LOS ALAMOS NATIONAL LABORATORY ◇ SPRING 2024

NATIONAL ★ SECURITY SCIENCE

THE DETERRENCE ISSUE

Deterrence defined: Los Alamos plays a crucial role in national security and global stability.

Beyond the blast: Scientists study what happens when a nuclear weapon detonates.

A bomber's point of view: Nuclear weapons play an evolving role in national security.

Deterrence at sea: A Los Alamos employee remembers his time onboard a nuclear-armed submarine.

+PLUS:

Coming in 2024: stockpile-bound plutonium pits	Nuclear forensic technology identifies hazardous material	FA52 Army officers get educated at Los Alamos

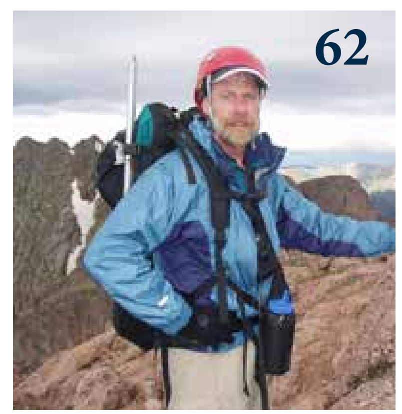
PHOTOBOMB

▼

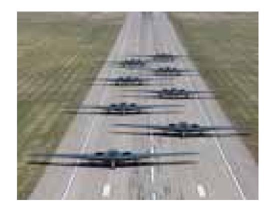
An unarmed Minuteman III intercontinental ballistic missile launches from Vandenberg Space Force Base in California on September 6, 2023. “These test launches demonstrate the readiness of U.S. nuclear forces and provide confidence in the lethality and effectiveness of the nation’s nuclear deterrent,” said Colonel Bryan Titus in a news release.

When armed, the Minuteman III can carry the W78 warhead, which was designed by Los Alamos National Laboratory. Today, the Laboratory maintains the W78 through science-based stockpile stewardship (see p. 18 for more). ★

Photo: U.S. Space Force/Kadielle Shaw



IN THIS ISSUE



About the cover: B-2 Spirit stealth bombers taxi at Whiteman Air Force Base during an exercise in November 2022. “The B-2 is the only aircraft on the planet that combines stealth, payload, and long-range strike,” said 509th Operations Group commander and former Los Alamos Air Force Fellow Colonel Geoffrey Steeves in a news release. “We are charged with delivering the nation’s most powerful weapons for our most important missions.” The B-2 can deploy the Los Alamos–designed B61 nuclear gravity bomb—a key component of the U.S. nuclear deterrent. ★

Photo: U.S. Air Force/Bryson Britt

THE DETERRENCE ISSUE

Los Alamos National Laboratory's nuclear weapons work plays a vital role in keeping the nation safe.

BY BOB WEBSTER
DEPUTY DIRECTOR FOR WEAPONS

J. Robert Oppenheimer, the first director of what is today Los Alamos National Laboratory, once said that "it did not take atomic weapons to make man want peace."

Yet, he went on to explain that the creation of the atomic bomb—for which he was largely responsible—was "the turn of the screw" that "made the prospect of future war unendurable." That, in a nutshell, is nuclear deterrence theory.

Deterrence, however, is nuanced and multifaceted. Even here in the United States, its meaning often varies between individuals, organizations, and administrations. (We offer our own definition on p. 18.) But what is consistent—and has been consistent for the nearly 80 years that nuclear weapons have existed—is the role of Los Alamos National Laboratory in creating and sustaining the nuclear deterrent.

Los Alamos has designed and maintained the majority of the weapons in the past and present U.S. nuclear stockpile. Today, the Laboratory is responsible for four of the nation's seven weapons systems: the B61 family of gravity bombs, the W76 family of warheads, the W78 warhead, and the W88 warhead. Los Alamos scientists and engineers continually evaluate the health of these weapons, all of which are decades old. We scrutinize the smallest details—such as how a material is aging or how a component will function at certain temperatures—to ensure the weapons are safe (that they will not go off by accident) and that they will perform as intended if the president orders their deployment.

The credibility of our weapons—which includes their safety, reliability, and effectiveness—is backed by technical data that is uniquely generated, documented, and analyzed at the Laboratory's state-of-the-art experimental and other facilities. Using this data, we create high-resolution, 3D computer simulations of the inner workings of weapons to better understand their health and what's necessary for optimal safety and performance. Innovative, responsive, world-class science, engineering, and technology are the backbone of national security, and you can read more about our science-based stockpile stewardship program—how we maintain our weapons without nuclear testing—on p. 18.

Although Los Alamos is primarily a research and development institution, we do produce some weapons components, including plutonium pits, which are essential to all nuclear weapons. In 2024, the Laboratory will transition from making development (practice) pits to war-reserve (stockpile-quality) pits. The new pits add another layer of credibility to our already very robust and dependable weapons. Learn more about this upcoming milestone on p. 11.

Understanding what happens once a weapon is detonated—the weapons effects, as we say—is also part of having a credible nuclear deterrent. Our adversaries know that our weapons are designed to hit specific targets and have certain consequences. The reverse is also true. Decades of weapons effects data help Los Alamos scientists anticipate what might happen to U.S. troops, military targets, and infrastructure in the event of a nuclear attack on American soil. Read more about these efforts on p. 28.

This issue of *National Security Science* also highlights the relationship between Los Alamos and the U.S. Department of Defense, which owns and operates the delivery systems for all nuclear weapons systems. On p. 52, you will read about Los Alamos manufacturing manager David Flores, a Navy veteran who served on the USS *Tennessee*, a submarine capable of launching the W76 and W88 warheads. On p. 40, our junior Air Force Fellow, Major Chandler Anderson, discusses the bomber aircraft that support deterrence.

Because nuclear weapons are at any given moment atop ICBMs, onboard submarines, or loaded in the bomb bays of aircraft, many people here at the Laboratory and across the nuclear security enterprise like to say that "nuclear weapons are used every day." That is also deterrence in a nutshell. Having credible, ready-to-launch nuclear weapons actually helps keep the peace. It goes without saying that the best war is the war that's never fought, and we've not experienced warfare on a global scale for more than 70 years. That's a testament to the vital deterrence work taking place daily at Los Alamos. ★

■ Photo upper left: Bob Webster discusses stockpile stewardship during a visit to Nevada National Security Site.

MASTHEAD
EDITOR Whitney Spivey
ART DIRECTOR Brenda Fleming
WRITERS Jake Bartman, Jill Gibson, Jenny Humbert, Ian Laird, J. Weston Phippen
COPY EDITOR Anne Jones
3D DESIGNER Margaret Doebling
WEB DESIGNER Hans Sundquist
PHOTOGRAPHER David Woodfin
EDITORIAL ADVISOR Michelle Mosby

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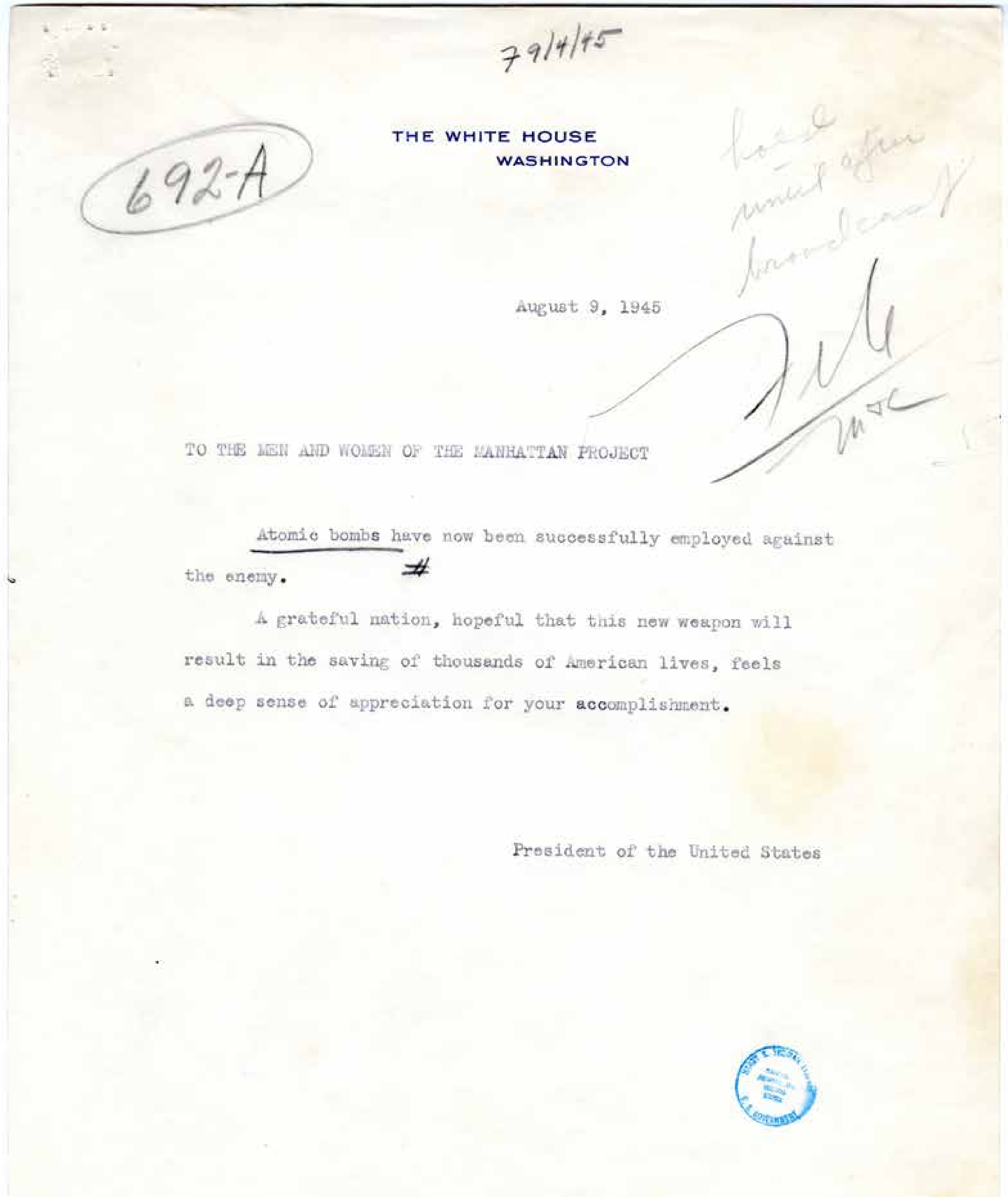
NSS STAFF SPOTLIGHT

The *NSS* team members upgraded their attire from Los Alamos casual (flannel shirts and jeans) to business casual for the 2024 Nuclear Deterrence Summit in Washington, D.C. During the three-day event, industry experts discussed the management of the nuclear complex, the security of the stockpile, arms control negotiations, and strategic policy. Pictured from left are J. Weston Phippen, Ian Laird, Jake Bartman, Jill Gibson, Brenda Fleming, and Whitney Spivey. ★



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THE WHITE HOUSE
WASHINGTON

August 9, 1945

TO THE MEN AND WOMEN OF THE MANHATTAN PROJECT

Atomic bombs have now been successfully employed against the enemy.

A grateful nation, hopeful that this new weapon will result in the saving of thousands of American lives, feels a deep sense of appreciation for your accomplishment.

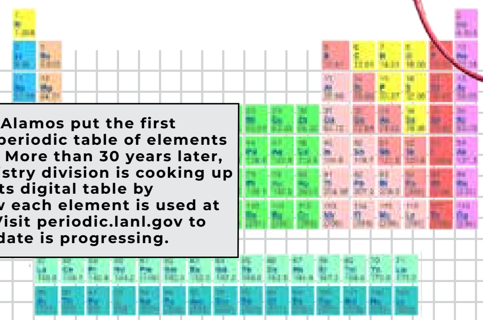
President of the United States

■ U.S. President Harry Truman sent this brief message to members of the Manhattan Project three days after the bombing of Hiroshima and on the same day a bomb was dropped over Nagasaki. The next day, August 10, Japan declared its intent to surrender, which finally brought World War II to an end. ★
Photo: Harry S. Truman Presidential Library & Museum

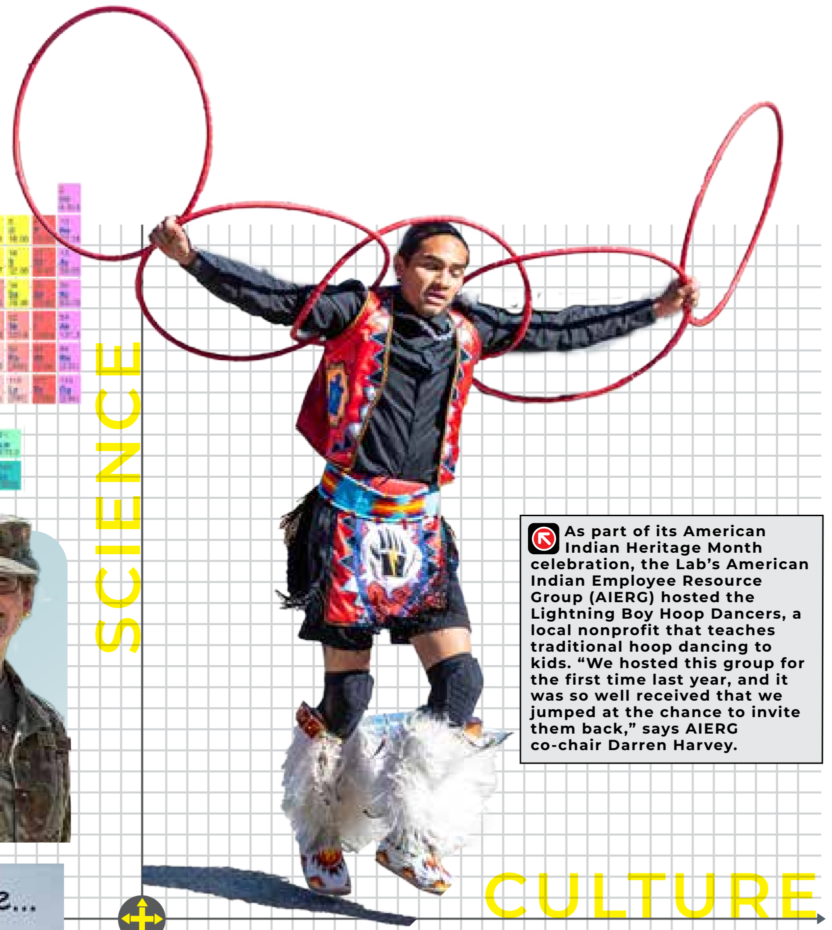
INFOGRAPHIC

THE INTERSECTION

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



In 1992, Los Alamos put the first interactive periodic table of elements on the internet. More than 30 years later, the Lab's Chemistry division is cooking up an overhaul to its digital table by showcasing how each element is used at the Lab today. Visit periodic.lanl.gov to see how the update is progressing.

