LOS ALAMOS NATIONAL LABORATORY ◇ SPRING 2023

NATIONAL ★ SECURITY SCIENCE

THE ENTERPRISE ISSUE

Nuclear enterprise road trip: Hit the road to learn more about the labs, plants, and sites responsible for America's nuclear deterrent.

Beyond the enterprise: What is a nuclear weapon without a delivery system? That's where the United States military comes in.

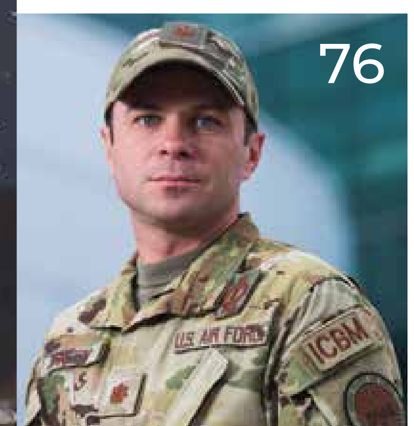
+PLUS:

The USS *Enterprise* inspires career paths	Q&A with the National Nuclear Security Administration's Jill Hruby	Missileers go on alert at Minot Air Force Base

PHOTOBOMB

▼

The Vulcan Firebird Global Security series of experiments took place in 2022 at the Nevada National Security Site's Big Explosives Experimental Facility. Data from the series, which was a collaboration among seven national laboratories, including Los Alamos National Laboratory, and the University of Illinois Urbana-Champaign, will inform the nation's nuclear nonproliferation efforts. Learn more about the Nevada National Security Site on p. 62. ★



IN THIS ISSUE

About the cover: Holly Jencka, of the Visible Team at Los Alamos National Laboratory, created this issue's cover artwork using a combination of Adobe Photoshop and Blender. "The bomb depicted here needs each puzzle piece—each lab, plant, and site—to be complete," she explains. ★

THE ENTERPRISE ISSUE

From coast to coast, collaboration among the National Nuclear Security Administration's laboratories, plants, and sites ensures that America's nuclear deterrent will remain safe, secure, and effective now and into the future.

BY THOM MASON, Los Alamos National Laboratory Director

Since the beginning of the atomic age, Los Alamos National Laboratory has played a key role in ensuring that the United States maintains a safe, secure, and effective nuclear stockpile. Today, achieving this goal requires collaboration and partnerships that stretch from coast to coast. This issue of *National Security Science* magazine focuses on the importance of the many pieces of the nuclear enterprise and the myriad ways these labs, plants, sites, and—most importantly—people work together. Each individual part of the complex is an essential component. Together, we support nuclear deterrence and maintain the stockpile through the application of unparalleled science, technology, engineering, and manufacturing.

The nuclear security enterprise began in 1942 with the establishment of the Manhattan Project, which was executed through government-owned, contractor-operated laboratories and production sites that have evolved throughout the decades. Facilities now include three national laboratories, three fabrication and materials production plants, an assembly and disassembly site, and a research and testing site. You can read about these interdependent facilities, the people who work there, and the work they do as you travel across the country on a nuclear enterprise road trip (p. 14).

Understanding the roles and responsibilities of each part of the enterprise is a crucial part of our success. The people and processes that make up the complex are interdependent and connected on every level; yet each lab, site, and plant has a unique and crucial role to play. As you flip through these pages, you will visit Los Alamos (p. 22), Livermore (p. 30), and Sandia (p. 36) national laboratories, the Kansas City National Security Campus (p. 44), the Y-12 National Security Complex (p. 48), the Savannah River Site (p. 52), the Pantex Plant (p. 56), and the Nevada National Security Site (p. 62).

Responsibility for U.S. nuclear weapons resides in both the Department of Defense (DOD, p. 72) and the Department of Energy (DOE). DOE, and its semiautonomous National Nuclear Security Administration (NNSA, p. 18), oversee the research, development, testing, and acquisition programs that produce, maintain, and sustain the nation's nuclear warheads and bombs. To achieve these objectives, the facilities that make up the nuclear security enterprise produce and recycle nuclear materials, design and fabricate nuclear and nonnuclear components, assemble and disassemble nuclear weapons, conduct scientific research and analysis to maintain confidence in the reliability of the deterrent, integrate components with nuclear weapons delivery vehicles, conduct support operations, and much more.

Across the enterprise, people move between labs and sites, learning, growing, and collaborating. This interchange between the various facilities is an essential part of understanding how we all work together to fulfill the overall mission. On p. 84, you will read about 11 Los Alamos employees who've worked at other facilities within the enterprise.

I know I benefited from what I learned, starting as a doctoral student, working at other DOE labs and leveraging capabilities at multiple labs to develop new facilities before moving to Los Alamos.

I understand the need for all employees within the nuclear security enterprise to see the big picture. Common elements of science and engineering expertise exist across the labs, and certain production responsibilities have been added to some labs' responsibilities, but each institution has a unique role in the enterprise. We rely on one other to achieve our mission. That's why I hope this magazine will offer some insight and will encourage employees from across the enterprise to learn more. This issue of *National Security Science* will shed some light on how all the parts of the nuclear security enterprise work together to enhance global nuclear security and protect the world. ★

MASTHEAD

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National Security Science (*NSS*) highlights work in the Weapons and other national security programs at Los Alamos National Laboratory. *NSS* is unclassified and supported by the Lab's Office of National Security and International Studies. Current and archived issues of the magazine are available at lanl.gov/magazine. Unless otherwise credited, all images in the magazine belong to Los Alamos National Laboratory. In the "Nuclear enterprise road trip" feature, images are courtesy of their respective sites.

To subscribe, email magazine@lanl.gov, or call 505-667-4106.

LA-UR-23-24182

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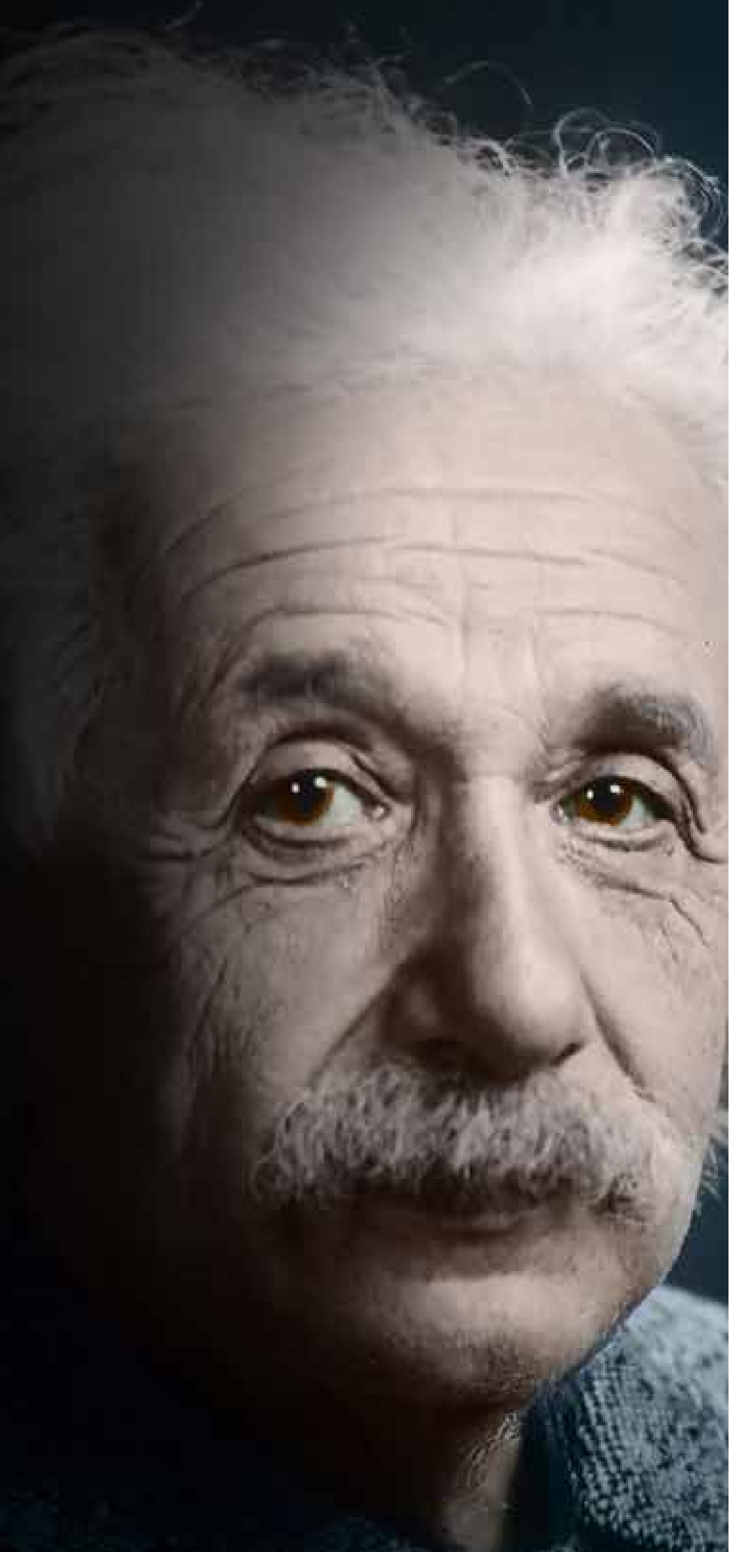
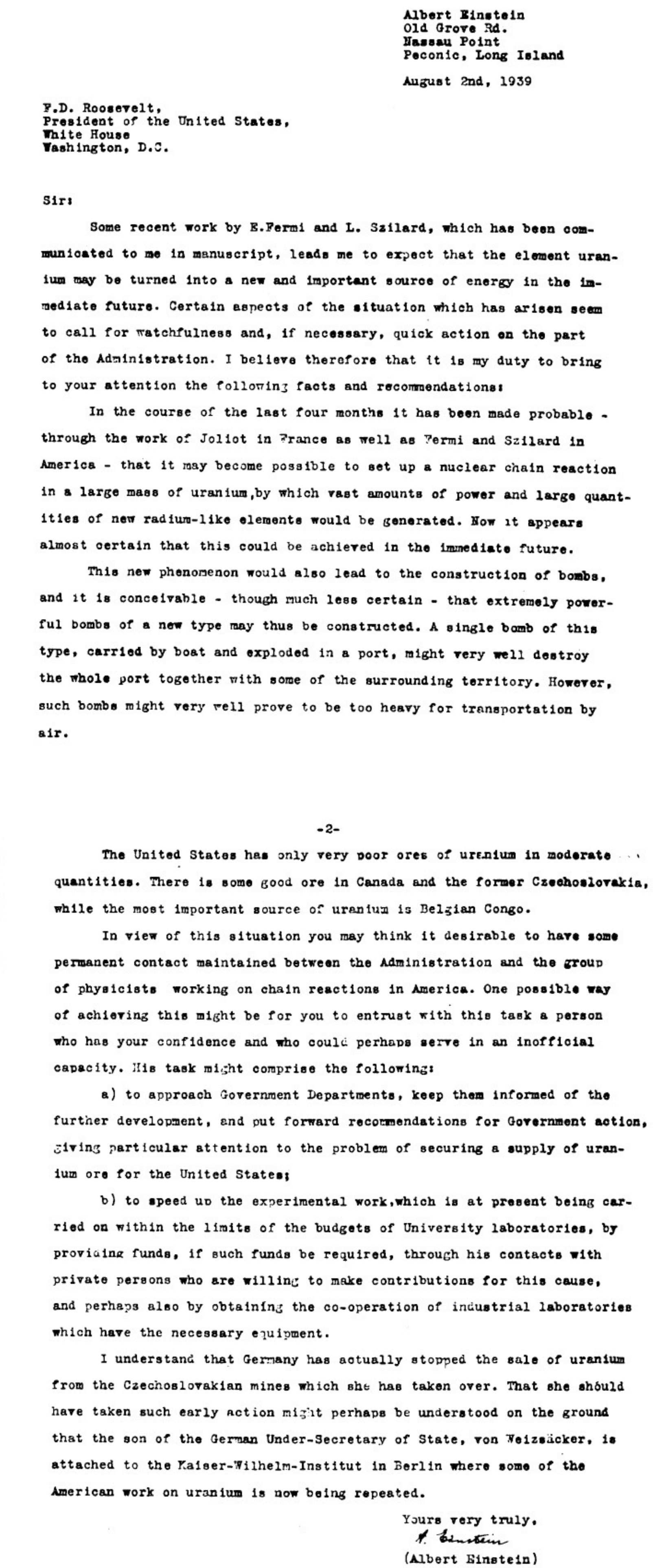
NSS STAFF SPOTLIGHT

Art director Brenda Fleming captures a photo of her reflection in one of the many mirrors erected at the Big Explosives Experimental Facility, or BEEF, at the Nevada National Security Site. The mirrors allow high-speed cameras to record conventional high explosives experiments while staying protected from flying fragments. For this issue, Fleming, along with editor Whitney Spivey and writer Jill Gibson, traveled to Nevada to tour historical testing sites, the U1a facility, and BEEF. To read about their visit and see more images, turn to p. 62. ★



■ On August 2, 1939, physicist Albert Einstein wrote to President Franklin Delano Roosevelt that the United States should research atomic weapons before the Germans harnessed this deadly technology. The letter, which fellow physicist Leo Szilard helped Einstein draft, urged the United States to stockpile uranium ore and begin work on its own atomic weapons. In 1942, after conducting research in response to Einstein's letter, the government launched the Manhattan Project, the scientific and military undertaking to develop the first atomic weapons. To learn more about the beginning of the atomic age—and what would become the nuclear security enterprise—see p. 14. ★



Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work,which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
A. Einstein
(Albert Einstein)

Administrator Hruby speaks to Los Alamos employees in August 2021.

Q&A

ENGINEERING THE ENTERPRISE

Jill Hruby brings a technical perspective to leading the National Nuclear Security Administration.

BY WHITNEY SPIVEY

The nuclear security enterprise—the complex of laboratory, production, and testing facilities overseen by the National Nuclear Security Administration (NNSA)—exists to ensure that America's nuclear deterrent is safe, secure, and effective. The enterprise is also responsible for enhancing nuclear nonproliferation (tracking peaceful nuclear activity and countering the spread of nuclear weapons materials and technologies) and for designing nuclear reactors for U.S. Navy submarines and surface ships.

"In the world we live in, it is critical to have a deep understanding of this mission in order to contribute to national decision-making in real time," says Jill Hruby, an engineer and former director of Sandia National Laboratories, who has been NNSA administrator since July 2021.

Hruby says her technical background has proved useful in leading NNSA. "Managing a large enterprise takes problem-solving skills learned at every level of engineering and every level of management," she says. "It is very useful to know how the enterprise works from multiple perspectives."

Hruby recently took time out of her busy schedule for a brief conversation with *National Security Science*.

What is the role of collaboration within the nuclear enterprise?

The nuclear enterprise is built as an interdependent system, even with some aspects of competition. We cannot successfully accomplish any of our missions at one site. The key is for everyone to do what they are the very best at and then work with others in their institutions and across the enterprise to deliver the best solutions. Personally, I find collaboration energizing and interesting. By working with others, much more can be accomplished.

What have been NNSA's greatest achievements under your leadership?

My main intent has been refocusing the NNSA enterprise on maximizing efficiency and effectiveness and reminding everyone that our work gets done in a distributed enterprise. The NNSA reorganization and the Enhancing Mission Delivery Initiative have been two large parts of this. Also, the pay packages for our M&O [management and operating] partners and the increase in benefit flexibilities have been aligned with this intent. In mission space, my focus has been on our work in Ukraine, our advancement of weapon and production modernization, and our continued efforts in nonproliferation while paying attention to emerging threats.

Administrator Hruby visits the Los Alamos Plutonium Facility in February 2023.

What have been the NNSA's greatest challenges under your leadership?

Changing the culture of the enterprise to be more responsive and to take measured risk. The world we live in today is not one where we can move slowly if we are going to help.

What is the role of supercomputing in the future of the enterprise?

Supercomputing is at the heart of science-based stockpile stewardship and increasingly at the center of many of our other missions. But the modeling we do on supercomputers needs to be well-grounded by experimental work. Increasingly, we will need to have supercomputers that incorporate more artificial intelligence and neuromorphic computing. The NNSA enterprise must help advance supercomputing and its components. This is an area where working with industry early is also helpful. Supercomputing is going to be both a national security and economic competitiveness topic for years to come.

How do you prioritize and complete infrastructure projects to support the stockpile of the future while also recruiting and retaining a workforce dedicated to successfully executing the work we are doing today?

We have to simultaneously do our mission work and build new infrastructure, and we are. Every site I visit has many demolition and rebuilding projects underway—it's really impressive how much is going on. Like other things, we are learning as we go on infrastructure projects. Our biggest challenge is getting our capabilities in time to contribute to ongoing efforts. I think we need to cultivate a construction workforce separate from our lab, plant, and site workforce.

Describe the significance of the plutonium pit mission. Why is this such an important part of deterrence?

It's simple. We can't have nuclear weapons without the ability to make plutonium pits. We now know that we can't reuse pits forever, and even if we don't know every last detail, we know we need to reestablish our ability to produce pits. I'm glad Los Alamos (p. 22) and Savannah River (p. 52) are making good progress on this capability. It's really hard.

Please describe the significance of subcritical experiments in stockpile stewardship.

Subcritical experiments at scale with real materials have been lacking, and our efforts today are aimed at filling this gap. The Enhanced Capability for Subcritical Experiments is sustaining and advancing capabilities at the Nevada National Security Site (NNSS, p. 62) more than anything we've done since the cessation of nuclear explosive testing. The Scorpius accelerator and its associated capabilities are key to taking stockpile stewardship to the next level.

What is your vision for the future of the nuclear enterprise?

I have a vision of a more flexible, resilient enterprise where we can make adjustments as needed in response to changing global conditions. I want to create an enterprise that is energized and a rewarding place to work. It should be innovative and collaborative and focused on getting things done. And our science should be the envy of the world. ★

Learn more about NNSA and the rest of the nuclear security enterprise on p. 14.

ABSTRACTS

INFOGRAPHIC

THE INTERSECTION

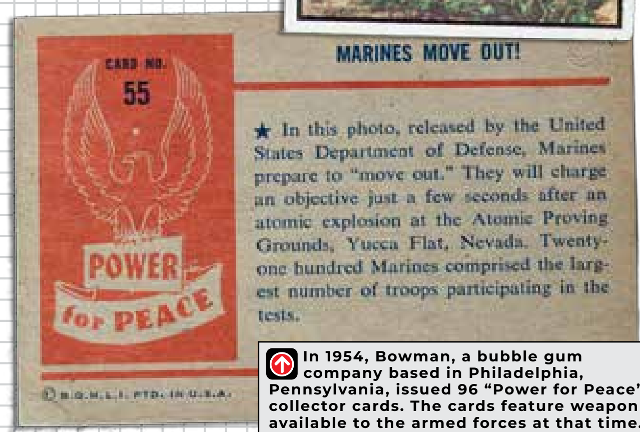
Science and culture converge in northern New Mexico—and beyond.

SCIENCE

CULTURE

Los Alamos National Laboratory's virtual tour of Manhattan Project National Historical Park sites located in downtown Los Alamos and on Laboratory property is now live. The sites on Laboratory property are inaccessible to the public, so the virtual, interactive tour allows users to experience the sites in their present condition and also as they were in the 1940s.

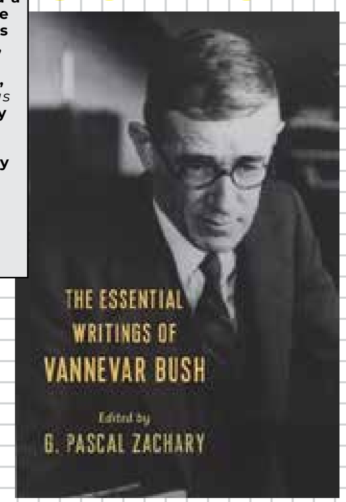
SCAN QR CODE WITH A SMARTPHONE CAMERA
Tour the park.

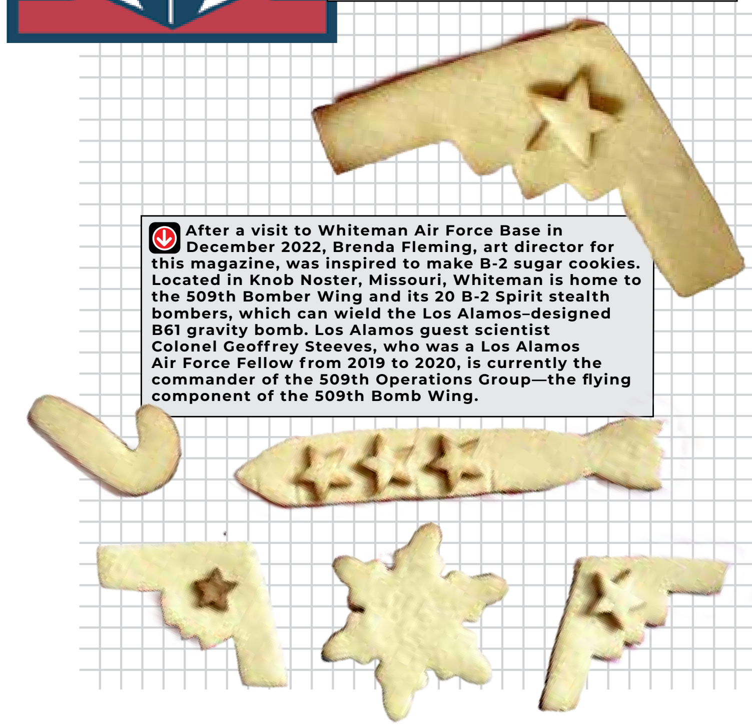


In 1954, Bowman, a bubble gum company based in Philadelphia, Pennsylvania, issued 96 "Power for Peace" collector cards. The cards feature weaponry available to the armed forces at that time. This particular card, which belongs to the father of a Los Alamos employee, shows U.S. Marines at Operation Tumbler-Snapper, a series of Los Alamos–designed nuclear tests that took place at the Nevada Test Site in 1952. For more on Nevada's nuclear testing days, turn to p. 68.

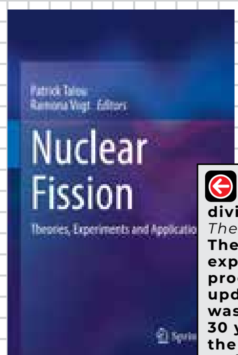
In November 2022, the National Park Service designated Los Alamos County as an American World War II Heritage City where "scientists, engineers, technicians, military, and support personnel … worked on an unprecedented, top-secret World War II government program in which the United States rushed to develop and deploy atomic weapons that hastened the end of the war." To learn more about Los Alamos' role in World War II, see p. 22.

Vannevar Bush led the U.S. Office of Scientific Research and Development during World War II, played a major role in organizing the Manhattan Project, and was present for the Trinity test, the first detonation of an atomic device. A new book, called *The Essential Writings of Vannevar Bush* (edited by G. Pascal Zachary) collects Bush's most important writings, including an essay that became the blueprint for how the government should support research and development through a system of national laboratories.





After a visit to Whiteman Air Force Base in December 2022, Brenda Fleming, art director for this magazine, was inspired to make B-2 sugar cookies. Located in Knob Noster, Missouri, Whiteman is home to the 509th Bomber Wing and its 20 B-2 Spirit stealth bombers, which can wield the Los Alamos–designed B61 gravity bomb. Los Alamos guest scientist Colonel Geoffrey Steeves, who was a Los Alamos Air Force Fellow from 2019 to 2020, is currently the commander of the 509th Operations Group—the flying component of the 509th Bomb Wing.



Patrick Talou, a senior staff scientist in the Lab's Computational Physics division, has published *Nuclear Fission: Theories, Experiments and Applications*. The book covers modern theoretical and experimental studies of the fission process, representing a significant update since the last book of this type was edited by C. Wagemans more than 30 years ago. Talou's book also discusses the importance of the fission process in various applications, for example nuclear reactors, nonproliferation, and astrophysics.

LISTEN

THE SOUNDS OF SCIENCE

A podcast series details work at the Nevada National Security Site.

The *National Security Science* podcast—a spin-off of this magazine—brings you three episodes that explore past, present, and future work at the Nevada National Security Site.

- Episode 1: Historical nuclear testing
- Episode 2: The testing moratorium and the pivot to stockpile stewardship
- Episode 3: Subcritical testing in the U1a underground laboratory

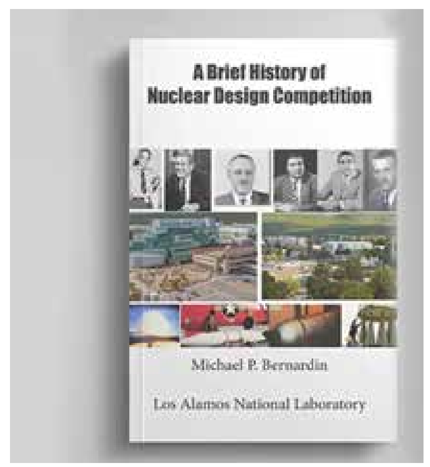
Listen and subscribe anywhere you download podcasts, or scan the QR code below. To learn more about the Nevada National Security Site, turn to p. 62.

■ Former Los Alamos Test Director Ron Cosimi stands inside the Icecap tower at the Nevada National Security Site.

SCAN QR CODE WITH A SMARTPHONE CAMERA
Listen to the *National Security Science* podcast.

EXCERPT

"Looking back over nearly four decades during the Cold War, **the country was extremely well served having two nuclear weapon design laboratories** [Los Alamos and Lawrence Livermore]. Each laboratory brought forth unique, innovative ideas and complementary capabilities. They pushed each other as they competed best-ideas for the future stockpile … they offered the [Department of Defense] a broad menu of options, likely broader than either lab would have brought forward if there was only a single weapons-design organization. Additionally, the two labs provided a weapons research community of peers. Within this community, they held classified scientific conferences; executed peer reviews of new weapon designs, technical analyses, and research papers; and they learned from each other." ★



—An excerpt from *A Brief History of Nuclear Design Competition* by Michael Bernardin, former associate Laboratory director for Weapons Physics at Los Alamos National Laboratory. To request a digital copy of the book, email nsrc@lanl.gov. For more on Los Alamos, see p. 22. For more on Livermore, see p. 30.

■ Mark Anthony, a champion for the Asian Pacific Islander employee resource group, speaks at one of the group's events.

Q&A

ASK AN ASSOCIATE DIRECTOR

Mark Anthony, head of Plutonium Infrastructure, answers three questions.

BY ALEXA HENRY

The infrastructure projects necessary to support Los Alamos National Laboratory's plutonium work are so numerous and complicated that in June 2021 a new organization was created to handle the work.

The Associate Laboratory Directorate for Plutonium Infrastructure (ALDPI) is led by Mark Anthony, an engineer and former Marine with more than 32 years of experience leading large organizations focused on technical work.

Now nearly two years into his new role, Anthony spoke to *National Security Science* about ALDPI's ambitious mission.

How does ALDPI's mission resonate with you?

I spent five years building the European Spallation Source research facility in Lund, Sweden. I've performed maintenance on reactors, led major equipment upgrades, and run large-scale projects through most of my career. Some may find it odd, but I enjoy leading large and complex technical organizations with significant responsibilities. The ALDPI project portfolio checks all the boxes. As a former Marine, joining the Lab offered another opportunity to address our country's national security challenges. *Semper Fi.*

What's your approach to meeting project milestones while ensuring, as you often say, that the team works safely and securely or not at all?

We have a team well prepared to take on the massive, multiyear projects in our portfolio, and we have great support from our federal partners. The list of deliverables doesn't stop. Staying on schedule doesn't just mean going faster in our line of work—it means decreasing risk through thorough planning. Your confidence level goes up when you can remove not only barriers but also potential risks. If you plan and do your homework upfront, you will not be caught off guard when problems happen. Your team will be ready and able to get to a resolution quickly. We value continuous improvement and are willing to take steps back, review lessons learned, and discuss how we can improve. We've had a strong safety record here. In its first 15 months, ALDPI logged more than 1.7 million hours worked without a recordable or lost-time injury. This didn't happen by luck or by chance—it was a result of deliberately implementing best practices, using good human error prevention techniques, and having an overall healthy questioning attitude.

ALDPI is rapidly hiring and expects to double in size to more than 1,500 staffers by 2024. What do you want prospective applicants to know about your organization?

Continued growth of ALDPI will be in the mid-management and below levels, including craft and technicians. Right now, there are more than 920 full-time employees supporting ALDPI, and that number is going up. But this isn't just about filling jobs. What would I tell prospective applicants? I go back to my first impression of the Laboratory five years ago: this is a great team of professionals who are very proud of their work. If you're enthusiastic about supporting our national security mission and you like seeing results, there is no other place to be. ★

Photo: Dreamstime

CULTURE

THE OTHER ENTERPRISE

A fictional spaceship inspires generations of scientists and engineers.

BY JILL GIBSON

Long before some Los Alamos National Laboratory employees joined the nuclear security enterprise, they were fans of another enterprise: the USS *Enterprise*, the fictional starship in the *Star Trek* media franchise.

The original *Star Trek* series debuted in 1966 and has expanded into movies, multiple television series, video games, novels, and comic books. *Star Trek* has inspired generations of fans to pursue careers in science and technology, including several self-declared trekkies who've ended up at Los Alamos.

"*Star Trek* is one of the reasons I decided to go back to school for mechanical engineering," says Joseph Sparto, a mechanical designer in the Lab's Pit Technologies division. "I really liked how the crew members were always pushing themselves to continue to learn and further technology. That was what really attracted me to study engineering and accept a position at the Lab."

Michael Linch, who works in operational safety at Los Alamos, saw his first episode of the original series as a first grader and from there, "I was mesmerized," he says. "*Star Trek* inspired my interest in math and science." Growing up, he also drew inspiration from key characters. "Kirk sparked my interest in the military and tactics. Spock encouraged me to solve problems in a logical, methodical manner. Scotty piqued my interest in engineering."

Star Trek also shaped the career of Los Alamos historian Nicholas Lewis. "*Star Trek* depicted the value of research and scientific knowledge, and the importance of society concurrently developing the maturity to utilize that knowledge and associated technological advancements wisely," Lewis explains. "This interest in the social construction of technology is what led me to study the history of computing—one of the most powerful technologies our species has ever created—which is what brought me to Los Alamos to study the Lab's important role in the development of electronic computing."

These Lab trekkies also point out the influence of *Star Trek* on technology. Linch says that as a child, he felt drawn to the high-tech devices in the show. "I often wondered whether fictional things like the transporter and talking computers could one day be real."

"What is interesting is that in the shows they had devices, like digital tablets, that we have now," Sparto says. The franchise's communicators, tricorders, phasers, tablets, and optical visors all now have real-life equivalents. Some of the franchise's technology, such as a 3D virtual reality holodeck that uses holograms to create an immersive 3D experience, are in development today.

Another groundbreaking characteristic of the *Star Trek* franchise is its approach to cultural issues, such as diversity. Lewis says this had a lasting impact on him. "I was not of the dominant culture where I grew up, so I felt extremely isolated," he remembers. Lewis turned to *Star Trek* for inspiration. "*Star Trek* provided a positive depiction of the future where our species had evolved out of its infancy to embrace inclusion and diversity, and to eliminate war and poverty, eventually becoming part of a vast interstellar community. Those were powerful messages that gave me hope and helped shape who I am today."

One thing the Los Alamos trekkies may not know is that the Lab played a part in the 1979 film *Star Trek: The Motion Picture*. In 1980, *The Atom*, a Laboratory magazine, reported that Lab employees created the computer animation that appeared on the monitor on the bridge of the USS *Enterprise* in the movie. Mel Prueitt, one of the employees who created the animations, is quoted as saying the graphics received a "tremendous response" from the public, which "helps create and maintain an interest in science and technology."

