a better tomorrow by collaborating with Historically Black Colleges and Universities (HBCU) to strengthen the pipeline of STEM students into safety and security positions at the Lab.

VPP and WSST plan to present the Jane Hall Award twice a year based on employee safety and security nominations that meet the award's criteria.

The Lab's Radiation Generating Device Team received the first Jane Hall Award for Safety Improvement. Team members include (pictured, from left) Dennis Mims, Michelle Lee, Gilberto Estrada, and (not pictured) Matthew Carradine. Associate Director for Environment Safety and Health Bill Mairson is pictured on the far right.

THE BIGGEST NATIONAL SECURITY CHALLENGES OF THE FUTURE

Six Lab directors share insights at panel discussion.

On July 31, five former Laboratory directors joined current Director Terry Wallace for a panel discussion titled "75 Years of Solving National Security Challenges." The directors—Donald Kerr (1979–1985), John Browne (1997–2003), Robert Kuckuck (2005–2006), Michael Anastasio (2006–2011), Charles McMillan (2011–2017), and Wallace (2018)—discussed the past, present, and future of the U.S. strategic deterrent and how world events impacted their leadership of the Lab. Here are their responses to the question: **WHAT DO YOU THINK THE BIGGEST NATIONAL SECURITY CHALLENGE WILL BE IN THE FUTURE?**

ROBERT KUCKUCK: One thing is science-based stockpile stewardship. It might get more confident, but should we really, truly have that confidence? I think that can only get worse as time goes on. I don't see how we can possibly know better as we go. And also, our society values human life, fairness, equality, and so forth. Having to defend that society against totalitarian threats by building tools that contradict a lot of those values is a fundamental underpinning of the trauma we always have finding a governance system that works, finding a way to deal with each other. The challenge to all of us is to really understand that those concerns are valid. We have to take those as serious and try to understand them.

MICHAEL ANASTASIO: This country needs to marshal all its resources to defend its way of life. I agree with the hybrid warfare. What's the threshold of pain that we'll take? What's the threshold of disruption before we respond? We need to have many capabilities, whether they're economic or natural resources or science or nuclear weapons. How do you marshal all those things together in a coherent way? It's that whole range of capabilities that we have to marshal and wield in a strategic way to continue to defend the things that we believe in.

CHARLES MCMILLAN: I certainly agree with the challenges that colleagues have raised. I'm going to touch on one more: people. Because today this Laboratory and many of the other laboratories are in a period of generational change. The generation that I am a part of came to the Laboratory in the early '80s, and we developed a way of doing business through the course of our careers, and it's now time for us to move off the stage. That is both a challenge and an opportunity. I have had the privilege of meeting many of the young people who are the Laboratory of the future, and they are amazing people. It is going to be the challenge of your generation to deal with some of the problems that my colleagues have articulated so well. I have confidence that it can be done in a place like this Laboratory by the people who are coming to this Laboratory today, but only if we stay focused on our mission and ensuring that we're bringing in people today who share that mission.

BETTER SCIENCE = BETTER SECURITY

BIG PROBLEMS ARE OPPORTUNITIES FOR BIG SOLUTIONS. LOS ALAMOS HAS BEEN SOLVING THE MOST ARDUOUS NATIONAL SECURITY CHALLENGES SINCE 1943.

TERRY WALLACE: National security is built around this concept of protecting our borders and our economy. I am not sure that we have a national economy anymore—it's a global economy. If you take the five largest technology companies in the United States, they're the fourth largest economy in the world. Are they our enemy or our friend? I worry that the challenge in 2030 will not be centered on some latitude-longitude definition of a country; it will be about a concept. The concepts are the values that our nation was founded upon. National security may no longer be related to just our borders and our boundaries. How are we prepared for that? We're not prepared for it. That's my concern. Humanity has had challenges within a decade that are just so different than they were in 1943 when we worried about an existential threat from an alliance.

JOHN BROWNE: I stay up nights thinking about information warfare against our military assets—whether we lose stealth someday or someone can find our submarines or whether they can just take out our satellites. But more than that, the information warfare against our society, our democratic way of life. Just think of how many times you look at social media today and someone believes something is true because someone else has put something out there. I think that threatens our democratic way of life.

DONALD KERR: Gray or hybrid warfare. The best existing example is in eastern Ukraine, where, in effect, you have a war going on that's undeclared. You have men who are not active duty military personnel (they say), you have cyber warfare going on, and you have a future promise of cyber physical activity. You really have to ask how nuclear deterrence fits into this new construct of warfare between states that are going after economic targets, health targets, and behavioral targets. Social media has enabled things we never thought of years ago.

MASTER OF THE LOOM

At work, mechanical engineer Donald Sandoval designs nuclear weapons. At home, he weaves tapestries—and thinks about nuclear weapon design.

BY OCTAVIO RAMOS Donald Sandoval of the Lab's Primary Physics group stands before a loom made by his father and weaves a tapestry. The weaving process itself is not too complicated but does take time, so Sandoval's mind tends to wander. His thoughts often venture to his day job as a mechanical engineer supporting the Laboratory's national security mission. Sandoval says he has often solved complicated engineering and mathematical problems while working at the loom.