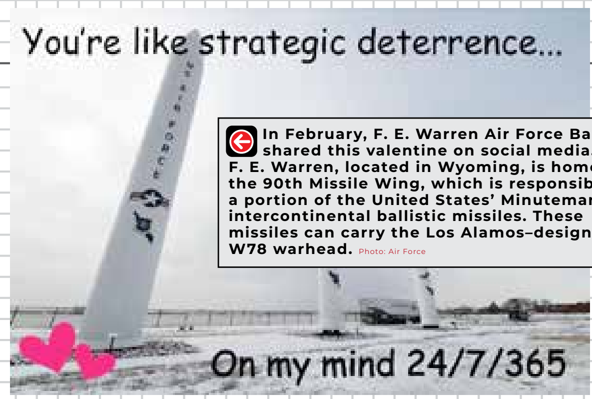


SCIENCE

CULTURE

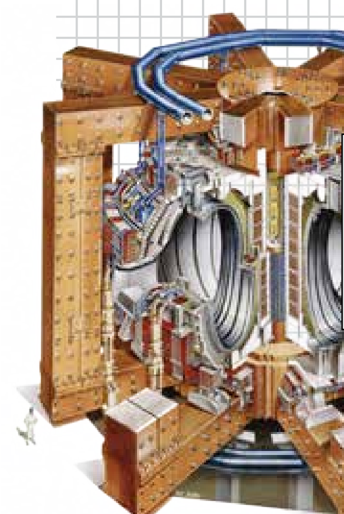
As part of its American Indian Heritage Month celebration, the Lab's American Indian Employee Resource Group (AIERG) hosted the Lightning Boy Hoop Dancers, a local nonprofit that teaches traditional hoop dancing to kids. "We hosted this group for the first time last year, and it was so well received that we jumped at the chance to invite them back," says AIERG co-chair Darren Harvey.

In January, Major General Stacy Jo Huser became the first female commander of Twentieth Air Force. In this role, she is responsible for more than 12,000 Airmen providing nuclear global strike and nuclear weapons sustainment for the U.S. Air Force. Huser was previously the principal assistant deputy administrator for Military Application at the National Nuclear Security Administration (NNSA) and was most recently at Los Alamos in May 2022, when she presented the NNSA Defense Programs Awards of Excellence.



In February, F. E. Warren Air Force Base shared this valentine on social media. F. E. Warren, located in Wyoming, is home to the 90th Missile Wing, which is responsible for a portion of the United States' Minuteman III intercontinental ballistic missiles. These missiles can carry the Los Alamos–designed W78 warhead. Photo: Air Force

The film Oppenheimer, about the first director of what is today Los Alamos National Laboratory, won five Golden Globe Awards and seven Academy Awards. To read more about the movie being filmed in Los Alamos—and the many Lab employees who were cast as extras—scan the QR code above. Photo: Universal Studios



Using 0.2 milligrams of fuel, researchers at the Joint European Torus in England generated 69 megajoules of energy over five seconds in a record-setting fusion experiment in February. Learn more about fusion research—and specifically Los Alamos' contributions—by scanning the QR code below. Photo: UKAEA

U.S. Air Force Second Lieutenant Madison Marsh (aka Miss Colorado) is the first active-duty Air Force officer to be crowned Miss America. Marsh, a graduate of the U.S. Air Force Academy, has a degree in physics. She took the reins from Miss America 2023 Grace Stanke, a nuclear engineer. "Here's to showing the world that women can do anything," Marsh wrote on Instagram after her win. Photo: PBS

MOVIES

WHAT TO WATCH

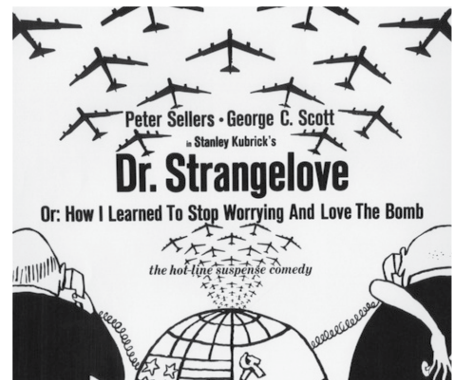
A nuclear movie buff recommends four films—including (no surprise!) *Oppenheimer*.

Drew Kornreich, an engineer at Los Alamos National Laboratory, kicks off his popular "Weapons 101" class with a slide that lists several dozen movies about nuclear issues. "The nature of the films' applications of nuclear weapons and related issues is widely varying," he says, "from the fantastical, where nuclear weapons are simply a means to motivate the story—think 1950s monster films—to downright depressing—films that attempt to seriously display the aftermath of a large-scale nuclear exchange."

Kornreich, who is part of the Lab's Weapons Production associate directorate, sat down to discuss four of his favorites. He shares them here, in his own words:

OPPENHEIMER

This 2023 film generally uses the central thread of J. Robert Oppenheimer's clearance revocation hearings to tell the larger story of his life and the Manhattan Project—the top secret effort to build atomic weapons to help end World War II. Toward the end of the film, director Christopher Nolan pulls the thread on Oppenheimer's desire to implement deterrence via a global organization that would oversee nuclear-related issues. Although such a goal was noble, the ability to implement it in a world with sovereign nation states was doomed to fail, as the film, and history, have shown.



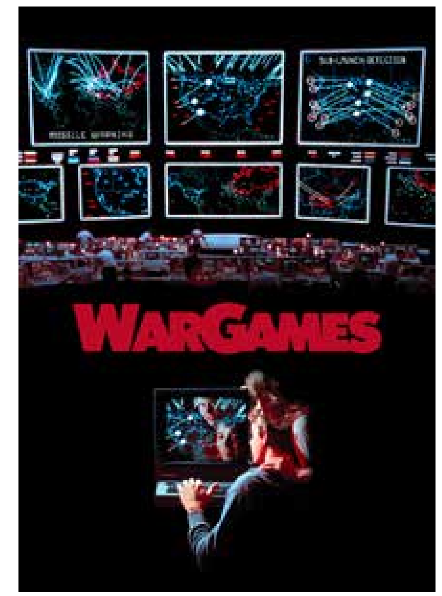
DR. STRANGELOVE OR: HOW I LEARNED TO STOP WORRYING AND LOVE THE BOMB

This 1964 film touches on the intricate nature of deterrence. A rogue base commander orders a bomber squadron to independently strike the Soviet Union with nuclear bombs to intentionally start a nuclear war. The U.S. government attempts to foil his plan.

The psychology of deterrence is showcased when an Air Force general advocates for a first strike to disable the Soviet Union before the rogue bombers deliver their weapons. A first strike would prevent the Soviet Union from launching a massive retaliatory strike (per the doctrine of mutually assured destruction). The president, naturally, is averse to this plan, noting that he does not want to "go down in history as the greatest mass murderer since Adolf Hitler!" In this instance, the president is functionally deterred by his own nuclear weapons and the moral implications of using them for military aggression.

FAIL SAFE

Fail Safe (the 1964 version and the 2000 CBS network version, both of which are star-packed) addresses essentially the same topics as *Dr. Strangelove*. The movies are based on different books that are so similar that copyright infringement lawsuits were filed and settled out of court. Functionally, the key difference is that *Fail Safe* is a serious drama while *Dr. Strangelove* is a dark satire. If you are going to watch these movies, watch *Fail Safe* first, and don't watch it right before bedtime.



WARGAMES

This 1983 film opens with two Air Force personnel in a missile launch control bunker; they are given a drill that they believe is real. When one person has moral concerns about launching a nuclear weapon and refuses to turn the launch key, the government gives a computer control over launching nuclear weapons. The story proceeds to entertainingly examine the risks of removing humans from this system.

In the final scenes, the computer ultimately determines that "the only winning move is … not to play." In some regard, this conclusion is a hat-tip to the doctrine of mutually assured destruction and its fundamental goal of avoiding playing the "game" of actual nuclear war. ★

■ Jessica Bishop and Mark Bayless, both from Los Alamos, work with Sandia's James Duncan (right) during a RAP training exercise.

GLOBAL SECURITY

ANSWERING THE CALL

The Radiological Assistance Program helps keep the public safe from nuclear terrorism and other hazards.

BY JAKE BARTMAN

On February 12, 2023, some 68,000 people gathered at State Farm Stadium in Glendale, Arizona, to watch the Kansas City Chiefs take on the Philadelphia Eagles in Super Bowl LVII. Behind the scenes, more than 600 people organized by the Department of Homeland Security (DHS) worked to keep attendees safe from explosive, biological, chemical, cyber, radiological, and other hazards.

Among those 600 was a 7-person team from Los Alamos National Laboratory, which helped monitor State Farm Stadium and the surrounding area for radiological threats, including explosive devices. "We're tasked with ensuring public safety—with seeing that the public isn't unnecessarily exposed to any kind of radiological source," says the Laboratory's Kat Leyba, who heads the Los Alamos team involved with the Department of Energy's (DOE) Radiological Assistance Program (RAP). Monitoring large events such as the Super Bowl, in conjunction with DHS, is just one of the ways RAP protects the public.

RAP has been around since the late 1950s. At that time, nuclear technologies—such as nuclear power plants and medical devices—were occupying an ever-larger place in American society.

■ RAP team members wore backpacks containing neutron and gamma detectors that allowed them to covertly scan for radiological sources during Super Bowl LVII.

Foreseeing that this trend would continue, the Atomic Energy Commission (precursor to the DOE) created RAP to conduct radiation monitoring, decontamination assistance, and medical advice and analysis.

Today, RAP team members act as first responders to radiological, or potentially radiological, incidents. Over the years, RAP has responded to events that include the 1979 reactor meltdown at Three Mile Island; the September 11, 2001 terrorist attacks; and the March 2011 damage to three Fukushima Daiichi reactors in Japan, following the Tōhoku earthquake and tsunami.

RAP is divided into seven regions across the United States, and each RAP region comprises teams from DOE facilities. Los Alamos is a part of RAP Region 4, which is responsible for responding to radiological incidents in Arizona, Kansas, New Mexico, Oklahoma, and Texas.

That's why the Los Alamos RAP team went to the Super Bowl in 2023. The members of the Los Alamos team, who are primarily scientists and health physicists, arrived in Phoenix two weeks before the game itself. In collaboration with RAP teams from Sandia National Laboratories (in Albuquerque, New Mexico), the Waste Isolation Pilot Plant (in Carlsbad, New Mexico), and the Pantex Plant (in Amarillo, Texas), and with RAP Region 7 responders (who were there to train before hosting Super Bowl LVIII in 2024), the Los Alamos team surveyed both State Farm Stadium and the surrounding area. During the game itself, RAP personnel inside the stadium were ready to respond to any potential radiological incidents.

RAP personnel can make their presence known or blend into crowds, depending on what's needed at an event. At the Super Bowl, Los Alamos' RAP team members used backpacks containing neutron and gamma detectors that allowed them to covertly scan for radiation sources. These backpacks, which provide feedback to users through earbuds, also transmitted data in real-time to other RAP team members, who helped monitor the tools' feedback from afar.

The team also used detectors disguised to look like pagers. Had a radiological source been located, RAP team members could have used other detectors to help characterize the specific materials.

"One of the most important things about nuclear materials is that they're talking to us—we just have to have the ears to listen," says Jeff Golden, who manages the Lab's Nuclear Emergency Support Team, of which RAP is a part.

At events like the Super Bowl, RAP's detectors frequently pick up on non-hazardous radiological sources. The most common false alarm comes from people who have recently had medical treatments, such as chemotherapy, that involve radioactive substances. Certain kinds of tools—such as nuclear density gauges, which are often used to measure the composition of asphalt—contain radioactive substances that can trigger detectors, too. RAP team members work closely with law enforcement officers, who are responsible for interacting with the public when detectors pick up on a radiation source.

Not all of RAP's work involves large events like the Super Bowl (or Major League Baseball's All-Star Game, which the Los Alamos RAP team has also supported). In fact, much of the team's work involves incidents that are closer to home. For example, RAP responded in February 2020 when construction workers unearthed World War II–era waste near downtown Los Alamos.

Through its efforts in Los Alamos and farther afield, RAP helps ensure that nuclear materials aren't used for nefarious purposes and that events like the Super Bowl remain safe—even if some attendees, like those Eagles fans who traveled to Arizona to watch their team lose to the Chiefs, are bound to return home disappointed. ★

■ From left, John Ledet and Allan Crowder, from Sandia, and Jason Martinez, from Los Alamos, work with an ORTEC Detective—a high-purity germanium radioisotope identification device.

■ A Constant Phoenix aircraft collects particulate and gaseous debris from the accessible regions of the atmosphere in support of the Limited Nuclear Test Ban Treaty of 1963. Photo: U.S. Air Force

GLOBAL SECURITY

FLOURISHING FORENSICS

New technology helps determine the origin and history of hazardous material.

BY IAN LAIRD

At Los Alamos National Laboratory, nuclear forensic scientists analyze samples of radioactive material to better understand nuclear crimes, such as the detonation of a nuclear device, the proliferation of nuclear material, or changes to a nuclear facility that go beyond what was previously disclosed in treaties.

Los Alamos scientists work continually to enhance nuclear forensics capabilities. Here are three Laboratory projects that were developed to help researchers analyze more types of samples more quickly and accurately. Each of these projects is funded through Los Alamos' highly competitive Laboratory Directed Research and Development program.

Nuclear geology

In 2023, a team led by scientists Ann Junghans and Vlad Henzl developed a new sample collection technology—a coating that solidifies around a sample to preserve the chronological order of isotopes produced in a facility.

"You can imagine this like geology, where you have different defined layers of sediment that you can ideally trace to a certain period of time," Junghans explains. "The idea was to preserve the layer structure—meaning the oldest material that was deposited first is at the bottom of the sample and the newest is on top."

When applied to surfaces and heated with a handheld ultraviolet (UV) lamp, the polymer coating solidifies, trapping any heavy metals and other contaminants. Because sampled substances are encased in the polymer, they are not dangerous to handle. In its original state as a liquid, the coating can be applied to cracks and crevices that are difficult to clean and sample. "We were able to almost completely retrieve the material and keep the layer structure intact," says Junghans of an early experiment with the coating.

"This is compared to the traditional swipes, which do not have the resolution to see what is the first layer or second layer or third layer and can take several months to analyze," adds Henzl, noting that the sample analysis took about 10 minutes.

In the future, this technology will enable facility inspectors to take more samples at a facility and thus develop a better understanding of what's happening inside it. For example, explains scientist Rollin Lakis, "if a nation goes from producing low-enrichment uranium to high-enrichment uranium, there would be trace contaminants in its facilities that show that evolution to a possible weapons-relevant program. This product could see if that nation, in between making agreed upon concentrations of uranium in the context of a domestic fuel program, made high-enriched uranium for a clandestine weapons program and then tried to clean it up."

Accelerating nuclear forensics

In October 2023, another Los Alamos team began working to decrease the time necessary to chemically separate elements within a sample. The isotopic composition and concentration of elements are pieces of evidence that reveal information about a sample, such as where the sample came from, when it was created, and what its intended use might be. That collective information is called "the provenance" of a sample. The provenance can give authorities actionable data, allowing them to prosecute potential nuclear crimes or trace producers and users.

"To make a claim based on a sample, we have to do a lot of chemistry and destructive analyses to extract very small and low-level concentrations of elements," says scientist John Engel. "Current methods require multiple chemists working at multiple fume hoods for weeks."

That's why Engel and fellow scientist Jo Denton are trying to speed up the process—from one month to one week. Engel's initial research developed a method for separating neptunium, americium, and plutonium from uranium samples. Now, he and Denton are working to add thorium and protactinium to that list.

To separate specific elements from a uranium sample, Engel and Denton use stacked column chromatography, in which a solid sample is dissolved in acid. The resulting fluid is placed into a series of vertically stacked columns containing different resins that bind certain elements. "In the first column, we have a resin that we know attracts neptunium and plutonium, and we're hoping to show protactinium and thorium as well," Engel says. "Then the rest drips through and americium sticks in the next column, and uranium continues through." Users are then left with individual "cuts" of each purified element.