Here's hoping that interest continues to "live long and prosper" at Los Alamos National Laboratory and beyond. ★

■ Joseph Sparto (second from left) and his wife, Michelle, pose with Star Trek actors Patrick Stewart and LeVar Burton in 2011.
Photo: Joseph Sparto

PARTNERSHIPS

THE MUTUAL DEFENSE AGREEMENT

For 65 years, the treaty between the United States and the United Kingdom has allowed the two countries to exchange nuclear materials, technology, and information.

BY MICAELA HESTER

Nuclear collaboration between the United States and the United Kingdom dates back to World War II. Not only were the two countries allies, but British scientists contributed to the first atomic weapons developed during the Manhattan Project.

After the war, political and scientific leaders on both sides of the Atlantic wrestled with how to manage nuclear capabilities and information exchange across nations. Following the restrictive United States Atomic Energy Act of 1946, the two countries were unable to share nuclear information. They pursued separate, parallel nuclear capabilities over the next several years, with the United Kingdom successfully testing its first atomic weapon in 1952. After years of discussions, negotiations, and the continued development of the countries' respective nuclear programs, the U.S.–U.K. Mutual Defense Agreement (MDA) was signed on July 3, 1958. The bilateral treaty (officially titled the Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America for Cooperation on the Uses of Atomic Energy for Mutual Defense Purposes) provides for the exchange of defense information relevant to nuclear weapons, naval nuclear propulsion, and nuclear threat reduction.

After the MDA was signed, U.K. and U.S. nuclear collaborations flourished and continue to thrive today, nearly 65 years later. Exchanges through the MDA benefit both the United States and the United Kingdom by advancing each country's understanding of the safety, security, and effectiveness of their respective nuclear weapons stockpiles.

The current scientific exchange is primarily conducted among Los Alamos, Livermore, and Sandia national laboratories in the United States and the Atomic Weapons Establishment (AWE) in the United Kingdom. As both countries continue to modernize their nuclear weapons, one area of recent collaboration has been the W93—a potential new warhead being designed at Los Alamos (p. 22) that would be deployed on submarines.

"The W93 continues our strong partnership with the United Kingdom," explained Jill Hruby, head of the National Nuclear Security Administration, at the 2023 Nuclear Deterrence Summit. "Our efforts in this area constitute a separate but parallel effort to the UK's replacement warhead project for its submarine-based missiles." Through this work, the two independent but allied nuclear powers will continue to support one another's national security as well as the defense needs of the North Atlantic Treaty Organization.

The MDA will be up for renewal in 2024. ★

■ Scientists use AWE's Orion laser facility to research high-energy density plasma physics phenomena, which occur at the heart of nuclear explosions and inside stars. Photo: AWE

■ Shipments of transuranic waste head to WIPP. Photo: WIPP

TALKIN' TRASH

Waste disposal plays an important role in the nuclear security enterprise.

BY JILL GIBSON

The Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, permanently stores transuranic waste, which is a byproduct of the nation's nuclear weapons work. This waste consists of materials contaminated with radioactive elements, mostly plutonium. These elements have atomic numbers greater than uranium on the periodic table of elements (thus the name "trans-uranic," or beyond uranium).

Some of the waste WIPP receives comes from the remediation of sites across the country where atomic weapons were produced during World War II and through the Cold War. This legacy waste is stored at WIPP alongside waste generated from the current development and production of nuclear weapons components at National Nuclear Security Administration sites across the country.

"We're absolutely a critical component in a variety of ways," says Mark Bollinger, acting manager for the Carlsbad Field Office, which oversees WIPP. "From a site cleanup perspective, being able to safely manage and permanently dispose of transuranic waste allows the rest of the nuclear enterprise to continue its mission and not have waste stored at the generator sites."

Bollinger says that every step of the process focuses on safety. First, WIPP employees oversee the packaging of waste containers at generator sites, such as Los Alamos or Lawrence Livermore national laboratories. In preparation for transport, the waste is placed in special containers that have undergone numerous tests. "The containers go through 30-foot drop tests, get impaled on spikes, get submerged in water for several hours, and are put in fire for a period of time, all of which has to demonstrate that in all conditions the packaging is very secure and will not leak," Bollinger says.

WIPP is also responsible for transportation of the containers from generator sites to the repository. "We have a very robust shipping and transportation program and that goes from the packaging, the waste loading into the containers, all the way through to the receipt at WIPP," notes Bollinger. "Our drivers are among the finest in the country. There are very strict standards associated with them as employees." Real-time satellite tracking of vehicles ensures the vehicles are monitored at all times, and the states and the communities they pass through receive training and technology to prepare for the unlikely event of a motor vehicle accident.

Located about 26 miles east of Carlsbad in a naturally occurring underground salt bed, WIPP has been operating for more than 20 years and can hold 6.2 million cubic feet of waste. In 2022, WIPP received 235 shipments from five generator sites. Since its opening in 1999, WIPP has received approximately 13,000 shipments that were safely transported more than 15 million cumulative miles. Los Alamos is the fourth-biggest shipper of transuranic waste to WIPP in the nation.

"We place the waste about a half a mile below the surface in the middle of a half-a-mile thick layer of salt," Bollinger explains. "It is a very stable geological environment. Over time, the salt encloses the waste, sealing it in place and permanently isolating it from the environment."

WIPP is the only waste repository of its kind in the United States. "One of the things that's unique about WIPP is that the geological salt bed moves every day—something you don't typically think about in a nuclear facility," Bollinger says. "The intent is to have that salt move and encapsulate and isolate the waste from the environment. We have to work with mother nature while we work to keep the facility open and able to meet the nation's needs." Because of this, the WIPP staff includes geologists, seismologists, mining experts, hydrologists, electrical engineers, ventilation experts, and others.

Bollinger acknowledges that the facility's one-of-a-kind nature means it has unique environmental regulations. Meeting these requirements is paramount, Bollinger says. "We are not just an asset to the nation, but to New Mexico, and we are interested in being good stewards to our community." ★

ENTERPRISE LEADERSHIP

THE NUCLEAR WEAPONS COUNCIL

Nuclear Weapons Council members and affiliates visit Los Alamos.

BY WHITNEY SPIVEY

The Nuclear Weapons Council (NWC) is the ruling body that, since 1987, has directed interagency activities to maintain the safety, security, reliability, and performance of the U.S. nuclear weapons stockpile. The NWC meets regularly to discuss status, paths forward, and resolve issues between the Department of Defense (DOD) and the National Nuclear Security Administration (NNSA) regarding strategies for stockpile sustainment and modernization.

"The NWC is charged with cradle-to-grave management of the existing nuclear weapons stockpile and for planning for the future nuclear deterrent," according to the *Nuclear Matters Handbook*. "The NWC develops and promulgates a number of important policy documents and provides significant information on nuclear weapons safety, security, and effectiveness to the President and Congress."

The NWC is comprised of six voting members:

- Under Secretary of Defense for Acquisition and Sustainment (currently William LaPlante)
- Vice Chairman of the Joint Chiefs of Staff (currently Admiral Christopher Grady)
- Under Secretary for Nuclear Security of the DOE and NNSA Administrator (currently Jill Hruby)
- Under Secretary of Defense for Policy (currently Colin Kahl)
- Under Secretary of Defense for Research and Engineering (currently Heidi Shyu)
- Commander, U.S. Strategic Command (currently General Anthony Cotton)

These six voting members are supported by staff and committee members, many of whom visited Los Alamos on August 17, 2022. "I was honored to host two dozen visitors with various ties to the Nuclear Weapons Council for a visit that really highlighted the importance of our work to national security," says Laboratory Director Thom Mason. "I'm hopeful that after touring our various facilities, our visitors from NNSA and DOD came away with a better understanding of the world-class science, technology, and engineering required to maintain America's nuclear weapons." ★

Lieutenant General James Dawkins, deputy chief of staff for Strategic Deterrence and Nuclear Integration, and Austin Long, vice deputy director at The Joint Staff, arrive at the Laboratory via helicopter on August 17 as part of the NWC's visit to Los Alamos.

Los Alamos Director Thom Mason (right) speaks to NWC visitors at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. For more on DARHT, see p. 28.

ENTERPRISE ADVISORS

THE STRATEGIC POSTURE COMMISSION

Los Alamos hosts members of the bipartisan advisory group.

BY WHITNEY SPIVEY

On November 8, 2022, six members of the 12-person Congressional Commission on the Strategic Posture of the United States arrived at Los Alamos National Laboratory for a three-day visit that included tours of Laboratory facilities and briefings on various aspects of the nuclear security enterprise.

The Commission members, accompanied by their staff members and advisers, Marv Adams (head of Defense Programs at the National Nuclear Security Administration), and senior leadership from Lawrence Livermore and Sandia national laboratories, visited the Laboratory's Nicholas C. Metropolis Center for Modeling and Simulation, the Plutonium Facility, the Los Alamos Neutron Science Center, and the Sigma Facility. They also discussed workforce challenges, received background information from Global Security personnel, and attended briefings on stockpile modernization, pit production, the W93 warhead, infrastructure priorities, and more.

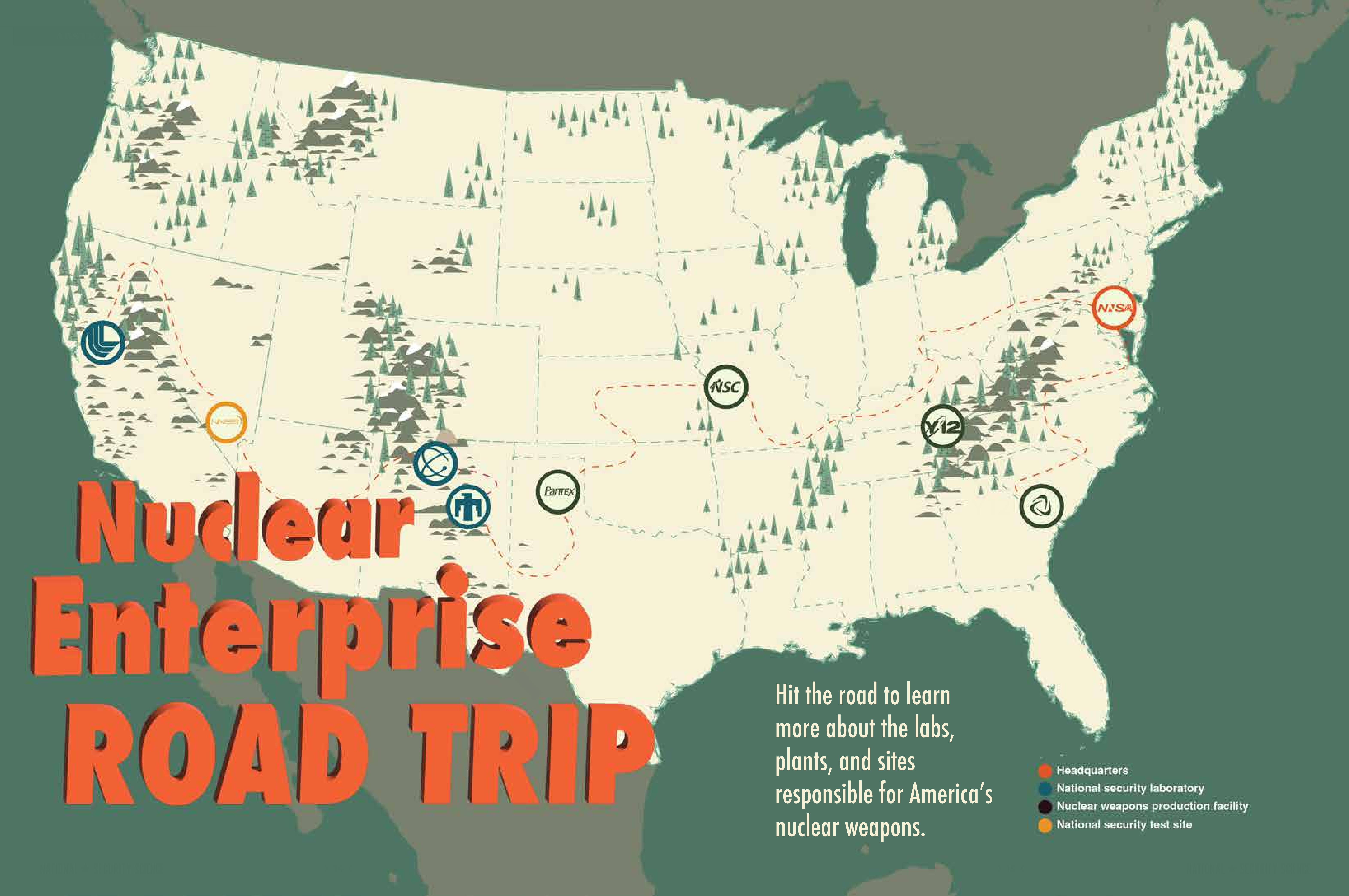
Using what they learned at Los Alamos—which included information on the entire nuclear security enterprise, not just the Laboratory—the bipartisan Commission members will review U.S. strategic posture and nuclear weapons policy and assess threats facing the country. In accordance with the National Defense Authorization Act, they must deliver a report to the President and Congress with recommendations for "the most appropriate strategic posture and most effective nuclear weapons strategy" for the United States.

"The Commissioners expressed appreciation for the importance of our people, science and computing, RDT&E [research, development, test, and evaluation] facilities, and other elements of stockpile stewardship," says Los Alamos Director Thom Mason. "They noted that the information provided, including the need for the enterprise to respond to changing circumstances, will help them as they formulate their report."

The 12-person Commission is composed of two appointments by the majority and minority leaders of the Senate, two appointments by the speaker and minority leader of the House, four appointments by the chairs of the Senate and House Armed Services Committee, and four appointments by the ranking members of the Senate and House Armed Services Committees. The Commission members are government, industry, and academic experts. ★

Commissioner Lisa Gordon-Hagerty speaks during a panel discussion about workforce challenges and opportunities. General (retired) John Hyten, another commissioner, sits to her left.

Deputy Laboratory Director for Weapons Bob Webster (right) hosts Commission members at the Los Alamos Plutonium Facility.



Nuclear Enterprise ROAD TRIP

Hit the road to learn more about the labs, plants, and sites responsible for America's nuclear weapons.

80 years of the nuclear enterprise

Dozens of facilities across the United States have supported nuclear weapons production since the 1940s.

BY JILL GIBSON

What would become the nuclear security enterprise began in 1943, as the U.S. Army oversaw the construction of the first atomic weapons during the Manhattan Project. At that time, the majority of this work occurred in Los Alamos, New Mexico; Oak Ridge, Tennessee; and Hanford, Washington.

Following the end of World War II, President Harry Truman transferred the control of atomic energy from the military to the Atomic Energy Commission (AEC), a government agency. As the Cold War became a reality, the nuclear security enterprise grew to keep pace with the demand for nuclear weapons production. The locations for sites were often chosen with certain factors in mind: they usually avoided populated areas, offered sufficient resources (such as land and electricity), and were inland areas less vulnerable to attack. Politics also often influenced where facilities were built.

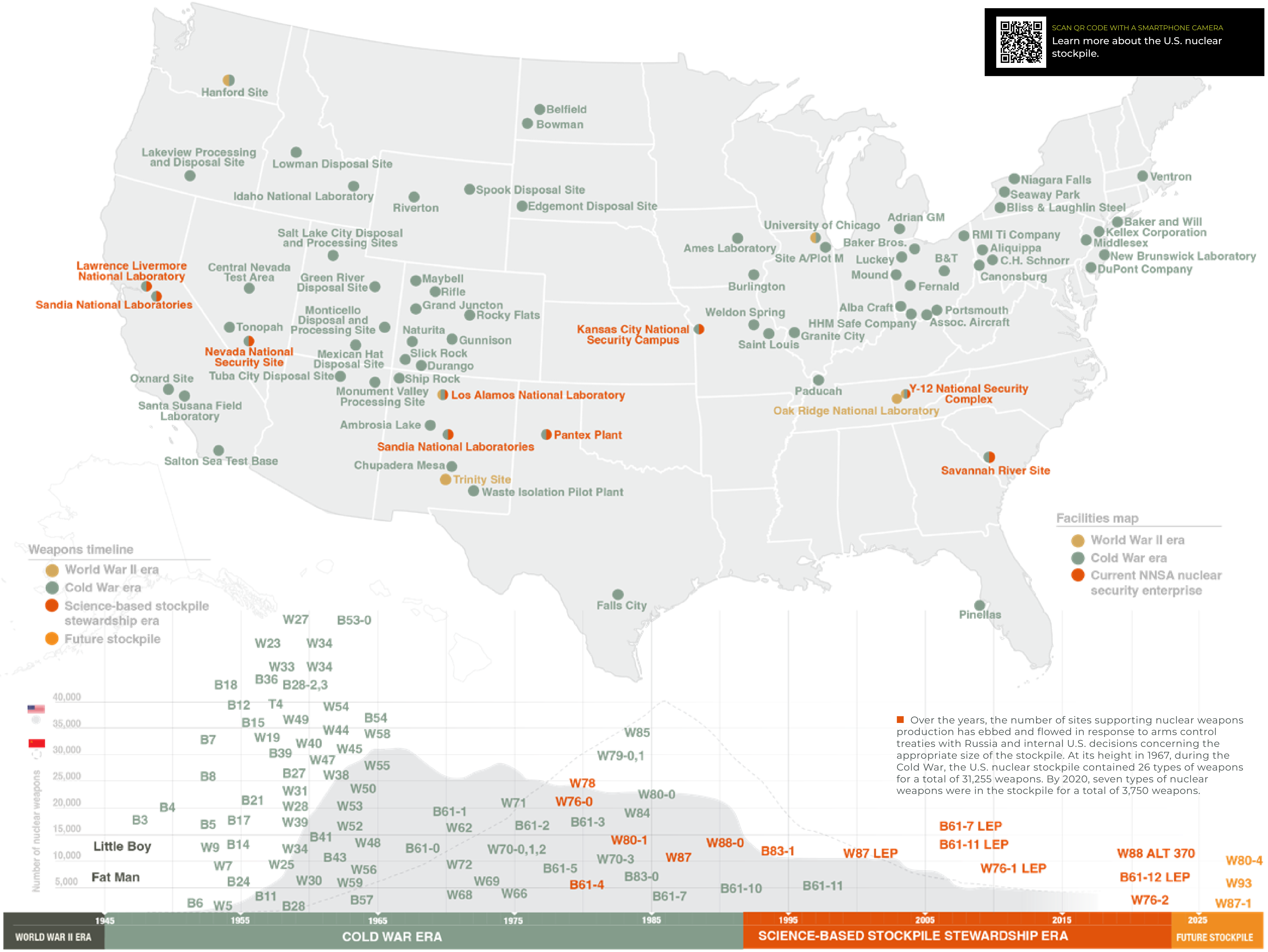
Since the end of the Cold War, the number of sites involved in nuclear weapons production has declined, as the United States has reduced the number of weapons in its stockpile while maintaining the capability to sustain the remaining nuclear weapons.

Today, the National Nuclear Security Administration (NNSA, see p. 18), a semiautonomous federal agency within the Department of Energy, manages seven of the eight government-owned, contractor-operated sites that comprise the modern nuclear security enterprise. (The Savannah River Site, which is currently overseen by the Department of Energy's Office of Environmental Management, will come under NNSA management in 2025.)

These sites, which include Los Alamos National Laboratory (p. 22), are responsible for the research, development, testing, and acquisition programs that produce, maintain, and sustain nuclear weapons.

NNSA also works closely with the Department of Defense, which generates the military requirements for nuclear weapons, and develops, deploys, and operates the missiles and aircraft that deliver the weapons. Learn more on p. 72. ★

SCAN QR CODE WITH A SMARTPHONE CAMERA
Learn more about the U.S. nuclear stockpile.



■ Over the years, the number of sites supporting nuclear weapons production has ebbed and flowed in response to arms control treaties with Russia and internal U.S. decisions concerning the appropriate size of the stockpile. At its height in 1967, during the Cold War, the U.S. nuclear stockpile contained 26 types of weapons for a total of 31,255 weapons. By 2020, seven types of nuclear weapons were in the stockpile for a total of 3,750 weapons.

Greetings from the National Nuclear Security Administration

HEADQUARTERS ESTABLISHED 2000

PRIMARY LOCATIONS

WASHINGTON, D.C.

ALBUQUERQUE, NEW MEXICO

GERMANTOWN, MARYLAND

Ensuring a safe, secure, and effective nuclear stockpile requires excellence from coast to coast.

BY J. WESTON PHIPPEN

The headquarters of the National Nuclear Security Administration (NNSA) is not, technically, a single headquarters.

Instead, the NNSA main offices are spread across three sites: the James V. Forrestal Building in Washington, D.C.; a site in Germantown, Maryland; and an office in Albuquerque, New Mexico.

Working along with the three headquarters are eight NNSA field offices, spread from coast to coast. Together, these offices oversee the nation's nuclear security enterprise: the three national labs, three fabrication and materials production plants, one assembly and disassembly site, and one research and testing site whose

combined 50,000 employees and contractors are collectively responsible for the health of America's nuclear weapons and related work.

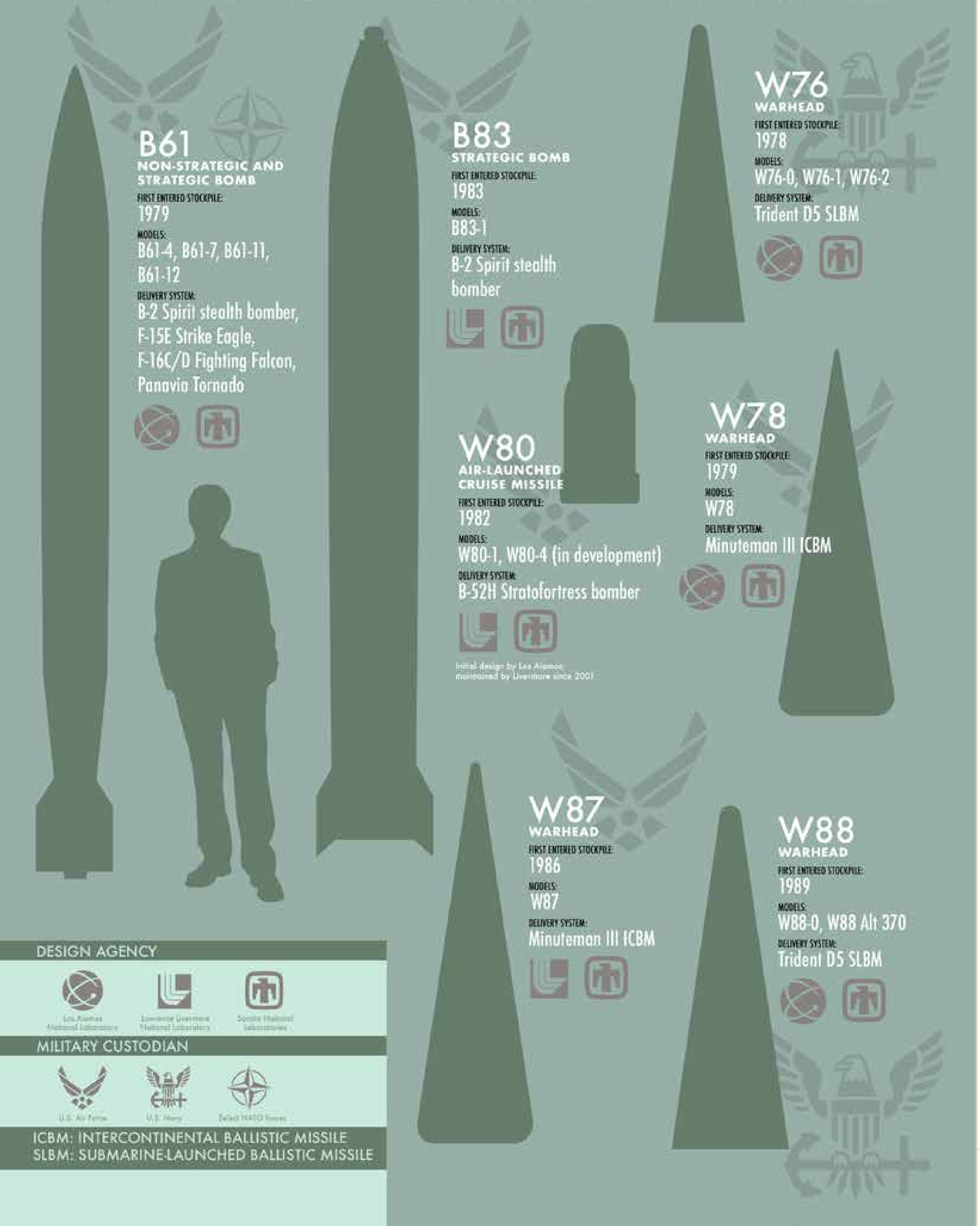
"Our nuclear deterrent remains the cornerstone of our national defense and provides critical assurance to our allies in Europe and the Indo-Pacific," NNSA Administrator Jill Hruby remarked at the 2023 Nuclear Deterrence Summit. "The rapidly changing nature of the challenges we face requires an enterprise capable of responding to those challenges in a timely manner. The nuclear security enterprise of the future we envision as resilient and flexible."

NNSA was created in 2000 when Congress passed the National Defense Authorization Act, which placed three previously existing Department of Energy (DOE) organizations (Defense Programs, Defense Nuclear Nonproliferation, and Naval Reactors) together under a new semi-autonomous agency still housed within DOE.

To better understand how NNSA manages its missions across many sites, it helps to focus more narrowly.

The NNSA field office at Los Alamos National Laboratory, for example, is led by Field Office Manager Ted Wyka, who came to Los Alamos in 2021 from NNSA headquarters in Washington, D.C. Collectively, Wyka's 98-person team of NNSA employees provides contract oversight for Los Alamos—helping ensure the Laboratory completes projects safely and on

ACTIVE U.S. NUCLEAR STOCKPILE



time while also meeting quality requirements. Some of the NNSA Los Alamos Field Office employees even work in Lab facilities, where they collaborate directly with researchers.

"We're all part of the same mission. We're all part of the same nuclear security enterprise," Wyka says. "For example, I may only have a dozen safety professionals in the field office. But we have 6,600 in the enterprise, so if there's something specific that I or the Lab needs support with, we have that expertise on hand."

"Communication is a piece of everything we do here," he continues. "We have to work closely with federal and state regulators, and up in Los Alamos, we have four Pueblo neighbors, and it's really important for us to stay in constant communication with them."

One of NNSA's top priorities nationally is pit production, for which both Los Alamos and the Savannah River Site (see p. 52) will manufacture plutonium pits, or nuclear weapon cores. To accomplish this mission at Los Alamos, Wyka's team meets regularly with Lab leadership and relays progress and needs to headquarters.

The pit production mission requires a lot of new infrastructure and equipment, so Wyka's team has been busy coordinating with federal and state environmental agencies. One day Wyka might speak with the Pantex Plant (see p. 56), in Texas, where weapons are assembled and disassembled. The next day, he might communicate with the NNSA field office at Lawrence Livermore National Laboratory (see p. 30), in California, which is assisting in new facility design for the pit mission. Then he might be on the phone with the Waste Isolation Pilot Plant (see p. 11), in southern New Mexico, because producing pits means more nuclear waste to dispose of safely.

"It's definitely an enterprise-wide project," Wyka says. "We're constantly working at every level of the Lab, at every level of NNSA, at every level of the nuclear security enterprise, to ensure we can deliver on this mission."

Every day, the same level of coordination is needed at all eight field offices, which in turn coordinate with the three headquarters, which in turn relay information back down the chain, all the way to the scientists and engineers who steward America's nuclear weapons. It's a circle of oversight that keeps the nation safe. ★

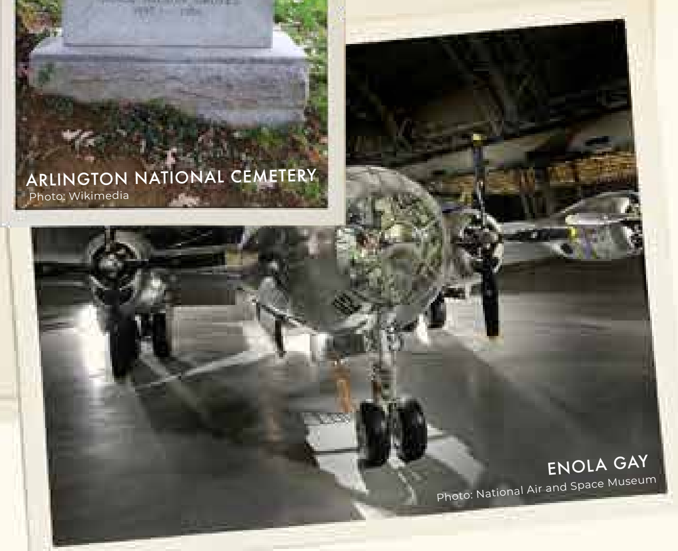
National Nuclear Security Administration

NUMBER OF EMPLOYEES: 2,500
FISCAL YEAR 2023 BUDGET: $22.2 BILLION
FALLS WITHIN THE: DEPARTMENT OF ENERGY

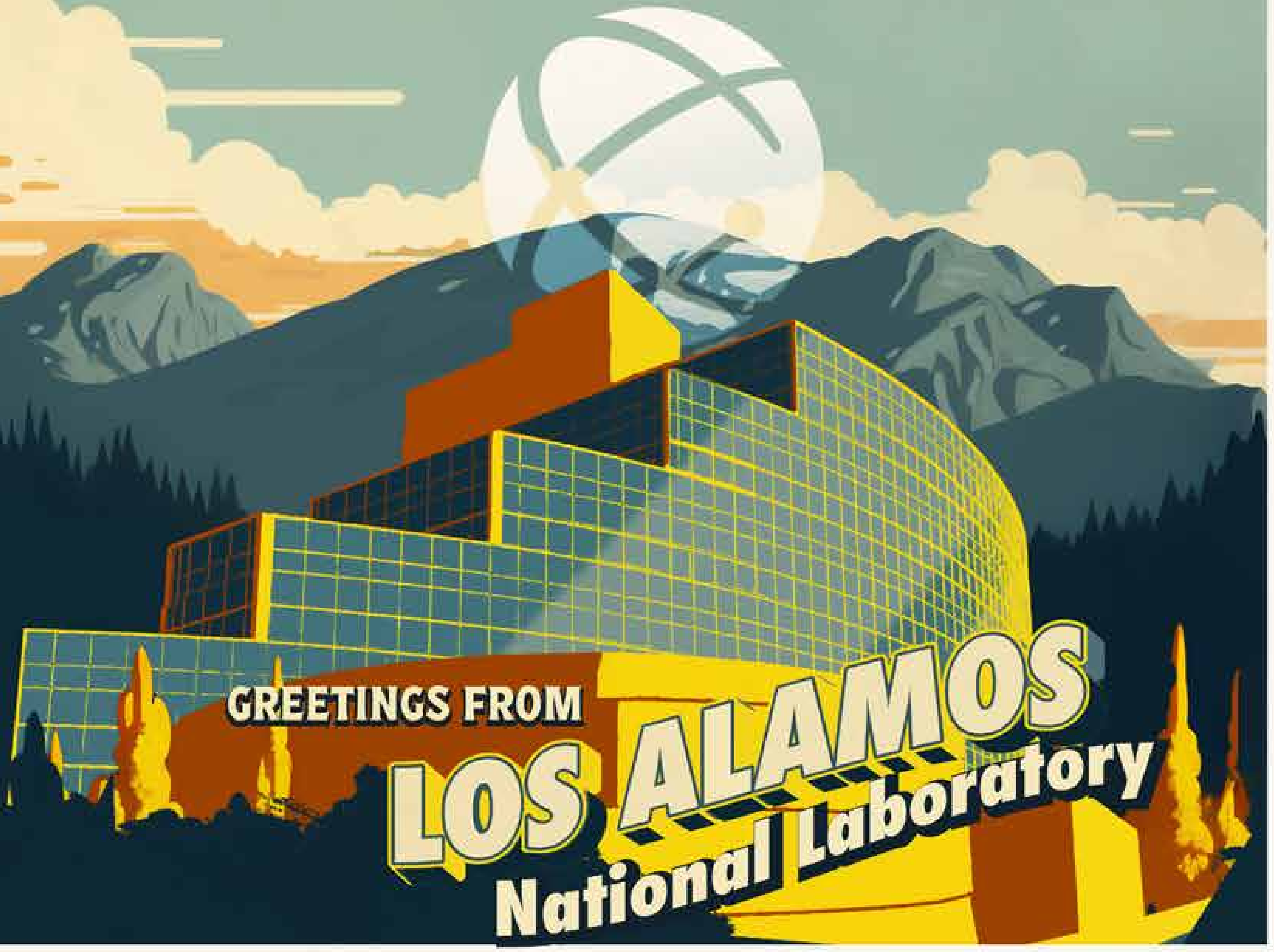
CHECK OUT:

- The National Air and Space Museum's Steven F. Udvar-Hazy Center, which houses the Enola Gay, the B-29 aircraft that dropped the Little Boy bomb on Hiroshima, Japan, on August 6, 1945
- Arlington National Cemetery, where General Leslie Groves, director of the Manhattan Project, is buried

ARLINGTON NATIONAL CEMETERY
Photo: Wikimedia



ENOLA GAY
Photo: National Air and Space Museum



NATIONAL SECURITY LABORATORY

ESTABLISHED 1943

PRIMARY LOCATION
LOS ALAMOS, NEW MEXICO

MISSION

RESEARCH & DEVELOPMENT
- PLUTONIUM R&D
- HIGH EXPLOSIVES R&D
- TRITIUM R&D

WEAPONS DESIGN & ENGINEERING
- HYDROTESTING
- MAJOR ENVIRONMENTAL TESTING

WEAPONS PRODUCTION
- PLUTONIUM PIT PRODUCTION
- NONNUCLEAR COMPONENTS PRODUCTION

The remote New Mexico laboratory has designed the majority of weapons in the past and present nuclear stockpile.