More than 30 years ago, Sandoval earned a bachelor's degree in electrical engineering. While working on his undergraduate degree, Sandoval secured an internship at Los Alamos under noted theoretical physicist Frank Harlow. Harlow introduced Sandoval to the field of computational fluid dynamics, and Sandoval was hooked.

"I finished my undergraduate degree at New Mexico State University, but even at that time I found myself more interested in mechanical engineering because of my work with Dr. Harlow," Sandoval explains. "For my master's and doctorate, I switched to mechanical engineering. I focused my dissertation on fluid mechanics, and it's something that I continue to explore to this day."

Science for national security applications

Sandoval's father worked at the Laboratory for more than 30 years in one of the old computing groups in what's now the High Performance Computing Division. Growing up, Sandoval knew about the Lab's principal mission, and as he grew older he wanted to contribute to ensuring America's national security. Once he earned his Ph.D., Sandoval joined the Laboratory as a full-time staff member, getting his chance at last to make his contribution.

"I work in the Primary Physics Group, which performs analyses related to stockpile stewardship," Sandoval says. "I mostly work with legacy designs. Right now, I lead the primary physics effort to rebuild the primary in the W88 Alt 370 program—these nuclear warheads are deployed on the U.S. Navy's submarine-launched ballistic missile system."

Sandoval believes that a combination of education and experience enables him to remain essential to the Laboratory for more than 30 years now. In addition to his formal education, Sandoval cites his work with Harlow as a critical influence. Sandoval was also one of the first graduates of the Laboratory program known as TITANS, the Theoretical Institute for Thermonuclear and Nuclear Studies. TITANS's goal is to sustain the cadre of nuclear weapons scientists who are well grounded in nuclear weapon science, design, and analysis.

"I would say that I harness my understanding of the physics and engineering associated with nuclear weapons every day that I am on the job," Sandoval notes. "Long ago, I was an intern learning from Frank Harlow. Today, I share my experience to help others achieve key milestones and mentor the group's younger members so that they can also contribute to the Lab's mission."

Fifth-generation weaver

Before going to graduate school at the University of Washington, Sandoval did not have a full understanding of his family's artistic background.

"I knew my family had been in Northern New Mexico for several generations, with my grandparents growing up in Truchas," Sandoval says. "My first year of graduate school I was pretty lonely, as I did not know anyone. These were the days before the internet, so I went to the library and started researching New Mexico. It was during this research that I discovered the involvement of my family in the arts, particularly with the works created by the santeros."

Sandoval found that his own grandfather had been Hermano Mayor (Major Brother) for the Truchas Penitente Morada, that his grandmother had been a weaver, and that his own father built weaving looms. Excited by all this newfound knowledge, Sandoval began to spend his summers in New Mexico learning from his father how to weave on the loom, dye his own wool with naturally made pigments, and even paint retablos (devotional paintings of Roman Catholic saints).

"I'm a fifth-generation weaver," Sandoval says, "and now I am teaching my youngest daughter how to weave so that she can carry on the tradition."

Sandoval today is known at the Santa Fe Spanish Market for tapestries with bold colors and design elements grounded in tradition but also with a modern flair. He has participated in the annual Spanish Market since 1994, winning numerous awards and selling various pieces to museums that span from Santa Fe to England.

When it comes to the arts and the sciences, Sandoval notes that one common thread between them is what he calls the mathematics of design.

"It's about patterns," he says. "Rather than think in terms of pure mathematics, I am able to touch upon the creative side of problem solving. I then use that side of my thinking process and apply it to any technical challenges at work. I usually analyze the technical patterns from a creative perspective and that in turn helps me come to a creative yet science-based solution." ★

Donald Sandoval (right) and his mentor, Frank Harlow, in 1987.

BETTER SCIENCE = BETTER SECURITY

DONALD SANDOVAL LEADS THE PRIMARY PHYSICS EFFORT TO REBUILD THE PRIMARY IN THE W88 ALT 370 PROGRAM.

A fifth-generation weaver, Donald Sandoval dyes his wool with natural pigments and weaves on a loom made by his father.

Left: One of Sandoval's tapestries.

ACCOLADES

SHOWCASING THE DISTINGUISHED ACHIEVEMENTS OF LOS ALAMOS EMPLOYEES.

BETTER SCIENCE = BETTER SECURITY

AN ENGAGED WORKFORCE MEANS A MORE CREATIVE WORKFORCE. A MORE CREATIVE WORKFORCE MEANS BETTER IDEAS. BETTER IDEAS MEAN BETTER NATIONAL SECURITY.

TWO LABORATORY SENIOR FELLOWS NAMED

Deputy Principal Associate Director for Weapons Programs **BRETT KNISS** and Deputy Principal Associate Director for Global Security **ANDY ERICKSON** have been named Laboratory Senior Fellows. The designation of senior fellow is bestowed on staff for extraordinary service to the Laboratory and the nation.