Fully separating the elements from each column requires further steps, but "the results can then be used as a screen of the data to get the ultimate level of precision through the established ways," Engel explains. "With this information, we can make better decisions faster."

Plutonium fingerprints

Scientist Kim Hinrichs is leading a project that focuses on low-level (containing tens of thousands of atoms) plutonium post-detonation samples—samples that could indicate whether a nuclear detonation has taken place.

Hinrichs collects plutonium samples from air filters onboard Constant Phoenix, a WC-135 aircraft that's flown above potentially contaminated areas. Because only very small amounts of plutonium are collected in these filters, Hinrichs uses mass spectrometry—a process where atoms are separated by weight—to analyze them. Currently, this method works for all isotopes of plutonium except plutonium-238. That's because if a sample contains naturally occurring and often abundant uranium-238, the measurements for plutonium-238 become skewed.

Hinrichs hopes to get accurate readings for plutonium-238 by developing a way to remove some uranium-238 from samples and also mathematically correct for uranium-238's natural presence. With an accurate reading of all plutonium isotopes, analysts will be able to assess a sample more exactly and with higher confidence. This is important because different isotopes of plutonium are used for different applications—from nuclear weapons to heat sources for spacecraft.

"Essentially, you're measuring an isotopic fingerprint for plutonium, and that fingerprint, that unique distribution of isotopes, tells you something about what the intended use or source of that plutonium might've been," says program manager Stephen Lamont. "By being able to analyze more samples, we have a better chance of catching a bad actor and verifying whether a country is complying or out of compliance with its declared activities."

Learn about NDAlpha, another new nuclear forensic technology, on p. 14.

■ John Engel inspects a sample of intercepted material at Los Alamos' Clean Lab.

■ In August 2023, MEDAL participants toured the Spirit of Kitty Hawk, a B-2 Spirit stealth bomber, at Whiteman Air Force base.

PROFESSIONAL DEVELOPMENT

DEFENDERS OF DETERRENCE

Los Alamos National Laboratory is developing a new generation of nuclear thought leaders.

BY J. WESTON PHIPPEN

Developing leaders who understand the nuances of nuclear deterrence and can bridge the gap between science and policy contributes to the success of Los Alamos National Laboratory's national security work.

"People may not be paying attention," says Avneet Sood, a senior scientist with the Lab's Weapons Physics associate directorate, "but there's a large community dedicated to nuclear deterrence in the United States that is just as active as ever, and at Los Alamos we've taken several steps to ensure this next generation is ready to meet future challenges."

In fact, Los Alamos has several programs dedicated to developing the next generation of nuclear deterrence leaders. Here are a few:

National Security and International Studies Fellows Research Program

The Lab's Office of National Security and International Studies (NSIS) is akin to a think tank: a bridge between the technical work being done at Los Alamos and policymakers in Washington, D.C.

In 2022, NSIS started its Fellows Research Program to fund up-and-coming technical experts as they explore a research topic at the intersection of nuclear science and security policy. The current cohort includes 15 fellows, each of whom will spend up to two years pursuing research that addresses a current national security policy challenge. For instance, Nora Jones, a program director with the Lab's International Threat Reduction group, is researching how Los Alamos has participated in past denuclearization agreements.

"In tumultuous times—those like the world currently finds itself in—we often turn to arms control agreements," Jones says. "The Lab plays an important role in these moments, but when I investigated what we'd done there was no easily accessible documentation. With the Fellows Program, I'm compiling a case study of how the Lab has helped in the past because we're likely to turn toward this strategy in the future, so that going forward we are prepared to stand up and offer that same support."

The National Security Affairs Program

In addition to being one of the Lab's operators, Texas A&M University (TAMU) offers a course to train future deterrence leaders that was set up, in part, by Los Alamos experts. The program is run by Texas A&M's Bush School of Government and Public Service and is called the National Security Affairs Program. The program is offered annually and includes four graduate-level classes.

"This initiative was started by the Lab to take mid-career professionals to the next level," says Andrew Ross, who holds a joint appointment with TAMU and Los Alamos. "Many of the courses are taught by a combination of professors and working scientists, some of whom are from Los Alamos."

■ MEDAL participants walk through the State Department before a meeting with Mallory Stewart, assistant secretary for the Bureau of Arms Control, Deterrence, and Stability.

So far, 85 people have completed the course and received a certificate in national security affairs. Some of these graduates have gone on to leadership roles at the U.S. Department of Energy, National Nuclear Security Administration (NNSA), the U.S. Department of State, and the Lab.

MEDAL

Since 2018, the Mid-/Early career Deter-detect-prevent Advanced Leadership (MEDAL) program has offered promising young Los Alamos leaders a chance to explore how their work intersects with national policy, emphasizing the Lab's core missions of deterrence and countering global threats, nuclear proliferation, and terrorism.

The program includes meetings with senior Los Alamos staff and culminates in a trip to Washington, D.C. that includes meetings at the NNSA, the Department of Defense, the Department of State, the Office of Science and Technology Policy, and other organizations. Since 2018, 49 leaders have completed the program.

"The D.C. trip provided great perspective on where the Los Alamos mission fits into the greater national security landscape," says Michelle Bourret, a team leader in the Geophysics group. "I found it valuable to see different ways that someone like me can serve the Laboratory and the nation." ★

QUOTED

"Our greatest asset is the people of the nuclear security enterprise, whose expertise is the core of the United States' nuclear deterrence."

—Jill Hruby, administrator of the National Nuclear Security Administration, in her introduction to the Stockpile Stewardship and Management Plan for Fiscal Year 2024. ★

PRODUCTION

THE CORE OF DETERRENCE

SCAN QR CODE WITH A SMARTPHONE CAMERA
Take an in-depth look at plutonium pit production.

Soon, newly manufactured plutonium pits will be used in stockpiled weapons.

After successfully manufacturing dozens of development (practice) plutonium pits in 2023, Los Alamos National Laboratory is on track to make its first war-reserve (stockpile-quality) pits in 2024.

A plutonium pit is the core of a nuclear weapon; when uniformly compressed by explosives inside a warhead or bomb, a pit generates incredible amounts of energy—kilotons or even megatons of explosive power.

Los Alamos' pit production mission, commissioned by the National Nuclear Security Administration in 2019, represents an essential component of deterrence. "A nuclear deterrent is only good if it's credible and reliable, and that's why we're making new pits," says Matt Johnson, division leader for Pit Technologies at Los Alamos.

These newly manufactured pits, created using recycled plutonium from decades-old pits, will be shipped to the Pantex Plant in Amarillo, Texas, where they will be placed in Lawrence Livermore National Laboratory–designed W87-1 warheads. Eventually, newly manufactured pits will be placed in other weapons systems as well.

"We're the only place in the nation where plutonium pits are currently made," says Mark Davis, chief operating officer for Weapons Production at Los Alamos. "Our work here by technical experts and all the skilled staff who support them is the foundational reason that individuals like Vladimir Putin of Russia or Kim Jong Un of North Korea know our stockpile is credible and reliable, and that deters them from using their own."

Johnson agrees, saying, "Our mission is more important than it's ever been." ★

■ Gloveboxes are essential for safely manufacturing pits.

■ Ryan Mier inspects a part produced using rapid response steel tooling.

PRODUCTION

LAYERS OF SUCCESS

New additive manufacturing technology streamlines the process for making tooling.

BY IAN LAIRD

Forging, forming, stamping. These processes are how metal is shaped into everything from the screws you buy at a hardware store to the intricate components of nuclear weapons. These processes also impose high levels of wear and tear on machinery. When machinery—also called tooling—inevitably breaks, production is disrupted as manufacturers wait for equipment to be repaired or replaced.

"Delays from broken tooling are consequential here at Los Alamos National Laboratory. For me and my team, the frustration comes when a project timeline is set back because we are waiting on tooling," says engineer Ryan Mier. "For industry and private companies, there is a direct financial impact where every day that a machine is not producing parts, revenue is lost. In both cases, when deadlines are approaching, these issues definitely cause stress."

In an effort to reduce downtime and modernize the production process, a team at Los Alamos developed rapid response steel tooling, a new additive manufacturing (AM) process that won an R&D 100 Award in November 2023.

During AM, which is similar to 3D printing, layers of material are deposited on top of one another to form a desired shape. In the case of rapid response steel tooling, layers of steel and metal alloys are used to make the tools required for metal processing.

"While AM has been around for decades, the widespread use of metal AM—specifically more exotic and high-performance metals—is fairly new," says Mier, who led the development of rapid response steel tooling.

Traditionally, tooling production starts with conversations between designers and manufacturers about what designs are feasible. Then, the tooling is produced using subtractive machining—a process in which desired shapes are cut from large steel rods, which results in a lot of metal waste scraps. Those parts must then be heat-treated to harden the steel. This process can be complicated, time consuming, and expensive—especially if there's a mismatch between design and manufacturing and the process has to be redone.

Rapid response steel tooling streamlines this production process considerably. First, designs can be programmed into AM machines. If a design isn't feasible, it can't be programmed. In other words, there is no potential for a mismatch between design and production. The high temperatures and subsequent rapid cooling of AM materials also means additional heat treatment is not required. And because AM uses only the necessary materials, no metal waste is produced.

Perhaps most importantly, rapid response steel tooling allows users to design, produce, and iterate more complex shapes than can be produced through subtractive manufacturing. Consider, for example, tooling that is used in an extremely hot environment. To prevent deformation, the tooling often contains hollow cooling channels. With traditional methods, producing tooling with channels is a multistep process in which pieces are welded or bolted together. Rapid response steel tooling, however, can produce this tooling in one step. And often, the resulting products are lighter and thus more user-friendly.

"In one case at the Lab, a tool that is 8 inches in diameter was made using both methods," Mier says. "The machined tool was over 80 pounds. The AM tool was 52 pounds. That 35 percent reduction in weight is substantial and makes the tools safer for operators."

And although the tools are lighter, they are just as strong, tough, and wear resistant as their predecessors, says researcher Kevin Le, who notes that "the shift from cutting tooling out of large chunks of material to growing tools through additive manufacturing is revolutionary." ★

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

GLOBAL SECURITY

ACCOUNTING FOR ALPHA RADIATION

A new device developed by Los Alamos scientists raises the bar for alpha spectroscopy.

BY JENNY HUMBERT

Remember the Fukushima nuclear accident in 2011? The Tōhoku earthquake, east of Japan, caused a tsunami that disabled three reactors at the Fukushima Daiichi nuclear power plant. Nuclear emergency response officials needed to know immediately if the reactors were leaking radioactive material, and if so, which ones, how much, and where.

One way this information was determined was by using alpha spectrometers. Alpha spectrometers measure alpha radiation, which is energy emitted by actinide elements, including plutonium and uranium. Measuring alpha radiation is one way to determine the presence and quantity of actinide elements.

Alpha spectroscopy has traditionally required extracting a sample, transporting it to a specialized laboratory, and carefully preparing it using a time-consuming process that involves strong chemicals and generates radioactive waste. In addition, workers separating and purifying the sample risk exposure to radiation and chemicals. What would have been useful at Fukushima is a portable, reliable, remotely operated alpha spectrometer, which could have quickly and safely provided information at the scene of the accident.

Fast-forward 13 years, and scientists at Los Alamos National Laboratory have developed NDAlpha, the first field-deployable alpha spectrometer capable of point-and-shoot scanning to immediately measure on-site alpha radiation. The "ND" in the name stands for "nondestructive:" there is no need to remove a sample for evaluation.

The NDAlpha device is slightly larger than a soda can and has a small (5 by 25 millimeter) thin plastic window on one end. The operator points the window at a nuclear material or contaminated surface. Alpha particles pass through the window and deposit their energy in a silicon detector, which produces an energy spectrum. The details of the energy spectrum are analyzed with software designed to identify materials and quantify their composition.

"All the operator needs to do is position the device near a spent fuel for a few seconds to get an answer," says NDAlpha developer Mark Croce, who notes that NDAlpha can also be used remotely—mounted on a remotely operated vehicle, for example—which protects operators from hazardous environments.

Croce explains that many materials also emit beta particles and gamma rays—often with great intensity—which can sometimes make alpha radiation difficult to measure. With this in mind, NDAlpha was built with a magnetic filter to redirect beta particles away from the internal silicon detector, and the thin active region of the silicon minimizes sensitivity to gamma rays.

Croce also notes that alpha radiation can sometimes be tricky to measure because alpha particles lose energy every time they travel through material—even air—which is why careful sample preparation is usually required. But the software that NDAlpha uses to assess a material accounts for this loss of energy. "The algorithm we developed can handle it," Croce says. "We're able to accurately measure any thick piece of material, such as fragments of nuclear fuel in the field."

Scientist Katherine Schreiber, who helped develop NDAlpha, says the technology will be particularly helpful to the nuclear emergency response community. "It could also become an important part of process monitoring in a nuclear fuel facility, allowing on-site alpha spectroscopy," she continues, "and it could even be used in the decommissioning and cleanup of nuclear facilities." ★

■ NDAlpha scans contaminated surfaces or materials found in the field to quickly measure uranium, plutonium, and other alpha-emitting actinides.

COLLABORATION

ASSESSING THE NUCLEAR INFLECTION POINT

A Los Alamos team analyzes national security risks and capabilities.

BY JILL GIBSON

The world is standing at a "nuclear inflection point," according to Jill Hruby, head of the National Nuclear Security Administration.

Noting that changes in the geopolitical environment are driving changes in U.S. nuclear strategy, Hruby has charged Los Alamos, Sandia, and Lawrence Livermore national laboratories with developing a "net assessment" capability that analyzes the trends, key competition, risks, opportunities, and challenges that impact the U.S. military capability—with a focus on the country's nuclear deterrent.

"The future of deterrence must be conceptualized," Hruby said at the 2023 Strategic Weapons in the 21st Century symposium. "As a wider array of adversaries advance capabilities, as technologies emerge, and as the geostrategic realities change, building more weapons cannot be the only answer and could be the wrong answer. Integrated deterrence (see p. 18), net assessments, and disruptive technologies are being examined to maintain a U.S. advantage over our adversaries."

In the spring of 2023, that work got underway. "Each lab has a team, and then we work together to build consensus between the three teams and write reports," says Jim Cooley, who leads the Strategic Analyses and Assessments office at Los Alamos. The Los Alamos team includes policy experts, intelligence analysts, data analysts, and weapons scientists.

Cooley initially led the Los Alamos team but has passed the baton to Beth Hornbein, an intelligence and systems analyst. "We are well-positioned to collect and evaluate information that is relevant to our nuclear weapons mission," Hornbein says. "Our team can draw on subject matter expertise that doesn't exist anywhere else in the United States' government."

The concept of net assessment isn't new, but "it can be difficult to explain," Hornbein says. The U.S. Department of Defense's (DOD) Office of Net Assessment was founded in 1973 to provide strategic insights for DOD leadership. American foreign policy strategist Andrew Marshall led that office for 40 years, and Hornbein says the Lab team draws on assessment methods that Marshall pioneered.