BY WHITNEY SPIVEY

Los Alamos National Laboratory, which unfolds from the base of New Mexico's Jemez Mountains eastward across narrow mesas and rugged canyons to the Rio Grande, is one of the largest national laboratories in the United States, both in terms of number of employees and physical footprint. More than 16,000 people work across its sprawling 40-square-mile campus, in satellite offices in nearby Santa Fe, or remotely (approximately 11 percent of the workforce is part of the telework program that launched during the COVID-19 pandemic).

Although the Laboratory excels at all types of science, technology, and engineering research and development, Los Alamos is at its core a nuclear weapons laboratory; its primary mission, backed by an unprecedented $4.6 billion budget in fiscal year 2023, is to help the United States maintain a robust and credible nuclear deterrent.

"That's our responsibility to the nation," explains Bob Webster, deputy Laboratory director for Weapons at Los Alamos. "The United States relies on nuclear deterrence to provide defense of our homeland and our allies. Our job as a national nuclear security laboratory is to make sure the nuclear deterrent is safe, secure, and effective—now and into the future."

THE EARLY DAYS

Los Alamos was founded in January 1943 as "Project Y" of the Manhattan Project—the U.S. government's top-secret effort to build the world's first atomic bombs to help end World War II.

A top-secret effort requires a top-secret location, so a remote mesa in northern New Mexico was deemed appropriate by the few government officials who knew about the project. Scientists, engineers, and their families came from across the world to the hastily erected "secret city," which was enclosed by a barbed-wire fence and guarded by Army soldiers. The new residents endured shoddy government housing, censored mail, and unpaved roads but also enjoyed raucous parties, adventures in the surrounding mountains, and day trips to Santa Fe (where P.O. Box 1663 was their official mailing address).

Twenty-eight months later, they had designed and built the Gadget—the world's first nuclear device, which was detonated at the Trinity site in southern New Mexico on July 16, 1945. Just a few weeks later, they provided the Little Boy and Fat Man bombs to the military. The weapons were dropped on Hiroshima and Nagasaki, respectively, in August 1945. World War II came to an end, but the Atomic Age had just begun.

THE COLD WAR YEARS

On the heels of World War II came the Cold War, which saw both the United States and the Soviet Union designing, testing, and producing nuclear weapons at an increasingly rapid pace. At its height in 1967, the U.S. stockpile contained 26 types of weapons for a total of 31,255 weapons. "At this time, most Americans feared the Soviet Union and supported having a big stockpile with a diverse array of nuclear weapons," says Los Alamos senior historian Alan Carr. "People realized how valuable these weapons were in deterring Soviet aggression."

Carr notes that the Cold War solidified the Laboratory's future as a nuclear weapons laboratory. "Project Y was now Los Alamos Scientific Laboratory, and its mission was to refine the weapons developed during World War II, as well as develop entirely new weapons designs," he explains. Those designs ranged from the W54, the 1950s-era warhead that could be carried by an individual, to the W53 thermonuclear warhead, which weighed more than four tons and topped Titan II missiles from 1962 to 1987.

Of course, not every Los Alamos weapons design made it into the stockpile. Many nuclear devices were tested (106 in the Pacific Marshall Islands, 928 at the Nevada Test Site, and 20 in other locations) to gauge their potential. These tests, which occurred in the atmosphere, underwater, or underground, provided data on the many complex aspects of a nuclear detonation that occur simultaneously on a nanosecond time scale. These data allowed scientists to better understand nuclear explosion characteristics and evolve their designs accordingly.

LOS ALAMOS TODAY

The United States has not fielded a newly designed nuclear weapon since 1991 and has not conducted a full-scale test of a nuclear weapon since 1992. These decisions are influenced by national policy and reinforced by treaties, such as New START, which caps the number of nuclear weapons in the U.S. stockpile, and the Comprehensive Nuclear-Test-Ban Treaty, which prohibits all nuclear testing.

Over many decades, the U.S. stockpile has become smaller (with fewer weapons—3,750 as of September 2020) and less diverse (with fewer types of weapons systems). Today, seven types of weapons systems are in the stockpile. Some of these systems include variants—different models that have been updated to be safer or to meet changing military requirements.

Los Alamos designed and is responsible for four of these weapons systems: the B61 bomb and the W76, W78, and W88 warheads. Lawrence Livermore National Laboratory (see p. 30) is responsible for the other three systems: the B83 bomb, and the W80 and W87 warheads.

On average, the weapons for which Los Alamos is responsible are older than most people who work at the Laboratory. All but a handful of these weapons are significantly older than the oldest weapon tested during the nuclear testing era, and all weapons contain components that are older than the oldest components tested during a nuclear test. "Thus, every modern-day assessment of our weapons involves extrapolation," Webster says. "Confidence in these extrapolations demands world-class science, technology, and engineering, as well as cutting-edge experimental and computational capabilities." This approach is called stockpile stewardship.

Trinity supercomputer

Proton radiography

Glovebox training

Detonator production

Through stockpile stewardship, Los Alamos works in conjunction with other labs, plants, and sites across the nuclear enterprise to assess and ensure the safety, security, and effectiveness of the B61, W76, W78, and W88.

Each weapon requires surveillance (a thorough physical examination of a representative sample weapon that starts at the Pantex Plant and continues at other sites) and routine maintenance. If at any time Los Alamos becomes concerned about the health of a weapon, the weapon may be retired, or in some cases, refurbished via a life extension, alteration, or modification, each of which provides various degrees of updates that enable the United States to maintain a credible nuclear deterrent without producing new weapons or conducting underground nuclear tests.

Each September, Los Alamos' assessments of its weapons systems culminate in a letter from the Lab director to the secretary of energy, the secretary of defense, and the chair of the Nuclear Weapons Council (see p. 12). This letter informs the president of the United States of the director's confidence that the B61, W76, W78, and W88 are safe, secure, and effective as a result of sustainment and modernization efforts.

STOCKPILE STEWARDSHIP TOOLS

The success of stockpile stewardship at Los Alamos—the continued assessment and maintenance of the B61, W76, W78, and W88—is largely due to the development of the tools and infrastructure required to understand what happens to weapons materials and components as they age. Investments in scientific, experimental, engineering, and computational capabilities at Los Alamos allow the Laboratory to confidently extend the service lives of the nation's nuclear weapons without full-scale underground testing.

"We are entering an unprecedented and exciting transformation of the Laboratory campus," says David Teter, associate Laboratory director for Infrastructure and Capital Projects. "We are investing approximately $1 billion per year for the next five to ten years to modernize the infrastructure required to deliver on stockpile stewardship now and into the future."

Perhaps more than any other capability, high-performance computing has facilitated the success of stockpile stewardship. Many modern weapons experiments generate enormous amounts of data that can be used in or compared against computer calculations so that scientists and engineers can make informed decisions about the nation's deterrent.

To manage all this information, the Lab maintains world-class modeling, simulation, and visualization capabilities, including some of the world's most powerful supercomputers. Currently, the Trinity supercomputer enables large-scale data analysis and visualization capabilities that help scientists test their hypotheses and solutions. In 2023, the Lab will activate two new supercomputers, Crossroads and Venado, which will advance Los Alamos' ability to study the most complex physical systems for science and national security.

Data that is compared against supercomputer simulations is generated at facilities such as the Laboratory's Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. Each axis of the building contains an accelerator that's used to produce radiographs (high-powered x-ray images) of a mock nuclear device as it detonates inside a spherical confinement vessel. During these types of detonations, the device implodes at speeds greater than 2.5 miles per second, and the radiographs allow scientists to "see" the movement of materials. For more on DARHT, see p. 28.

Like DARHT, the Lab's proton radiography (pRad) facility at the Los Alamos Neutron Science Center also images internal characteristics of explosions. Here, a high-energy proton beam is captured on video as it probes a range of materials under extreme pressures, strains, and strain rates.

Los Alamos scientists also obtain data at the Laboratory's many high-explosive laboratories and firing sites. The experimental work carried out at these places provides scientists and engineers with important information on aging explosives, as well as new and safer explosive formulas.

The Laboratory's 233,000-square-foot Plutonium Facility is the only fully operational plutonium science and manufacturing facility in the nation. Here, researchers can safely investigate the material properties of plutonium as well as other radioactive elements. In 2009, Los Alamos was named the nation's Plutonium Center of Excellence for Research and Development by the National Nuclear Security Administration (NNSA).

Finally, the Lab's Sigma facility supports prototype fabrication, materials research, and research and development in metallurgy and ceramics—all of which can be applied to a variety of weapons activities.

Los Alamos Director Thom Mason says these facilities—most of which are in the process of being updated—are perhaps more essential now than at any time since the height of the Cold War. "The importance of our mission at Los Alamos has been really highlighted with the geopolitical tensions we see around the world," he says. "With our state-of-the-art tools and infrastructure, our people are helping ensure the reliability of the deterrent that serves as the ultimate guarantor of our security."

FARTHER AFIELD

Los Alamos' large and relatively remote campus enables quite a bit of on-site explosives and experimental work, but projects requiring nuclear materials or significant amounts of high explosives are conducted at the even larger and more remote Nevada National Security Site (NNSS, see p. 62). The Laboratory maintains full-time employees at NNSS to facilitate this work and collaborates closely with NNSS employees.

For example, Los Alamos is leading the Advanced Sources and Detectors (ASD) Project at NNSS. The project, also known as Scorpius, is a 125-meter-long linear induction accelerator that will be installed in an underground laboratory. The device will allow scientists to take multiple images of subcritical experiments—contained experiments that incorporate nuclear materials but are configured so no self-sustaining nuclear fission reaction occurs.

"Scorpius will give us an unprecedented level of detail about the behavior of our current and future stockpile," says ASD senior director Mike Furlanetto. "That detail will allow us to certify that the stockpile will remain safe, secure, and effective without needing to return to nuclear testing."

Scheduled to be operational by 2030, the accelerator represents a partnership among Los Alamos, Lawrence Livermore, and Sandia national laboratories, which are each responsible for different parts of the machine.

Los Alamos also partners with Livermore, Sandia, and other institutions to run experiments at their facilities, such as Livermore's National Ignition Facility and Sandia's Z Machine. Likewise, researchers from other institutions perform experiments at Los Alamos facilities.

PIT PRODUCTION

Although Los Alamos is primarily a research and development institution, the Laboratory has always done some manufacturing of nuclear and nonnuclear weapons components. Two of those components are plutonium pits and detonators.

A plutonium pit is the core of a nuclear weapon—a compressed pit generates nuclear energy. Los Alamos produced the first plutonium pits in 1945 and has conducted limited pit production over the years. But from 1952 to 1989, the majority of plutonium pits for U.S. nuclear weapons were manufactured at the now-defunct Rocky Flats Plant near Denver, Colorado.

These pits are now at least 34 years old, and research is continually being done to understand how their age might affect their performance. "As plutonium ages, it undergoes changes, and decay impurities build up—both of which could impact the way the pit works," explains David Gubernatis, deputy division leader in the Pit Technologies Division at Los Alamos. To assuage any

An explosives test at Los Alamos' Minie firing site in December 2020

concerns, NNSA has tasked Los Alamos with developing a pit production program to replace all aging pits in the stockpile. Another facility, the Savannah River Site (see p. 52), has also been tasked with producing pits.

Pit production will not require new plutonium but rather salvaged plutonium from existing pits that are not in use. "Plutonium is very recyclable," Gubernatis says. "What we're doing is removing aged plutonium from old pits, then reprocessing that plutonium into new pits."

Los Alamos is currently developing the processes for manufacturing pits for the Lawrence Livermore–designed W87 warhead. In 2022 and into 2023, the Lab has manufactured many development pits, which are pits that are not meant to go into weapons but are part of the research and development phase of the pit mission.

"Los Alamos' workforce demonstrated its technical and operational leadership to the nation through producing development pits over the past few years," says David Dooley, senior director of the Defense Programs Office (see p. 85). "We've solved technical challenges, enhanced expertise, and improved disciplined operations. We're pleased with our progress and successes that will support our continued efforts in the pit mission."

Eventually, Los Alamos will produce "war-reserve" pits that meet all design, manufacturing, and quality requirements. These pits will be shipped to Pantex, where they will be placed inside stockpiled weapons.

DETONATOR PRODUCTION

For a plutonium pit to implode inside a nuclear weapon, the pit must be compressed uniformly by the high explosives that surround it. The high explosives are triggered by small devices called detonators. Since 1989, detonators for all nuclear weapons in the U.S. stockpile have been manufactured by Los Alamos.

"Detonator production is key to the Los Alamos mission and the nation's nuclear deterrent," says Patrick Garcia, senior director of the Lab's Non-Nuclear Production Office. "The unique skills of our engineers, technicians, and inspectors are implemented every day to reliably and repeatedly produce, package, and ship detonators with their accompanying cable assemblies. The team continues to grow to be in position to meet current and future needs of the nation's nuclear stockpile."

Over many decades, detonators have evolved to be smaller and safer. Los Alamos is currently advancing optical detonators for stockpiled weapons. Optical detonators are initiated by lasers (as

opposed to electrical power) and thus are less likely to inadvertently detonate. The Lab's Detonator Production division is also exploring new capabilities, such as additively manufacturing (similar to 3D printing) detonator components. "Utilizing additive manufacturing capabilities will continue the progression of detonator manufacturing technology," Garcia says. "We are now working on the foundation for additive manufacturing of detonators with the objective that they meet the same level of technical and quality standards of our current detonators—able to perform their function in a qualified and certified weapon system."

LOOKING FORWARD: THE W93

"The overarching purpose of the Los Alamos weapons program is to ensure the current and future effectiveness of the United States' nuclear deterrent," Webster explains. "We must lead the nation in evaluating, developing, and ensuring effectiveness of our nuclear deterrent, including in design, production, and certification of current and future nuclear weapons."

One potential future weapon is the W93 warhead, which would be deployed on both Ohio- and Columbia-class submarines beginning in the 2030s. As the warhead's lead physics design agency—the organization responsible for the design and certification of the nuclear warhead package and some of the nonnuclear components—Los Alamos must determine if the W93's proposed military requirements are technically feasible. If a design moves forward, the W93's nuclear components will likely be based on currently deployed and previously tested weapons. However, the W93 would incorporate modern technologies that improve safety, security, and flexibility to address future threats.

"At any moment in time, the nation's nuclear deterrent must be fit-for-purpose," Webster continues. "In a changing world, we must be prepared for any situation. Since the 1940s, Los Alamos has risen to that challenge, and we will continue to guarantee the value of the nuclear deterrent today and into the future." ★

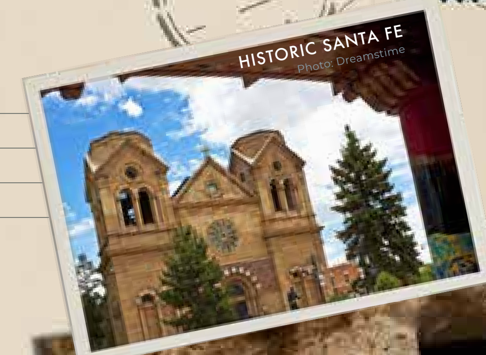
SCAN QR CODE WITH A SMARTPHONE CAMERA
Learn more about the Los Alamos mission.

LOS ALAMOS NATIONAL LABORATORY

NUMBER OF EMPLOYEES: 16,000
FOOTPRINT: 40 square miles
FISCAL YEAR BUDGET: $4.6 billion
CURRENT OPERATOR: Triad National Security, LLC

CHECK OUT:

- Three national parks: Bandelier National Monument, the Valles Caldera National Preserve, and the Manhattan Project National Historical Park
- Historic Santa Fe, the oldest and highest-altitude capital city in the country



The individual induction cells that form the DARHT Axis 2 accelerator weigh 17,000 pounds each.

SIDE STORY

SCAN QR CODE WITH A SMARTPHONE CAMERA
Watch a video about DARHT.

The Dual-Axis Radiographic Hydrodynamic Test facility

Powerful accelerators help ensure national security.

BY JILL GIBSON

> "We are never done with science at Los Alamos."
>
> —HOWARD BENDER

The soaring ponderosa pines, expansive views, towering mountain ranges, and dramatic canyons of northern New Mexico offer many opportunities for breathtaking photographs. Tucked into that scenery is the sprawling campus of Los Alamos National Laboratory, where scientists are taking breathtaking pictures of an entirely different sort.

The Lab's Dual Axis Radiographic Hydrodynamic Test (DARHT) facility is used to take high-speed images of mock nuclear devices and other materials as they implode. Howard Bender, a group leader in the Lab's Integrated Weapons Experiments Division, says the facility's two massive electron accelerators are used to produce critical data—in the form of radiographs—that help ensure the safety, security, and effectiveness of the United States' nuclear deterrent. "When it comes to nuclear weapons, scientists have constant questions regarding the safety, materials, aging, new designs, and other aspects of the various systems," Bender says. "DARHT helps us answer these questions."

Currently, scientists are using DARHT to carry out hydrodynamic experiments on plutonium surrogates—materials that behave similarly to plutonium but do not create a nuclear reaction. These tests provide essential experimental data to constrain computational codes for nuclear weapons, which is a critical component of maintaining the nuclear weapons stockpile. These tests also provide useful data for experiments at the Nevada National Security Site (see p. 62), which is the only place where subcritical experiments using actual plutonium can take place.

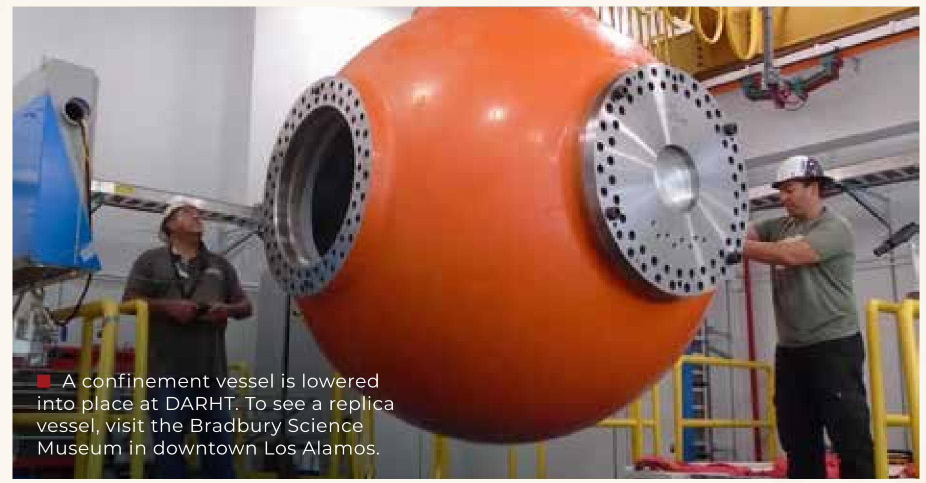
DARHT's two accelerators, located in above-ground concrete bunkers, intersect at a right angle. Each bunker stretches about the length of a football field. During an experiment, each accelerator generates a stream of electrons that travel down the length of the machine, gaining energy along the way. In the Axis 1 accelerator, the electrons reach a kinetic energy of 20 million electron volts and are moving close to the speed of light when they hit a heavy metal target that converts them into a pulse of high-powered x-rays. Simultaneously, a mock nuclear weapon is detonated inside a steel confinement vessel just beyond the accelerator. A high-tech camera concurrently captures an image—a radiograph—that shows what's happening inside the confinement vessel. The radiograph looks like something you'd see at the dentist's office, but instead of molars, the image shows a cloud of weapons parts and materials moving more than 2.5 miles per second.

The Axis 2 accelerator works similarly, but it creates a longer stream of electrons that are sliced into four shorter pulses. Each pulse is converted into x-rays, and a camera captures four images in rapid succession.

Bender says there is a slight delay in between the firing of the test and the time the images appear on the computer screens in the facility's control room. "Until the images pop up, we are on pins and needles," he says.

DARHT is the only linear accelerator facility in the nation that uses a dual-axis approach to generate images. The single image from Axis 1 can be combined with any of the four images from Axis 2 to create dual-angle digital images that can be used to generate three-dimensional computer simulations. Both the images and the simulations provide a unique view of what happens to mock nuclear weapons as they detonate. Bender says a long-term goal for DARHT is to produce radiographs from additional angles, which will improve 3D modeling and continue to advance scientists' understanding of weapons implosion. "We are never done with science at Los Alamos," he says.

Since 1999, when Axis 1 was completed, scientists have run 77 full experiments and more than 70,000 reliability and preparation tests. "It can take up to three years and millions of dollars to design and fabricate a device for a test," says Bender, noting that after all the preparation work, the accelerators must perform perfectly to capture radiographs. "We get one shot at a specific experiment. One shot and that's it." The reliability and repeatability of each of the thousands of engineering subsystems that make up the accelerators are crucial to achieving the goals of each experiment.



A confinement vessel is lowered into place at DARHT. To see a replica vessel, visit the Bradbury Science Museum in downtown Los Alamos.

To ensure consistent and predictable performance, the facility requires constant upkeep and upgrading. In 2020, a weather enclosure was built around the firing point (the area where detonations occur), creating a controlled environment for experiments. The enclosure also shields the facility's cameras and other diagnostic equipment from poor weather conditions.

Bender says that although the enclosure contributes to the facility's success, the key to DARHT's performance is the people. "Everybody here is really good at what they do—tremendous experts," he says. "The engineers, scientists, technicians, operators, diagnostics people, data specialists—everyone is here to make this work, and it works because they do a phenomenal job." ★

NATIONAL SECURITY LABORATORY

ESTABLISHED 1952

LOCATION
LIVERMORE, CALIFORNIA

MISSION

RESEARCH & DEVELOPMENT
- PLUTONIUM R&D
- HIGH EXPLOSIVES R&D
- TRITIUM R&D

WEAPONS DESIGN & ENGINEERING
- HYDROTESTING
- MAJOR ENVIRONMENTAL TESTING

Cutting-edge science keeps the nation's nuclear deterrent safe, secure, and effective in an era without nuclear testing.

BY JAKE BARTMAN

Depending on who you talk to, the Cold War was less a conflict between the United States and the Soviet Union than it was between the United States' own nuclear superpowers: Lawrence Livermore and Los Alamos national laboratories.

Today the two facilities, which for seven decades have designed the United States' nuclear weapons, collaborate more than they compete. But for much of the Cold War, when the laboratories routinely vied for contracts to design the bombs and warheads that compose the nation's nuclear arsenal, their relationship tended toward rivalry. As one Livermore weapons scientist joked to anthropologist Hugh Gusterson in the late 1980s, "The Soviets are the competition, but Los Alamos is the enemy."

Unlike the conflict between the United States and the U.S.S.R., though, the arms race between Los Alamos and Livermore was by design—a way of putting competition to use for the benefit of the nation's security.

"Our lab was explicitly founded to provide competition in the design of nuclear weapons," says Mark Herrmann, program director for weapons physics and design at Livermore. "I think we've seen, over many decades, that the combination of collaboration and competition has really provided benefits—new ideas, better ideas—that push us forward."

Today, in the era of stockpile stewardship—which aims to ensure the safety, security, and effectiveness of the nation's nuclear deterrent, without resorting to nuclear testing—ties between Los Alamos and Livermore have never been closer. "Our partnership, in an era without underground nuclear testing, is even more important," Herrmann says. "It's even more important for us to be working together and providing peer review, because we can't go out and test out ideas to the extent that we could."

NUCLEAR RIVALS

Los Alamos was almost a decade old when, in 1952, Livermore was founded (as the University of California Radiation Laboratory at Livermore) by Manhattan Project alumni Ernest Lawrence and Edward Teller. A World War II-era naval air base in rural Livermore, California, 45 miles east of San Francisco, was selected as the site of the new laboratory, partly for its remoteness. The town, separated from the Bay Area by a line of golden hills, wouldn't be serviced by a highway until the 1970s, which made the new laboratory better suited for classified work than Lawrence's laboratory in metropolitan Berkeley, California.

From the outset, Los Alamos scientists resented their new colleagues. Researchers at Los Alamos were piqued when, in 1952, the media incorrectly attributed the world's first successful test of a hydrogen bomb to Livermore, rather than Los Alamos. Due in part to this perceived slight, Los Alamos' scientists were gleeful when, a year later, Livermore's first two nuclear weapons tests "fizzled," or failed.

Despite these early setbacks, Livermore soon distinguished itself with its efforts to design thermonuclear weapons that were small in size but high in yield. In 1956, Teller shocked attendees of a naval conference by declaring that within five years, Livermore could design a 1-megaton-yield thermonuclear weapon that would fit atop a submarine-launched missile. Such a warhead would have to be less than one-tenth the size of any such weapon hitherto developed.

Teller's audacity proved justified. In 1960, the Navy deployed the first Polaris missiles topped with the Livermore-designed W47—a small-yet-powerful warhead that signaled a turning point in nuclear weapon design.

Acrimony between the laboratories persisted, with scientists at times publicly questioning each other's work. But in commenting on a dispute between the laboratories in the 1970s, Teller took tensions between the two in stride: "The laboratories need each other to keep each other honest," he said.

"Livermore and Los Alamos each have history, and culture, and perspective, and they've each brought things to our nuclear enterprise that are absolutely essential to how it operates today," Herrmann elaborates. "I see the advances that have been made in our nuclear weapons capability, and how good ideas from both labs have ended up in our nuclear weapons systems. The labs' relationship has made all of our systems stronger."

THE CHALLENGE OF STOCKPILE STEWARDSHIP

Today the formerly rural town of Livermore has been absorbed into Bay Area sprawl. Once a modest air base, Lawrence Livermore National Laboratory now boasts an array of glassy buildings spread across a 1.3-square-mile campus whose walkways are shaded by oak trees and other native flora.

In the post-Cold War era, Livermore is responsible for three of the seven weapons systems that make up the nation's enduring nuclear stockpile (Los Alamos is responsible for the other four). But while Livermore and Los Alamos each maintain responsibility for different weapons, in the past three decades the laboratories have come more and more to share their capabilities.

"In the Cold War era, we were both developing systems and expertise on all the fronts we needed," Herrmann says. "Now, we both need to be experts in different areas, but we're also focusing on areas and investments and capabilities that we can use in a national way to develop the experimental data, and the computational data, that we need to have confidence in our systems."

Much of the laboratories' increased collaboration can be traced to the cessation of underground nuclear testing in the United States. The United States hasn't tested a nuclear weapon since 1992, when President George H.W. Bush signed a moratorium on testing into law. In 1996, President Bill Clinton signed (but Congress did not ratify) the Comprehensive Nuclear-Test-Ban Treaty,

The Sierra supercomputer

The National Ignition Facility

Livermore Director Kim Budil

An explosives experiment

which prohibits any kind of nuclear testing. That same year, the science-based Stockpile Stewardship Program was inaugurated by the Department of Energy to ensure that the nation's nuclear weapons continue to perform as expected, even without testing.

Bruce Goodwin, who previously served as associate director for defense and nuclear technologies at Livermore, has likened the challenge of stockpile stewardship to inheriting an aging automobile. Imagine that you've been given the keys to a car that hasn't been started in 40 years. Many of the car's parts will be corroded or broken, but replacements might no longer be available, nor the materials to fabricate new parts.

Now imagine that you've been challenged to ensure, with 100 percent certainty, that the car will start every time someone turns its key—and that you must achieve this feat without ever starting the engine yourself.

This, in essence, is the dilemma posed by stockpile stewardship. Of course, nuclear weapons are no aging Ford: they rely for their effects on materials like plutonium, the most complicated element on Earth, and hydrogen, which in a nuclear detonation undergoes a series of reactions that commonly take place inside stars—although in a weapon these reactions occur more than 20 orders of magnitude faster than they do in, say, the sun.

The complexities of ensuring the safety, security, and effectiveness of nuclear weapons in the post-testing era are such that no one facility can shoulder the burden of stockpile stewardship alone. Gone are the days when Los Alamos or Livermore might have worked in isolation to complete weapon initiatives like the W87-1 modification program, which is underway now at Livermore. The W87-1's design is based on previous stockpile designs, including the W87-0, which was developed in the 1980s.

"There really is no one facility that can deliver this design to the Department of Defense," says Alicia Williams, project engineer for the W87-1. "The design agencies design it, but they have to work with the production agencies that modify the design and make sure it's manufacturable. The design agencies also have lots of test facilities that we need to leverage."

As a part of the Stockpile Stewardship Program, the National Nuclear Security Administration (NNSA) administers modification programs that refurbish or build new weapons based on previously tested components. Other modification programs, such as the W76-2 program at Los Alamos, have used a mix of old and new components. The W87-1 modification program differs in that it is the nation's first 100 percent new-manufacture nuclear weapon system since the end of the Cold War, meaning that every part of the warhead will be fabricated specifically for use in the system.

Once the W87-1 goes into production in 2030, the W87-1 will replace the W78, which has served atop the land-based Minuteman III since the mid-1970s. (The Minuteman III, which entered service in 1970, will be retired and replaced with the LGM-35A Sentinel intercontinental ballistic missile.)

To complete the W87-1 modification program, Livermore is collaborating with facilities across the country, including Sandia National Laboratories—located both in Albuquerque, New Mexico, and in Livermore, California, just across the street from Lawrence Livermore National Laboratory—the Kansas City National Security Campus, and the Pantex Plant in Amarillo, Texas.

Collaboration with Los Alamos also will be crucial. In addition to making use of facilities like Los Alamos' Dual-Axis Radiographic Hydrodynamic Test (DARHT, see p. 28) facility, Livermore will rely on Los Alamos for both detonators and plutonium pits—two essential components of all nuclear weapons. Without these production capabilities, new manufacture of the W87-1 wouldn't be possible.

"As an enterprise, we do have to work as a team," Williams says. "When I played high school soccer, my coach would always say, 'You've got to communicate with each other. You've got to talk to each other and make sure you understand what the other players are doing, and that you're ultimately working toward your goals together.' It's really no different doing this work."

PEER REVIEW

Today Los Alamos and Livermore conduct annual peer reviews that allow the laboratories to offer each other input on the design of weapons, such as the W87-1.