Kniss is a 35-year veteran in the NNSA complex with a background in weapons manufacturing and nuclear facility planning. "Throughout his career, Brett has proven to be an invaluable resource on all plutonium pit-related topics," says Bob Webster, principal associate director for Weapons Programs. "He is recognized for both his leadership and technical abilities in championing programs and initiatives to strengthen the plutonium mission in support of national security."

Kniss has been awarded six distinguished performance awards by Los Alamos and five Defense Programs awards of excellence. He is the sole recipient of the NNSA distinguished associate award for re-establishing pit manufacturing at Los Alamos after the closure of the Rocky Flats Plant.

Erickson began his career at Los Alamos National Laboratory more than 20 years ago, providing quick-response tools to help Global Security sponsors address emerging threats. He also served as a nuclear incident responder on the NNSA's Joint Technical Operations Team, leveraging the Laboratory's weapons experience to design and build the tools needed to counter an improvised or stolen nuclear device. He was named deputy principal associate director of Global Security in February 2015.

"Andy excels at recognizing and fostering curiosity for innovative possibilities far beyond conventional practice," says Nancy Jo Nicholas, principal associate director for Global Security. "He is truly a strategic thinker in the area of emerging threats and is a recognized and respected leader within the Laboratory, the tri-lab enterprise (with Livermore National Laboratory and Sandia National Laboratories), the Department of Energy, and the Intelligence Community."

In June, talented young researchers received Early Career Research Program Funding awards from the U.S. Department of Energy's Office of Science. The recipients from Los Alamos are:

CESAR DA SILVA, for "Gluon Saturation Search in the Deep Small Bjorken-x Region using the Large Hadron Collider Beauty Experiment (LHCb)" in the nuclear physics program area.

STEFANO GANDOLFI, for "Weak interactions in nuclei and nuclear matter," in the nuclear physics program area.

ALEX ZYLSTRA, for "Studying Nuclear Astrophysics with Inertial Fusion Implosions," in the fusion energy sciences program area.

For the third year in a row, the Laboratory was named a top-50 science, technology, engineering, and math (STEM) workplace for Native American professionals by the American Indian Science and Engineering Society.

Each year the Laboratory recognizes individual employees and groups of employees who have distinguished themselves through their outstanding scientific, technical, operational, and/or administrative contributions in support of the Laboratory's mission. The 2017 Distinguished Performance Award individual winners include Phillip Jacobson (Space and Remote Sensing), Adrienne LaFleur (Safeguards Science and Technology), and Patrick Younk (Neutron Science and Technology).

Laboratory Fellow Jaqueline Kiplinger is a new fellow of the American Chemical Society. SHE IS ONE OF ONLY SEVEN LOS ALAMOS SCIENTISTS HONORED IN THIS WAY DURING THE 75-YEAR HISTORY OF THE LABORATORY.

The Department of Energy recognized the Lab with a **GreenBuy Gold Award** for achieving excellence in sustainable acquisition for fiscal year 2017. DOE also recognized the Lab for having won the award three times—in 2012, 2016 and 2017.

Under the GreenBuy Award Program, DOE sites receive recognition for purchasing programs that obtain sustainable products, save energy, conserve water, and reduce health and environmental impact in "green purchasing" that extends beyond minimum compliance requirements.

Peter Work received the exceptional achievement (individual) award as part of the 2017 Defense Programs Awards of Excellence, which were awarded in August 2018. Work implemented laser measurement systems across detonator production lines, reducing the worker-hours required to perform manual and mechanical inspection by nearly 78 percent.

The American Geophysical Union (AGU) named two Los Alamos National Laboratory scientists fellows in recognition of their leadership and excellence in earth and space sciences. **Geoffrey Reeves** and **Peter Gary** are among 62 new fellows who will be honored at AGU's annual conference in December in Washington, D.C. Only 0.1 percent of AGU's 60,000-plus member scientists are named fellows each year, according to the international organization.

LOOKING BACK 65 years ago

MAY 8, 1953 Pool-goers at the Hotel Last Frontier in Las Vegas, Nevada, observe the mushroom cloud from Encore, a 27-kiloton nuclear test at the Nevada Test Site. The test device, which was designed and built by Los Alamos, was airdropped from a B-50 bomber at 22,000 feet and detonated at 2,423 feet. On the ground below, industrial buildings, railroad trestles, an imported ponderosa pine forest, and 44 anesthetized pigs dressed in various materials were assembled at various distances from ground zero to show the effects of the blast. Photo: Bettmann/Getty Images

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Project Y of the Manhattan Project was constructed around Ashley Pond in Los Alamos. Project Y became Los Alamos Scientific Laboratory in 1947 and is pictured here in 1957.

THEN & NOW

Los Alamos Scientific Laboratory became Los Alamos National Laboratory in 1981. In June 2018, the Laboratory celebrated its 75th anniversary with a picnic at Ashley Pond Park.

NNSA National Nuclear Security Administration

Los Alamos NATIONAL LABORATORY EST.1943