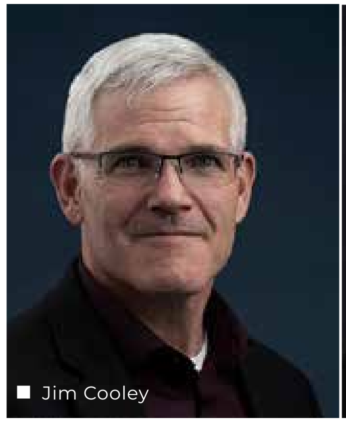
The team conducts research, holds workshops, and will eventually add wargames (conflict simulations) to its activities. "We are examining the country, our adversaries, and their relative strengths and weaknesses to identify strategic risks and opportunities," Hornbein explains. "The power of net assessment is that it can provide a fuller picture for decision-makers. Hopefully, the information we provide will help them as they wrestle with tough decisions that will impact the competitive fitness of the nuclear security enterprise and the future of our nuclear deterrent."

Cooley, who continues to advise the effort, describes net assessment as an "artform that informs policy at the highest level."

Hornbein says the process is extremely challenging. "It requires the ability to extract meaning from a wide range of information, both quantitative and qualitative, taking into consideration our adversaries' perspectives, and to apply those findings to big, strategic issues."

She also notes that net assessment can lead to surprises. "It can uncover asymmetries or opportunities that may be counterintuitive. There are some great examples from the historical literature where an in-depth net assessment challenged the conventional wisdom and forced decision-makers to rethink their approach to important national security issues."

Hornbein says that although the work is difficult, she finds it inspiring. "We are on the cusp of what could be a very different international security landscape—with three nuclear-armed superpowers—and our work could impact how the United States plans for this future." ★



■ Jim Cooley

■ Beth Hornbein

LISTEN

NATIONAL ★ SECURITY SCIENCE PODCAST

The *National Security Science* podcast is a spin-off of *National Security Science* magazine. Listen to stories from Los Alamos National Laboratory's Weapons Programs—stories that show how innovative science and engineering are key to keeping America safe. Scan the QR code above to hear more about Los Alamos' clean energy research.

MILITARY

POWERFUL PARTNERSHIPS

At Los Alamos National Laboratory, FA52 Army officers further their understanding of nuclear weapons effects.

BY J. WESTON PHIPPEN

Not long ago, the U.S. Army regularly sent FA52s—officers who specialize in various aspects of nuclear operations and efforts to counter weapons of mass destruction—to Los Alamos National Laboratory. For several years, these officers worked alongside scientists on special projects as National Nuclear Security Administration stockpile associates.

"Los Alamos is an excellent place for an FA52," says Major R. Boone Gilbreath, who recently spent three years at the Lab while also completing a doctoral degree. "You're in an environment surrounded by some of the best minds in nuclear physics, weapons effects, and many other topics that pertain to nuclear weapons."

Although the stockpile associates program officially ended in 2015, Los Alamos still sees the occasional FA52. "A lot of people might ask why the Army has nuclear specialists, despite having no organic means to employ a nuclear weapon," Gilbreath says. "The Army doesn't have stealth bombers, submarines, or nuclear missiles. But it's imperative that we develop and maintain nuclear weapon effects expertise because if nuclear weapons are ever detonated on a battlefield, by an adversary, or by the United States, the Army must be prepared to operate and dominate in large-scale combat operations."

FA52 officers are a specialized few—only about 300 exist. Their purpose is to advise senior military leaders and policymakers on nuclear matters and how to counter weapons of mass destruction.

"We are the Army's only subject matter experts on nuclear weapons and weapons effects," says Lieutenant Colonel Daniel "Baha" Bahaghighat, an FA52 who completed the stockpile associates program in May 2015. "In my current capacity, I advise military leadership on how we train for and what we would do in a theater of war if an enemy or the United States deployed a nuclear weapon." Of his experience at Los Alamos, Bahaghighat says "there are other avenues to train people like us, but there's nothing like national lab training."

Gilbreath agrees. "My time at Los Alamos trained me to think in a different way," he says. "That's what happens when you sit in a room of scientists with a combined 100 years of experience thinking critically about nuclear weapons and weapons effects."

At Los Alamos, Gilbreath focused on specific questions: What capabilities (including soldiers, communications devices, and vehicles) would a modern-day military fighting force retain on a battlefield after being hit by a nuclear weapon? What assets would be degraded—and how?

■ After three years at Los Alamos, Gilbreath now works at U.S. Strategic Command, where he advises military leaders on nuclear effects.

"I was able to lean on the expertise of scientists, engineers, and nuclear testing data available at Los Alamos to address these problems," Gilbreath says. "With the benefit of this expertise and 15 years of military experience, I developed an analytical method and computer application to provide answers to these important questions."

Gilbreath produced the Nuclear System of Systems Capabilities Analytic Process (NuSCAP), a software program that incorporates detailed information on human and hardware elements of a military unit, as well as a variety of detailed nuclear weapon environment data (everything from the yield—explosive power—of various weapons to how much radiation—gamma rays and neutrons—are emitted during a detonation).

"I combed through thousands of pages of reports made when the United States still conducted nuclear tests, as well as current U.S. Army regulations and technical manuals, in an attempt to better understand nuclear weapon effects on current military systems," Gilbreath says.

While more work remains, Gilbreath's research has demonstrated the ability to evaluate the vulnerability of U.S. forces on a hypothetical nuclear battlefield. During wargames, in which leaders try to plan out and respond to different scenarios, the NuSCAP approach can more accurately convey what capabilities are maintained by a military unit. Previously, a vehicle might have been labeled as "functional" or "not functional." But with NuSCAP, an entire new level of granularity is available. Now, for example, NuSCAP can determine if a vehicle is damaged and to what extent the vehicle functions—maybe it can only drive a certain speed or fire its weapon a reduced distance.

In September 2023, Gilbreath completed his time at Los Alamos and was reassigned to U. S. Strategic Command (STRATCOM), where he incorporates what he learned at the Lab into his new duties. "My experience at the Lab is invaluable," he says. "And now I've carried that knowledge forward to my new post at STRATCOM, where I work on a team responsible for communicating to senior U.S. officials the consequences of U.S. or adversary nuclear weapon employment."

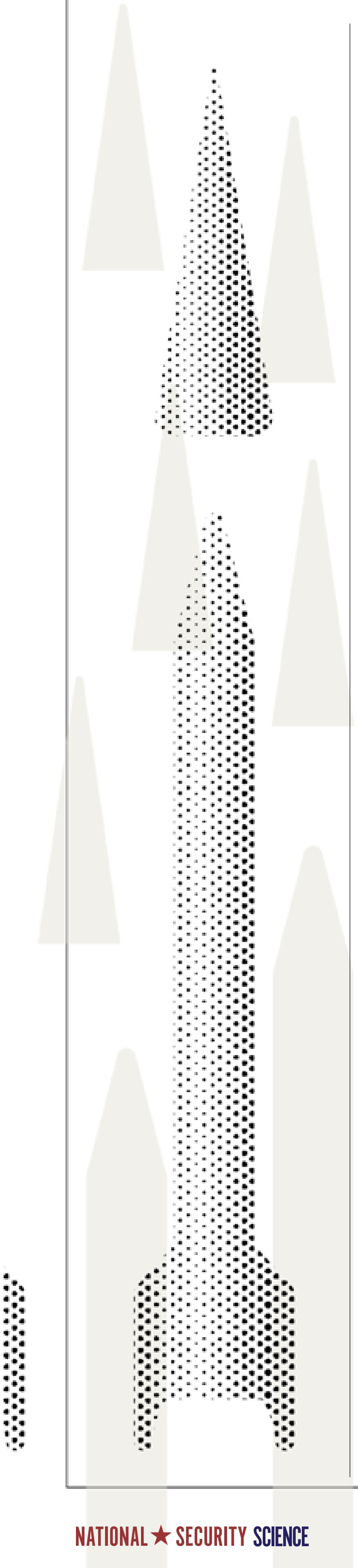
For more on weapons effects, see p. 28. To meet another FA52, turn to p. 60. ★

DETERRENCE defined

Los Alamos National Laboratory is responsible for four of America's nuclear weapons systems, playing a crucial role in national security and global stability.

By Jill Gibson and Whitney Spivey

■ A red confinement vessel is lowered into place at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. Read more about DARHT, a crucial experimental capability for maintaining the nuclear stockpile, on p. 24.



DETERRENCE:

prevents an adversary from taking unwanted actions, such as an armed attack.

Ask three people to define "deterrence" and you'll probably get seven or eight different definitions and at least one uncertain shrug.

Deterrence is a complex topic, particularly when discussed in the context of the United States' defense policy. Add in the threat of nuclear weapons, and the complexity builds.

At its heart, deterrence simply means preventing something. Most people associate deterrence with preventing war, keeping America safe, and convincing potential adversaries to seek alternatives to aggression. Under those umbrellas, you will find many theories, approaches, strategies, and schools of thought.

Yes, it's complicated, but *National Security Science* has sorted through the jargon to compile a simple deterrence dictionary (okay, it's really a glossary, but we liked the alliteration). So, before you dive into deterrence, take a look at the definitions to the right.

How does Los Alamos contribute to deterrence?

For nearly 80 years, the United States has relied on nuclear deterrence—the threat of using nuclear weapons to discourage other nations from military aggression—to ensure global stability and prevent war.

For nuclear deterrence to work, the nuclear deterrent must be credible. That's where Los Alamos National Laboratory comes in.

Los Alamos, which is overseen by the Department of Energy's National Nuclear Security Administration (NNSA), is responsible for the design, production, and certification of current and future nuclear weapons. Los Alamos designed five of the seven weapons systems currently in the

Deterrence dictionary

DETERRENCE BY DENIAL: Deters an action by making the action infeasible or unlikely to succeed, thus denying a potential aggressor confidence in attaining its objectives.

DETERRENCE BY PUNISHMENT: Threatens severe penalties if an attack occurs. Also called deterrence by cost imposition.

DETERRENCE BY RESILIENCE: Relies on the ability to withstand, fight through, and recover quickly from disruption.

INTEGRATED DETERRENCE: Leverages all instruments of national power (including diplomatic, economic, and military channels).

STRATEGIC DETERRENCE: Integrates all capabilities in all domains (land, sea, air, space, cyber, and information) across all the combatant commands, government organizations, and alongside allies.

TAILORED DETERRENCE: Applies classic deterrence notions to specific cases.

DIRECT DETERRENCE: Prevents attacks on a country's territory.

EXTENDED DETERRENCE: Discourages attacks on third parties, such as allies or partners.

GENERAL DETERRENCE: Prevents unwanted actions over the long term and in noncrisis situations.

IMMEDIATE DETERRENCE: Prevents a specific, imminent attack, most typically during a crisis.

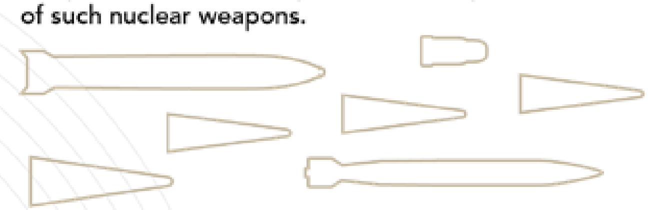
IN-DOMAIN DETERRENCE: Deters attacks in which the intended consequences unfold in the same domain as the target. U.S. military operations can be divided into domains such as land, sea, air, space, cyber, or information.

CROSS-DOMAIN DETERRENCE: Deters attacks in which the intended consequences unfold in a different domain than the target.

CYBER DETERRENCE: Uses cyberspace operations to deter both malicious adversary cyberspace activities and kinetic conflict.

SPACE DETERRENCE: Deters attacks on space assets (primarily satellites and space flight), attacks in space, and attacks from space.

NUCLEAR DETERRENCE: Relies on a country's possession of nuclear weapons systems and a plan for the employment of such nuclear weapons.



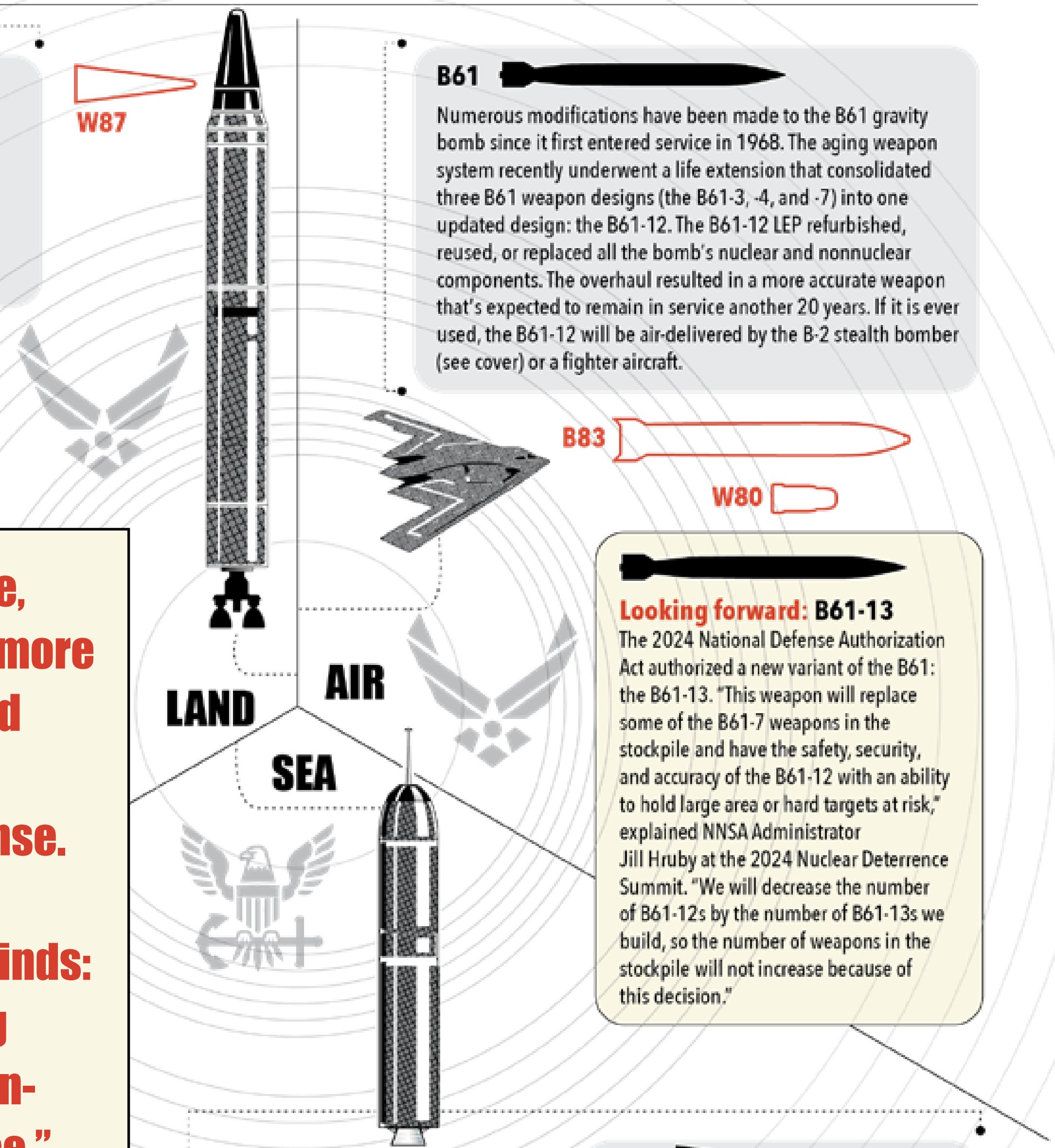
COMPELLENCE: Encourages an actor to take a certain action. Compellence is closely related to but different from deterrence.

ESCALATION MANAGEMENT: Keeps military confrontations from erupting into war and keeps limited wars from spinning out of control.