In the nuclear testing era, peer reviews between Livermore and Los Alamos were less frequent and less comprehensive, in part because data from tests often furnished each laboratory with the means to validate its designs. After nuclear testing was halted in 1992, Livermore and Los Alamos began to conduct the peer reviews that now inform each laboratory's annual assessment of its weapons. Every year, teams of scientists from each laboratory consider a series of weapon design problems faced by researchers at the other laboratory, offering input on one another's challenges. As the nation's only two nuclear weapon design laboratories, Los Alamos and Livermore furnish each other with perspectives that neither can find anywhere else.

Herrmann says that this makes for a singular relationship between the two laboratories. He notes that although Livermore also works closely with partners like Sandia—which designs and fabricates nonnuclear components for bombs and warheads—the fact that Livermore specializes in nuclear explosives means that Livermore and Sandia don't have the kind of peer review relationship that Livermore and Los Alamos do. The peer review process is a way of ensuring that both laboratories work together, if also in productive competition, for the national good.

"Between Los Alamos and Livermore, it's that collaboration-competition relationship that's special," Herrmann says.

Few resources better reflect Livermore and Los Alamos' collaboration-competition relationship than Livermore's Sierra supercomputer.

Throughout the Manhattan Project—which led to the creation of the world's first nuclear weapons—and the Cold War, computing was used in tandem with testing to affirm that nuclear weapons would perform as expected. The end of nuclear testing has made computing even more central to ensuring the efficacy of the nation's stockpile. Today, as the United States' weapons age and evolve beyond the devices that once were tested, the computer codes used to simulate nuclear explosions have evolved to become more predictive, allowing researchers to leverage legacy data acquired from testing alongside newer experimental data.

Both Los Alamos and Livermore have developed high-performance computing capabilities that support their nuclear weapons research. With a peak capacity of 41.5 petaflops (a petaflop is one quadrillion floating point operations per second), Los Alamos' Trinity supercomputer was the seventh fastest computer in the world when it went into service in 2017. But Livermore's Sierra system is even faster. When Sierra was commissioned in 2018, the computer became the third fastest in the world, boasting a peak capacity of more than 125 petaflops. These speeds make possible routine three-dimensional weapons simulations, which previously were used only to double-check two-dimensional simulations.

Sierra is housed in a 48,000-square-foot facility that is also home to Livermore's other supercomputers, on a floor where the whine of cooling fans is so loud that visitors are encouraged to wear earplugs. Encrypted high-speed connections allow Los Alamos and Sandia to access the machine, too. In fact, use of Sierra is divided equally among the three laboratories. But while the laboratories share use of Sierra, the codes that each laboratory uses in its weapons simulations are developed separately.

"We make a very explicit decision to keep those codes separate from one another," Herrmann says. "We have different computational tools that take different approaches to different scenarios, and each has its strengths and weaknesses."

Scott Futral, who is the development environment group leader in Livermore's computing division, agrees. "There's no such thing as a perfect code," he says. "Independence in methodology allows the laboratories to compare their results."

The laboratories' shared computing endeavor will receive a further boost in 2023, when the El Capitan supercomputer is expected to enter service at Livermore. This new system will be an exascale computer at least 10 times as powerful as Sierra. El Capitan is expected to be capable of reaching 2 exaflops, or 2 quintillion calculations, per second, making the computer the second in the world to achieve exascale speeds (after Oak Ridge National Laboratory's Frontier supercomputer).

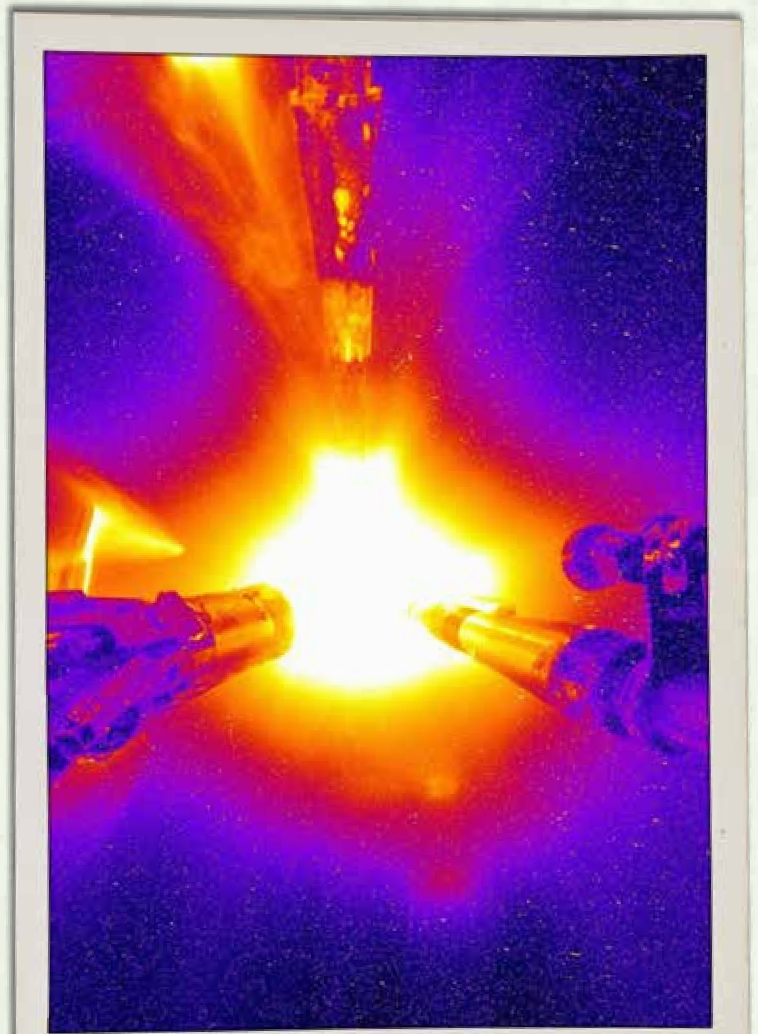
TRUST, BUT VALIDATE

Although high-performance computing has reduced scientists' reliance on legacy data from nuclear tests, researchers still depend on experimental data to validate computer codes' accuracy. Today Livermore and Los Alamos collaborate to develop the enhanced capabilities for subcritical tests that make this validation possible.

Since 1995, both laboratories have used the U1a Complex at the Nevada National Security Site (NNSS, see p. 62) for subcritical tests, in which high explosives compress plutonium without bringing it to the point of a self-sustaining chain reaction. Los Alamos is leading the development of Scorpius, a particle accelerator that will be used for subcritical testing at U1a. However, Livermore is developing the pulsed power that will drive the accelerator. (Sandia and NNSS are contributing to Scorpius' development as well. Scorpius is expected to become operational by 2030.)

The National Ignition Facility (NIF), which is housed at Livermore, also helps validate the computer codes developed by Livermore and Los Alamos. NIF is the world's largest and most energetic laser. Since opening in 2009, the facility has allowed researchers to study in novel ways the materials used in nuclear weapons. By focusing 192 laser beams onto a target the size of a pea, NIF can induce temperatures of more than 180 million degrees Fahrenheit and pressures greater than 100 billion Earth atmospheres—making a target at NIF briefly the hottest place in the solar system.

No other facilities in the world can generate such effects. NIF allows researchers from Livermore and Los Alamos to conduct



A deuterium-tritium implosion

experiments on elements like plutonium and hydrogen in ways that previously would have been possible only with underground testing, but to do so with fewer hazards and greater repeatability. The heat and pressures induced at NIF mean that different kinds of tests can be conducted there than are possible at facilities like the Joint Actinide Shock Physics Experimental Research Facility (JASPER), which Livermore operates at NNSS.

NIF also allows researchers to conduct experiments in materials properties, radiation transport, hydrodynamics, and weapons survivability, making it a versatile resource for scientists who work in the Stockpile Stewardship Program.

"NIF fills a specific niche that other facilities don't," says Heather Whitley, associate program director for high energy density science at Livermore. "There is some overlap in terms of things that we can do at Z"—Sandia's Z Pulsed Power Facility, which uses magnetic fields to produce extreme conditions—"but even the Z machine doesn't operate in the same regime as NIF. Both NIF and Z are supplying data to inform design decisions for the W87-1."

NIF operates 24 hours a day, with technicians conducting some 400 "shots" there every year. At the head of NIF's NASA-style

control room, screens show images of the inside of the facility's aluminum target chamber, which when viewed from the outside resembles the kind of futuristic machinery one might find aboard *Star Trek*'s USS *Enterprise*. (As a matter of fact, in 2012 NIF served as a set for the film *Star Trek: Into Darkness*; for more on the "other enterprise," see p. 9.)

Experiments conducted at NIF have addressed stockpile challenges such as the energy balance problem, which dogged researchers for decades. In the 1960s, data collected during nuclear tests suggested that some of the energy scientists expected to be produced by explosive devices was "missing"—a violation of the law of conservation of energy. Beginning in the early 2000s, Livermore physicist Omar Hurricane led a team of researchers who conducted a series of experiments, including at NIF, that helped solve the decades-old mystery. The energy balance problem's resolution will support initiatives like the W87-1 modification program.

As NIF's name implies, one of the facility's goals has been to achieve fusion ignition, in which more energy is produced by a reaction than is put in. This goal was achieved on December 5, 2022, when a NIF shot delivering 2.05 megajoules of energy resulted in 3.15 megajoules of fusion energy output.

The achievement of fusion at Livermore expands the range of experiments that can be performed at NIF in support of stockpile stewardship. Moreover, researchers around the world are investigating the prospect of harnessing fusion energy as an energy source. Many barriers remain in this endeavor, meaning that technologies like fusion-powered electrical plants are years in the future. But Livermore's fusion achievement nevertheless amounts to a major breakthrough.

"The pursuit of fusion ignition in the laboratory is one of the most significant scientific challenges ever tackled by humanity, and achieving it is a triumph of science, engineering, and most of all, people," said Livermore Director Kim Budil in a news release. "Crossing this threshold is the vision that has driven 60 years of dedicated pursuit—a continual process of learning, building, expanding knowledge and capability, and then finding ways to overcome the new challenges that emerged. These are the problems that the U.S. national laboratories were created to solve." ★

NATIONAL SECURITY
LABORATORY

ESTABLISHED
1949

LOCATION
ALBUQUERQUE, NEW MEXICO

MISSION

RESEARCH & DEVELOPMENT
- HIGH EXPLOSIVES R&D

WEAPONS DESIGN & ENGINEERING
- NONNUCLEAR COMPONENTS
- FLIGHT TESTING AT TONOPAH TEST RANGE
- MAJOR ENVIRONMENTAL TESTING
- RAD-HARD MICROELECTRONICS

WEAPONS PRODUCTION
- NEUTRON GENERATOR DESIGN/PRODUCTION

The engineering-focused facility meets national security needs.

BY JILL GIBSON

The best way to understand Sandia National Laboratories' role in the nuclear security enterprise is to think of a car. That's according to the National Nuclear Security Administration's (NNSA's) former deputy administrator for Defense Programs. Before moving to NNSA, Don Cook spent many years in leadership at Sandia. He also happens to love automobiles.

"Picture a nuclear weapon as a car," Cook says. "The engine would be designed and created by either Los Alamos or Livermore national laboratories. What Sandia does is build the engine compartment and all the fasteners. Sandia provides the brakes, the wheels, and all of the automotive electronics. Sandia provides the fuel system, although it gets pieces to build that from Savannah River and Kansas City. The actual assembly of the vehicle is done at Pantex. Sandia is the integration part. All of the elements of the car, except for the engine, are provided by Sandia or Sandia working with the plants."

Located about two hours south of Los Alamos National Laboratory, with its primary facility in Albuquerque and a second lab in Livermore, California, Sandia employs about 15,000 people. The labs also operate at three other sites, including the Tonopah Test Range in Nevada, the Weapons Evaluation Test Laboratory in Texas, and the Kauai Test Site in Hawaii.

Sandia's Albuquerque facility, which lies within the Kirtland Air Force Base in the southeast part of New Mexico's largest city, sprawls across nearly 21 square miles of land and contains everything from particle beam accelerators and experimental and engineering nuclear reactors to testing facilities that require large land areas and unusual terrain. Over its nearly 80 years of existence, Sandia's mission has grown dramatically, but at its core, Sandia is an engineering lab with a systems integration role.

"A system integrator is the organization that gets all the information from all the other labs and sites and then looks at the weapon as a whole," Cook says. "There are Livermore weapons and there are Los Alamos weapons, but every weapon is a Sandia weapon."

MODERNIZING NUCLEAR DETERRENCE

One of those weapons is the B61 thermonuclear gravity bomb, which recently underwent a life extension that consolidated three B61 weapon designs (the B61-3, -4, and -7) into one updated and more accurate design: the B61-12. The B61-12 life extension program refurbished, reused, or replaced the bomb's nuclear and nonnuclear components. Sandia was responsible for many of the nonnuclear components.

"In addition to design development of nonnuclear components, we completed the highly rigorous qualification, verification, and validation testing to demonstrate that the B61-12 will always work with high reliability when authorized and never function under any other conditions," says David Wiegandt, a senior manager of Sandia's B61-12 program.

Sandia's role in the B61-12 exemplifies how Sandia differs from the other two national laboratories. While Los Alamos and Livermore National Laboratories design the nuclear explosive packages (the car engines) for U.S. nuclear weapons, Sandia designs, develops, and tests the parts and systems that are required to prepare and fire a weapon to military specifications.

"Sandia's role within the complex is unique," says Jim Handrock, Sandia Weapons Systems Engineering director. "We have the design engineering responsibility for the nonnuclear components and also the key systems integration role to put all the individual parts together to make sure that everything does what needs to be done to provide the full system to the military."

A HISTORY OF ENGINEERING AND INTEGRATION

Sandia's unique responsibility for engineering and integration dates back to the 1945 creation of Z Division at Project Y, the Los Alamos branch of the Manhattan Project (which would eventually become Los Alamos National Laboratory).

Site selection for Z Division—which would handle weapons development, testing, and assembly—began in July 1945, according to Sandia historian Rebecca Ullrich. Los Alamos was getting crowded, and Lab officials sought a location with more space that was near a military base. They eventually chose Albuquerque's Sandia Base, which would later merge with Kirtland Air Force Base. The word "Sandia" (Spanish for "watermelon") is a nod to the nearby Sandia Mountains, named for the pink hue they take on as the sun sets.

After World War II, work at Z Division increased as U.S. leaders sought to build up the nation's weapons stockpile. In 1948, Z Division was reorganized and elevated to a separate branch of Los Alamos, named Sandia Laboratory. The site continued to expand its workforce and facilities to meet demands.

But, according to Ullrich, Norris Bradbury, then director at Los Alamos, had concerns about running two large operations, and on November 1, 1949, Sandia separated from Los Alamos and became an independent engineering lab that would support the design functions of Los Alamos and later Livermore.

"From the very beginning, Los Alamos and Lawrence Livermore were working from a physics point of view, but Sandia was working on the engineering side," Ullrich says. "Sandia took on that role and still has that role of being able to assess the stockpile for safety and reliability separate from the design activities."

Sandia is also responsible for testing many weapons components. "Another element of building a car is safety and survivability in a crash," Cook refers back to the car analogy. "Sandia does security and safety systems and conducts survivability testing. That's another element of the Sandia mission."

B61-12 vibration testing

Medical isotope producing reactor

Biofuel research

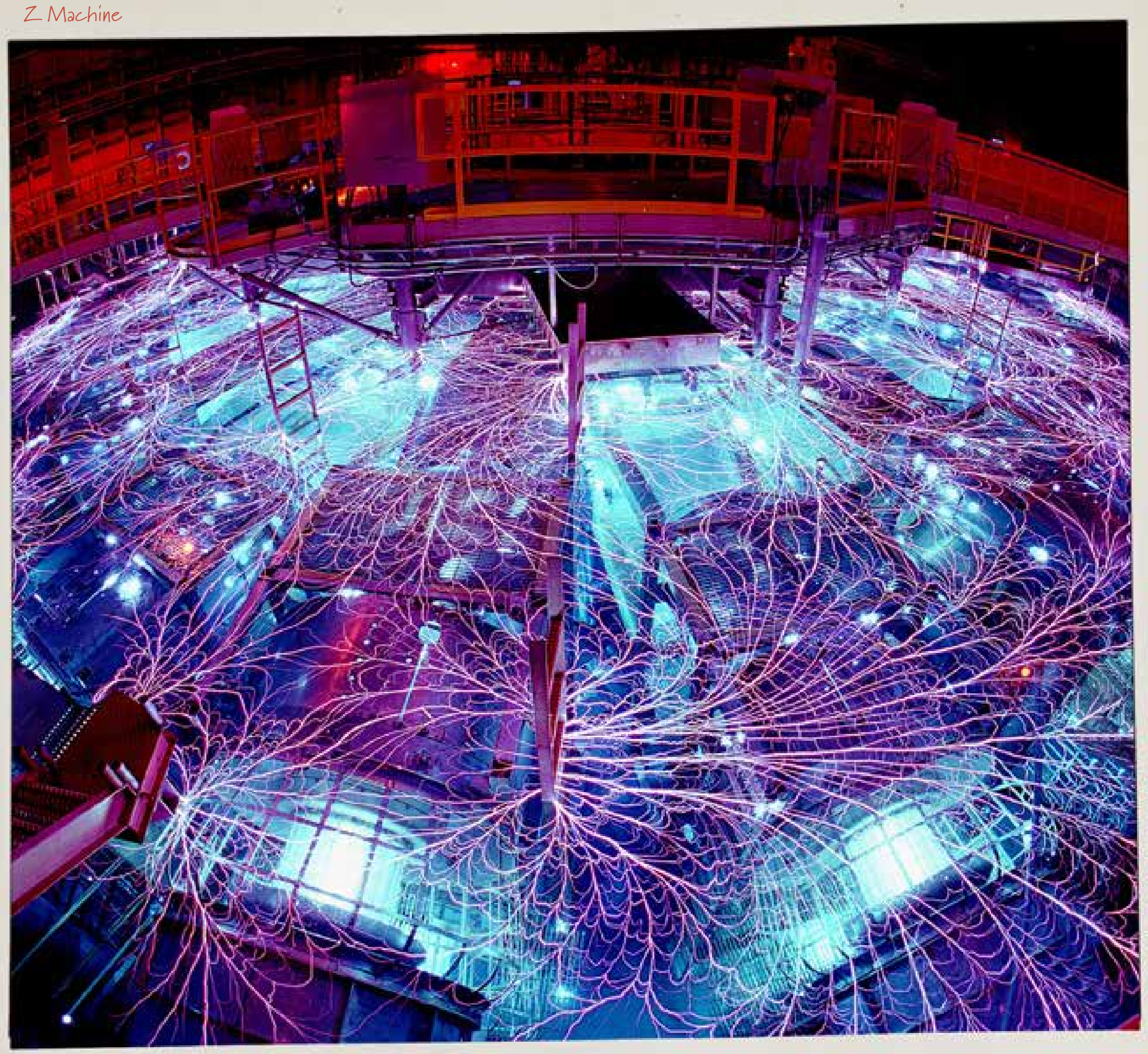
A B61-12 acoustic test

"Sandia can test everything they need to test in normal and abnormal environments; they can run a rocket at a very high speed into a wall, drop it, or subject it to fire, unusual temperatures, or hostile environments," Cook says.

CREATING CONDITIONS FOUND NOWHERE ELSE ON EARTH

One of the ways Sandia tests components is by using a device called the Z Machine that creates conditions found nowhere else on Earth. The machine is the world's most powerful and efficient laboratory radiation source. One goal of Z is to produce high pressures and densities to test the properties of materials used in nuclear weapons. Another objective is to produce fusion, the joining of two atomic nuclei, which is the process that powers the sun. To fuse nuclei, scientists must force them to collide with one another at extremely high speeds.

Z Machine



"Z uses a method called inertial confinement fusion, which releases fusion energy by heating and compressing a fuel target," says Daniel Sinars, the director for the Pulsed Power Sciences Center and the Sandia executive for the NNSA's Inertial Confinement Fusion and Science programs. "The machine takes electrical energy stored over a few minutes and then compresses that electrical energy in both space and time to create a very powerful and short burst of electrical power and energy at the very center of the machine," he explains. "So we store up energy in the capacitor banks at the perimeter of the machine, it gets discharged, and then we compress it. We have the laser trigger switches so we can pull the energy out basically at the speed of light. For a few fractions of a second, we're exceeding the total electrical production capacity of the world."

Sinars says many of the tests conducted with the Z Machine provide insight into what happens in the nuclear explosive package during a detonation and can also represent the hostile conditions produced by an adversary's nuclear weapons. The machine also produces data used to validate physics models in computer simulations, which are essential to stockpile stewardship—the science-based program that allows researchers to evaluate the health and extend the lifetimes of America's nuclear weapons without full-scale nuclear testing. "The goal of creating a lot of energy in the laboratory has always been so that you could do some forms of stockpile stewardship outside of an underground weapons test," Sinars says.

MOVING BEYOND ENGINEERING

The development of the Z Machine exemplifies how Sandia has expanded beyond its original engineering role and moved into design-related research. "You can't separate this kind of science from engineering," says Stephen Slutz, a Sandia physicist who played a key role in developing an approach to using the Z machine to create magnetized liner inertial fusion, a method to control nuclear fusion that combines a massive jolt of electricity with strong magnetic fields and a powerful laser beam.

"We're not inventing. We're using known physical principles and trying to make something happen in nature," Slutz says. "So, it's not pure science—it's kind of a bit on the exotic side of engineering. We're trying to bend nature to our will—not just discover it."

One way researchers are using the Z Machine to try to bend nature to their will is by investigating the possibility of harnessing fusion as a commercial energy source. "Fusion energy is challenging, right?" Sinars says. "Can people make it work? A lot of questions there."

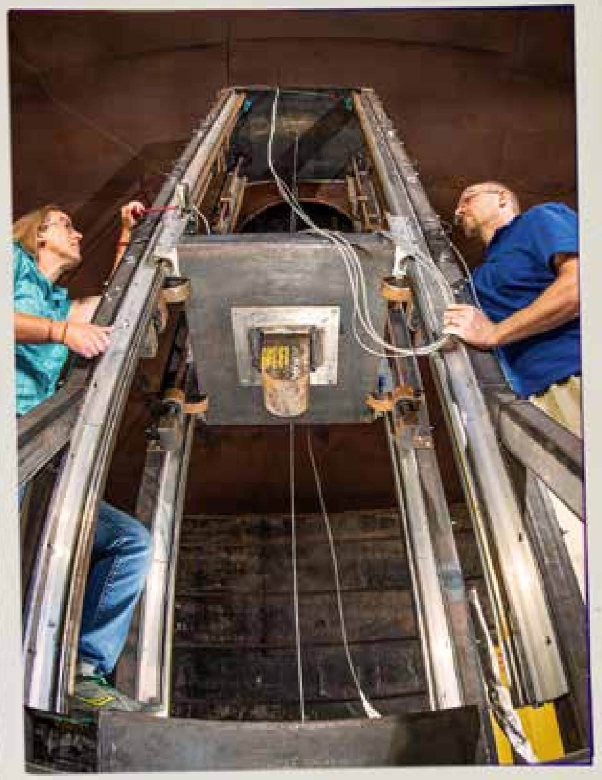
Sinars says Sandia's next goal is to build a more powerful machine than the 26-year-old Z Machine. He is working with scientists at Los Alamos and Livermore on a proposal for a facility that will be created in the 2030s.

"Our design capabilities and our stewardship capabilities are improving with time because we're making measurements on facilities like Z," Sinars says. "That is science being able to do things better, more clearly, more accurately, and allowing us to push the envelope in the future of what might be possible. That's the discovery process. It's what makes this constantly interesting."

A CULTURE OF COLLABORATION

For Sinars and his colleagues, the collaborative approach has always been an essential part of their research. Sinars oversees research that is often classified. "It's vital that the people who can have access to classified data are talking, are sharing ideas, and are providing peer review. That is happening in a very vibrant way across the three labs."

As the director of the Pulsed Power Sciences Center at Sandia, Sinars works closely with scientists from multiple laboratories. He describes a recent experiment during which Sandia's theory and modeling scientists collaborated closely with their counterparts on experiments that were designed at



Shipping containers are tested using a drop tower

Bo Song of Sandia's Environmental Impact Mechanics lab

Livermore and fielded by another group of Sandia scientists. In the same experiment, many of the diagnostics were created by Los Alamos scientists and adapted from work developed at Livermore.

"That was truly a tri-laboratory achievement," Sinars says. "It's really exhilarating because it brings us together, and we're truly a team doing all this research together. The exchange of ideas is phenomenal."

Three labs are better than one, according to Steve Girrens, the Sandia associate labs director for Nuclear Deterrence Stockpile Management, Components, and Production. "With three labs you have diversified talent. If you can have diversified science and engineering you can collaborate, which creates the best outcomes. We collaborate for the national interest," he says.

Some of those joint projects have involved large-scale weapons modernization and life extension programs. From supercomputing, computational modeling, and simulations to hypersonics and satellite programs, collaboration is key.

"There's always this sharing of resources," Girrens says. "And with that comes the subject matter expertise that is resident at the individual facilities, which are always helping contribute to the overall success of the project. It builds a better outcome when you have multiple people contributing in their areas of specialty."

Ullrich says the collaborative approach is essential for the overall success of the nuclear security enterprise. "Who does what? I'm not sure you can always draw the line. It's kind of ziggety," she says, tracing a jagged line in the air with her hand. "The National Nuclear Security Administration provides the broad overview and can see the perspective. Big programs actively work together."

Girrens says that often the three labs' work is similar or overlapping, which isn't a coincidence. One example is gas transfer systems, which are used in nuclear weapons to increase the primary fission reaction. "Right now there's a situation where both Los Alamos and Sandia make gas transfer systems, but Los Alamos makes gas transfer systems for Los Alamos weapons and Sandia does the gas transfer system for Livermore weapons." These mirrored programs have a clear benefit, according to Girrens. "Now you've become peers of each other and are doing peer review. We're not afraid to challenge each other. I think that there's a lot of value in that," he says.

AN EVER-EXPANDING MISSION

Over the years, Sandia's mission has continued to expand, and the labs' many contributions to national security are evident in the diverse nature of their projects and their ongoing evolution to meet military needs. The labs worked carefully with U.S. Strategic Air Command to develop devices, called Permissive Action Links, that stop the unauthorized use of U.S. nuclear weapons by preventing arming or launching a weapon without a code. Later Sandia would develop nonproliferation programs and reach out to help other countries develop technology to monitor nuclear activity. In the 1970s, Sandia's mission expanded into developing new sources of energy—a focus that is ongoing. Other mission areas have included anti-terrorism programs, biological and chemical terror prevention technology, satellite detection and sensor systems, and integrated military systems supporting missile defense.

Another area in which Sandia is pushing the envelope is in technology-transfer partnerships. The labs collaborate with industry, small businesses, universities, government agencies, and other labs to bring new technologies to the marketplace and contribute to economic growth. "Sandia is committed to nurturing small and diverse business partnerships to achieve our national security mission and further economic prosperity," says David Dietz, Sandia's director of integrated supply chain management. "We could not deliver success without small business." So far Sandia has provided technical assistance to companies in cybersecurity, energy, robotics, and medical industries, using these collaborations to bring new ideas and products into the marketplace.

A DESIRE TO SOLVE PROBLEMS

Ullrich notes that Sandia has grown from a single facility with an easy-to-define core mission to a sprawling institution with thousands of employees. Over the years, Sandia has expanded its capabilities and sought opportunities for spin-offs and diversification, always keeping national security at the forefront. A commitment to strategic thinking about the future and the nation's needs is a hallmark of the labs, she says. "When Sandia takes on something new, the labs' leaders are intentional and look for things they can build on."

Cook stresses that even as the Sandia mission expands, the foundational focus remains on engineering and systems integration. "And the result: you put all the parts together for the car, you start it up, and it runs," he says. ★

Sandia
NATIONAL LABORATORIES

NUMBER OF EMPLOYEES: 14,500
FOOTPRINT: 21 square miles
FISCAL YEAR BUDGET: $4.4 billion
CURRENT OPERATOR: National Technology and Engineering Solutions of Sandia, LLC

CHECK OUT:

- The National Museum of Nuclear Science and History, a Smithsonian facility complete with a B-52B Stratofortress, an F-16 Fighting Falcon, and other military aircraft and missiles
- Sandia Peak Tramway, which ascends 10,378 feet to the crest of the Sandia Mountains, just east of Albuquerque

NUCLEAR MUSEUM

TRAM
Photo: Dreamstime

■ Among the many relics that visitors to Sandia's Legacy Hardware Laboratory can see is the Navy's first submarine-launched ballistic missile, the Polaris, pictured here circa 1964, which played a strategic role during the Cold War in the 1960s.
Photo: U.S. Department of Defense

Preserving the past

Decades of old weapons components find a home at Sandia's Legacy Hardware Laboratory.

BY JILL GIBSON

When employees of Sandia National Laboratories retire, clean out an office, or uncover a pallet of mysterious, unlabeled boxes, they often contact Pete Terrill. That's because Terrill runs the Legacy Hardware Laboratory, a working laboratory of nuclear weapons components ranging from the first iterations of certain devices, including a rare version of the infamous Fat Man bomb, to parts of weapons that are in the nuclear stockpile today.

Well over six feet tall with close-cropped hair and decades of experience in the military and the nuclear enterprise, Terrill says he has found "the job of a lifetime."

As he leads a group through the two warehouses he oversees, he enthusiastically gazes over his collection. "It's Costco with a Q clearance," he jokes, pointing to row after row of parts that include detonators, firing sets, and more.

Terrill started the facility in 2013 when Sandia began cleaning out storage areas at Kirtland Air Force Base. "We still have unopened boxes," he says, gesturing to an x-ray device he uses to peek inside the many unlabeled storage drums and boxes he receives at the facility. "Some of this stuff is still radioactive, so we have to check and take precautions," he says.

Terrill likes to compare himself to the stars of *American Pickers*—the cable series featuring two men who drive around the country salvaging antiques from country barns and forgotten corners. "People give me stuff," he says. "They find out when they retire that they can't keep it."

> We haven't found the Ark of the Covenant yet, but we do like to compare ourselves to Indiana Jones."
>
> —PETER TERRILL

Former Sandia Vice President Gerry Yonas says when he retired from Sandia, he had the tail of a B-61 bomb in his office. "Someone had given it to me, so I wanted to take it home and put it in my yard—kind of like lawn décor," quips Yonas. "Turns out security wouldn't let me. I bet Pete has it now."

■ Some visitors to the Legacy Hardware Laboratory receive a commemorative "coin." Both sides are pictured here.

Terrill is quick to point out that he isn't running a museum. "This is a laboratory, and everyone from visiting engineers, scientists, military personnel, weapons interns, external customers—they can come here and train with the real things. They can take things apart and put them together. We have about 500 people come through here each year."

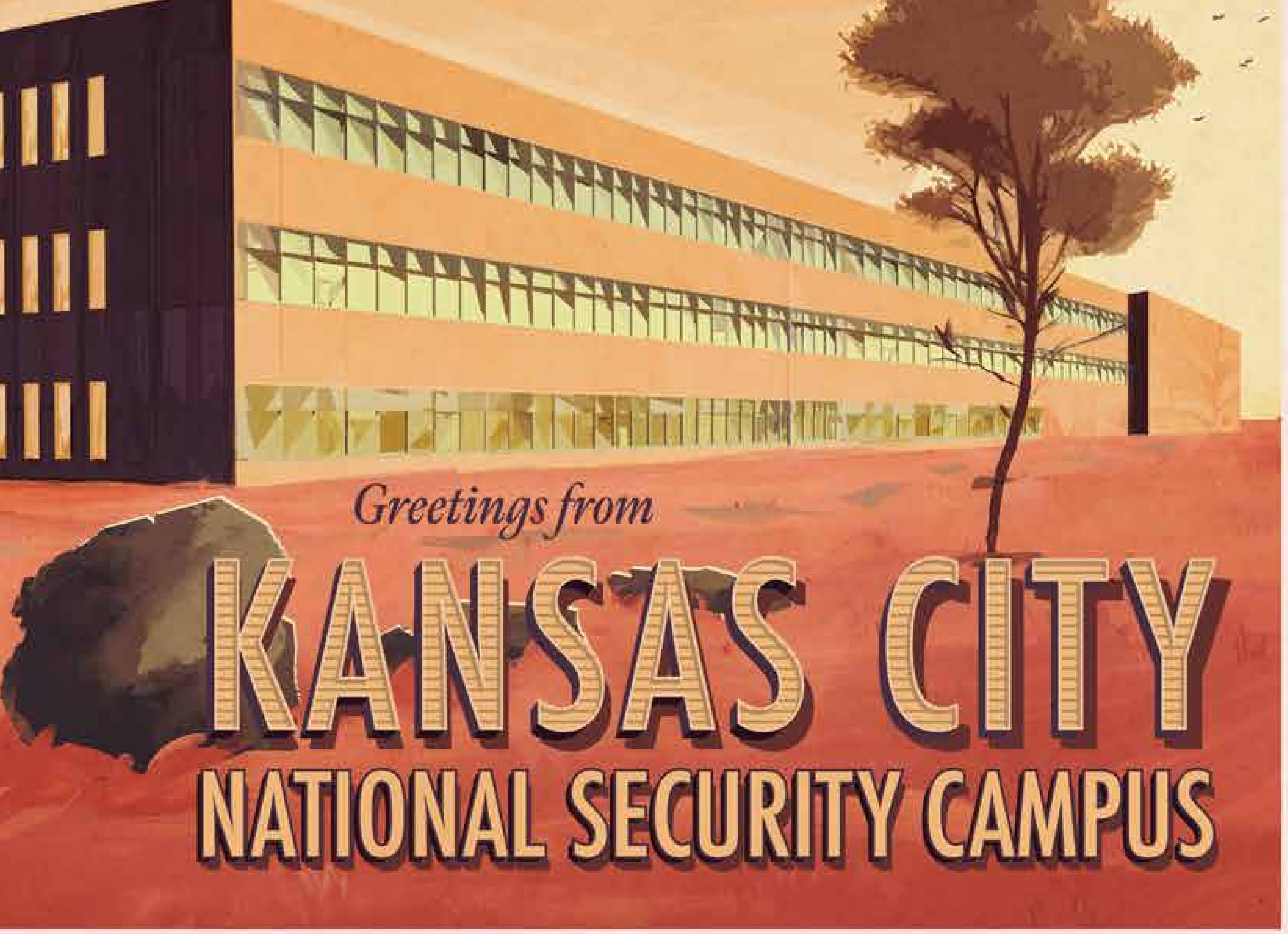
Terrill attributes the depth and variety of devices he has accumulated to Sandia's unique role in the nuclear enterprise. "Sandia is the integrator," he says. "Sandia has their fingers on everything."

And everything appears to be stored in this laboratory—the first nuclear artillery shell, earth penetrators, the first Polaris missile, and a rare 1968 "bayonet" gun weapon are stored beside each other. In between are boxes with labels such as "Little Boy Parts" and brochures once used to brief congressional staffers about new devices. Terrill knows where every item is and can share its complete history.

"There are 6,000 parts in the average nuclear weapon," he tells a tour group. No one doubts that he can identify each part. "These weapons are very complex," he continues. "Here people can touch them—can practice dismantling them and reassembling them, can learn to understand the function and the safety measures. We do real training with real stuff."

But although the facility serves a highly serious purpose, Terrill doesn't deny how much fun he has sharing his knowledge of weapons engineering and nuclear weapons history. He has grown his staff to five people and has received authorization to expand his warehouse space to accommodate his ever-growing collection, which also includes original documents, schematics, drawings and paintings of weapons, and more.

Terrill plans to keep collecting. "We haven't found the Ark of the Covenant yet, but we do like to compare ourselves to Indiana Jones." ★



NUCLEAR WEAPONS PRODUCTION FACILITY

ESTABLISHED 1949

PRIMARY LOCATION
KANSAS CITY, MISSOURI

MISSION

WEAPONS PRODUCTION
- NONNUCLEAR COMPONENT MANUFACTURING & PROCUREMENT

Eighty percent of the nonnuclear components in America's nuclear weapons are made by the plant, which has locations in Missouri and New Mexico.

BY WHITNEY SPIVEY

"Thank you for choosing to do work that matters" is painted in navy blue all-caps above two sets of double doors at the Kansas City National Security Campus (KCNSC) in southeast Kansas City, Missouri. The glass doors and their surrounding windows are covered with a large American flag laminate that glows as the sun shines through from outside.

The patriotic exit way is a reminder to all who pass through it that KCNSC's mission—producing nonnuclear components for nuclear weapons—is essential to America's national security and that the success of that mission is because of the plant's 6,700 dedicated employees.

"The culture here is 'commitments made, commitments kept'," explains Director of Program Management Julie Aitkens, who has worked at Kansas City for nearly 23 years. "We're Midwest. We're not too confrontational. We like to get it done and make people happy."


Precision manufacturing


The Assembly Tooling Lifting Alignment System moves sections of a B61 bomb


Testing components in an anechoic chamber

A SECRET MISSION

KCNSC was established as the Kansas City Division of the Bendix Corporation in 1949. Bendix—an American manufacturing company traditionally known for making automotive brake systems—had been selected by the U.S. Atomic Energy Commission to build the nonnuclear components of nuclear weapons. According to KCNSC's website, "the employees guarded the nature of the mission so well that, for many years, the community assumed the plant made washing machines."

Seventy-four years and several name changes later, KCNSC's mission remains the same. The plant—now headquartered in a 1.95-million-square-foot facility in Kansas City with additional facilities in Albuquerque, New Mexico—develops, procures, produces, and delivers more than 80 percent of the nonnuclear components in current and future U.S. nuclear weapons systems.

Nonnuclear components can be anything electrical, mechanical, or engineered that doesn't incorporate nuclear materials (such as plutonium and uranium). Nonnuclear components range from fiber optics and firing systems to radar systems, reservoirs, and items that are additively manufactured or made from special polymers and metals. Kansas City is also responsible for inspecting and testing the components made at the plant.

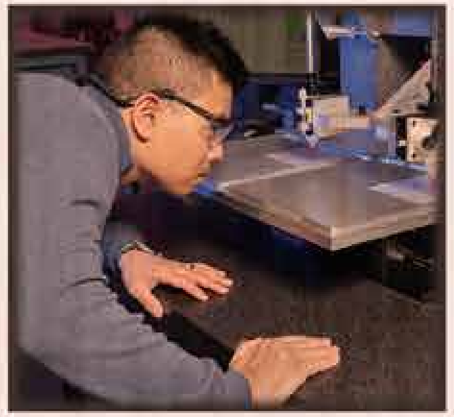
THE BIRTH OF A PART

The seven types of nuclear weapons in the current stockpile are decades old; many of them are undergoing (or have undergone or will undergo) updates to ensure their reliability and effectiveness now and into the future. These updates typically involve swapping out old components for new components.

The process starts when the design agency for a particular weapon component proposes an update. Los Alamos National Laboratory is the design agency for the nuclear explosives packages (which include nonnuclear parts) in the B61 bomb and the W76, W78, and W88


Electrical assembly area


Testing material samples


Monitoring 3D printing capabilities


Nonnuclear weapons components

warheads; Lawrence Livermore National Laboratory is the design agency for the nuclear explosives packages in the B83 bomb and the W80 and W87 warheads. Sandia National Laboratories is the design agency for many nonnuclear components in all seven of these weapons systems.

As the production agency, Kansas City is almost immediately looped into the discussion. "We have a seat at the table very early because making design changes is easier when the design is not firm," Aitkens explains. "It's an iterative process; we are all equal partners, and we each have a lot of knowledge about what the other does."

Many of the components requested by the design agencies are components that Kansas City has produced before—but not always. "The amount of crazy the design agencies give us is about 10 percent," Aitkens laughs. "The ideas people have can seem so abstract—but we can make them real, or we can offer different, better solutions."

The W93 warhead is an example of an abstract idea. The warhead doesn't exist yet and may never exist, but Los Alamos, as the design agency, is leading studies and conversations to determine how this potential new weapon might materialize. "The W93 is a new system for all of us," Aitkens says. "Understanding what that means is exciting, and we already have people who are more immersed in what it might look like, even though we aren't making anything yet."

MAKING A PART

Once it's been decided what components are needed, Kansas City either sources the components from a vendor, makes the components in house using parts and materials that are sourced from vendors, or a combination of the two.

"We have a huge vendor portfolio," says communications manager Shaun Manley. "We reach into commercial industry. When we need something, and it's determined best to buy versus make, it's our relationship with those vendors that means there is no impact to schedule."

Kansas City also benefits from its Supply Chain Management Center, which develops purchasing agreements not just for itself but for 22 other Department of Energy (DOE) sites. The center saves time by ensuring that sites aren't duplicating efforts, and it saves money by negotiating lower prices. "It's the Costco or Sam's Club rationale across the DOE," Manley explains. "The 18 people who staff the center are saving millions of dollars for the entire nuclear enterprise and beyond."

Once parts or materials have been purchased and delivered to Kansas City, weapons components are made and assembled in specific areas around the plant. "We have a lot under one roof; it's a sea of manufacturing equipment," Aitkens says. "The diversity in manufacturing is extreme, especially for one facility."

Aitkens explains that the plant is arranged by process—electrical fabrication, for example—rather than by weapons system. "There's not a B61 production line even though I would love for there to be one," she says. "Components for the B61 get made all over. Our employees don't necessarily know what parts go to what weapons. All parts just have to get done."

TESTING A PART

Both the design and production agencies must consider that rate production—making hundreds or thousands of a weapons component—is very different than making just one component.

"Anyone can figure out how to make one component, but to make a lot of components to the exact specifications of the design agencies requires the workforce and machinery here at Kansas City," Manley says. "I'm talking about parts that need to be assembled under microscopes using tweezers or parts that are so incredibly complicated they take years to build and assemble."

Rate production is where Kansas City prides itself on quality. Aitkens explains that "quality needs to come first because components need to last for 30 years or longer."

To ensure quality, Kansas City tests and inspects components. A component might be shaken, vibrated, accelerated, heated, cooled, dropped, spun, or shocked. "Whatever a nuclear weapon might go through—such as transportation, ejection, extreme environments, you name it—that's what we are replicating," Manley explains. "We want to make sure parts don't break or change states when they're not supposed to."

If a component doesn't perform as expected, a team of experts inspects it to find out why and then solve the problem.

"Our people want to produce quality components," Manley says. "Our pride is in being able to be able to hit specs."

OUT FOR DELIVERY

Once a component is finished, it's typically sent to the Pantex Plant (see p. 56), where it's assembled into a weapon. Depending on the component, this milestone could come months or even years after Kansas City first began working on it. "That's why we celebrate not just the milestones but also the inch-stones as we meet them," says Natalie Burris, a senior program manager at Kansas City. "Every single person comes to the table to make our mission successful." ★

KANSAS CITY NATIONAL SECURITY CAMPUS

POST CARD

NUMBER OF EMPLOYEES: 6,700
FOOTPRINT: 2.1 million square feet
FISCAL YEAR BUDGET: $1.8 billion
CURRENT OPERATOR: Honeywell Federal Manufacturing & Technologies, LLC

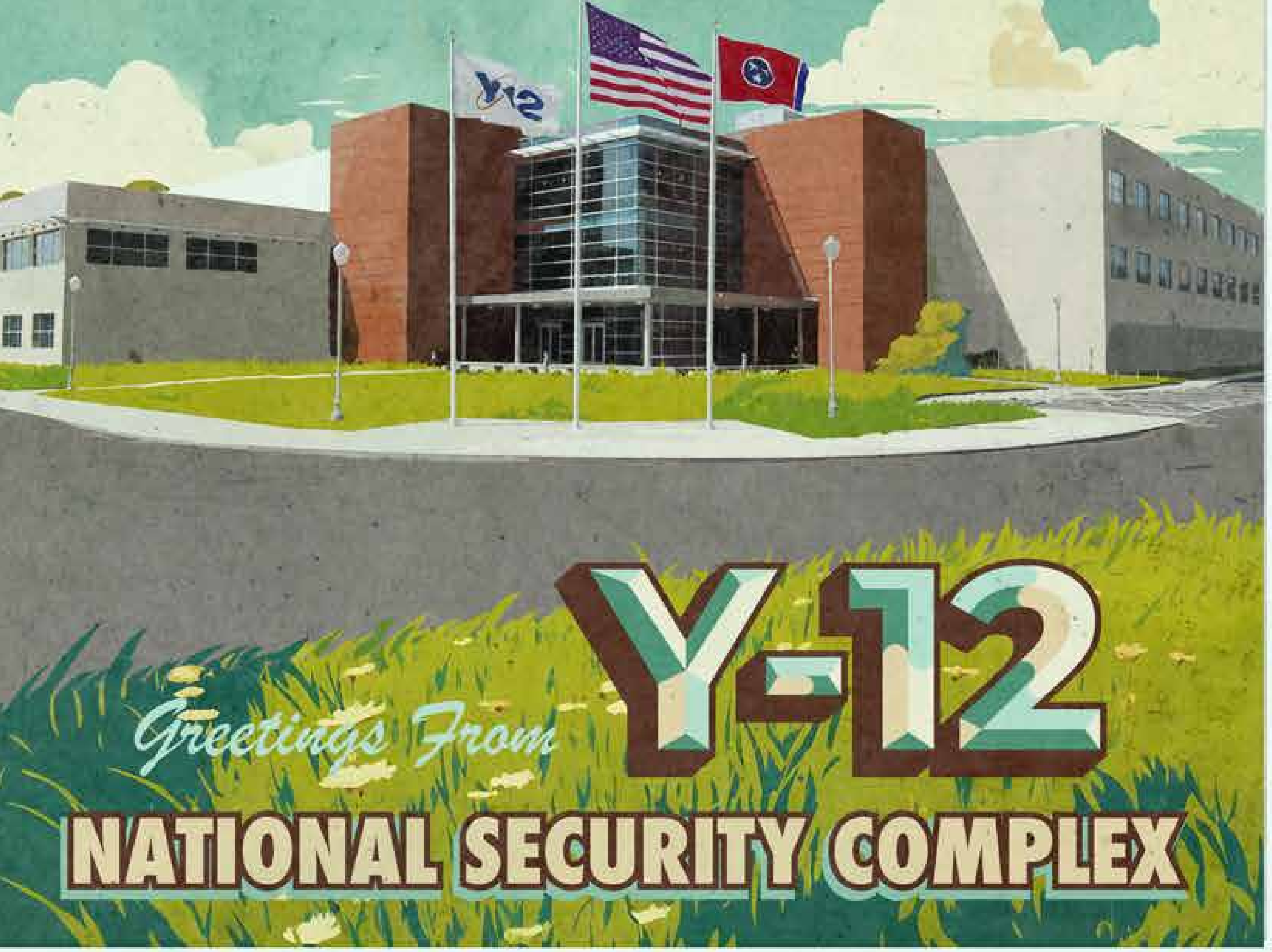
THIS SPACE FOR ADDRESS ONLY.

CHECK OUT:

- The National WWI Museum and Memorial: the most comprehensive collection of World War I artifacts in the world
- Dozens of restaurants featuring Kansas City–style barbecue, which is slow-smoked and served with a thick tomato-based sauce

EMPLOYEES AT A JUNETEENTH EVENT


KANSAS CITY BARBECUE
Photo: Dreamstime



NUCLEAR WEAPONS PRODUCTION FACILITY

ESTABLISHED 1943

LOCATION
OAK RIDGE, TENNESSEE

MISSION

WEAPONS MATERIALS
- LITHIUM PROCESSING
- URANIUM PROCESSING

WEAPONS PRODUCTION
- URANIUM COMPONENTS
- SECONDARY STAGES

For 80 years, the Tennessee site has managed the nation's enriched uranium.

BY IAN LAIRD

Names often herald origins or indicate purpose. That is not the case for Y-12, a national security site in the formerly remote Bear Creek Valley of east Tennessee. Because neither the letter nor number signifies anything, Manhattan Project officials—who stood up the facility in 1943 to convert naturally occurring uranium into enriched uranium for use in atomic weapons—thought no one would deduce what was happening at the site from the name alone. The enriched uranium produced at Y-12 was used in the Little Boy bomb dropped on Hiroshima on August 6, 1945. World War II ended shortly thereafter.

Eighty years later, Y-12 is still responsible for the production, storage, and handling of enriched uranium in the United States. Since 1953, Y-12's mission has included the manufacturing and maintenance of secondary stages for nuclear weapons.

Ironworkers prep structural steel for pipe supports installation in the Main Process Building.

Y-12 is located in Tennessee's Bear Creek Valley

A secondary stage contains enriched uranium and significantly increases the yield of a nuclear weapon.

"Anything to do with enriched uranium occurs here at Y-12," says Gene Sievers, site manager for what's known today as the Y-12 National Security Complex. "Our legacy is a source of pride for the workforce. We continue that work to this day, and the nation continues to look to Y-12 for answers to very complex problems."

In 2007, the site was recognized by the National Nuclear Security Administration as the nation's Uranium Center of Excellence.

'COLLABORATION IS THE WORD'

Y-12 works closely with the rest of the nuclear security enterprise to ensure the safety, security, and effectiveness of America's nuclear weapons. The design agencies—Los Alamos, Lawrence Livermore, and Sandia national laboratories—work with production agencies—Y-12, the Pantex Plant, and the Kansas City National Security Campus—to maintain and update weapons. "The enterprise has a large work scope; it's too big for any one place to do," Sievers explains. "Each lab, plant, and site has its own expertise, so we leverage one another to get the mission done. Collaboration is the word."

The production agencies turn concepts from the design agencies into reality. At Y-12, production and technology realization teams are assigned to different weapon systems to facilitate the transition from design to manufacturing. "As anyone who has gone through an engineering class probably knows, you can design anything," Sievers says, "but the real trick is designing something that can be built, and in this case, that can be built at rate production."

At any given time, Y-12 is performing work on multiple weapons systems. This work could involve the production of nuclear components (such as secondary stages), surveillance testing to determine how certain weapons components are aging, and the dismantlement of retired weapons, which involves the removal of nuclear material.


A radiochemist


Sunrise over the Uranium Processing Facility


Chief Scientist Jenn Charlton


Rebar installation at the Highly Enriched Uranium Materials Facility

Sievers, who served in the U.S. Navy on both nuclear-powered and nuclear-armed submarines before coming to work at Y-12, says his military background informs his commitment to Y-12's—and the nuclear security enterprise's—mission, which is to ensure that the missiles and bombs in America's nuclear stockpile are reliable and can be used effectively by the United States military if and when necessary.

"Our airmen and sailors spend zero time worrying about what is on the tip of a missile because we have proven there is essentially zero defect," he says. "I never want the sailor or the airman to doubt for a second what is on the end of that delivery platform."

AN EVOLVING MISSION

As the nation's Uranium Center of Excellence, Y-12's mission extends beyond weapons in the active nuclear stockpile.

As part of its global security work, Y-12 offers training to nuclear industry workers, emergency responders, and security forces on how to safeguard and handle nuclear material.

Y-12 also provides the enriched uranium for the U.S. Navy's nuclear-powered submarines and aircraft carriers. The uranium used in naval reactors comes from dismantled nuclear weapons and powers the vessels. To date, according to the Department of Energy (DOE), naval vessels have safely traveled approximately 200 million miles on nuclear power.

Y-12 also occasionally collaborates with Oak Ridge National Laboratory, which is located one ridge and several miles to the southeast. Sievers explains that "Oak Ridge is a DOE laboratory with a national science mission, and Y-12 is more focused on production."

In addition to Y-12 supplying fuel for Oak Ridge's high-flux isotope reactor, which creates medical-grade isotopes for cancer treatments, the two facilities also collaborate on computer modeling efforts.

"Oak Ridge has the high-speed computing capability over the hill there," says Y-12 Chief Scientist Jenn Charlton. "We work with their modeling groups to help inform how we do our production sciences." High-fidelity computer models allow Y-12 employees to better understand the materials they're working with before starting any manufacturing.

INFRASTRUCTURE UPDATES

Although much of Y-12's machinery and processes have been updated over the years to match technological breakthroughs, the buildings that shelter them haven't always received the same attention. In recent years, that has started to shift.

In 2010, operations began at the 100,000-square-foot Highly Enriched Uranium Materials Facility, which contains state-of-the-art equipment and infrastructure for the secure storage of highly enriched uranium. "We receive materials in this facility from all over the world as part of the global threat reduction initiative, as well as material from sister sites all over the country," explains an operations manager in a 2010 video. "Weapons are brought in from other sites for storage here, many of these weapons are either disassembled or go through a quality evaluation process for future shipment back out into the stockpile." The facility, which is made of concrete and steel, was built to withstand flooding, lightning strikes, seismic events, and tornadoes.

One of the most expensive construction projects in Tennessee history—the Uranium Processing Facility, or UPF—is currently in the works and on track to be completed in 2025 at a cost of $6.5 billion. UPF will replace building 9212, where uranium is currently enriched using 1940s-era machinery from the Manhattan Project. UPF will allow for safer and more cost-efficient operations.

In late 2023, ground will be broken for Y-12's new Lithium Processing Facility, which is expected to be completed in 2031 with operations fully commencing in 2034. Y-12 has been processing lithium, a soft, low-density metal that is a key component in secondary stages, for seven decades.

"There are two strategic materials we deal with, enriched uranium and enriched lithium," Sievers says. "So, it makes all the sense in the world for the nation to invest in modern infrastructure for those two strategic materials and those are the first two major construction projects at Y-12."

THE WORKFORCE OF THE FUTURE

As infrastructure is being revamped, so is Y-12's workforce of approximately 8,000 people.

"Work continues to increase, but we're also finding that the workforce is turning over faster," says Senior Director of Analytical Chemistry Amy Wilson. "In previous generations, a person might stay in one job for his or her entire career. That is not the current generation."

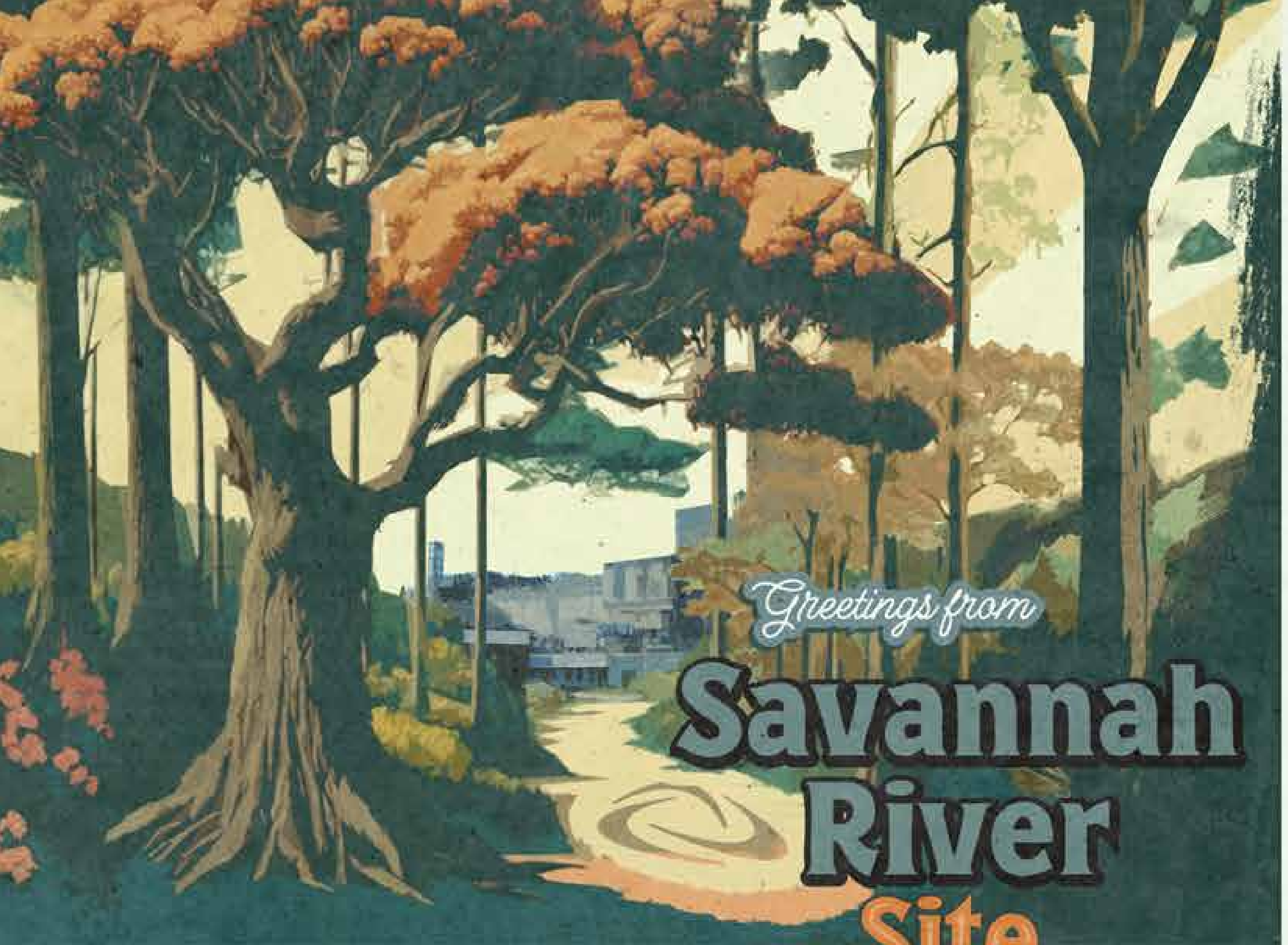
The changing workforce, however challenging, also offers opportunities. In addition to growing an organization to capture the knowledge of people who are leaving, "we're expanding our research and development group from 113 to nearly 200 researchers," Charlton says. "It just creates a more energized research and development environment. A lot of energy has come from the new facilities we have coming online and our evolving mission space; it's really exciting." ★

Y-12
NATIONAL SECURITY COMPLEX

NUMBER OF EMPLOYEES: 8,000
FOOTPRINT: 1.3 square miles
FISCAL YEAR BUDGET: $2 billion
CURRENT OPERATOR: Consolidated Nuclear Security, LLC

CHECK OUT:

- Great Smoky Mountains National Park—America's most visited national park, which is well known for its mountains, waterfalls, and biodiversity
- The Oak Ridge branch of Manhattan Project National Historical Park



Greetings from Savannah River Site

NUCLEAR WEAPONS PRODUCTION FACILITY

ESTABLISHED 1952

LOCATION
AIKEN, SOUTH CAROLINA

MISSION

- RESEARCH & DEVELOPMENT
  - TRITIUM R&D
- WEAPONS MATERIALS
  - TPBAR PROCESSING
- WEAPONS PRODUCTION
  - PLUTONIUM PITS (FUTURE)
  - TRITIUM PRODUCTION AND PROCESSING

The South Carolina facility leverages its unique history to tackle new challenges.

BY JAKE BARTMAN

A few days after Thanksgiving in 1950, the Atomic Energy Commission (AEC) announced that nearly 400 square miles of South Carolina farmland would become the Savannah River Plant, a new AEC facility. The news release heralding the facility's creation was brief—only one page—but every turn of phrase was carefully crafted. The authors noted that the new facility would be a "production plant" that would "not involve the manufacture of atomic weapons."

In nearby towns, however, rumors circulated that a "bomb plant" was coming to the area. No sooner had the AEC made its announcement than South Carolinians and the media began to refer to the Savannah River Plant as "the H-bomb factory."

The nickname stuck, and today locals and journalists alike still refer colloquially to the Savannah River Site (SRS, as the facility is now named) as a "bomb factory"—even though, true to the AEC's original news release, no nuclear weapons have ever been manufactured there.

Instead, throughout the Cold War, SRS played a crucial role in ensuring the United States' nuclear security by producing or processing key materials, such as plutonium and tritium, that were used in weapons manufactured elsewhere.

Today, SRS is working closely with Los Alamos National Laboratory as the two facilities restart the United States' plutonium pit production capability—an endeavor crucial to ensuring the ongoing safety, security, and effectiveness of the nation's nuclear deterrent.

Unlike other facilities in the nuclear enterprise that are operated by contractors on behalf of the National Nuclear Security Administration (NNSA), Savannah River is managed by a contractor on behalf of the Department of Energy's Office of Environmental Management. In 2025, NNSA will assume primary authority for the site.

TWO KEY MATERIALS

Although Savannah River's recent missions encompass projects ranging from ecological research and environmental remediation to the recovery of highly enriched uranium for use in the manufacturing of new commercial nuclear reactor fuel, the facility was built primarily to produce two materials: plutonium-239 and tritium.

In 1950, the Hanford Site in Washington state was already producing plutonium (for use in nuclear weapon cores) and tritium (which increases a weapon's explosive power). But in the aftermath of the Soviet Union's first successful nuclear weapon test in 1949, President Harry Truman felt that the United States needed to augment its nuclear weapons production capability—and fast. The AEC would need to construct a sister facility to Hanford to meet production targets.

After a nationwide search, the AEC settled on a site along the Savannah River, which forms most of the border between South Carolina and Georgia. This site had several advantages. For one thing, the Savannah River would furnish abundant water, which would be necessary to cool the facility's five reactors and produce heavy water, a more hydrogen-rich liquid that's key to effective fission chain reactions. Moreover, the site was far enough inland to mitigate the risk of Soviet air attacks and remote enough to ensure secrecy. (To prevent erosion and further bolster security, the Forest Service planted 40,000 pine seedlings per day between 1952 and 1956 on reclaimed farmland on site. In 1968, the Forest Service planted its hundred millionth tree at SRS.)

Savannah River's first plutonium production reactor, R Reactor, went critical—achieved a sustained nuclear chain reaction—in December 1953. Four other reactors soon followed suit. For nearly four decades, Savannah River used these reactors to produce plutonium-239, the isotope of plutonium that is considered "weapons-grade," or adequate for use in nuclear weapons. This plutonium was shipped cross-country to the Rocky Flats Plant in Colorado for fabrication into pits. These pits would then be installed in weapons at the Pantex Plant (p. 56) in Texas.

Between 1953 and 1988, Savannah River produced some 36 tons of weapons-grade plutonium, or approximately one-third of all the United States' plutonium. Savannah River ceased its plutonium production at the end of the Cold War in 1992, the same year that Rocky Flats closed.

While Hanford produced most of the nation's plutonium, beginning in the mid-1950s, virtually all the United States' tritium was produced at Savannah River. During the Cold War, Savannah River produced tritium on site by irradiating lithium-aluminum rods, yielding tritium.

Tritium is a radioactive isotope of hydrogen that is a key component of modern nuclear weapons because it increases a weapon's yield—the amount of energy released after detonation. However, tritium decays to half its original amount in a little over 12 years, which necessitates periodic replenishment of the tritium inside weapons.

Today, Savannah River remains the only facility in the United States to extract, recycle, and purify tritium for use in nuclear weapons. Because its plutonium production reactors have been closed, Savannah River no longer irradiates lithium rods in reactors on site. Instead, rods irradiated in a commercial power reactor at the Tennessee Valley Authority's Watts Bar Nuclear Plant, located near Spring City, Tennessee, are sent to Savannah River, where the tritium is extracted.

From recovering and recycling the gases in old reservoirs, to loading, certifying, and shipping new reservoirs, tritium processing involves many steps. "Tritium production is something that sounds simple but is actually very complex," says Bryan Cox, a public affairs officer at Savannah River.

Because the United States' nuclear weapons require tritium to work, tritium must be processed to exacting standards and on demanding timeframes that ensure the nation's nuclear arsenal remains amply supplied. As Cox notes, Savannah River has

Glovebox

Spent nuclear fuel disposition

Waste storage

The Savannah River

always risen to the challenge. "In 75 years, SRS has never missed a tritium shipment," he says.