DELIBERATE ESCALATION: Deliberately increases the intensity or scope of an attack.

United States nuclear stockpile

■ =Los Alamos weapon   □ =Livermore weapon



W78
The W78 was first deployed in 1979 on U.S. Air Force Minuteman III intercontinental ballistic missiles (see inside front cover). The warhead is the one Los Alamos–designed weapon system that has not undergone a life extension, alteration, or modification.

B61
Numerous modifications have been made to the B61 gravity bomb since it first entered service in 1968. The aging weapon system recently underwent a life extension that consolidated three B61 weapon designs (the B61-3, -4, and -7) into one updated design: the B61-12. The B61-12 LEP refurbished, reused, or replaced all the bomb's nuclear and nonnuclear components. The overhaul resulted in a more accurate weapon that's expected to remain in service another 20 years. If it is ever used, the B61-12 will be air-delivered by the B-2 stealth bomber (see cover) or a fighter aircraft.

"This past year alone, NNSA has delivered more than 200 modernized weapons to the Department of Defense. There should be no doubt in anyone's minds: NNSA is modernizing our stockpile both on-schedule and at pace."

—NNSA Administrator Jill Hruby at the 2024 Nuclear Deterrence Summit

Looking forward: B61-13
The 2024 National Defense Authorization Act authorized a new variant of the B61: the B61-13. "This weapon will replace some of the B61-7 weapons in the stockpile and have the safety, security, and accuracy of the B61-12 with an ability to hold large area or hard targets at risk," explained NNSA Administrator Jill Hruby at the 2024 Nuclear Deterrence Summit. "We will decrease the number of B61-12s by the number of B61-13s we build, so the number of weapons in the stockpile will not increase because of this decision."

W88
The W88 warhead, which can be launched on missiles from Ohio-class submarines, entered the stockpile in 1988. In 2012, the W88 underwent an alteration–called the W88 Alt 370–to replace the warhead's arming, fuzing, and firing subsystem and to include safety enhancements. In 2015, the Nuclear Weapons Council expanded the scope of the alteration and asked Los Alamos to replace the W88's conventional high explosives and related components. Since October 2021, updated W88s have been gradually replacing older W88 warheads in the stockpile.

W76
Used atop Trident II submarine-launched ballistic missiles on Ohio-class submarines, the W76 warhead was introduced into the stockpile for the Navy in 1978. Since then, the warhead has undergone a life extension program, resulting in the W76-1, and a modification, resulting in the low-yield W76-2.

Los Alamos and Sandia national laboratories are the design agencies for the W76-1 LEP, which wrapped up in 2018 and extended the warhead's service life from 20 to 60 years.

The W76-2 is a modification of the W76-1 that provides a low-yield, sea-launched ballistic missile warhead capability. The first W76-2 was produced in February 2019, at the Pantex Plant in Amarillo, Texas.

Looking forward: W93
The W93 warhead will 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 how the W93 design will meet the requirements proposed by the Department of Defense. The design will be based on currently deployed and previously tested weapons and will incorporate modern technologies that improve safety, security, and flexibility to address future threats.

U.S. nuclear stockpile. Today, Los Alamos is responsible for maintaining four of those systems: the B61 family of gravity bombs, the W76 family of warheads, the W78 warhead, and the W88 warhead. (Lawrence Livermore National Laboratory is responsible for the other three systems: the B83 bomb and the W80 and W87 warheads.)

Stockpile stewardship

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 a testing moratorium went into effect in 1992. Today, instead of nuclear testing, the United States relies on nonnuclear and subcritical experiments coupled with advanced computer modeling and simulations to evaluate the health and extend the lifetimes of America's nuclear weapons. This approach is called stockpile stewardship.

"The Stockpile Stewardship Program provides the scientific and engineering capabilities that the Laboratory depends on to steward a safe, secure, and reliable stockpile," says Charlie Nakhleh, associate director for Weapons Physics at Los Alamos. "These cutting-edge research tools, facilities, and programs also underwrite our ability to execute the demanding stockpile modernization program that is currently underway, and, looking further ahead, they provide the foundation for the Laboratory's ability to respond quickly and innovatively to future threats and developments."

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

"Science-based stockpile stewardship put the laboratories in a powerful policy position because the responsibility of determining the health of the stockpile was theirs. If they ever believed that we had to go back to testing, they would have to say so. This is where scientific integrity comes in: You have to be able to say, no matter what the policy is, 'This is what the science tells us.'"

—Former Assistant Secretary for Defense Programs in the Department of Energy, Victor Reis, who spearheaded the development of the Stockpile Stewardship Program

Where science and strategy meet

"At Los Alamos, deterrence is our business," says Kirk Otterson, a program manager in the Lab's National Security and International Studies Office (NSIS).

But deterrence theory, planning, strategy, and policy are unlike science, engineering, and technology—the fields that dominate most work at the Lab. Los Alamos leaders say bridging that gap between science and policy can be tricky but is necessary. Defense strategy must drive technical decisions such as how the Lab should allocate resources and what capabilities the U.S. military needs. Likewise, technical information can inform policy.

"We provide advice to decision-makers based on sound scientific and technological knowledge and understanding," explains Los Alamos Director Thom Mason.

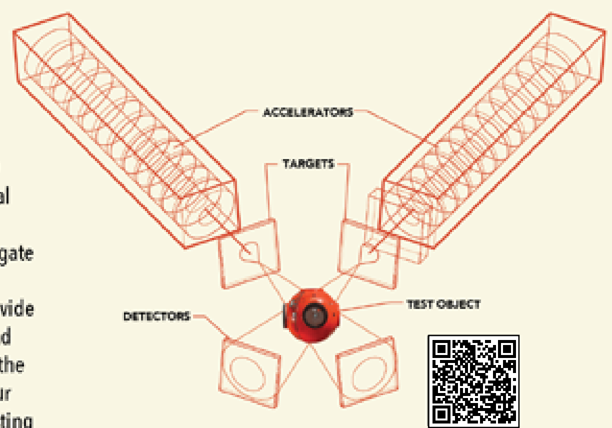
Otterson says that the Lab's NSIS office provides decision support on national security and technology issues relevant to the Los Alamos mission. "NSIS exists to help

Stockpile stewardship tools (just a few of many)

The Laboratory's capabilities range from advanced supercomputers that support the calculation, modeling, simulation, and visualization of complex nuclear weapons data to facilities where massive amounts of high explosives expose weapons to extreme environments so scientists can monitor how the weapons systems react.

DARHT

The Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility uses two massive electron accelerators to produce high-speed images of mock nuclear devices as they implode at speeds greater than 10,000 miles an hour. "DARHT has become the principal U.S. nonnuclear testing facility where nuclear weapons can be studied in full-scale with surrogate materials," says research and development engineer George Laity. "These experiments provide a unique opportunity to validate the physics and engineering models used to assess and certify the stockpile, evaluate designs as we modernize our weapon systems, and provide experimental testing capabilities that support global security missions. All these capabilities are exercised to increase our confidence in the overall nuclear deterrent."



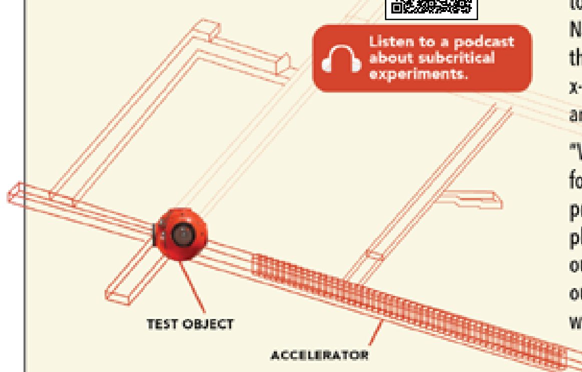
Watch a video about DARHT.

Scorpius

Los Alamos leads the Advanced Sources and Detectors Project, also known as Scorpius, a new diagnostic tool that will be housed underground at the Nevada National Security Site. Scorpius, a linear accelerator that is scheduled to be completed by 2030, will capture x-ray images of subcritical experiments, which use small amounts of plutonium.

"We are building something that is going to get used for decades," says Mike Furlanetto, senior director of the project. "Knowing the impact of getting this data about plutonium and the impact these findings will have on our work at Los Alamos is thrilling. Scorpius will increase our ability to make devices safer and more secure and will prepare us to meet new military needs."

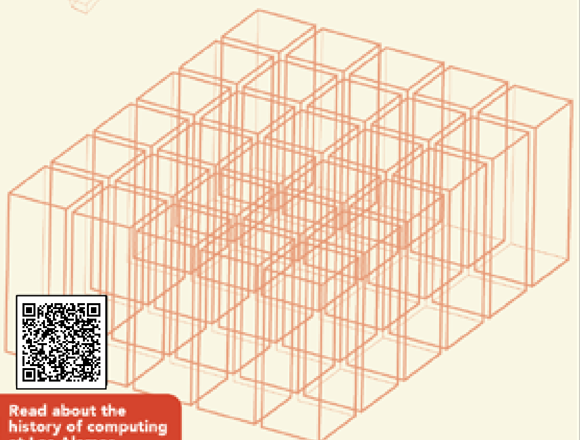
Listen to a podcast about subcritical experiments.



Supercomputers

For decades, high-performance computing has facilitated the success of stockpile stewardship. Supercomputers enable large-scale data analysis and visualization capabilities that help scientists test their hypotheses and solutions and make informed decisions about the nation's deterrent.

In 2023, the Lab began the deployment of two new supercomputers, Crossroads and Venado, which will advance Los Alamos' ability to study complex physical systems for science and national security.

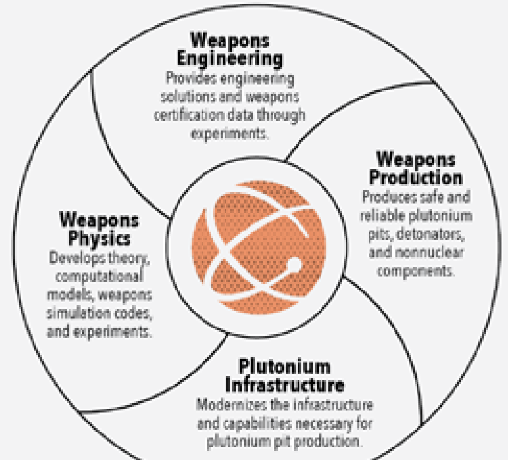


Read about the history of computing at Los Alamos

Los Alamos roles in U.S. nuclear deterrence

WEAPONS PROGRAMS

Weapons Programs at Los Alamos is made up of four associate directorates, each of which plays an important role in maintaining credible weapons systems.



ASSESSMENT

Annual assessment

Los Alamos continually assesses the health of the B61, W76, W78, and W88. Each September, these assessments 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. 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.

PRODUCTION

Pit production

A plutonium pit is the core of a nuclear weapon—a pit compressed by explosives generates nuclear energy, or yield. Los Alamos is currently developing the processes for manufacturing pits for the W87-1 warhead. For more, see p. 11.

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.

DESIGN

Life extension programs

For weapons at the end of their original design life, Los Alamos may increase the weapon's lifespan through a life extension program (LEP), which addresses aging and performance issues, enhances safety features, and improves security in an increasingly complicated and uncertain global environment. Through an LEP, scientists and engineers analyze a weapon's components and, based on that analysis, reuse, refurbish, or replace certain components. An LEP helps the United States maintain a credible nuclear deterrent without producing new weapons or conducting underground nuclear tests.

Alterations

Los Alamos may also conduct alterations (alts), which are changes to a weapon's systems, subsystems, or components. Not as extensive as an LEP, an alteration is a limited-scope change that affects the assembly, maintenance, and/or storage of a weapon. The alteration may address identified defects and component obsolescence without changing a weapon's operational capabilities.

Modifications

Weapons may also undergo modifications (mods), which change a weapon's operational capabilities. A modification may enhance the margin against failure, increase safety, improve security, replace limited-life components, or address identified defects and component obsolescence.

advise policymakers on what is technically possible and to advise technologists on what is policy desirable. We help bridge the gap between policymakers, senior Lab leadership, and technical communities, and serve as a think tank and action group," he says. "What do we need to defend the country? What does that cost? How long will it take to produce it? These are technical questions tied to strategic planning."

In 2019, John Scott, the Lab's Weapons Physics Theoretical division leader, kicked off an effort focused on the intersection of policy and technology by initiating a series of workshops called the Director's Strategic Resilience Initiative, or DSRI.

"DSRI was started as a means to spur cross-disciplinary technical work that looked at how we might maintain the efficacy of our stockpile given the quickly changing global and political landscape and our adversaries' evolving capabilities," Scott says. "Our aim is to demonstrate that Los Alamos, with its strong technical reputation in all things nuclear, can be a convening authority for policy decisions and establish a dialogue between policy and technical communities."

Scott says that policymakers and technical experts must work together. "Policymakers typically do not have technical training as part of their background and will rely heavily on technical expertise on new and emerging technologies. This demands that as technical folks, we need to be able to communicate challenging technical information to nontechnical folks. We need to do a good job of elaborating on the art of the possible and the practical."

Andrew Ross, who holds a joint appointment at Los Alamos and Texas A&M University, started at the Lab in 2021 to help coordinate the DSRI workshops. Ross and his colleagues engage with policymakers, think tank representatives, academics, and technical subject matter experts to help bridge the gap between policy and technical experts and inform, frame, and shape the debate on deterrence.

"I have spent my entire career at the intersection of policy and technology," Ross says. Topics the DSRI workshops examine include the role of nuclear weapons in strategic stability, escalation management, and the future of arms control.

"We bring together people with a diverse range of perspectives as we examine national security and defense planning in a rapidly changing geopolitical environment," Ross says. "We don't always agree; there's never going to be a self-evident right answer, and the game is never over."

But Ross says he is optimistic about the contributions the workshops are making to deterrence planning and policy. "Some options are better than others, and we need to identify those options and figure out how the Lab can facilitate those options. It's the whole reason we're here." ★

Voices of deterrence

Thom Mason
DIRECTOR
LOS ALAMOS NATIONAL LABORATORY

I've always been interested in those aspects of physics that have real-world impacts. My high school yearbook says I wanted to study applied physics, and I don't think there is any more applied physics than nuclear weapons. Science is wonderful and beautiful and lifts the human spirit, but in the end, science is worthy of public investment because it can solve problems that are important. The idea that public investments in science and technology are a worthy thing was really an outcome of the Manhattan Project; what we learned as a consequence of that crash program to bring to bear the most cutting-edge science in a timely way was that an appropriate public investment can achieve public aims. That is certainly true for national security and a variety of other areas. That was the secret sauce that won World War II and the Cold War, and I think that's the secret sauce that's going to get us through the current, very fraught geopolitical environment.

Quaye Quartey
TECHNICAL PROGRAM MANAGER
PLUTONIUM INFRASTRUCTURE

I believe deterrence is the ability to alter a behavior and/or action through the credible threat of retaliation. At Los Alamos, as a recent hire, I'm learning ways in which I can demonstrate data-driven continuous improvement initiatives to support the rapid modernization of the Lab's plutonium infrastructure and associated products. I constantly read literature, meet with subject matter experts, and pose questions to senior leaders in order to develop a more complete understanding of current processes, challenges, and limitations.