THE PIT PRODUCTION MISSION

Cox says that Savannah River's track record with its tritium mission reflects its workforce's "production mindset." In Cox's view, this mindset is part of the reason that Savannah River is well-suited for its newest mission: the fabrication of plutonium pits. "For this workforce, pit production is something that just makes sense," Cox says.

In 2018, the Nuclear Weapons Council (see p. 12) endorsed NNSA's plan for producing new plutonium pits. According to this plan, by 2030—or as soon as possible thereafter—Los Alamos National Laboratory will produce no fewer than 30 pits per year, while Savannah River will produce no fewer than 50 pits per year. Together the two sites will be able to restart the nation's pit production capacity, which has been dormant since the Rocky Flats Plant closed in 1992.

Los Alamos and Savannah River each bring unique assets to their pit production endeavors. The world's first plutonium pits were manufactured at Los Alamos in the 1940s as a part of the Manhattan Project, and in the intervening decades, researchers at Los Alamos have gained a comprehensive understanding of plutonium's properties. (In 2009, NNSA formally recognized Los Alamos' contributions to plutonium science by designating the Laboratory as the nation's Plutonium Center of Excellence.)

Although Savannah River doesn't have Los Alamos' familiarity with pit production, SRS's tritium mission means that its workforce is attuned to the demands of a tight production schedule, while its other endeavors have yielded extensive experience producing and handling plutonium. Moreover, Savannah River's Building 226-F is well-suited for conversion into a pit production facility. Built to be the Mixed Oxide Fuel Fabrication Facility, which would have converted surplus weapons-grade plutonium into fuel for use in commercial nuclear reactors, Building 226-F meets seismic requirements and has support facilities—including office, assembly, and fabrication spaces—that will allow the structure to be redeveloped into the Savannah River Plutonium Processing Facility (SRPPF).

CROSS-COMPLEX COLLABORATION

Savannah River and Los Alamos are working closely together as they ramp up their pit production missions. Employees from each site have begun to visit the other for short- and long-term assignments to better conduct training and exchange knowledge.

Savannah River program manager Leo Thompson recently accepted an assignment at Los Alamos. At the Laboratory, he will help coordinate the two pit production organizations, with the goal of finding opportunities for Savannah River's workforce to learn from Los Alamos' workforce. "Savannah River has experience in

plutonium production and handling, but we don't have experience in pit production," Thompson says. "To help us with our pit production mission at SRS, we're really counting on the experience that Los Alamos has."

Thompson says that Savannah River and Los Alamos are collaborating in three key ways. The first is in completing SRPPF's design, which will be based on the processes and equipment used at Los Alamos.

The second is through the Knowledge Transfer program, in which Savannah River personnel accept two-year assignments to plutonium pit production-related roles at Los Alamos. "After two years, they won't be experts in pit production," Thompson says. "But they'll be able to take knowledge back to Savannah River and increase our collective knowledge of what we need to do."

Third, the Mutual Support program sends Savannah River personnel to visit Los Alamos either in-person or virtually for short-term assignments to learn about topics including pit production support systems, training, equipment requirements, safety, and waste management. Meanwhile, Los Alamos will benefit from the SRS workforce's experience with processes such as maintenance engineering and a 24/7 production schedule, which the Laboratory adopted for its pit production in February 2022. Other areas of collaboration include the creation of software to facilitate pit production at both facilities, the completion of Los Alamos' Site-Wide Environmental Impact Statement, and the development of consistent public engagement practices at both sites.

Although Savannah River will continue to work with Los Alamos to provide materials that ensure the nation's nuclear security, there are still no plans to turn the site into the "H-bomb factory" that many South Carolinians anticipated seven decades ago. Instead, an ever-closer collaboration between Savannah River and Los Alamos will help the two organizations identify what Thompson calls "enterprise-wide solutions to enterprise-wide challenges."

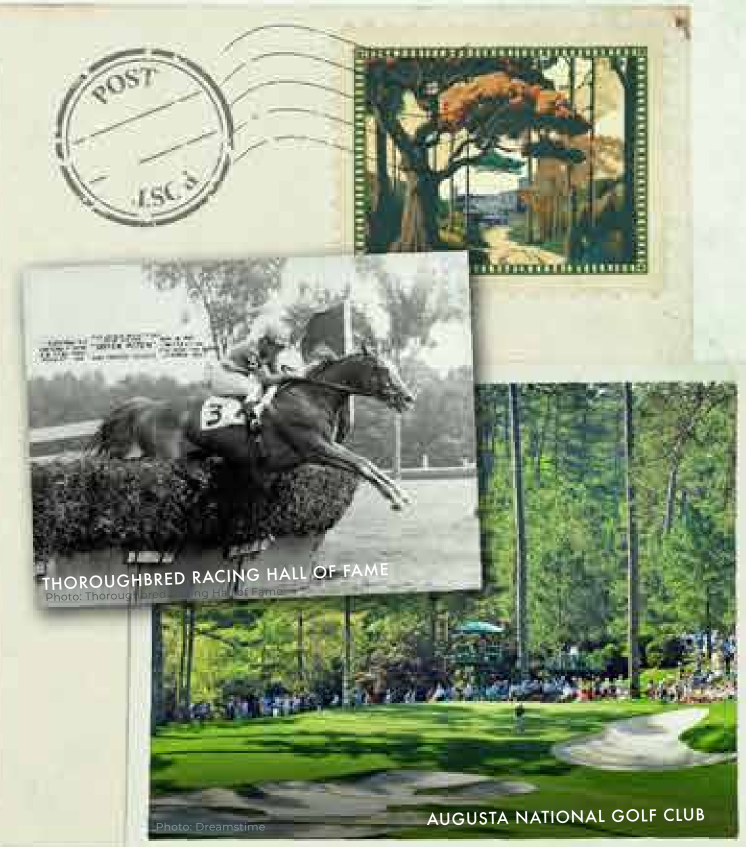
"Both sites are impacted by issues such as the competitive job market. So what can organizations do together to address these things, to make pit production a more attractive opportunity for young people entering the job market?" Thompson says. "Instead of a one-off collaboration here and there, both organizations are aligned and working together on dealing with these larger challenges. To establish the capacity to produce at least 80 pits per year will require ongoing collaboration between Savannah River and Los Alamos in the long term." ★

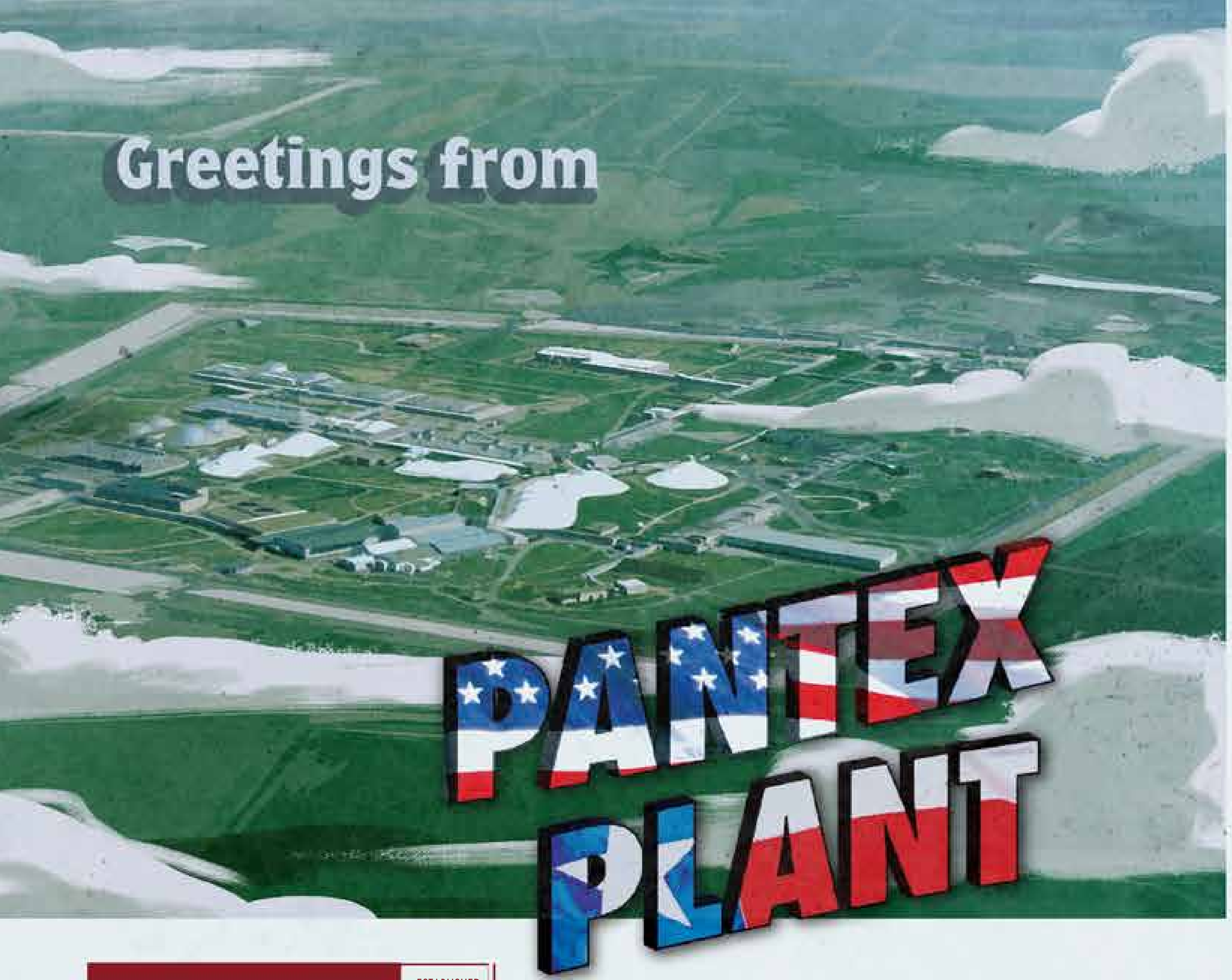
SAVANNAH RIVER SITE

NUMBER OF EMPLOYEES: 11,000
FOOTPRINT: 310 square miles
FISCAL YEAR BUDGET: $3 billion
CURRENT OPERATOR: Savannah River Nuclear Solutions, LLC

CHECK OUT:

- Hopelands Gardens, home of the Thoroughbred Racing Hall of Fame
- The Masters Tournament, which takes place the first week of April, at nearby Augusta National Golf Club





NUCLEAR WEAPONS PRODUCTION FACILITY

ESTABLISHED
1942

LOCATION
AMARILLO, TEXAS

MISSION

RESEARCH & DEVELOPMENT
- HIGH EXPLOSIVES R&D

WEAPONS PRODUCTION
- WEAPONS ASSEMBLY & DISASSEMBLY
- HIGH EXPLOSIVES MANUFACTURING

The nation's only nuclear assembly and disassembly plant sits at the center of the nuclear enterprise.

BY JILL GIBSON

"All roads lead to Pantex," reads the sign displayed in the administration building of the nation's only nuclear assembly and disassembly plant. Beneath the bold declaration lies a large map of the United States showing how every laboratory, site, and plant within the nuclear security enterprise feeds both in and out of the Pantex Plant.

"When I think of the saying, 'All roads lead to Pantex,' it reminds me of how Pantex fits into the enterprise," says Pantex Site Manager Colby Yeary. "Pantex is the final assembly point for our nation's nuclear weapons, and therefore it is the last stop in the supply chain prior to providing the assets to the Department of Defense" (DOD).

Located about 30 miles east of Amarillo, Texas, the remote 30-square-mile site has supported national security since World War II, when it was built to produce conventional bombs and artillery shells for the war effort. Now the plant serves as the primary assembly, disassembly, retrofit, and life-extension center for America's nuclear weapons.

"Either all weapons come here, or all weapons leave here and go back to the Department of Defense," says Jeff Yarbrough, the former Pantex site manager who moved to a position at Y-12 in October 2022. Stressing the interdependence of the various locations, he adds, "That interface is strong."

Yeary agrees, saying, "I often think of Pantex as the anchor leg in a track relay of National Nuclear Security Administration (NNSA) sites. Without the many contributions from the other NNSA sites and DOD partners, Pantex would not be able to deliver our mission."

Thousands of weapons have been assembled, disassembled, and modified at the plant, which grew in importance after the government consolidated nuclear weapons facilities in 1975. Pantex is also responsible for high-explosives manufacturing and testing along with interim storage and surveillance of plutonium pits, the key components of nuclear weapons.

Yarbrough says you can ask any of the plant's more than 4,200 employees and they will tell you why the facility exists.

"What we're about here is global security for our nation and our allies," says Monty Cates, Pantex senior director for high explosives. "We're protecting the world. That's what we do here. And that's not inconsequential."

SPOTLIGHTING SECURITY AND SAFETY

Due to the nature of this mission, the plant places a high emphasis on security. Only carefully vetted visitors are allowed to visit

■ "All roads lead to Pantex" is illustrated on a polished aluminum map in the lobby of the plant's administration building. Some of the weapons production roads are illustrated here.

Molecular weight analysis

Pantex Plant

Technicians with a B83 joint test assembly

Technician working on a W80

the remotely located site, where buildings are spread far and wide across grassy plains. Omnipresent armed security officers, concrete and steel barricades, and razor wire surround the facilities. Pantex is also home to carefully engineered concrete bunkers where nuclear weapons production operations take place. These bunkers are covered with an engineered system of small rocks and materials; in the unlikely event of a high-explosives accident, these "Gravel Gerties" contain the explosion. Throughout the plant, facilities have been constructed with safety and security in mind.

Safety and security are also the focus for the plant's security police officers. "When you think about all the quantities of material that we have on site, you have to have a best-in-class security force because nobody else deals with what we deal with: the combination of weapons, nuclear material, and high explosives," Yarbrough says. "Nobody deals with the stages of nuclear weapons that we deal with. Considering just the sheer amount of material, the decisions, processes and the scale of the work that we do, you have to have the best security force possible."

Another aspect of safety and security is the extensive training Pantex employees undergo and the plant's highly regimented procedures, as Deputy Site Manager Kenny Steward explains. "Production technicians will go through three to four months of general site training before we ever put them into training for a weapons program."

All of the work done at Pantex is documented in detail. "We take almost all of our knowledge and capture that into written step-by-step procedures, and that's very different from most all the other sites," Yarbrough says. "We need to do that here. You want that discipline. You want that repetitiveness when working on explosive weapons."

BUILDING BRIDGES

Operating much like a small city, Pantex has its own fire and medical departments; maintains its own water-treatment, sewage, and steam-generating plants; and produces its own well water. Five wind turbines, each more than 400 feet tall, generate more than 60 percent of the plant's annual power needs. An on-site facility produces concrete, and the plant conducts extensive wildlife and environmental monitoring.

Pantex exists independently from nearby cities. Its largest neighbor is Amarillo, which houses about 250,000 citizens, most of whom fully support Pantex as one of the area's primary employers. Local residents express few concerns about the nuclear materials stored at the plant. Yarbrough points out the benefits of being located in a highly patriotic part of the United States, where people value hard work, commitment, and service to the country. "We have great community, business, and educational support," he says.

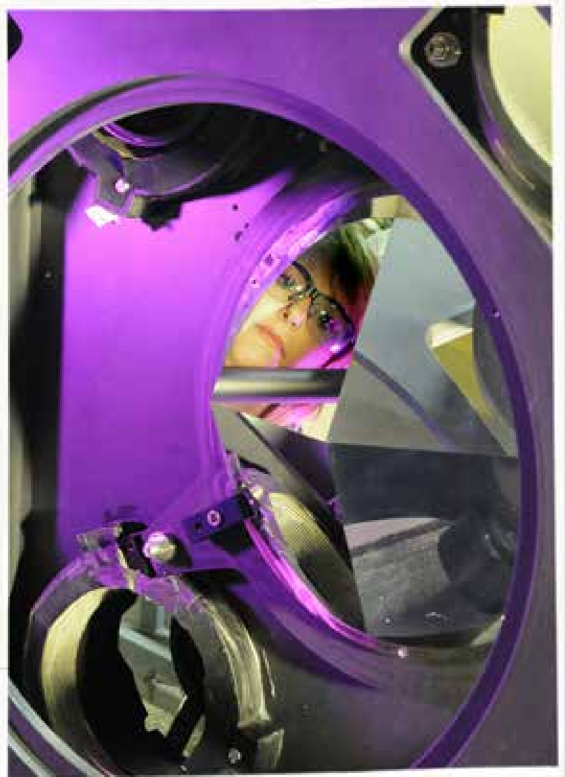
Pantex's positive relationship with the community is integral to its ongoing success, but what is even more important is the way the plant collaborates with other laboratories, plants, and sites in the nuclear enterprise. Pantex works daily with three national laboratories: Los Alamos, Livermore, and Sandia. "The labs do the primary science, physics, engineering, and chemistry to develop the material requirements, the systems requirements, and component requirements for nuclear weapons, and then we take those requirements and figure out how to make those into a production system," Cates says.

Yeary stresses the importance of that daily communication and collaboration. "Our missions have differences, but the relationship is symbiotic in many aspects of what we provide our nation," he says.

Yarbrough also emphasizes the importance of this relationship, pointing out, "Every day, any work we do is going to be within the design requirements that the national labs set for us. Also, we have to get the approval of those design labs for our processes, and for the work that we do on site. We don't do anything without some level of review and approval by the design agencies."

Information also flows from Pantex to the national laboratories, according to Yarbrough. "Parts that we take off nuclear weapons, we'll do testing on them and we'll send that data and that information to the laboratories, or in some cases, we will actually send the full part or the component back to the lab and to other plants as well. The work we do feeds a lot of the information back to the national labs, so they can make determinations on how the

Production technicians handle a W88 warhead



A quality assurance technician is reflected in the mirror of a computed tomography imaging system

The W76-1 Life Extension Program of Record completion ceremony

stockpile is performing and how those lab directors will certify the stockpile."

CREATING COLLABORATION

Arlan Swihart, a Los Alamos weapons systems safety analyst, is based full-time at the Pantex Plant, along with other personnel from Los Alamos, Sandia, and Livermore labs. "The way it works is that Los Alamos develops a design for weapons and comes up with all the criteria that the weapon must meet, and Pantex is ultimately charged with implementing the Los Alamos design." Swihart says the design agency personnel have a good relationship with the Pantex staff. "We tell them what they need to do and the specifications they need to do it, but exactly how they do it is up to them."

Darrell Schmidt is the Pantex production liaison from the Los Alamos Weapon Systems Engineering Division. "It's really invaluable to be co-located," Schmidt says, noting that he sometimes must travel to Los Alamos, which he calls "the mother ship," but most of his time is spent at the Pantex Plant. "We are the eyes and ears for the Lab on site and to help our associates back home," he explains. "We work together on a lot of overlapping issues related to quality and testing materials, as well as any corrections or improvements needed."

Steward says this close working relationship can avoid challenges that have occurred in the past, such as when the W84 nuclear warhead required hiring people with smaller hands and dexterity to carry out assembly work. "It does a designer no good to design a part that either can't be manufactured or can't be assembled. What happens if we can't get a tool in there to extract a screw or to tighten a bolt in a certain direction or to make an electrical connection? And so as they are designing, they're keeping in mind the design for manufacturing, assembly, and disassembly."

In addition to this daily interaction, Sandia National Laboratories has an on-site facility at the Pantex Plant. "As we build things or disassemble something, Sandia tests it, which simulates some aspects of the weapon system, and then they'll send it back to us and we'll disassemble that testbed, and we'll start the whole process over again," Yarbrough says.

The collaboration also extends beyond the national laboratories. "Because we are routinely shipping material back and forth with all the other sites, we have to have daily coordination, ship schedules, testing schedules, and you're having daily meetings within a product or program realization team," Yarbrough continues. "We might have a conference call today on a certain weapons system that would include all the sites. You know, logistically, when can you deliver this, when will I have that? When do I get the data that I need? When do I get the product? So, that goes on daily. The logistics of the entire nuclear security enterprise take that daily communication."

GEARING UP FOR GROWTH

Communication has taken on even greater importance recently at Pantex because the plant is facing a larger workload than it has in decades. Numerous weapons systems are simultaneously undergoing retirements and refreshments. To accommodate this work, the plant has begun focusing on modernizing its infrastructure and constructing new buildings. "Many of those facilities were 1940s- or 1950s-era facilities and to be able to reconstruct and then eventually move into a new high explosive science and engineering facility will give us a more modernized footprint," Steward says. "We're also currently constructing the advanced fabrication facilities so we can look at additive manufacturing and 3D printing of components, and we have other facilities on the books to replace."

New production technicians are being hired along with support people, engineers, security officers, maintenance workers, and more. "It is difficult to do the amount of work we're currently doing, and then increase our output on certain programs by 100 percent from year to year while we're upgrading our facilities and hiring and training new people. It's a big challenge, but we like that challenge," Yarbrough says. He points out that meeting that challenge represents a crucial part of the success of the nuclear security enterprise as a whole. "Every site within the enterprise has pride in what it does, and everybody thinks that theirs is the most important part. We like to say we're at the end of the supply chain and because of that, we have to integrate everything that all those other labs, sites, and plants do. We integrate all of the parts into a final package under the auspices of our three national laboratories. The product that leaves our site goes directly to the military and it is the most tangible thing that the nuclear security enterprise produces."

Cates agrees, saying that every lab, site, and plant has a crucial role to play. "We can't deliver nuclear weapons to the hands of the military without support from Los Alamos, Livermore, Sandia, Y-12, Savannah River, Kansas City, the Nevada National Security Site, our headquarters folks on site and in Washington D.C.," he says. "That's why it's called an enterprise. There's a little over 50,000 people that are engaged in this mission and it takes everyone to make that happen."

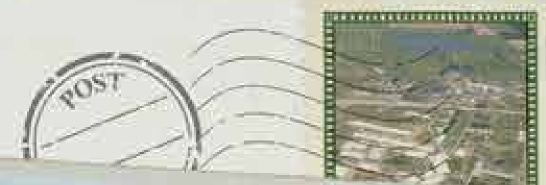
He pauses, then continues. "That's what gets me up in the morning, makes me excited to come to work, to make that long drive into the sunrise in the morning on those cold days. It's because I know what we do here is important, not only for our nation, but the world." ★

PANTEX PLANT

NUMBER OF EMPLOYEES: 4,200
FOOTPRINT: 28 square miles
FISCAL YEAR BUDGET: $1.225 billion
CURRENT OPERATOR: Consolidated Nuclear Security, LLC

CHECK OUT:

- The Cadillac Ranch, a public art installation featuring 10 Cadillacs buried nose first in the ground
- Palo Duro Canyon State Park, home to the country's second-largest canyon and the Official State of Texas Longhorn Herd



TEXAS LONGHORN
Photo: Dreamstime

CADILLAC RANCH
Photo: Dreamstime

NATIONAL SECURITY TEST SITE

ESTABLISHED 1950

LOCATION
MERCURY, NEVADA

MISSION

TESTING
- UNDERGROUND TEST READINESS
- HIGH EXPLOSIVES TESTING
- HYDROTESTING
- SUBCRITICAL EXPERIMENTS

The nuclear enterprise comes together to conduct crucial experiments.

BY JILL GIBSON

"You'll travel 965 feet below ground at a rate of 880 feet per minute."

Vince Gomes, a facilities manager at the Nevada National Security Site (NNSS), gestures toward a steel cage that transports scientists, miners, construction workers, and equipment from the Earth's surface to a massive subterranean laboratory.

"The tunnels are huge, and you're nearly 1,000 feet underground," adds Roger Rocha, the vice president and chief operations officer for Mission Support and Test Services, the contractor that operates and manages NNSS. "So go to a happy place."

COLLABORATING ON NATIONAL AND GLOBAL SECURITY

The main entrance to NNSS is about an hour northwest of Las Vegas. From that southernmost portion of the site, NNSS sprawls more than 1,355 square miles (larger than the state of Rhode Island) across both the Mojave and Great Basin deserts. Antelope sightings are common, and "tortoise crossing" signs appear every few miles along the site's major roads (in fact, many employees have taken desert tortoise training to ensure the safety of this threatened species).

Called the Nevada Test Site until 2010, NNSS is perhaps best known as the location for the majority of America's nuclear tests (see p. 68). Between 1951 and 1992, 100 atmospheric and 828 underground nuclear tests took place there. Although the United States halted full-scale nuclear testing in 1992, the site is still focused on national and global security work.

"It's a big place, and we do big jobs—big things that can't be done anywhere else," Rocha says.

Rocha and his staff collaborate with people from throughout the nuclear enterprise and various federal agencies on projects ranging from stewardship of the nation's nuclear deterrent, to nuclear and radiological emergency response training, to nuclear nonproliferation and arms control initiatives, and more.

"We refer to ourselves as the integrator," Rocha says. "We have the technical expertise to ensure the mission goals are achieved. We're also responsible for conducting training so that all the work is done safely and securely. It's a great partnership."

Rocha also points out that the remoteness of the site allows the Department of Defense and other agencies to carry out tests that require maximum security and unique conditions. "People can come here and do things they can't do anywhere else," he says.

For example, at NNSS, first responders can train under conditions they might encounter in real life. "We just did a training literally simulating an acid spill," Rocha says. "We had 65 firefighters from across the United States that were here, and we opened up the valves and dumped acid. It's fuming; there are clouds; they're in full personal protective equipment practicing the skills necessary to neutralize and contain an event like this. This is the only place in the country where you can do that."

Radiological and nuclear response personnel also visit NNSS to gain firsthand experience working in contaminated facilities. "Close to half a million people have been through here for training," Rocha says.

SEEKING ANSWERS UNDERGROUND

Because of its remote location and enormous footprint, NNSS can safely host nuclear weapons–related experiments that can't be done anywhere else.

Los Alamos (see p. 22), Lawrence Livermore (see p. 30), and Sandia (see p. 36) national laboratories each conduct, and often collaborate on, a great deal of national security work in Nevada. All three laboratories have employees based permanently at NNSS, and numerous other employees travel back and forth between the site and their home labs.

In fact, Los Alamos conducts so much work in Nevada that in 2020, the Laboratory created its Nevada Programs Office to streamline and coordinate the Los Alamos work happening at NNSS. "It was one of those things where success breeds demand," says Don Haynes, who leads the office. "And we've had a lot of success out there."

Following the 1992 moratorium on full-scale nuclear testing, Los Alamos, Livermore, and Sandia pivoted to subcritical experiments as one way to obtain data that's useful in evaluating the health and extending the lifetimes of America's nuclear weapons. Subcritical experiments incorporate nuclear materials, such as plutonium, but are configured so no self-sustaining nuclear fission reaction occurs. All subcritical experiments take place inside steel vessels at U1a, the underground laboratory where Vince Gomes is the facilities manager. After these experiments, the vessels are "entombed"—placed at the end of a tunnel and permanently sealed off from the rest of the facility.

Steve Sintay, a Los Alamos project manager and subcritical experiments test director in training, and Chris Frankle, a Los Alamos physicist and subcritical experiments diagnostics coordinator, both point out the crucial nature of these experiments. "In this facility, you get the closest to actual performance of the stockpile," Sintay says.

Currently, one subcritical diagnostic test bed is operational at U1a: a pulsed x-ray system called Cygnus that's used for small, focused experiments. Construction has also begun on two more test beds, Zeus and Scorpius, which will allow researchers to conduct subcritical experiments of different sizes and scales with comprehensive diagnostic coverage.

Scorpius, in particular, will play a critical role in understanding and predicting the behavior of plutonium, according to Haynes. Scheduled to be operational by 2030, the 125-meter-long linear induction accelerator represents a partnership among Los Alamos, Lawrence Livermore, and Sandia laboratories, which are each responsible for different parts of the machine. Scorpius will cost more than $1 billion to build and will weigh about one million pounds. Construction on the


Desert tortoise


BEEF Kappa West Firing Site


Employees on the U1a elevator


An explosion at BEEF Kappa West

underground tunnel that will house Scorpius is nearly complete, and the accelerator will be built in pieces and assembled underground.

Like its cousin, the Dual-Axis Radiographic Hydrodynamic Test (DARHT, see p. 28) facility at Los Alamos, Scorpius will be used to take radiographs of the late stages of weapon implosion. Unlike experiments at DARHT, experiments at Scorpius will use plutonium, which will allow scientists to better identify the effects of plutonium aging and ensure the proper functioning of the nuclear stockpile. Data from Scorpius' subcritical experiments will inform safety and other updates to nuclear weapons.

"With Scorpius, we're going to be able to take multiple, high-quality radiographic images of imploding systems—a capability that we do not currently have for subcritical experiments," Haynes says. "These experiments are being done to answer an important set of questions we've been wrestling with."

Data from these experiments will help calibrate and validate computer simulation codes used to make decisions. Haynes explains that "as our simulations are asked harder and harder questions, we need better research tools, better experimental tools, to make sure that those simulations are staying on track, and they're giving us accurate predictions."

Haynes stresses the magnitude of this project. "Scorpius will allow us to have reduced uncertainty and increased confidence in decisions that we make for our deterrent. In the absence of nuclear testing, we need a deeper scientific understanding of the processes that are important for the performance and safety of nuclear weapons."

EXPLORING THROUGH EXPLOSIONS

Back above ground, researchers at Nevada's Big Explosives Experimental Facility (BEEF) Kappa West Firing Site use massive amounts of high explosives to conduct training, support global security work, try out different diagnostics, and qualify the vessels that will contain subcritical tests.

Although high explosive (nonnuclear) tests are conducted at other places throughout the nuclear enterprise, the tests at BEEF are substantially more powerful. The key part of this facility's name is "Big," says Art Villalobos, the Los Alamos National Laboratory group leader for integrated weapons experiments in Nevada. Villalobos points out that 4,000 pounds of high explosives have been detonated at BEEF and that locations have been identified where up to 50,000 pounds can be detonated.

"Basically, we're creating explosions in a safe and controlled environment to expose weapons to extreme environments and monitor the weapons to see how they react to the different temperatures," he continues. "When we test a weapon, we want to determine the rate, distance, and size of the fragments coming out of the weapon, and how they disperse and affect the environment." The results of these experiments also provide safety information for different weapons systems.

The tunnel that will house Scorpius

Using high-speed video cameras and radiography, the scientists capture images of the explosions. Each experiment requires miles of diagnostic cables running from the firing site to a control bunker for detailed monitoring and data collection. Other experiments require ground motion monitoring and pressure sensors to help scientists learn to detect and distinguish different types of detonations.

"We set off large amounts of explosives to see what sort of diagnostic signals you would record either seismically or with infrasound," Haynes says. "This is an important part of nuclear nonproliferation—making sure that we have the ability to detect anyone who is attempting to evade detection for a nascent nuclear weapons program."

PERFECTING THE DETECTING

Approximately 11 miles north of BEEF is another experimental area called P Tunnel. Unlike U1a, which is accessed by elevator, P Tunnel is bored into the side of a mesa; scientists can walk in from the parking lot and take a train to various locations in the tunnel.

Today, an ongoing test series inside P Tunnel is helping scientists develop new ways to identify whether an adversary is hiding low-yield nuclear testing or developing nuclear weapons in violation of treaties. These tests improve U.S.

This dual-axis flash x-ray radiography system is used to examine the physical properties of plutonium during subcritical experiments

P Tunnel is used for seismic, acoustic, electromagnetic, and radionuclide experiments that inform nonproliferation and arms control initiatives

arms control and nuclear nonproliferation verification and monitoring capabilities. Researchers use the data collected, along with legacy data from actual nuclear tests, to validate physics-based computer models. The findings will extend their explosion detection capabilities to lower yields and different geological settings and will advance their ability to differentiate low-yield nuclear explosions from other seismic activity, such as mining operations and small earthquakes.

"We're using high explosives and extremely tiny releases of gases and particulates that we can trace to generate and collect data needed to validate our physics-based models," says Gordon MacLeod, a geophysicist at Los Alamos National Laboratory who is involved in the P Tunnel experiments. "On the surface we're testing whether we can track the tracer release to see if the models and sensors are working properly."