Matt Johnson
DIVISION LEADER
PIT TECHNOLOGIES

This is really important to me. You can look at world events today and see it's as dangerous as it's been since the Cuban Missile Crisis. Without a reliable nuclear deterrent, which includes plutonium pit manufacturing (see p. 11), we can't be credible. If our allies can't depend on us to produce pits in the quantities needed to support the global need, they're going to do it themselves. That could lead to an arms race, and the world would become a much more dangerous place. Our allies could develop these capabilities, but they don't because they count on us. It's safer and more secure if we do it and let our allies depend on us.

Miguel Santiago Cordoba
SCIENTIST
WEAPON SYSTEM SURVEILLANCE

I am reminded of a 1983 speech by Ronald Reagan:

"The purpose of our military is simple and straightforward: We want to prevent war by deterring others from the aggression that causes war. If our efforts are successful, we will have peace and never be forced into battle. There will never be a need to fire a single shot. That's the paradox of deterrence."

In this context, deterrence stands as a powerful force and living example of what can be accomplished through the fusion of cutting-edge technology, strategic vision, and precise execution in support of democracy. The Laboratory, as the design agency of four of the seven weapons systems in the on-alert deterrent, has played a central role ensuring the safety, security, and effectiveness of the U.S. nuclear deterrent. This task, far from trivial, requires the integration of multiple technical fields crossing the boundaries of conventional scientific and engineering disciplines and delving into strategic foresight in an intricate global landscape to ensure agility in our ability to respond to emerging nuclear threats and foster stability and security in our nation and the world.

Madeline Whitacre
HISTORIAN
NATIONAL SECURITY RESEARCH CENTER

Deterrence is the ability to avoid conflict due to the threat of retaliatory action.

The Laboratory's historians work to perform research and educate the Laboratory on the history of Los Alamos' deterrence efforts. Our work ensures that the Lab's deterrence efforts are preserved and interpreted for the benefit of the current and future workforce. Our job is to illustrate for the current Laboratory staff how our institution has responded to evolving threats for the past 80 years, ensuring our stockpile remains a viable deterrent.

Chris Gerthe
TEAM LEAD
WEAPONS MISSION TECHNOLOGY

The United States Constitution states that "We the people of the United States, in order to form a more perfect union…provide for the common defence." This means the United States has the power and authority to form military units to protect the country from its adversaries. This protection frequently takes the form of deterrence. For military units to project a credible, believable deterrent, they need to be provisioned with appropriate instruments. Some of those instruments are provided by Los Alamos. The Laboratory ensures the safety, security, and effectiveness of the U.S. nuclear deterrent—specifically the B61 gravity bomb, the W78 warhead, the W76 warhead, and the W88 warhead. Los Alamos designed and currently maintains these systems through modifications, alterations, life extension programs, and other science-based stockpile stewardship work.

Alan Carr
SENIOR HISTORIAN
NATIONAL SECURITY RESEARCH CENTER

To me, nuclear deterrence means relative peace and an opportunity to continue nurturing more effective patterns of behavior in an ever volatile and increasingly complex world.

In a 1965 CBS news interview, our first director J. Robert Oppenheimer noted that the existence of nuclear weapons helped alter long-standing destructive patterns of human behavior, such as increasingly devastating wars fought between the great powers. When we forget what nuclear weapons are capable of, nuclear deterrence is at risk; when nuclear deterrence is compromised, civilization runs the risk of reverting to patterns of behavior likely to bring unthinkable calamity.

The Laboratory's historians identify and interpret information useful for today's stockpile stewardship mission. And we help Los Alamos staff, stakeholders, and the public to remember the delicate nature of the peace made possible, in part, through nuclear deterrence.

Josh Carmichael
GEOPHYSICIST
NATIONAL SECURITY EARTH SCIENCE

My view as an explosion monitoring scientist is that a strong technical capability to monitor for signatures of threats creates an environment of deterrence from potential belligerents. When a state or agent believes that the United States has a scientific ability to detect, identify, and characterize a signature of a weapon, that state or agent is less likely to test or use that weapon. An optimal deterrence is an environment in which such a state or agent believes that U.S. technical ability is both incompletely known to them and beyond what they can evade.

"Integrated deterrence means using every tool at the Department's disposal, in close collaboration with our counterparts across the U.S. government and with allies and partners, to ensure that potential foes understand the folly of aggression."

—Secretary of Defense Lloyd Austin, in his introduction to the 2022 National Defense Strategy

Martin Herrera
DEPUTY DIVISION LEADER
PROTOTYPE FABRICATION

I am fascinated by the skill of our machinists to take material and transform it into complex geometry with very tight tolerances. Being a part of that has been truly rewarding, and knowing the role it plays in our nation's stockpile is inspiring. Even though my career has been dedicated to making weapons, my goal is that we never have to use one of those weapons. That's what deterrence means, and why I'm proud to be a part of it.

Nicholas Lewis
HISTORIAN
NATIONAL SECURITY RESEARCH CENTER

Deterrence is the framework of securing peace by establishing and maintaining the capacity to respond in kind to, or in excess of, potential hostile action from an adversary.

As a historian, I use historical source materials from both inside and beyond the Lab to demonstrate the crucial role that the nuclear deterrent has played in preserving national security, and to provide Los Alamos researchers with the informational resources they need to maintain the deterrent in the present.

Tessa Rose
LEARNING SPECIALIST
WEAPONS MISSION SERVICES

I have a pacifist worldview, and I don't believe that the nation's weapons stockpile is in itself the answer to the world's problems. However, I do believe the deterrence created by a viable stockpile is one strong answer to those problems. Our mission to support that deterrence is in alignment with my pacifist sensibilities, and I'm proud to be a part of it. I teach servant leadership and emotional intelligence skills to the Weapons Production workforce. Without positive leadership, strong interpersonal relationships, and healthy minds, there's no mission.

Mark Davis
CHIEF OPERATING OFFICER
WEAPONS PRODUCTION

Our mission is more important than it's ever been. Deterrence is only good if it's credible and reliable, and that's why we're making new pits, building new detonators, performing research and development, advancing materials science, and all kinds of other things. I'm humbled and honored daily to be involved in something so essential—and at the only place in the nation where that vital work occurs. ★

✦ The ground collapses several minutes after an underground detonation at the Nevada Test Site in August 1969. Cratering is one effect of nuclear blasts.

BEYOND THE BLAST

Scientists at Los Alamos National Laboratory study what happens when a nuclear weapon detonates.

BY JILL GIBSON

✦ A fireball rises into the sky following the 1945 Trinity test—the world's first detonation of an atomic device.

Scientists first witnessed the effects of a nuclear detonation some 210 miles south of Los Alamos, New Mexico, on July 16, 1945. At 5:29 a.m., an ocean of light exploded across the Jornada del Muerto desert. An enormous ball of roiling fire, flashing scarlet, green, and yellow, rose into the sky. Sand swept up into the fireball, fused together, and fell to the ground as radioactive green glass. The tower that had held the nuclear device was gone, vaporized, a shallow crater in its place. The atomic age had begun.

This was the Trinity test—the world's first detonation of a nuclear device and an important milestone in the Manhattan Project effort to build atomic weapons to help end World War II. During the days leading up to the test, scientists struggled to anticipate the outcome. What would be the explosive power, or yield? How far would its shock wave travel? Physicist Edward Teller even wondered if the detonation would set the atmosphere on fire. (Physicist Hans Bethe squashed this notion after an hour of calculations.)

During the test, physicist Enrico Fermi released slips of paper into the air and measured their motion in the shock wave. With this information, he estimated the device's yield to be about 10 kilotons. Fermi's experiment and initial calculations marked the first nuclear weapons effects test.

Eighty years later, scientists at Los Alamos National Laboratory are still studying weapons effects—but not by dropping pieces of paper and not by setting off any nuclear devices. (The United States has been under a nuclear testing moratorium since 1992.)

Instead, scientists rely largely on data from the 1,149 nuclear tests conducted by the United States between 1945 and 1992. This data is incorporated into state-of-the-art computer codes that run on some of the world's fastest and most advanced supercomputers, which produce high-resolution simulations of nuclear detonations and their effects—things like radiation, electromagnetic pulse, and shock waves in the air, ground, or underwater (see p. 32). Scientists can also simulate second- and third-order effects—such as impacts on people, vegetation, vehicles, structures, and electronics. Additionally, variables including topography, geology, weather, and the aboveground elevation of a detonation can be programmed into computer models to produce simulations that allow decision-makers to consider very specific scenarios both at home and abroad.

"There are lots of circumstances when the details really matter," says Los Alamos physicist and nuclear engineer Tim Goorley. "Those details support deterrence and keep the nation safe."

Jim Cooley, who leads the Strategic Analyses and Assessments office at Los Alamos, agrees, adding that the Laboratory's work in weapons effects is increasingly important. "The changing geopolitical landscape and the fact that the United States is facing a threat spectrum that involves multiple adversaries have led to increased focus on weapons effects research," he says.

Building on 80 years of research

Whether Goorley, Cooley, and others are briefing government officials or lecturing Air Force cadets, they draw on nearly 80 years of weapons effects research. The 1,149 nuclear tests conducted by the United States—which took place in the atmosphere, underground, underwater, and even in outer space—are the primary sources of data for weapons effects.

"A great advantage the United States has over almost any other country is that we have more than 1,000 tests worth of data," says Los Alamos senior historian Alan Carr. "Many different tests generated many different types of data, and we learned something from every test."

Much of that data is housed in the National Security Research Center, the Laboratory's classified library, which contains millions of records. "It's an amazing repository of real-world test data," Carr says. "It's of extreme value. Although the ground-shaking blasts of the past may be history, their technical and political legacies continue to guide scientists and policymakers alike in an ever-changing and ever-dangerous world."

During these tests, scientists used various types of diagnostic sensors to capture data. As decades passed,

> **"A key piece of having a credible deterrent is being able to achieve military and political goals on the battlefield."**
> —TIM GOORLEY

technology became more sophisticated, and the measurements and data generated became increasingly complex. By better understanding the variables impacting the detonations and their effects, scientists could refine weapons designs. Although the U.S. nuclear stockpile did grow in size and destructive power during this time, it also became safer as scientists were able to incorporate safety measures.

After the 1992 testing moratorium went into effect, scientists had to rely on computers to model and simulate nuclear detonations and then compare those simulations to past tests. If the comparisons were similar, the computer models were validated.

For more than 30 years, researchers have used high-performance computers and complex multiphysics

✦ Workers in protective gear prepare for the 1945 Trinity test.

WHAT AFFECTS EFFECTS?

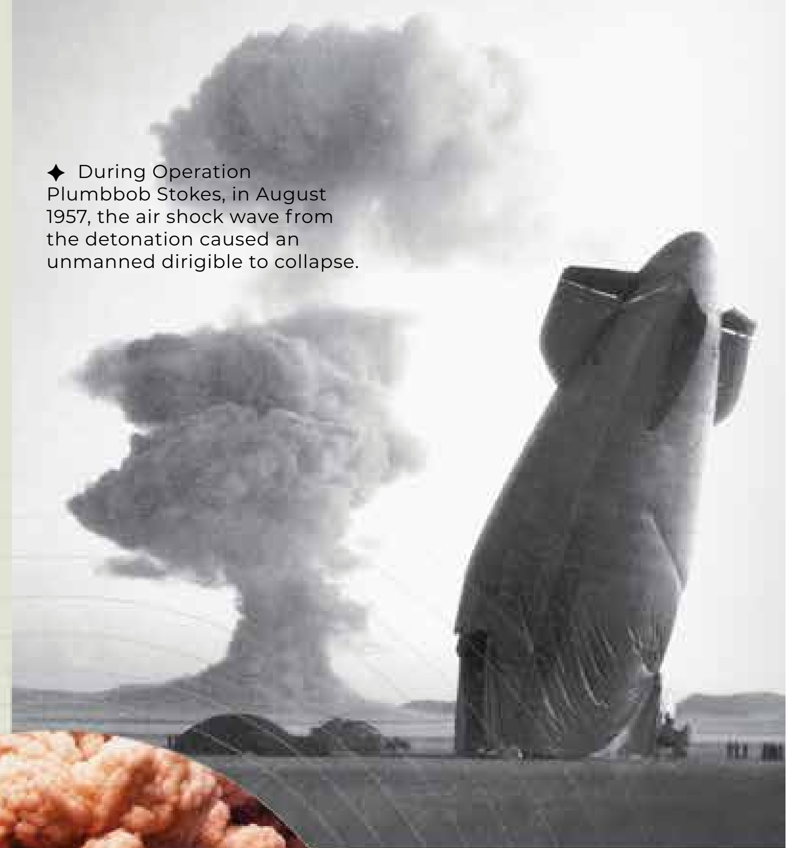
Multiple factors impact what happens as a result of a nuclear detonation.

BY JILL GIBSON

Using historical nuclear testing data and advanced computer simulations, scientists at Los Alamos National Laboratory study the way that nuclear weapons outputs interact with people, vehicles, structures, electronics, terrain, water, and air. The results of these interactions are collectively known as weapons effects.

During and after a nuclear detonation, buildings may collapse. Electronics, satellites, and the regional power grid may fail. Fires, flash blindness, optical sensor burnout, damage to ships and underground facilities, radiation sickness, and general destruction are all possible.

The flash from a nuclear weapon can cause temporary blindness to unprotected eyes, even when a person is not looking directly at the detonation. Thermal radiation can cause burns directly to the skin or can ignite clothing. Prompt (initial) nuclear radiation (gamma rays and neutrons) can lead to radiation sickness and death, or at lower levels, cause cancer. The shock wave radiating outward from the detonation can cause immediate injury, death, or damage to vehicles and buildings. ★



✦ During Operation Plumbbob Stokes, in August 1957, the air shock wave from the detonation caused an unmanned dirigible to collapse.

FALLOUT: Radioactive material—usually a mix of dirt and bomb debris—that is swept into the air during a nuclear detonation and falls back to the ground. Highly radioactive fallout near the detonation location can be deadly, but its rapid decay means that most areas are not highly hazardous for long.

PROMPT RADIATION: Radiation consisting of gamma rays and neutrons produced within a fraction of a second of detonation. Also called initial radiation, prompt radiation can be lethal to living organisms.

THERMAL RADIATION: An intense burst of radiated heat and light that may cause flash blindness, skin and eye burns, and fires. Fires can spread significantly beyond the detonation area.

ELECTROMAGNETIC PULSE (EMP): A brief burst of electromagnetic energy. The electromagnetic interference caused by an EMP can disrupt or damage communications and electronic equipment, computers, and electrical grids. See p. 38 for more.

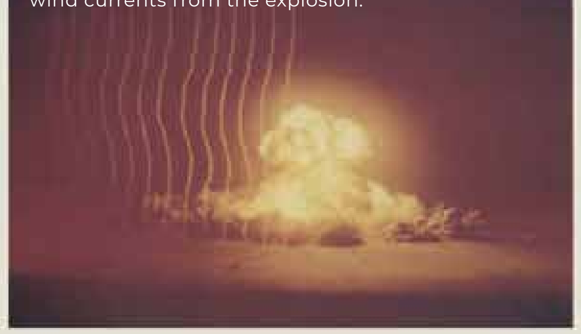
RESIDUAL RADIATION: Radiation produced more than one minute after the detonation, resulting from radioactive materials returning to Earth in the form of radioactive fallout.

GROUND SHOCK WAVE: A shock wave traveling through the ground. Disturbances in the ground produced from the passing of the ground shock wave produce seismic waves. Unlike shock waves, seismic waves do not produce permanent damage to the ground.

SHOCK WAVE: A compressive pressure wave traveling faster than the speed of sound through air, water, or solid material (such as the ground).