Scientists are also researching ways to detect low frequency electromagnetic signals, similar to those that would be created by a nuclear detonation. "We built an electromagnetic source that looks like a giant coil inside the tunnel, and we were able to detect low frequency signals that were actually traveling from that source through more than one kilometer of rock up to the surface," MacLeod says.

Other experiments will be conducted underground in the southern part of NNSS in an area called Rock Valley, which is known for shallow seismic activity. "A lot of our adversaries test in active earthquake areas," says Cathy Snelson, a project manager in the Los Alamos Geophysics group. "If you want to set off underground nuclear explosions, you can hide them in a seismically active area because earthquakes are energy-wise a lot bigger than an explosion is, and explosions tend to get buried in the noise."

Snelson says this testing location provides a unique opportunity to compare experiment results to shallow earthquake seismic activity data recorded in the same region decades ago. "From a nonproliferation and monitoring point of view, this has never been done before. We'll be placing a ton of sensors out both on the surface and below the ground. These will be unprecedented datasets. The amount of data, both geological and geophysical, that we'll be collecting is just incredible."

The researchers point out that the results of these experiments will contribute to treaty monitoring and negotiations. "Scientists from all three national labs and the Nevada National Security Site are working together on this. We're extremely excited," Snelson concludes.

CONTINUING THE COMMITMENT

Although the scope of the work taking place at NNSS is as vast as the Nevada desert, every training, experiment, and test shares a common purpose: to safeguard and advance national and global security. The commitment of the workforce to fulfill this mission is evident throughout the site, according to Haynes. "Much of the workforce travels more than an hour to work every day and puts in 10-hour days in challenging environments," he notes.

Brian Brown, the facility manager at P Tunnel, agrees and says he tells his team members what an important role they play in national security. "You're responsible for protecting United States citizens and global citizens. Know that when you're digging a trench, or you're putting up extra lighting, or you're making sure the ventilation is flowing, your work is having a more significant impact than you can imagine. You need to understand potentially how big of an impact you're having on the safety of America and the world in general."

That collaborative spirit is also evident among those involved in the Scorpius project underway at U1a. According to Dave Funk, the vice president of Enhanced Capabilities for Subcritical Experiments at NNSS and former senior director of the Advanced Sources and Detectors Project Office at Los Alamos National Laboratory, nearly 800 people from Los Alamos, Livermore, and Sandia national laboratories, NNSS, and the National Nuclear Security Administration have contributed to Scorpius so far. "What is really amazing about this project is the complexity of the partnerships and the process of bringing all these different cultures together and leveraging their strengths," he says.

The collaboration is indeed amazing but perhaps not surprising. After all, teamwork across the enterprise has been key to the success of the Nevada National Security Site since its very first full-scale nuclear test in 1951. For more than 70 years, the dedication of the scientists, engineers, and craftspeople who work at the site remains unchanged, according to Haynes.

"It's an amazing set of people," he says. "What they're doing is a great service to the country." ★

Nevada
NATIONAL SECURITY SITE

NUMBER OF EMPLOYEES: 2,400

FOOTPRINT: 1,355 square miles

FISCAL YEAR BUDGET: $1 billion

CURRENT OPERATOR: Mission Support and Test Services, LLC

CHECK OUT:

- The Las Vegas Strip, home to upscale casino hotels, performance venues, restaurants, neon lights, and other attractions
- The Atomic Museum in Las Vegas, an educational institution that tells the story of America's nuclear weapons testing program at the Nevada Test Site

The tower holding Icecap, a planned Los Alamos National Laboratory underground test, still stands at the Nevada National Security Site even though the experiment was canceled when a testing moratorium went into effect in 1992.

A blast from the past

A *National Security Science* writer travels back in time to explore relics of the nuclear testing era.

BY JILL GIBSON

> "Those who don't have goggles are told to face away from the blast and cover their eyes with their hands, but the reflection from the pale ground is so bright that most can see the bones in their hands."
> —BYRON RISTVET

"What are your plans today?" the Starbucks barista asks me. The coffee shop, buried deep inside a Las Vegas hotel and casino, is crowded with customers who, like me, are anxious to start the day with much-needed caffeine.

I hand the barista my credit card and consider how to describe my plans. Not that she actually cares, but I feel conflicted about how to answer. "Sightseeing," I reply. I'm not lying—I am about to spend the next three days sightseeing, and the sights will, literally, blow my mind.

I am embarking on a "technical orientation visit" to the Nevada National Security Site (formerly the Nevada Test Site and before that the Nevada Proving Grounds), where 928 nuclear devices were tested between 1951 and 1992. Today, no full-scale nuclear tests are conducted there, but the site is still used for nuclear weapons–related development and research, and many relics from the testing days remain scattered across the desert—a sort of museum documenting the first decades of the atomic age. Three retired scientists are leading the tour, which, as a national laboratory employee, I am privileged to attend. During my visit, I will explore the history of America's nuclear knowledge and get a peek into current developments. Nothing has prepared me for how much I will learn or the conflicting feelings I will have about our nation's nuclear legacy.

The Nevada National Security Site is located about an hour north of Las Vegas in an area initially chosen for its remote location. As the bus drives down the highway, I realize that, despite our relative proximity to the crowded Las Vegas strip, the land extending in every direction is barren—void of houses, stores, or other signs of civilization. Instead, brown, rock-studded mountains climb from the sandy desert on either side of the road. We turn onto the Mercury Highway and proceed to the main gate, where IDs are checked and badges issued. Warning signs on either side of the road read "Restricted Area," "Radiological Hazards," and "Obey All Posted Signs."

The first tests conducted in Nevada were atmospheric (above ground), carried out in the 1950s in response to a growing fear of Soviet attack. The bus passes a row of weathered benches where invited observers and members of the press would sit to watch, wearing special goggles to protect their eyes. "At first there is a very bright flash," explains scientist-turned-consultant Byron Ristvet, passing around some 1950s-era eyewear. "Those who don't have goggles are told to face away from the blast and cover their eyes with their hands, but the reflection from the pale ground is so bright that most can see the bones in their hands," he says. "Then, the side of their bodies facing the giant fireball becomes very warm. On a damp morning, peoples' clothes start steaming from the thermal pulse. Then all of the sudden the ground goes up and down like an earthquake, and you feel sort of queasy. That's the ground shock that runs across the desert at 5,000 feet per second, meanwhile the air blast is flattening down all the bushes and hits with the equivalent force of a 100-pound person running into you at 90 miles per hour."

This entire sequence occurs in silence, but then there's the sound. "It's a sharp crack initially. It sounds like a rifle shot going off and then it turns into a rumble, followed by numerous short cracks. The size of the blast determines the length of the effects," Ristvet explains, launching into a complex discussion of mathematical equations.

We roll on to a series of trenches where members of the military trained to fight through a nuclear attack. Further down the highway is Frenchman Flat, where various nuclear effects tests were conducted. Twisted rebar, crumpled metal, and concrete rubble remain from destroyed buildings, shelters, and even a bank vault. Empty animal pens stand by the road where long-ago scientists tested the nuclear effects on living creatures. "Don't worry," says Ristvet. "The pigs were heavily anesthetized and very well cared for."

Later we visit the Apple Houses, built from kits and furnished by JC Penney and Montgomery Ward. Mannequins were positioned throughout the house to represent a family, unaware of an impending nuclear attack. The houses still stand, paint scraped bare, windows long gone, but most of the damage we see now is a result of weather, our tour guides explain.

In 1963, all atmospheric testing was banned when the Limited Test-Ban treaty was signed in Moscow, giving rise to the underground testing age. The site was well-suited for underground testing. Here, below-ground water lies at the greatest depth in all of North America, and the terrain consists of dry alluvial sand, volcanic tuff, and basalt. The United States conducted 828 underground tests in this desert, studying all aspects and applications of nuclear detonations. We will visit many of the locations where those tests took place.

"We call it the crater crawl," Ristvet says as we climb into pick-up trucks capable of handling the rugged terrain we'll encounter after a long drive north. The size of the test

Byron Ristvet, scientist-turned-consultant, educates the tour group while wearing 1950s-era protective goggles.

site is a mind-boggling 1,355 square miles, larger than the state of Rhode Island. Miles and miles of nothing to see but Joshua trees, chamisa, tumbleweeds, and sagebrush stretching across the desert, framed by the mountains, cloudless blue skies above.

The drive is rough. Many of the dirt roads have not been maintained since a test moratorium went into effect in 1992. In my vehicle, we shout to hear each other as we drive across the lunar-like landscape. "What was your most memorable test?" I ask Ron Cosimi, a former Los Alamos National Laboratory test director.

Cosimi launches into a story about the time he was about to conduct a test, unaware that

The remains of domed concrete and aluminum shelters rise from the desert. The shelters with two-foot-thick concrete survived the detonations, but the thinner concrete shelters and those with aluminum domes collapsed.

The tour group stands on the platform beside Sedan Crater. Formed in 1962 by an explosion that displaced about 12 million tons of earth, the crater is 1,280 feet in diameter and 320 feet deep.

A bank vault remains largely intact after surviving a 1957 test to explore ways to protect records and valuables from a nuclear blast.

This two-story wooden house, called Apple 2, was part of an experiment to find out how an average American town would withstand a nuclear detonation.

two protesters had sneaked onto the test site. "We started the countdown. I turned to the guy and told him to push the button to launch the test, but suddenly I saw movement out of the corner of my eye on a screen that showed ground zero. I shouted, 'Stop. Stop the test.'"

Cosimi pauses, lost in the memory, then continues. "These two girls, protesters, somehow had gotten onto the site and when they heard the countdown on the loudspeaker, they started running toward the speaker, which happened to be on the other side of ground zero. The movement I saw was one of the girls jumping over a firing cable. They were running right toward ground zero."

Officials sent security to arrest the women, while a team checked the area for signs of sabotage. The countdown resumed, and the device was detonated. "The ground went up 15 feet in the air and then fell back into a hole; they would have been killed," Cosimi says. "I can't believe I saw them. It was fate I guess. I still have nightmares about it."

Exiting our vehicles, we hike up a hill to an underground test site similar to the one Cosimi has just described. The trail is steep and winds among giant basalt boulders, black with sharp edges, that were created by the blast. We top the ridge and look into Schooner Crater. In 1968, the approximately 30-kiloton blast formed a hole roughly 850 feet wide and 200 feet deep. The resemblance to the moon's surface is so striking that I'm not surprised to learn that NASA used Schooner Crater to train astronauts for moon landings. A few people in our group put on gloves to pick up rocks fused into glass by the heat of the blast. The radiation control technician checks our hands and feet with a Geiger counter before we leave, as some contamination remains even more than 54 years after the test.

Over the course of the next two days, we visit several more craters, all formed from underground nuclear tests with a wide variety of goals. Many of the tests were designed to study industrial applications of nuclear detonations, such as building canals, quarrying, stimulating natural gas production, and cutting railroad tracks through mountain ranges. Though the tests provided a great deal of useful information, the United States never actually used nuclear devices for any of these purposes due to lack of Congressional and public support.

The largest crater, the Sedan Crater, was formed in soft alluvium, soil made of loose clay and sand. The crater was created in 1962 by a Lawrence Livermore–designed device with a 104-kiloton yield and provides a clear demonstration of the potential power of nuclear detonation. Sedan is listed on the National Registry of Historic Places and is the most visited spot at the Nevada National Security Site.

As we continue the crater crawl, we also hear many stories of international collaboration. American scientists—most of them from Los Alamos and Lawrence Livermore national laboratories—carried out tests with counterparts from Russia, England, and France. Cosimi says along with building knowledge, they built friendships. The British test director was often a guest in Cosimi's New Mexico home, and Cosimi says he got to know the Soviets as individual people, rather than a faceless evil enemy. Although Cosimi spent much of his career testing weapons, he says that testing helped build connections and prevent war. "I have been asked by people, 'Why are you so warmongering?'" says Cosimi. "I say, 'You've got the wrong idea.' I actually have a hat that says 50 years without a major war by testing."

Underground testing was suspended abruptly in 1992 when the United States voluntarily joined with Russia, the United Kingdom, and France in a test moratorium. In 1996, the United States signed (but did not ratify) the Comprehensive Nuclear-Test-Ban Treaty, which prohibits any type of nuclear detonation.

Cosimi says the days leading up to the moratorium were marked by a frantic scramble to wrap up all in-progress tests, most of which took about 18 months from design to implementation. One of those tests, Icecap, was designed by the British to test nuclear detonation in extremely cold conditions. Today, the Icecap site remains frozen in the final stages before firing, a living museum of the history of nuclear testing. Left behind is a tower surrounding a 150-foot rack that would hold both the nuclear device and complex diagnostic equipment. (Right before detonation, the rack would have been lowered into the hole and the tower disassembled.) Scores of thick diagnostic cables run from the rack, out of the tower, and across the desert to a handful of monitoring trailers that sit on concrete pads, abandoned, never used. We climb the stairs inside the tower to see the rack, the spot where the device would sit, and the tangle of cables. It is a nuclear ghost town, everything left exactly the way it was the day the ban went into place.

An atmospheric test during the 1957 Operation Plumbbob.

But the Nevada National Security Site is more than a monument for the atomic era. It is the working home of multiple programs, tests, and initiatives to enhance national security. There is a definite sense of important stuff happening here, reinforced at the gate as they confiscate our cell phones (because of the cameras). When we stand on a mountain ridge overlooking the test site, our guide points out Area 51—the highly classified U.S. Air Force facility famous for possible alien activity.

This desert has seen a lot (although the jury is still out on UFO sightings). The drive to discover, the relentless pace of scientific curiosity, the horrifying power of humanity's ability to create weapons of war … all are embedded in both the sand and psyche of this place.

Returning to the hotel, tired and dusty, my head filled with test names and Ristvet's "simple science" lessons, I walk slowly through the building, down the hall, past the Starbucks. Was it only just that morning I had stopped there for coffee? It feels as though decades have gone by. The barista calls out a cheerful greeting, "How was your sightseeing?" and I stop to think for a moment before replying. "Truly, it was a blast from the past." ★

BEYOND THE ENTERPRISE

Nuclear weapons are designed, built, and maintained by the National Nuclear Security Administration's labs, plants, and sites for the Department of Defense.

■ Aboard an Osprey aircraft, a U.S. Marine Corps staff sergeant lowers a payload onto an Ohio-class submarine. These submarines carry D5 missiles armed with Los Alamos–designed W76 or W88 warheads.
Photo: U.S. Marine Corps

FROM SEA TO SHINING SEA

The U.S. Air Force and Navy are equipped to deliver nuclear weapons at a moment's notice.

BY IAN LAIRD

Based on the capabilities of its delivery systems—missiles, aircraft, and submarines—and the current and future threat landscape, the Department of Defense (DOD) generates the military requirements for U.S. nuclear weapon systems. DOD works closely with the Nuclear Weapons Council (see p. 12) and the National Nuclear Security Administration (see p. 18) on these requirements (which may range from new weapons designs to modifications of existing weapons) to ensure the United States is able to continue to credibly deter foreign adversaries.

Once they are in DOD hands, nuclear weapons can be deployed in three ways: atop U.S. Air Force intercontinental ballistic missiles; from U.S. Air Force bomber and fighter planes, and atop U.S. Navy submarine-launched ballistic missiles. This three-pronged capability provides the United States with methods to attack by land, sea, or air, and reduces the possibility that all of the United States' nuclear weapons could be destroyed in a single attack.

The following 10 military bases play particularly important roles in planning and executing the missions that involve nuclear weapons. ★

MALMSTROM AIR FORCE BASE

GREAT FALLS, MONTANA

The 341st Missile Wing resides at Malmstrom, which, in 1962, was the first base to activate Minuteman missiles. Minuteman III missiles are equipped with either Los Alamos–designed W78 or Livermore-designed W87 warheads.

MINOT AIR FORCE BASE

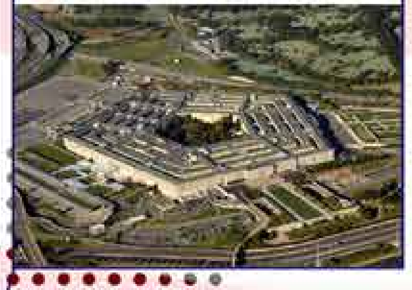
MINOT, NORTH DAKOTA

Constructed in 1957, Minot Air Force Base operates two prongs of the nuclear triad. As one of two bases maintaining B-52H bombers, Minot has an air-based nuclear deterrent in the 5th Bomb Wing. Minot also has a land-based nuclear deterrent in its 150 Minuteman III missiles, operated by the 91st Missile Wing. For more, see p. 76.

THE PENTAGON

WASHINGTON, D.C.

Headquartered at the Pentagon, DOD is the nation's largest government organization and encompasses all branches of the United States Armed Forces, including the Air Force and the Navy, both of which are custodians of nuclear weapons.



NAVAL BASE KITSAP

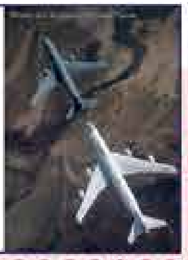
SILVERDALE, WASHINGTON

This base is home to 10 Ohio-class submarines, eight of which carry Trident II ballistic missiles that can be topped with Los Alamos–designed W76 or W88 nuclear warheads. The other two submarines are armed with cruise missiles. Starting in 2027, Ohio-class submarines will be replaced with Columbia-class submarines.

OFFUTT AIR FORCE BASE

OMAHA, NEBRASKA

Headquartered at Offutt, United States Strategic Command (STRATCOM) integrates and coordinates the strategic capabilities of the five branches of the military to deter strategic attacks or plan and execute nuclear military missions. The STRATCOM commander is part of the Nuclear Weapons Council (see p. 12).



WHITEMAN AIR FORCE BASE

KNOB NOSTER, MISSOURI

Whiteman is home to the 509th Bomber Wing and its 20 B-2 Spirit stealth bombers, which can wield the Los Alamos–designed B61 or the Livermore-designed B83 gravity bombs.

FRANCIS E. WARREN AIR FORCE BASE

CHEYENNE, WYOMING

The oldest continuously active United States Air Force military installation, Francis E. Warren Air Force Base was built in 1867 and became the nation's first operational intercontinental ballistic missile base in 1959. The 90th Missile Wing now controls the base's missile system and operates Minuteman III missiles currently armed with Los Alamos–designed W78 or Livermore-designed W87 warheads.

KIRTLAND AIR FORCE BASE

ALBUQUERQUE, NEW MEXICO

Because of Kirtland's proximity to Los Alamos, the base became a shuttling point for people and materials involved in the Manhattan Project. In 2006, Kirtland's Nuclear Weapons Center was created as Air Force Materiel Command's nuclear-focused center. The Nuclear Weapons Center helps synchronize aspects of nuclear weapon systems management across all Air Force nuclear facilities.

BARKSDALE AIR FORCE BASE

SHREVEPORT, LOUISIANA

Headquartered at Barksdale, Air Force Global Strike Command oversees the aerial and land aspects of the nuclear triad—including the Barksdale-based 2nd Bomb Wing, home to B-52H bombers, which can carry the Los Alamos–designed and Livermore-maintained W80-1 warhead. Barksdale also oversees the development of three new delivery systems: the B-21 Raider stealth bomber (which will replace the B-2 Spirit stealth bomber), Sentinel missiles (which will replace Minuteman III missiles), and Long Range Standoff nuclear-armed missiles (which will phase out older cruise missiles).

NAVAL SUBMARINE BASE KINGS BAY

ST. MARYS, GEORGIA

This base is home to eight Ohio-class submarines, six of which carry Trident II ballistic missiles that can be topped with Los Alamos–designed W76 or W88 nuclear warheads. The other two submarines are armed with cruise missiles. Starting in 2027, Ohio-class submarines will be replaced with Columbia-class submarines.

Every day, at Air Force bases across the northern United States, missileers tend to the nation's Minuteman III intercontinental ballistic missiles. Most shifts are uneventful, but not always.

By J. Weston Phippen

■ About 40 miles south of the Canadian border, cars enter North Dakota's Minot Air Force Base.
Photo: U.S. Air Force

On the plains of North Dakota, U.S. Air Force Major Kevin Johnston rode an elevator nearly six stories underground. The old machine creaked as it lowered and stopped with a shudder. The elevator opened to reveal an eight-ton concrete door designed to withstand a nuclear blast. Beyond the door was a small room, called a launch control center. This would be Johnston's home for the next 24 hours.

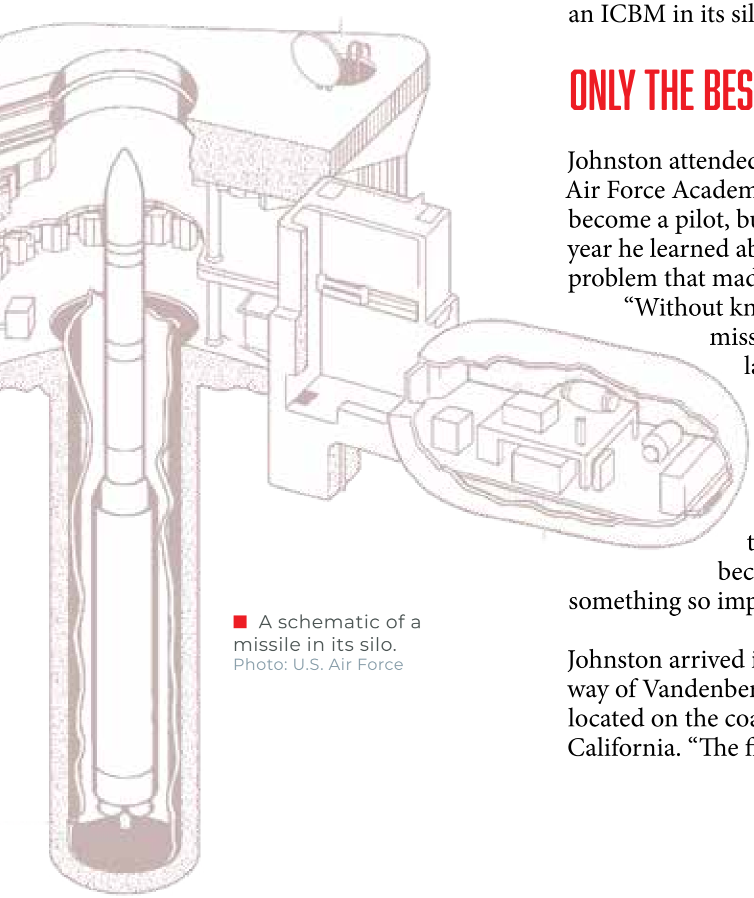
On any given day, 90 missileers like Johnston make a similar journey. At 45 different locations spread across five states, pairs of missileers ride elevators 60 and sometimes 90 feet underground to relieve the pair working the previous shift. They then sign their names into a logbook and assume responsibility for a portion of the country's 400 intercontinental ballistic missiles (ICBMs), each of which carries a nuclear warhead, either a W78, designed by Los Alamos National Laboratory (see p. 22), or a W87, designed by Lawrence Livermore National Laboratory (see p. 30).

By placing missileers in launch control centers, the underground rooms from which ICBMs can be launched, the United States is able to respond to an attack at any moment, 365 days a year. But because the nation has never launched an armed ICBM—and hopes never to do so—going on alert often means that missileers must find productive ways to pass time.

"There's a lot of maintenance we regularly perform on every ICBM, so that takes up a portion of your on-alert shift," says Johnston, currently the junior Air Force Fellow at Los Alamos National Laboratory. "There are exercises we run and daily actions we need to complete, but there's often a lot of down time that we try to make the most of. I was working on my master's degree, so I studied a lot."

At Minot Air Force Base in North Dakota, where Johnston was stationed until 2015, missileers typically pull on-alert duty eight times a month. Most shifts are routine. But occasionally something happens that makes those 24 hours anything but boring. Johnston remembers one shift that took a strange turn after an alarm sounded.

"Each alarm has a different sound," Johnston remembers. "This alarm indicated that something had jostled an ICBM in its silo."



A schematic of a missile in its silo. Photo: U.S. Air Force

ONLY THE BEST COME NORTH

Johnston attended the United States Air Force Academy and planned to become a pilot, but during his senior year he learned about an eyesight problem that made flying impossible. "Without knowing much about missileers, I made a last-minute career switch," Johnston remembers. "But the more I got involved in the nuclear mission, the more excited I became to play a role in something so important."

Johnston arrived in North Dakota by way of Vandenberg Air Force Base, located on the coast of sunny southern California. "The first month I lived in Minot, a blizzard dumped so much snow that by spring, the snowmelt caused the worst flood the town had seen since the 1960s," he remembers. "It was a culture shock, for sure."

Appropriately, a sign above Minot's guard gate reads, "Only the best come north."

> "THIS ALARM INDICATED THAT SOMETHING HAD JOSTLED AN ICBM IN ITS SILO."
>
> —KEVIN JOHNSTON

Less than an hour from the U.S.-Canada border, the base occupies 5,000 acres of offices, family housing, airplane hangars, and runways. If the distant missile silos and launch control centers are included, Minot spreads across more than a half million acres of prairie.

Minot is the only Air Force base in the country with both a nuclear-capable bomber wing and a missileer wing. The 91st Missile Wing, where Johnston worked, oversees more than 150 Minuteman III ICBMs. The missile wings at F.E. Warren and Malmstrom Air Force bases in Wyoming and Montana, respectively, oversee additional ICBMs that are located in those two states plus Colorado and Nebraska. Altogether, the United States' 400 ICBMs constitute the nation's only ground-based nuclear deterrent.

First developed 60 years ago, the Minuteman III stands 60 feet tall and weighs more than 79,000 pounds. The missiles are kept in underground silos, but they have no trouble breaking free of their subterranean homes: in 180 seconds, an ICBM can reach 750 miles

Each time they go on alert, missileers run through a series of tests and checklists that help verify the safety and reliability of the ICBMs under their control. Photo: U.S. Air Force

The Missile Gallery at the National Museum of the United States Air Force showcases a variety of missiles, including the Minuteman III (circled).
Photo: National Museum of the U.S. Air Force

above Earth, where its expended rocket motors separate and fall back to Earth and its single nuclear warhead, tucked inside its reentry vehicle, continues on to a predetermined destination. From start to finish, a Minuteman III can deliver a nuclear attack to the other side of the world in fewer than 30 minutes.

SETTLING IN

The day had begun normally enough. On the morning of his shift, at 7 a.m., Johnston reported to a briefing room on base, where he and the other missileers reviewed the hand-over briefings, the notes that discussed scheduled ICBM maintenance, mission-related exercises, and security concerns from the previous shift.

After the meeting, Johnston and his partner drove across the plains to their appointed missile alert facility. "If you've ever watched the movie *Fargo*," Johnston says, "the landscape looks pretty much like that—a whole lot of grass and not much else."

Spread across the barren landscape are missile alert facilities that look like old warehouses. These facilities are the gateways to the launch control centers, which are linked to 10 ICBMs via computers and from which ICBMs can be launched.

"As missileers, we may be the people sitting underground behind launch control," Johnston says. "But it's a team effort to maintain a secure site and a secure nuclear deterrent. Every time you go on alert, you become very aware of how many people are behind the mission."

Approximately 1,800 members of the 91st Missile Wing work together to ensure that the ICBMs at Minot are ready to launch at a moment's notice. There's the 91st Missile Maintenance Group, which runs diagnostics on the weapons and fixes anything that needs fixing. There's the 91st Security Forces Group, the armed guards who patrol the base, the silos, and who ensure no unauthorized personnel enter the missile alert facilities. And there are approximately 200 missileers like Johnston, 30 of whom are on alert every day in Minot's 15 launch control centers.

Inside the missile alert facility, Johnston and his partner checked in at the guard

Airmen at Malmstrom Air Force Base repair a launch control center blast door.
Photo: U.S. Air Force / Alyssa M. Akers

> "EVERY TIME YOU GO ON ALERT, YOU BECOME VERY AWARE OF HOW MANY PEOPLE ARE BEHIND THE MISSION."
>
> —KEVIN JOHNSTON

office and chatted with the security force team. They stepped into the elevator and rode down. At the bottom of the elevator shaft, the eight-ton blast door appeared. Like the door to a bank vault but bigger, this particular blast door was painted with a fire-breathing dragon guarding a castle, an ICBM in place of a turret.

Standing in front of the door, Johnston held a phone to his ear that buzzed the on-duty missileers on the other side of it. The door swung open. Before the on-duty team left, Johnston and his partner signed the logbook. They'd now taken custody of 10 ICBMs.

The room where the missileers spend the day on alert is about 10 feet wide and 20 feet long, shaped like a pill. In one corner is a bed where the two missileers can alternate catching some shut eye during shifts. There's a toilet in another corner, racks of electrical equipment, and the launch control console—a metal unit the size of a credenza covered in knobs, keyboards, and monitors.

As Johnston settled in for a long day, the room wobbled ever so slightly. The launch control center is completely suspended to minimize shaking if an enemy's nuclear weapon were to strike the ground above. "Technically, in the event of an attack, there's an escape route from the launch control center," Johnston explains. "But there's little chance of us being able to leave the room after taking a direct nuclear hit. That's what you sign up for when you become a missileer."

In a scenario like that, Johnston and his partner would receive orders from the U.S. president on how to respond. The president might order an ICBM strike,

Nearly every day at Minot Air Force Base, the 91st Missile Wing's Missile Maintenance Team can be found in the field, making sure the nation's ICBMs are safe, reliable, and ready to operate if needed. Photo: U.S. Air Force/Kristoffer Kaubisch

in which case the missileers on alert would quickly review the classified launch codes to ensure the legitimacy of the order, flip a series of switches, and one missileer would insert a key in the computer frame, arming and firing an ICBM at a preordained target.

DON'T BE ALARMED

For the first half of Johnston's shift that day, everything was normal. He and his partner ran a systems test that guaranteed the computer and ICBM were in working order; they ran through the preventive maintenance checklist. Johnston opened a book to study for his master's degree, when an alarm beeped.

Alarms can go off when a silo door opens, if equipment on an ICBM fails, or if someone passes beyond a fence line in restricted areas. During a 24-hour shift, it's not unusual for an alarm to sound, or even several alarms, and in most cases the cause is an animal—usually a rabbit—that tripped a motion sensor.

"We take the security of our ICBMs very seriously," Johnston says. "Even if we know wildlife most likely triggered the alarm, we still send a guard out to check. It may be a false alarm 1,000 times in a row, but we have to be prepared for any possibility."