WATER SHOCK WAVE: A shock wave traveling through the water. Disturbances in the water produced from the passing of the water shock wave produce hydroacoustic waves.

AIR SHOCK WAVE (ALSO CALLED AIR BLAST): A shock wave in air that radiates outward from ground zero (the detonation site) and produces sudden changes in air pressure that can crush, topple, and throw objects, such as buildings, cars, and trees.



✦ During the Upshot-Knothole Annie test in 1953, researchers used rocket smoke trails to record the propagation of shock waves and wind currents from the explosion.

codes that simultaneously model different aspects of weapons systems and the interactions among them. The result is what's called high-fidelity simulations—high-resolution 3D representations of processes that allow scientists to virtually explore weapons and weapons effects.

As this computational modeling capability has improved over decades, researchers have refined the tests and gathered more data. "The Lab has had decades of development of high-fidelity modeling tools to provide accuracy and confidence," Goorley says. "Visualization of these models and their results has also advanced, which makes communicating key concepts far easier."

Today, modern codes run on extremely large multi-processor computers, such as Crossroads, which was installed at Los Alamos in 2023. High-fidelity simulations typically take from a single day to a month to run, although with recent computer advancements, some can now run in hours.

"Computer simulations provide a way to use high-fidelity mathematical models to study the complex physics of real-world systems and phenomena," says Scott Doebling, senior director for Advanced Simulation and Computing and division leader for Computational Physics. "Scientists can study the complex interactions of physics across a wide range of time- and length-scales following a nuclear detonation."

Other, older computer codes, called legacy codes, are engineering-based, creating 1D and 2D simulations that can be generated much faster than the more complex, physics-based simulations that the high-fidelity codes

> **"Hollywood gets a lot of things wrong."**
> —TIM GOORLEY

create. Legacy codes can analyze the possible effects of a detonation on thousands of targets in just minutes and can be run on a laptop in the battlefield.

"We continue to work with the legacy codes because they can provide information and predictions quickly," says Trevor Tippetts, a research and development engineer at Los Alamos. "Although these simulations are less sophisticated than the high-fidelity simulations, they could be invaluable for the military to explore many possible outcomes and optimize for the best case."

Goorley points out that regardless of the codes used, additional experiments are needed to validate the

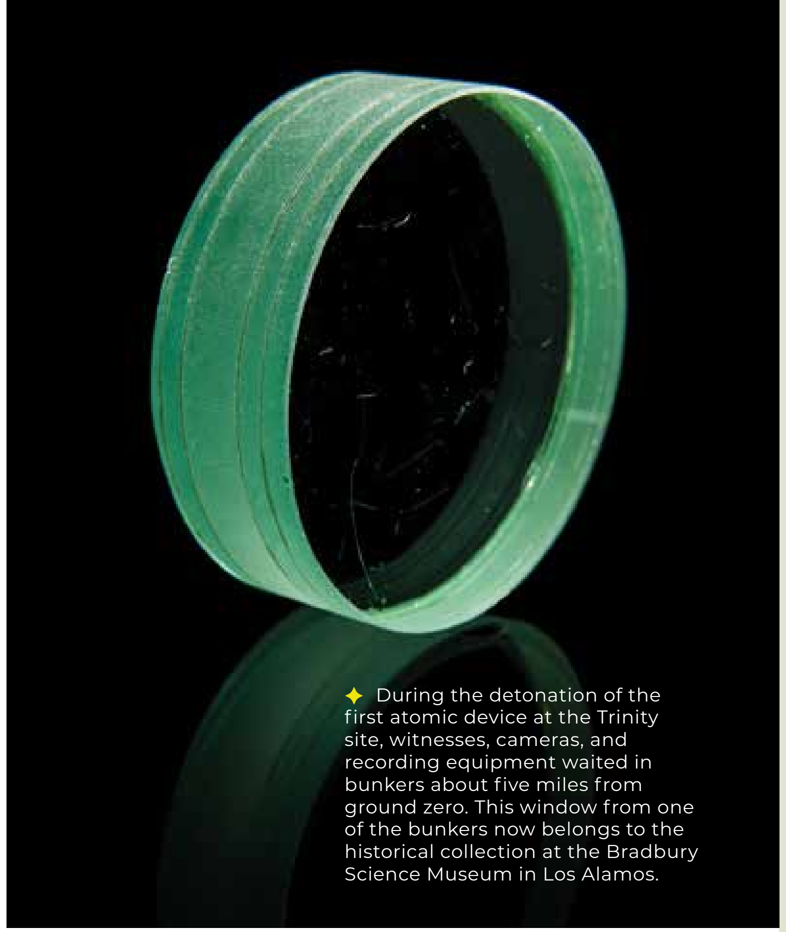
✦ This pair of protective goggles was used by an observer of the Trinity test in 1945. The dark glass, similar to welding glasses, helped shield the onlooker's eyes from the bright light emitted from the blast.

simulations. That's where nuclear effects emulators come into play.

Nuclear effects emulators are experiments that imitate real-life conditions like those that occur during an actual nuclear blast. Emulators may mimic the extreme heat of thermal radiation or the electromagnetic interference a detonation creates.

One example is the White Sands Solar Furnace at the White Sands Missile Range near Alamogordo, New Mexico. The 45-foot-tall by 100-foot-long facility focuses and concentrates the Sun's rays using mirrors to generate a temperature of more than 4,500 degrees Fahrenheit, similar to the heat from a nuclear blast some distance away. Other devices such as the Large Blast Thermal Simulator and the Gamma Radiation Facility produce environments that allow researchers to examine specific weapons effects.

"We can look at how military and civilian equipment and hardware and various types of electronics will withstand the intense thermal radiation and powerful shock waves," Goorley says.



✦ During the detonation of the first atomic device at the Trinity site, witnesses, cameras, and recording equipment waited in bunkers about five miles from ground zero. This window from one of the bunkers now belongs to the historical collection at the Bradbury Science Museum in Los Alamos.

Defending the homeland

Weapons effects simulations and emulations, backed by historic testing data, continue to inform national security policy, particularly for thinking about a nuclear attack on American soil.

After the Soviet Union detonated its first nuclear weapon in 1949, the U.S. military wanted to understand how to fight through the aftermath of a nuclear blast and win on the battlefield. From 1951 to 1957, 30 nuclear detonations in the Nevada desert were accompanied by military exercises. Some units conducted simulated infantry, armored, and airborne assaults with associated live fire to test equipment functionality, while others observed the detonations from a few miles away. The exercises involved extensive testing of equipment, vehicles, and fortifications, as well as assessing the impact of flash blindness from atomic blasts and the amount of radiation protection that armored vehicles provided. Psychologists conducted interviews before and after the exercises to understand the role of training and preparation in enhancing combat capability.

> "Understanding weapons effects is part of developing a stable, well-defined nuclear strategy and policy."
> —JIM COOLEY

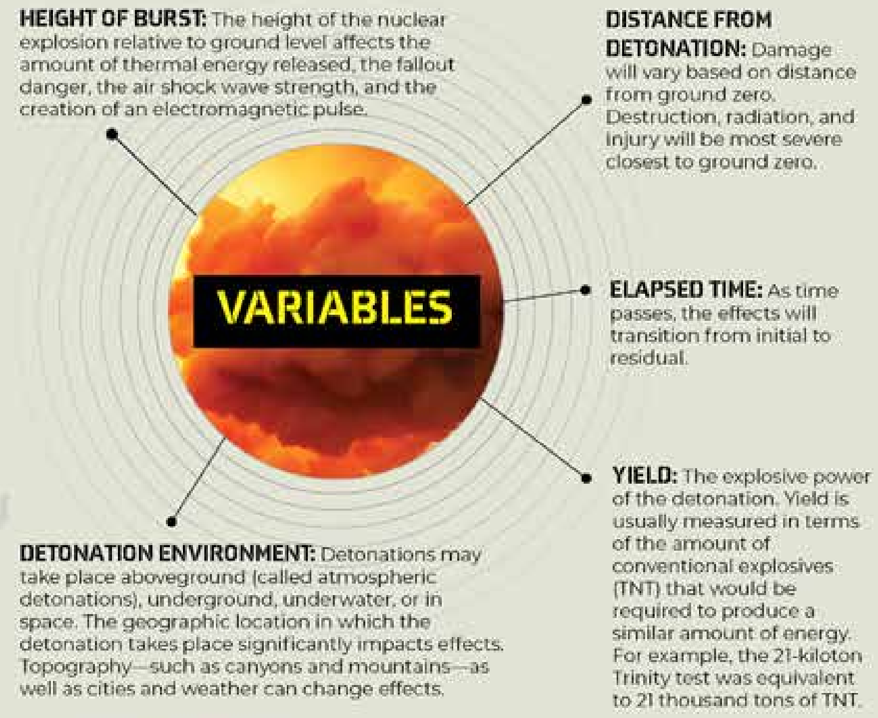
"There are many things we have learned from these tests about how to ensure troops, equipment, and facilities are secured against adversary attack," Goorley says. "Resilience and survivability matter. A key piece of having a credible deterrent is being able to achieve military and political goals on the battlefield."

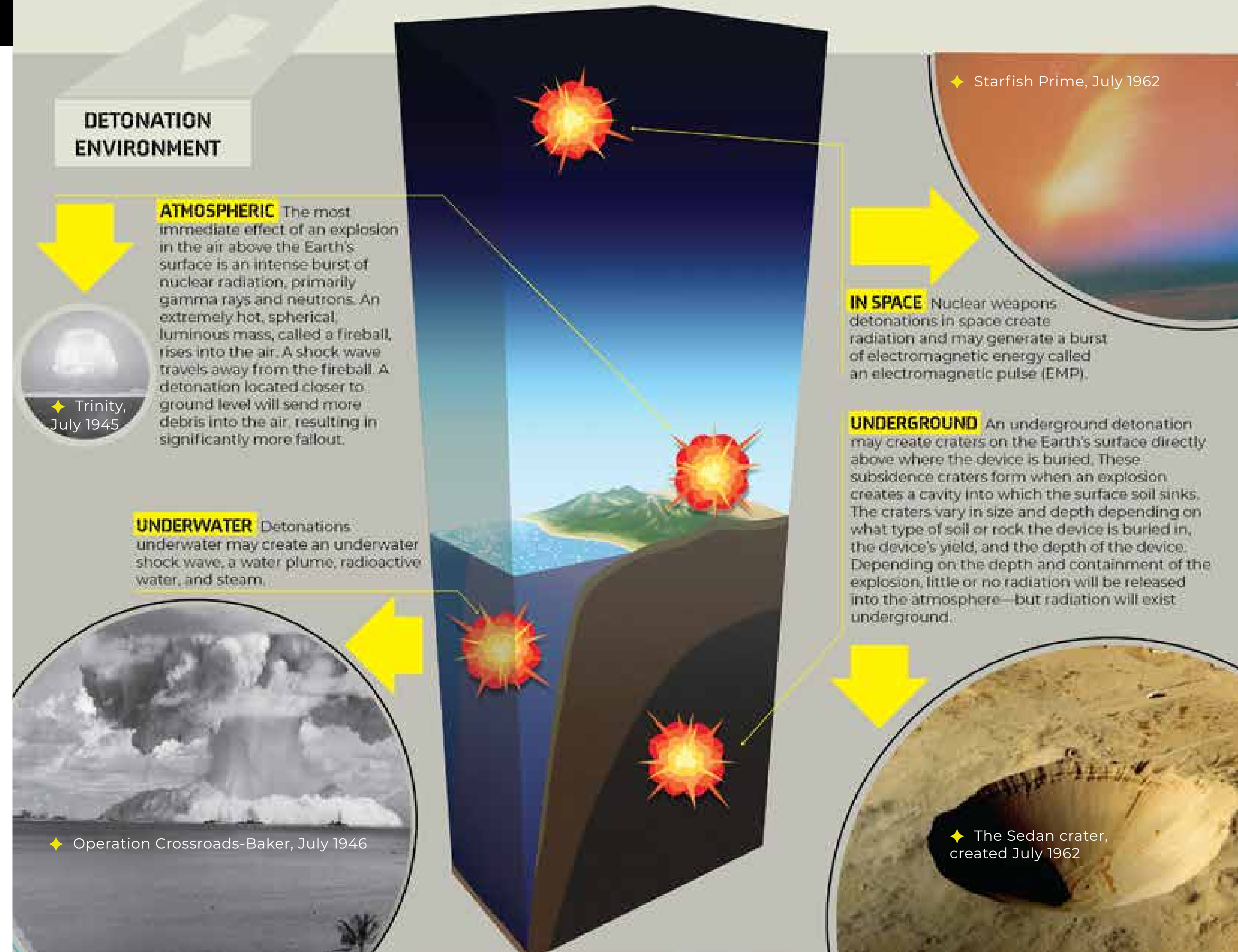
Another rationale behind studying nuclear weapons effects is preparing first responders for the possibility of a nuclear weapons attack. Los Alamos physicist Randy Bos says movies and television have shaped the public's perception. "When I worked with the Federal Emergency Management Agency on nuclear weapons response strategies, I realized how many myths there are. Understanding the truth about weapons effects is essential for emergency responders and healthcare workers," he says. "Ultimately, there is lifesaving that can be accomplished by the emergency responders if they understand and plan for the realistic, limited impacts of these detonations."

FACTORS IMPACTING MAGNITUDE OF EFFECTS

The design and explosive power of a nuclear weapon can change the impact of a nuclear detonation. Other important factors include the height of the burst above ground level, the distance of structures or living organisms from ground zero, the amount of time elapsed from the moment of detonation, and the environment in which the detonation takes place.

Residual effects and other long-term consequences may follow the initial impact of a nuclear detonation. These may include destruction or irradiation of major population centers, contamination of the food supply, and electrical disruptions. ★





A bank vault remains largely intact after surviving a 1957 nuclear test.

U.S. Air Force Lieutenant Colonel James Bevins, of the Defense Threat Reduction Agency's Nuclear Assessments Division, is a former Los Alamos Air Force Fellow. Bevins points out that many of the injury and damage prevention measures for a nuclear detonation are similar to those implemented to protect people from the effects of conventional weapons. "Understanding how people can be triaged and treated and how modern construction can provide shielding is key," Bevins says. "Simple measures can go a long way to reduce casualties."

Another misconception about nuclear weapons effects focuses on a nuclear detonation's ability to create a powerful wave of electromagnetic energy called an electromagnetic pulse (EMP, see p. 38) that has the potential to disrupt electronics, the power grid, and communications technology. "People tend to think an EMP is going to knock us back into the Stone Age," Bevins says. "While it is a challenge to predict and work around EMP effects, it won't knock out all electrical systems. There may be some disruption and damage, but we can build protected and redundant systems thanks to our understanding of EMP effects."

Computer models and simulations also allow scientists to predict how fires might spread following a detonation. "Nuclear detonation–induced fires could be a major concern for first responders," Bos says. "Computer simulations allow us to predict how a detonation's initial thermal pulse will start fires. These fires may then combine with secondary fires caused by broken gas lines and ruptured fuel lines, spreading rapidly and threatening large areas."

Similarly, simulations provide insight into effects on modern structures and the way trees and similar items deflect and absorb energy. The complex computer codes consider the many factors that shape the impact of a nuclear detonation. Two of those factors are the geographic location and the weather at the time of the detonation. Simulations can provide realistic representations of topographical locations, including canyons, mountains, and cities. The codes can even create simulations of how underground structures would be affected.