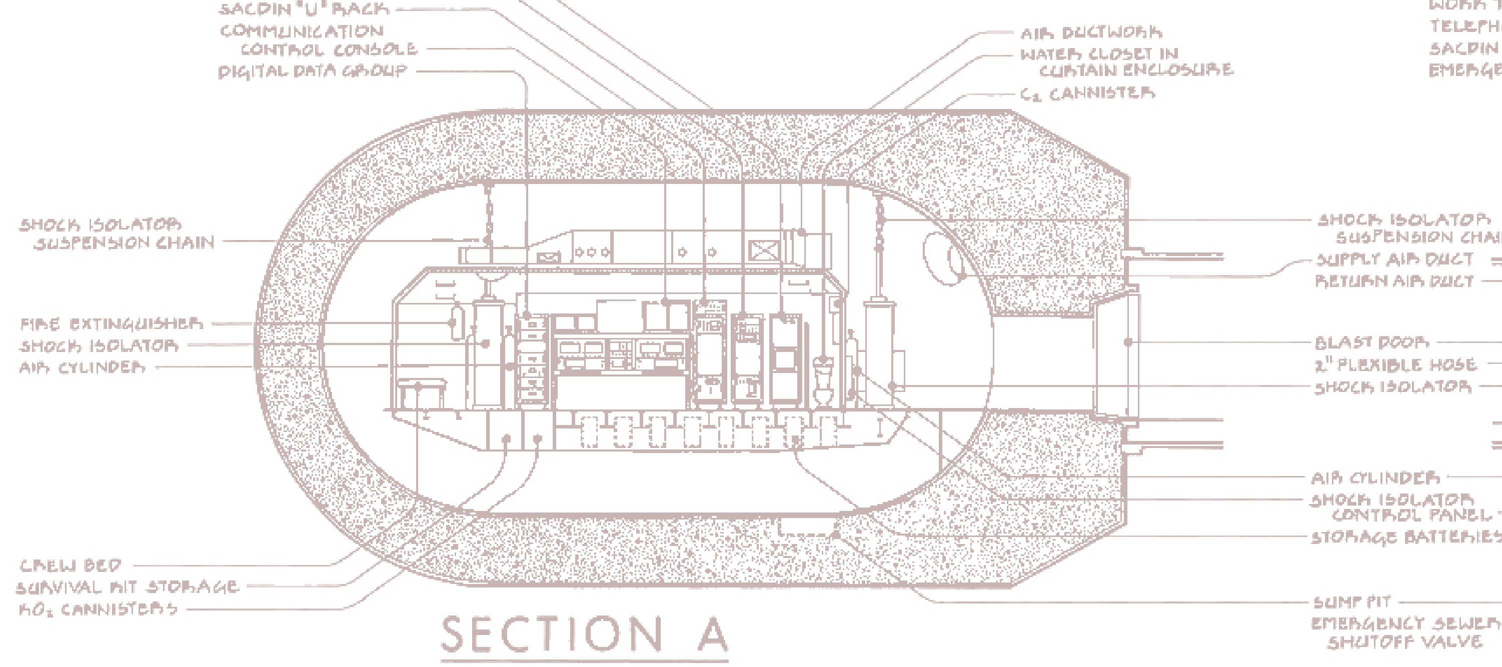
The alarm that day was triggered by a gyroscope inside a missile. Gyroscopes—devices used for measuring or maintaining spatial orientation and angular velocity—are part of the Minuteman III's internal guidance system, which was designed decades ago by Boeing Company. The system does not use GPS; instead, the missile relies on inertial navigation, a series of complex accelerators and hypersensitive gyroscopes that relay to the ICBM its speed and position and guide the missile to its target. The guidance system steers the missile through the atmosphere and beyond the bounds of Earth orbit, about twice as high as the International Space Station. Once the ICBM reaches a predetermined point in space, it releases its reentry vehicle with its nuclear warhead onboard.

"I was taught to visualize a virtual tunnel in the sky," Johnston says. "The inertial guidance set flies the missile through that virtual tunnel to hit a specific window in space at a precise speed. Once the ICBM reaches that point, it releases the reentry vehicle, and the warhead follows a ballistic trajectory the rest of the way. It's similar to throwing a football, except instead of being launched by your arm, it's launched by a rocket."

As Johnston looked at the computer monitor, he noticed that another gyroscope had registered an alarm, then another, and another, until all 10 gyroscopes on all 10 ICBMs in his control had alarmed.

Johnston didn't understand what was happening. He knew that ICBMs must be ready to launch at any minute, so gyroscopes are always active, spinning even as they rest in the silos. Sometimes gyroscopes fail due to regular wear and tear, in which case they're quickly replaced. But this was no mechanical failure.

A patch on Johnston's uniform.



This schematic shows a launch control center. The underground "capsule" of thick concrete and steel holds a chamber suspended on giant shock isolators to protect the crew and sensitive electronics from nuclear attack. Photo: U.S. Air Force

> "TO ME, THESE MISSILES ARE A TECHNOLOGICAL MARVEL."
>
> —KEVIN JOHNSTON

Johnston again turned to his checklist, a booklet that contains a list of possible error messages and explanations of how to fix these errors. As he flipped the pages, he remembered something he'd heard in training.

"I remembered a scenario that had been brought up about earthquakes," Johnston says, "about how the gyroscopes are so sensitive that they can register tremors from far away. But it's one thing when you see this described in a slideshow, and it's another thing when a bunch of silos start throwing gyroscope fault codes all at the same time."

Johnston reported the sensor alert to the 91st Security Forces Group. He also radioed the 91st Missile Maintenance Group. Everyone snapped into action. After a quick systems test, the alarm stopped, and everything looked normal. "There was never any danger," Johnston says, "but at that point I hadn't experienced anything similar."

A little later, Johnson turned on a television in the launch control center.

Sure enough, there'd been an earthquake—on the other side of the world. "It reminded me how much design and engineering it took to create these missiles—to be durable enough to fly to outer space, then precisely drop a warhead onto a target, but sensitive enough to register an earthquake on another continent," Johnston says. "To me, these missiles are a technological marvel."

Hours later, Johnston repeated the day's events in reverse: he welcomed the two missileers who reported for the next shift, and he watched as they signed the logbook and assumed control of the ICBMs. He rode the elevator up to the surface, then drove across the plains to base and, a bit later, to his house, where his wife, newborn daughter, and two dogs were waiting. Johnston's day on alert was over, but for 90 other missileers, their shifts had just begun. ★

Major Kevin Johnston is the 2022 Los Alamos National Laboratory Junior Air Force Fellow. Each year, two highly accomplished airmen come to the Laboratory to learn from scientists and also to share their experiences of working with Lab-designed weapons.

TAKEAWAY

BETTER SCIENCE = BETTER SECURITY

As part of its national security mission, the Lab fosters relationships with partners across the nuclear enterprise, including the men and women of the U.S. Air Force who interact with nuclear weapons everyday.

ENTERPRISE EXPERIENCE

Meet 11 current and former Los Alamos employees who spent portions of their careers at different sites across the nuclear security enterprise.

BY IAN LAIRD

Although the labs, plants, and sites of the nuclear security enterprise have individual strengths and missions, they work together and collaborate on a common mission: maintaining a safe, secure, and effective nuclear deterrent.

Many people across the enterprise spend their careers at a single location, but many people also move among the labs, plants, and sites. Here, 11 Los Alamos employees who've worked at other locations across the enterprise share how those experiences inform their current work.

John Benner

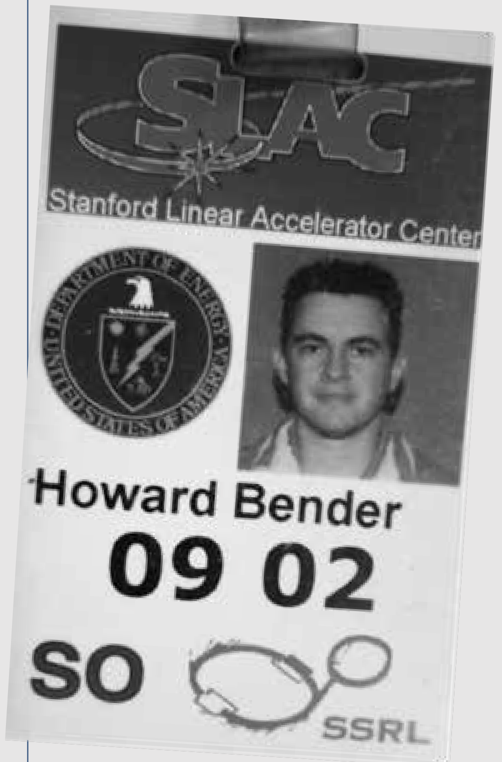
ASSOCIATE LABORATORY DIRECTOR, WEAPONS PRODUCTION

Formerly at Nevada National Security Site, National Nuclear Security Administration

John Benner was 24 years into his career at Los Alamos when he decided it was time for a new experience. In 2017, he began working as the vice president and chief operating officer for the management and operating contractor of the Nevada National Security Site. There, Benner was responsible for operational and technical integration of all experimental operations. "Being familiar with a site from the outside is different than running it," Benner says. "I found dimensions and complexity that I didn't know existed."

In 2019, Benner took a one-year assignment as a senior technical advisor to the deputy administrator for Defense Programs at the National Nuclear Security Administration (NNSA). This role helped him better understand the breadth of Los Alamos' work. "If you have an opportunity to go on assignment in Washington, D.C., I recommend you take it to help you get a better perspective and understanding of the Lab and its mission," Benner says. "You begin to realize what a powerful integrating force Los Alamos is across the enterprise."

Today, Benner is back at Los Alamos, where he leads the Weapons Production associate directorate and has regular interaction with the plants and sites that support the Lab's mission to produce plutonium pits (nuclear weapon cores) and other weapons parts. ★



Howard Bender III worked on the Stanford Synchotron Radiation Lightsource—a division of the Stanford Linear Accelerator Center.

Howard Bender III

RESEARCH AND DEVELOPMENT MANAGER, INTEGRATED WEAPONS EXPERIMENTS

Formerly at Sandia National Laboratories, Nevada National Security Site, National Nuclear Security Administration

In 2000, Howard Bender III began working at Sandia National Laboratories, where he participated in a cooperative research and development agreement for semiconductor manufacturing. Two years later, he took a job with Los Alamos National Laboratory that was based at the Nevada National Security Site (then called the Nevada Test Site). There, he helped support the development of the second axis of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. Located at Los Alamos, DARHT produces radiographs of materials that implode at speeds greater than 10,000 miles an hour. These radiographs help scientists ensure that weapons in the nuclear stockpile are safe and effective. "I was not that familiar with DARHT initially, but it seemed exciting and like a new frontier for my career," Bender says.

Bender has been in his current role since 2021 and appreciates the perspective his varied career has afforded him. "All the places I've worked are all unique entities with specific purposes, skilled people, and the infrastructure to do their jobs," he says. "I highly recommend anyone with the interest and ability to take some career detours and move around the enterprise to gain experience and perspective." ★

Tom Bratvold

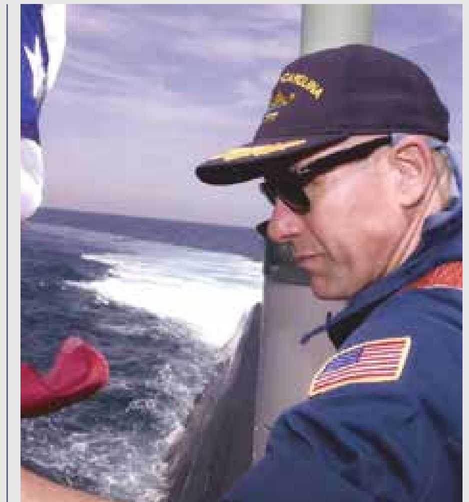
SENIOR DIRECTOR, LOS ALAMOS PLUTONIUM PIT PRODUCTION PROJECT OFFICE

Formerly at Hanford Site

Tom Bratvold was looking for a way to close out his career after 30 years at the Hanford Site in southeast Washington state. The site is known for producing plutonium during the Manhattan Project and for decades after, but its reactors were shut down by 1987. Since that time, Hanford's mission has been to clean up the site.

"There wasn't really anything left for me to do there that I hadn't done," Bratvold says of his work at Hanford. So, he took a job at Los Alamos to help with the Lab's effort to produce plutonium pits. "My children were all grown and the opportunity to be a part of this mission was an incredible motivator," Bratvold says. "Being a part of returning pit production to the nation seemed like a fitting last chapter in a long career."

In this role, Bratvold has put his "priceless experience" to use in support of national security, and he is particularly appreciative of how integrated the NNSA labs, plants, and sites are in undertaking the pit mission. ★



Mark Davis' 36 years in the U.S. Navy included deployments on nuclear-powered submarines.

Mark Davis

CHIEF OPERATIONS OFFICER, WEAPONS PRODUCTION

Formerly at Savannah River Site, U.S. Navy

"Passion, effort, and an attachment to the mission are really big when you're on a submarine," says U.S. Navy Captain (retired) Mark Davis. "And so, as I was coming out of the Navy, I was concerned about finding that same passion—but I have."

In 2017, Davis became the senior vice president of NNSA Operations and Programs at the Savannah River Site, where he was responsible for tritium operations and nuclear nonproliferation programs. Through his work, Davis was able to find that sense of mission that drove him during his time in the military.

While working at Savannah River, Davis became familiar with NNSA's pit production mission, which is supported by both Savannah River and Los Alamos. When a position to support this mission opened at Los Alamos, Davis jumped at the opportunity. Upon arrival in 2022, Davis recognized that many of the challenges Los Alamos faces are similar to those he saw at Savannah River and in the Navy. "The people are different, but the challenges are pretty much the same," Davis says. "How do we attract and retain the right people?" Giving mission-driven people reasons to stay and to continue putting passion and energy into their work is vital to the success of the enterprise, he says. ★

David Dooley

SENIOR DIRECTOR, DEFENSE PROGRAMS OFFICE

Formerly at Hanford Site, Savannah River Site

A nuclear engineer and material scientist by training, David Dooley worked at Los Alamos National Laboratory for 10 years before embarking on other opportunities, including a senior management position at Savannah River. "At Savannah River, I had the chance to apply the technical and business lessons I learned from Los Alamos and Hanford," Dooley says. "Finding practical applications of business systems and processes helped us get work done."

In 2018, Dooley landed back at Los Alamos, where he leads the Defense Programs Office, which is part of the Lab's Weapons Production associate directorate. As a leader, he works to remove obstacles that prevent employees from having positive experiences on the job. "I want to enable our workforce to work effectively and safely," Dooley says. "There is so much talent across all the nation's facilities, and the entire nuclear enterprise can benefit greatly from that talent—I really want that to be honored in our day-to-day work." ★

David Feather

SENIOR DIRECTOR, PRODUCT AGENCY TRANSFORMATION OFFICE

Formerly at National Nuclear Security Administration, Rocky Flats Plant, Sandia National Laboratories, Savannah River Site, Department of Energy headquarters, Kansas City National Security Campus, Nevada National Security Site

David Feather, an electrical engineer, began working at the Department of Energy's Office of Defense Programs in 1992 and shortly thereafter took assignments at the Rocky Flats Plant, Sandia National Laboratories, and the Savannah River Site. In 2002, Feather moved to the Kansas City National Security Campus, and from 2017 to 2020, he worked at the Nevada National Security Site.

By the time Feather ended up at Los Alamos in 2022, he had a pretty clear picture of how the labs, plants, and sites of the nuclear security enterprise work together. He also understood the importance of collaboration across the enterprise. "When I worked at [NNSA] headquarters, I always had the ability to see the overhead view," Feather says. "That experience allowed me to appreciate and respect the environment I work in, but I can also implement different perspectives."

Today, Feather is helping the Lab's Weapons Production associate directorate transition from being a historically research-focused organization to an organization that produces plutonium pits, detonators, and other weapons components. "To do that, we'll work to identify and prioritize system improvements to enable sustainable and resilient performance," he says. "Through empowering people, we'll institutionalize discipline into our processes. Both are essential as we scale to meet the rising demand and to practice the top-tier production excellence to which we aspire." ★

● David Feather worked at the Rocky Flats Plant in the early 1990s. This is his Respirator Certification Card.

Charles McMillan

DIRECTOR EMERITUS

Formerly at Lawrence Livermore National Laboratory

After earning a doctorate in physics from the Massachusetts Institute of Technology, Charles McMillan began working at Lawrence Livermore National Laboratory. During his 23 years there, McMillan worked his way from experimentalist to division leader. In 2006, when his mentor and friend Michael Anastasio became lab director at Los Alamos, McMillan followed him to New Mexico. Within five years, Anastasio retired, and McMillan became the next director of Los Alamos.

In this role, McMillan says it was tempting to bring elements of Livermore's culture into Los Alamos, but ultimately, he decided against it to preserve the perspectives of the two labs. McMillan likens the difference to getting a second opinion from a doctor. "They're not the same opinion twice. They bring different technical traditions to the table," McMillan says. "You don't always get the same answer. When I moved from one lab to another, I felt that was very important to preserve for the nation."

Despite the differences, the now retired McMillan has found recent efforts at collaboration between the Los Alamos and Livermore, such as sharing experimental facilities and datasets, to be encouraging. ★

Thomas Mueller

PROGRAM MANAGER, INTELLIGENCE AND SYSTEMS ANALYSIS

Formerly at Kansas City National Security Campus, Sandia National Laboratories, Department of Energy

After graduate school at the University of Missouri, Thomas Mueller moved to Kansas City and began working as an engineer at the Kansas City National Security Campus (then the Kansas City Plant). During his 11 years there, he had two detail assignments: a one-year stint at Sandia National Laboratories and two years at the Department of Energy's Office of Intelligence and Counterintelligence.

In 2014, Mueller moved to Los Alamos, where he started working as an intelligence analyst. His time at Kansas City proved useful to the new job. "I learned a lot while I was at Kansas City through formal and informal training opportunities," Mueller says. "I learned how to be an engineer, how to manage projects and programs, and how to communicate with colleagues and partners." And, his time at Sandia and DOE helped him understand that "each site has its own well-established culture and its own definition of success. Those cultures and those definitions drive how each organization looks at a problem. To partner well with each of those sites requires understanding and respecting those cultures and those definitions." ★

Jeffrey Paisner

PROJECT-PROGRAM DIRECTOR, WEAPONS

Formerly at Lawrence Livermore National Laboratory

At one point during his 29 years at Lawrence Livermore National Laboratory, Jeffrey Paisner worked on an isotope separation program. Los Alamos had its own version of the program, and in the early 1980s, the government decided only one would be funded. "It was a peer competition to the death," Paisner remembers. "And I consider myself the terminator of the Los Alamos program; it was my assessment of the program's performance that killed it."

Despite occasionally ruffling feathers at Los Alamos, Paisner says he's always valued the relationship between the two weapons laboratories. "There's tension," he says, "but there's a richness in that."

In fact, over the years, Paisner worked closely with colleagues at Los Alamos and was recruited to work at the Laboratory in 2003. Among Paisner's initial responsibilities was leading teams that successfully executed hydrodynamic experiments. "I have a knack for assembling multidisciplinary teams of talented people," Paisner says. "If you grow up in New York—like I did—and you don't choose your own team and advocate for them, you don't survive."

Until 2018, Paisner worked on many Los Alamos–designed subcritical experiments, including the Gemini series, for which he and his team earned the 2013 Secretary of Energy Achievement Award. Today, as a project-program director in the office of the Lab's deputy director for Weapons, Paisner continues to apply his 49 years of experience at the weapons laboratories to pressing national security challenges. ★

● Jeffrey Paisner holds his 2013 Secretary of Energy Achievement Award.

Tri Tran

DIRECTOR, STOCKPILE AND ENTERPRISE ANALYTICS OFFICE

Formerly at Lawrence Livermore National Laboratory, National Nuclear Security Administration

Tri Tran likens the rapport between Los Alamos and Livermore to a fraternal relationship where the similarities are more prominent than the differences. "Los Alamos and Livermore have been managed [at least partially] by the University of California since the beginning," Tran explains. "So, the processes, the people, the way we do things, and the roles and responsibilities are pretty comparable."

Tran worked at Livermore for 23 years, including a three-year assignment at NNSA in Washington, D.C. That experience allowed him to work closely with people from Los Alamos, and eventually he took a job at the New Mexico laboratory. Tran says the most difficult part of the move wasn't work related at all. "It was the weather, just mostly weather."

Today, Tran works in the Stockpile and Enterprise Analytics Office, which requires him to consider dependencies and impacts of program decisions within Los Alamos and across the enterprise. "Having been at another site and headquarters where there were different priorities," he says, "I'm always thinking about who else is being affected: the programs, the people, and the bigger picture." ★

● In 1990, Darrell Schmidt (second from left) was involved in the Bowie underground nuclear test at the Nevada Test Site.

Darrell Schmidt

TRI-LAB PROJECT OFFICE MANAGER, WEAPONS SYSTEMS: PRODUCTION LIAISON

Formerly at Pantex Plant

Darrell Schmidt began working at Pantex in 1982 and spent part of his seven years there working on the W56, W70, and B53 weapons systems as the lead process engineer. In this role, he worked with Los Alamos, Livermore, and Sandia national laboratories and was in charge of developing the assembly and disassembly processes for the weapons systems. Over time, Schmidt became interested in weapons design.

In 1989, he took an "exciting and satisfying" position at Los Alamos and was involved in the assembly and fielding of five underground nuclear tests at the Nevada Test Site and various nonnuclear tests at Los Alamos.

Having worked on both ends of the production process, Schmidt says design and manufacturing should be a two-way street. "The more open the communication between sites and the customer, the better the outcome," he explains. "We should remember, design influences manufacturing and manufacturing influences design." In that regard, Schmidt believes there is progress to be made. Across the enterprise, he believes a focus on administrative details has hindered the cooperative efforts of product realization teams. Still, Schmidt sees the strengths in the enterprise. "I have found that each site truly wants to do the right thing and build the best product possible," he says. ★

■ "In my unbiased opinion, the Laboratory's team of classification analysts is the gold standard of teamwork, shared outcome, trustworthiness, and technical excellence," Hollis says. "All day, every day, we're learning and teaching."

PROTECTING THE ENTERPRISE

Classification Officer Diana Hollis safeguards secret information.

BY DIANA DEL MAURO

Classification is the process of identifying information that can and must be withheld from public disclosure in the interest of national security. Since 2004, Diana Hollis has worked in Los Alamos National Laboratory's Classification Office, where she helps employees navigate the sometimes blurry lines between what information is OK to share and what's not. To do this, Hollis and her team use an array of federal classification guides—and plenty of critical thinking.

"It should be in the DNA of everybody who works up here to be mindful that our mission is classified," Hollis says. "We need people to really dig into what they're reading, what they're seeing. What information is being conveyed and is that information sensitive? It's an intellectually and technically challenging endeavor."

Taking charge

Despite being among the most essential jobs at Los Alamos, being a classification analyst is often tedious and thankless. In 2019, the Laboratory was suffering from a loss of classification experts. Hollis herself was on the cusp of contributing to that loss—she was about to retire—when she reconsidered. "I felt a profound responsibility to communicate what I knew to be an impending classification crisis before I retired," she explains.

She took the opportunity at the annual gathering of the Lab's derivative classifiers—which she knew was attended by senior Lab leaders—to deliver a stark warning: The Lab was losing classification expertise faster than it was possible to attain and retain. Hollis held up a Lab-published book and one of the Lab's magazines and said, "You don't get to publish these without experts in classification. It's impossible."

Thankfully, she says, "my message was received in the manner it was delivered." Hollis was chosen to head the Office of Classification. She hired a team of multidisciplinary scientists and engineers who share her passion for their work as classification experts. "I knew what the problem was," Hollis says. "We'd lost our seat at the table in the greater classification community across the nuclear security enterprise, across the government really," she says. "We needed to get Los Alamos back at the table. And we needed to be the experts that we are."

Today, Hollis has built a team of devoted analysts, each of whom has expertise in at least one classified mission program (including materials science; nuclear, chemical, and mechanical engineering; and computer science) and the agility and curiosity to learn about the others. "An excellent classification program can only happen with excellent classification analysts," she says. "Those are very highly educated and experienced technical experts who can check their egos at the door."

Hollis works collaboratively with the team on challenging classification matters. "The magic that happens when we all sit around a big table and discuss the issue at hand from these varying technical perspectives in a variety of communication styles is invigorating," she says.

Consistency across the enterprise

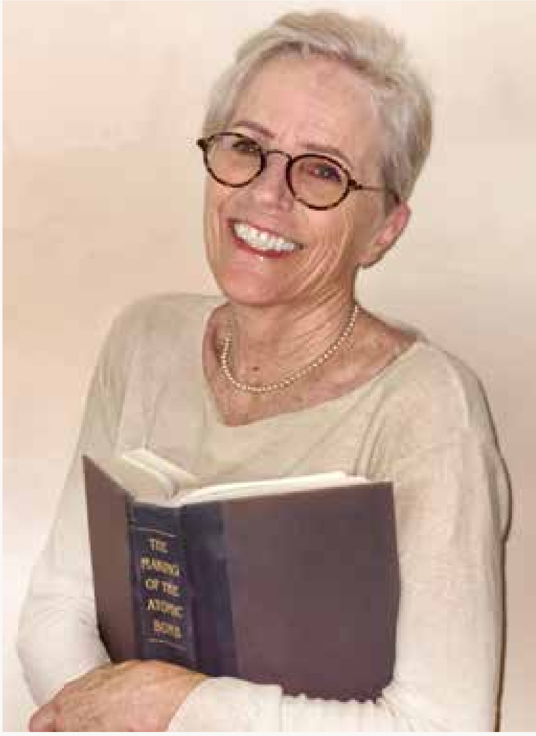
In addition to heading the Classification Office, Hollis is also the Lab's classification officer, which is a credential granted from the Department of Energy (DOE) and National Nuclear Security Administration Offices of Classification. The role gives her the reins to strengthen classification practices across the Lab, including recruiting and retaining derivative classifiers (volunteer subject matter experts across the Laboratory who serve as the first line of defense in identifying classified information as it is generated) and educating all Lab employees through various trainings.

"We've been successful with training, with getting the message out that we're not the police," she says. "If employees come to us early and often with questions, we can carve that safe-haven path that protects information."

Hollis' approach is becoming the standard across the entire nuclear security enterprise. "The way Diana has gone about building her team and her stature as an expert have caught the attention of the DOE Office of Classification," says Ken Quintana, a program manager helping her execute her vision.

In a recent assessment of the Los Alamos program, the DOE Office of Classification recognized the Lab's new training approach for derivative classifiers as a best practice within the nuclear security enterprise and later asked Los Alamos to present its training model to all DOE classification officers at their annual Technical Program Review. Since then, classification officers from other laboratories have requested help from Los Alamos with their training of derivative classifiers and classification analysts; some sites are even planning to have their employees shadow the Lab's analysts.

In October 2022, Hollis was chosen by classification officers across the nation to chair the annual Weapons Complex Classification Conference, during which classification experts discuss issues and best practices. "Today's national security threats are far more complex than they were when I started my classification career," Hollis says. "Complex threats mean complex classification." ★



■ Classification Officer Diana Hollis has bachelor's degrees in physics and biology and a master's degree in nuclear engineering and radiopharmacy.

BETTER SCIENCE = BETTER SECURITY

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

THE DISTINGUISHED ACHIEVEMENTS OF LOS ALAMOS EMPLOYEES

Nine researchers were named 2022 Los Alamos National Laboratory Fellows: David Chavez, Tim Germann, Neil Harrison, Ricardo Lebensohn, Hui Li, Babetta Marrone, Karissa Sanbonmatsu, Lin Yin, and Jianxin Zhu. "These nine researchers are some of the best minds in their fields, and it is an honor to recognize them as Laboratory fellows," says Laboratory Director Thom Mason.

Sara Del Valle and Catherine Snelson were awarded the 2022 Los Alamos Global Security Medal. The award recognizes the achievements of active or recently retired employees who have made significant contributions to the Laboratory's global security mission. "Sara is a standout epidemiologist whose insights have led to better models for a number of diseases and health threats, while Cathy's expertise in seismology has enabled great advances in nuclear explosion monitoring," says Director Thom Mason. "Their work makes the world a safer and better place, which is a key aspect of Los Alamos National Laboratory's broad national security mission."

The Los Alamos Operations Excellence Medal was awarded to Dina Siegel for her contributions to worker safety and health. As the Laboratory's biosafety officer and industrial hygiene and safety professional, Siegel was key to the Lab's COVID-19 response, helping the COVID Task Force establish policies, training, guidance documents, webpages, and hotline information so employees could continue to meet mission deliverables.

Anna Llobet Megias and Pierre-Yves Le Bas received the 2022 Los Alamos Community Relations Medal. Llobet is the founder of the Summer Physics Camp for Young Women, now in its sixth year. Le Bas has made significant, long-term contributions to STEM education robotics programs across northern New Mexico.

Three Los Alamos scientists were elected fellows by the American Physical Society: Mary Hockaday, division leader for Nuclear Engineering and Nonproliferation; Nicole Lloyd-Ronning, astrophysicist in the Computational Physics and Methods group; and Rolando Somma, formerly with the Theoretical Division.

Los Alamos National Laboratory Fellow and computational biologist Bette Korber was named among the "Best Female Scientists in the World 2022 Ranking" by Research.com. Korber is well known for her genetics, virology, and DNA research.

Computational physicist James Gubernatis received the American Physical Society's John Wheatley award. The award, given biannually to one recipient, recognizes physicists who have contributed to the international development of physics. Now retired, Gubernatis worked through the International Union of Pure and Applied Physics to cofound a computational physics school for students from Africa. Then, through the American Physical Society, he started an email newsletter that helps connect the African physics community.

Patrick Hochanadel was named a fellow of the 2022 American Welding Society. He was recognized for "a career of significant achievements in the technical and research arenas that has enhanced the image and impact of the welding industry."

Clarivate's annual Highly Cited Researchers list for 2022 acknowledges three Los Alamos researchers who demonstrated significant and broad influence as reflected in their publication of multiple highly cited papers during the past decade. The researchers are Victor Klimov of Physical Chemistry & Applied Spectroscopy, Wanyi Nie of the Center for Integrated Nanotechnologies, and Piotr Zelenay of Materials Synthesis and Integrated Devices.

Ellen Cerreta is the new associate Laboratory director for Physical Sciences. Cerreta is responsible for overseeing the development and application of materials science and experimental physics capabilities, including the stewardship and advancement of the Los Alamos Neutron Science Center.

Brendt Wohlberg, a scientist in the Applied Mathematics and Plasma Physics group, was named a fellow of the Institute of Electrical and Electronics Engineers. He was selected for his contributions to computational imaging and sparse representations.

Four Los Alamos scientists were named fellows of the American Association for the Advancement of Science (AAAS): Stosh Kozimor, Rangachary Mukundan, Tanja Pietrass, and Sergei Tretiak. "For Mukund, Sergei, Stosh, and Tanja, this recognition as an AAAS fellow speaks to the important contributions they have each made in their disciplines and to the Laboratory," says Deputy Laboratory Director for Science, Technology & Engineering John Sarrao. "Their achievements are a result of their commitment to hard work, collaboration, and ingenuity and have been invaluable in helping the Laboratory advance its national security and scientific mission."

For the fourth consecutive year, Los Alamos National Laboratory was recognized by Family Friendly New Mexico, a statewide initiative developed to recognize employers that have adopted policies that give New Mexico businesses an advantage in recruiting and retaining the best employees. In 2023, the Lab received the platinum-level Family Friendly Business Award, which is the highest recognition for businesses that prioritize family friendly policies. ★

IN MEMORIAM:

Noted physicist Paul Robinson, the Los Alamos weapons chief who became Sandia Labs director and president of Sandia Corporation, passed away March 2, 2023. Robinson joined Los Alamos as a staff member in 1967 and left the Lab in 1985 after serving as the Lab's principal associate director of the National Security Program. Before joining Sandia, Robinson served as a U.S. ambassador and the chief negotiator during the Nuclear Testing Talks between the United States and the Soviet Union. He retired from Sandia in 2006. ★

78 YEARS AGO

On August 14, 1945, Manhattan Project photographer Ed Westcott snapped this image of revelers at Jackson Square in Oak Ridge, Tennessee. These men and women—many of whom contributed to the Manhattan Project—had gathered to celebrate the surrender of Japan and the effective end of World War II.

Originally known as Site X or Clinton Engineer Works, Oak Ridge was one the Manhattan Project's "secret cities" and was responsible for the enriched uranium that was used in the Little Boy atomic bomb dropped on Hiroshima, Japan, on August 6, 1945.

See p. 16 for more on the early days of the nuclear enterprise. ★

Photo: Oak Ridge National Laboratory

Los Alamos NATIONAL LABORATORY

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THEN & NOW

Before World War II, homesteads and a boys' school occupied the remote mesa that would soon become Project Y—the Los Alamos branch of the Manhattan Project. The area was typically accessed by a dirt road (pictured here in the early 1900s) that zig-zagged up the side of the mesa. During the Manhattan Project, some of the switchbacks were too tight for military trucks, so in 1943, workers straightened the final hairpin turn and added an additional lane to accommodate the increase in people and materials coming "up the hill."

Today, the road—officially part of New Mexico Highway 502 and locally referred to as "Main Hill Road"—is still two lanes and is traveled by thousands of Los Alamos employees every day. ★

Photo: Los Alamos County