Resilient and survivable weapons systems

Weapons effects research is valuable not only for defending the United States but also in the event that the United States deploys a nuclear weapon against an adversary.

"Many people think that a nuclear weapon is just a nuclear weapon. That's not the case," says Bob Webster, deputy director for Weapons Programs at Los Alamos. He notes that Los Alamos scientists are working to design and maintain weapons that achieve specific purposes with particular targets. Successfully achieving this goal requires understanding all aspects of weapons effects.

"The point is to ensure that at any moment in time, our nuclear deterrent is fit for the purpose," Webster says. "In a changing world, you don't necessarily get to pick that time."

Webster notes that modern warfare requires a more specialized approach to weapons development. "It is becoming increasingly clear that our adversaries can make

EFFECTS IN ACTION

Los Alamos staff provide weapons effects analysis for military planners.

BY JILL GIBSON

Twenty-five-year-old Angel Padilla has devoted an entire year to blowing up bridges—simulated bridges, that is.

"Actually, what I do is run computer codes that simulate the effect of nuclear detonations on particular physical structures, such as bridges and buildings," says the research technologist at Los Alamos National Laboratory. "We have spent the past year focusing on one bridge."

Padilla's work is part of a collaboration between Los Alamos, Lawrence Livermore, and Sandia national laboratories to assess weapons effects on specified structures for the U.S. Department of Defense (DOD).

"We conduct highly complex nonlinear system modeling, with each lab using its own in-house developed computer codes," Padilla explains. The resulting simulations have allowed researchers to examine everything from blast orientation, height of burst, and range from target. The computer models even allow scientists to consider factors such as materials used to build structures and estimated time for repairs.

"Just at Los Alamos, we have used about four million CPU hours on this one project," she says, noting the simulations would not be possible without the Lab's supercomputers. Running a single analysis can take three to four days. "We also do a lot of validation and verification against other lower-fidelity codes and experimental data and compare results among the three labs to create a higher level of confidence."

Padilla, who has a background in civil engineering, started at Los Alamos in 2021 following an internship at the Lab during her master's program. She says she never anticipated a career analyzing weapons effects but finds the work fascinating. "Keeping up with multiple projects and building and running the simulations keeps me and my team very busy," she says. "I was surprised to learn how far-reaching and how many applications there are for the computer codes we use."

Padilla says the information the codes generate often takes months to dissect and analyze. "While there will always be a certain level of uncertainty, the results that the three labs working together have achieved provide confidence," says Padilla, adding that the team's next step is to present its findings to DOD and then start analyzing the next objective. ★

Angel Padilla, standing on a pedestrian bridge in Los Alamos, says the computer simulations she produces bridge important strategy gaps for military planners.

EMP: COULD IT HAPPEN TO ME?

A Los Alamos physicist debunks myths about electromagnetic pulse.

BY JILL GIBSON

It's a scene out of a science fiction movie: A nuclear detonation creates a burst of electromagnetic energy that wipes out communication and electronic equipment and disables the nation's power grids. From the internet to cell phones, all systems fail. Chaos erupts as America is thrown back into the dark ages—all technology and critical infrastructure suddenly gone.

Could that actually happen? Los Alamos National Laboratory physicist Randy Bos says, "Probably not."

Bos is a nuclear weapons effects specialist who has researched weapons effects for decades and has provided nuclear detonation response guidance for Federal Emergency Management Agency teams. "Yes, we know a nuclear explosion will generate an electromagnetic pulse (EMP), which, depending on the circumstances, could disrupt certain electronic equipment, but the doom and gloom scenarios will not happen. That stuff belongs in Hollywood," he says.

Bos explains that researchers first discovered that nuclear weapons generate a burst of electromagnetic energy in 1962, when a high-altitude nuclear test, called Starfish Prime, detonated above the Pacific Ocean and hundreds of streetlights in Oahu, Hawaii, more than 700 miles away, went dark.

Nuclear explosions generate gamma rays that can react with air molecules, causing a powerful wave of electromagnetic energy—electric and magnetic fields traveling at the speed of light. Because of the way high-altitude denotations interact with the atmosphere and the Earth's magnetic field, high-altitude EMPs can be especially destructive, having the potential for far-reaching effects on electrical and electronic systems. Bos notes that during nuclear detonations near or on the Earth's surface, areas that would experience significant EMP effects would also be severely impacted by air blast, thermal radiation, and fire. "When you're at ground zero of a near-surface detonation, EMP isn't going to be the biggest concern."

EMPs pose no threat to people, but they can cause dramatic voltage surges that may impact everything from car engines to cell phone transmitters. Bos says the key word here is "may." The crippling devastation EMPs produce in the movies are highly unlikely, according to Bos.

"In general, the EMP must occur at the right place and the right orientation to have a significant impact," Bos says. "There are multiple factors that must coincide."

Bos notes that the U.S. national laboratories and other government agencies are working with industry experts to study and develop systems that can withstand all types of electromagnetic disturbances. A 2019 executive order prioritized research and development to address the potential danger of an EMP. Los Alamos scientists are supporting that order through

✦ Summer Jones, assistant deputy administrator for Production Modernization in Defense Programs at the National Nuclear Security Administration, presented a Defense Programs Award of Excellence to Jim Cooley on March 20, 2023. Cooley was recognized for leading a team that completed several studies that characterized the impacts of EMP on critical infrastructure.

projects that calculate EMP effects and electrical power grid performance.

Bos says scientists have digitized and analyzed EMP data from historical testing and EMP emulators—devices that mimic the output of an EMP. They've also used computer simulations to examine EMP impacts. Multiple government studies have examined the EMP threat, and private companies have researched how an EMP will affect telecommunications and power grids.

The risks of EMPs are similar to those of geomagnetic storms—naturally occurring disturbances in the space around the Earth controlled by the planet's magnetic field. "The power industry has done a great deal of work to protect the nation's electric grid from power surges and potential outages caused by geomagnetic storms," says Bos, pointing out those measures also mitigate against a nuclear explosion–generated EMP.

"These technological advances and hardening measures help protect electrical production facilities, transformers, and power distribution lines," Bos says. "There was a period of time in the development of electronics, the power grid, and communications technology when the EMP threat would have been greater, but now most of the equipment will not be affected. Some unlucky people may end up with fried electronics, but most of us, at the worst, will just have to reboot our computer or cell phone." ★

certain targets more difficult to attack, so we need a more specialized approach," he explains. "Truly appreciating the effects of nuclear weapons factors into what weapons' designs and modifications look like."

U.S. Air Force Colonel Joshua Henderson, formerly a Los Alamos Air Force Fellow and now the National Nuclear Security Administration's executive action officer to the U.S. Nuclear Weapons Council, explains that robust communication is necessary between the national laboratories (that design the weapons) and the military (that uses the weapons). "This relationship between the armed services and the laboratories allows us to provide the best options and advice to senior leadership," he says. "By better understanding weapons effects, we can talk more specifically about what designs we need and for what end and purpose. We can say, 'I want this tool, with this power, by this date.'"

For Goorley, the bottom line is simple. "The Department of Defense [DOD] is the Lab's end customer. When we design a weapon, we need to be sure it does what they need it to do."

Modern nuclear weapons can be designed specifically to destroy underground targets, to disrupt electronics and communications systems, to level buildings and infrastructure, or to create casualties. Whatever the goal of a weapons system, experts say the design and the effects always go hand in hand.

"The goal is to ensure effectiveness," Goorley says. "In other words, does the military target get destroyed to the degree it needs to be destroyed?" Weapons designers must also consider more nuanced questions: Can a target be destroyed while minimizing civilian casualties? What does it take to render an airstrip unusable? Goorley notes that "each weapon has its own strengths and weaknesses—for instance, a weapon designed to function underwater for destroying submarines will be different from an air-deployed weapon." All of these factors must be considered by weapons effects researchers who endeavor to ensure the reliability and effectiveness of the nation's nuclear deterrent.

An emphasis on effects education

An increased focus on weapons effects recently resulted in a new position at the Laboratory: chief scientist of weapons effects. Goorley was selected for that role in July 2023 and now spends much of his time synchronizing new and ongoing nuclear weapon effects efforts across the Laboratory. Many of these efforts happen at the request of external stakeholders, such as DOD, and require additional expertise from other laboratories, especially sister labs Lawrence Livermore and Sandia, so Goorley finds himself coordinating across a broad spectrum of organizations.

"I'm excited that Los Alamos is placing more emphasis on nuclear weapon effects to address the increasing interest from the National Nuclear Security Administration, DOD, and other interagency partners," Goorley says. "I believe that the Laboratory is well positioned to not just contribute, but lead, several important nuclear weapons effects topics."

In addition to helping Los Alamos develop new modeling and simulation capabilities, one of Goorley's primary objectives is educating people—the public, policymakers, members of the military, and pretty much anyone else he encounters—about weapons effects. Armed with posters and talking points, Goorley is always ready to discuss what really happens when a weapon detonates. He often points out that a nuclear detonation is highly complicated and debunks myths and misunderstandings about nuclear devices. "People tend to believe what they see in TV and movies, but Hollywood gets a lot of things wrong," Goorley says. "Many movies suggest that a nuclear detonation will destroy most of life on Earth. That's not the case."

Bevins agrees that education is paramount because so many people have misconceptions about nuclear weapons. "In the current geopolitical environment, it is essential that we spread the word that Hollywood portrayals of nuclear weapons are often not accurate frames of reference for the threats we face," he says. "The challenges of operating in nuclear environments are immense but are more tractable than commonly believed."

Bevins says his goal is to increase what he calls "DOD's collective nuclear IQ."

"Examining our knowledge of weapons effects has many benefits," he says. "The information allows us to create resilient and survivable weapons systems. It helps in the development of battlefield strategies and prepares the military to operate in the face of a nuclear attack, which denies our adversaries the benefits of using nuclear weapons."

Cooley also stresses the need for Los Alamos scientists to provide military leadership with sufficient information to understand effects and ask the right questions. "Understanding weapons effects is part of developing a stable, well-defined nuclear strategy and policy," Cooley says.

To facilitate these conversations, Goorley has implemented a Lab-wide forum he calls Nuclear Weapons Effects Community Conversations. Subject matter experts, managers, and leaders from across the Lab gather each month to hear technical talks, program overviews, and policy updates. "All perspectives are welcome," Goorley says. "Together we can leverage information, achieve synergies, unite experts, and become aware of all capabilities across the Lab."

Cooley notes that although the study of weapons effects began in 1945 with the first nuclear detonation, the research continues. "The world is a dangerous and complicated place, and the study of weapons effects is part of the science and psychology behind deterrence." ★

A bomber's point of view

An Air Force Fellow's trajectory reflects the evolving role that nuclear weapons play in national security.

BY JAKE BARTMAN

A B-1 crew demonstrates its patriotism by "flying" an American flag in the cockpit. Photo: U.S. Air Force

Unlike many U.S. Air Force call signs that refer to an embarrassing incident in an airperson's history, Major Chandler Anderson's call sign, Mister, is benign. The name is a reference to *The Matrix*, whose protagonist Thomas Anderson is often addressed by the film's antagonist as "Mr. Anderson."

"The way the call sign was explained to me was, 'You're calm, cool, and collected. You've always done a good job. You've never done anything terrible—and so 'Anderson,' 'Mister'—it just went hand in hand," Anderson explains.

A "calm, cool, and collected" demeanor, like the one exhibited by *The Matrix*'s protagonist at the movie's climax, is key for someone in Anderson's line of work. Beginning in 2013, Anderson spent the better part of a decade as a weapons systems officer on a B-1 Lancer, where he was tasked both with dropping weapons and ensuring that his aircraft returned safely to base.

In the summer of 2023, Anderson and his family relocated from Barksdale Air Force Base in Louisiana, where he'd been stationed since 2020, to Los Alamos, New Mexico. Each year, Los Alamos National Laboratory hosts two members of the Air Force for a yearlong fellowship that aims to foster collaboration between those who design nuclear weapons and those who are tasked with potentially using them. Having been selected as the junior Air Force Fellow, Anderson came to New Mexico to learn about all of the ways in which the Laboratory supports the nation's security.

Those who are familiar with the Air Force might be surprised by Anderson's selection as a fellow at a nuclear weapons laboratory. After all, the B-1—or "Bone," as the bomber is nicknamed (a phonetic pronunciation of "B-one")—stopped carrying nuclear weapons in 1994, well before Anderson ever flew in the aircraft.

■ Chandler Anderson, second from right, with fellow B-1 crewmembers after a sortie—or combat mission—during Anderson's 2018–2019 deployment to Al Udeid Air Base, Qatar. Photo: Chandler Anderson

Anderson, however, sees the B-1 as part of the United States' broader endeavor to deter its potential adversaries. And the Air Force Fellow program helps prepare a new generation of leaders, like Anderson, to field the United States' nuclear weapons.

In fact, the arc of Anderson's career—his experience onboard an aircraft, followed by a transition to nuclear strategy-making with an emphasis on deterrence—reflects the shifting geopolitical environment that the United States faces, and the evolving role that the nation's nuclear enterprise is liable to play in helping to keep the country safe from potential adversaries.

"This is a phenomenal opportunity for us fellows, because we warfighters—the tip of the spear, as they say—are the ones potentially dropping the weapons," Anderson says. "But the folks at Los Alamos are the ones who make that happen for us. It's a great opportunity to bring that full circle."

By land, sea, or air

The United States' nuclear weapons can be delivered by three avenues that, taken together, are referred to as the nuclear triad. Aircraft that carry nuclear bombs and cruise missiles constitute the air leg of the triad, while ballistic missile-bearing submarines are the sea leg, and intercontinental ballistic missiles (ICBMs) are the land leg. Both the air and land legs of the triad are administered by the Air Force, while the U.S. Navy operates the sea leg. (For more on the United States' nuclear triad, see p. 22.)

> **"We warfighters—the tip of the spear, as they say—are the ones potentially dropping the weapons."**
>
> —CHANDLER ANDERSON

The air leg of the nuclear triad is considered the most flexible. Aircraft can be deployed in a crisis to indicate the United States' intentions and to reassure the nation's allies. Moreover, unlike missiles launched from silos or submarines, planes can be recalled. The B-2 Spirit stealth bomber and the B-52 Stratofortress, the Air Force's two nuclear-armed bombers, are capable of carrying a mix of nuclear weapons: the B-2 can carry both bombs and air-launched cruise missiles, while the B-52 carries cruise missiles.

Today, all three legs of the triad are being modernized. The Air Force's Minuteman III ICBM is slated to be replaced by the LGM-35A Sentinel missile, while the Navy's Ohio-class strategic ballistic missile submarines will be replaced with Columbia-class vessels. (See p. 52 for more on nuclear-armed submarines.)

The Air Force's heavy bomber fleet is undergoing a transition, too, with both the B-1 (Anderson's former aircraft) and the nuclear-armed B-2 slated to be retired and replaced by the stealth B-21 Raider. Meanwhile, the B-52, which flew its first mission for the Air Force in the 1950s, is expected to remain in service until at least the 2040s.

This plan represents a departure from what the Air Force envisioned when the B-1 entered service in the 1980s. Indeed, the supersonic B-1 was intended to replace the relatively slow B-52 as the Air Force's flagship nuclear-armed bomber. Yet the history of the B-1 captures some of the ways in which the United States' nuclear strategy has evolved over the past half century.

A brief history of the Bone

During the first years of the Cold War, the U.S. Air Force focused on developing aircraft that flew at sufficiently high altitudes and speeds to keep them safe from surface-to-air missile defenses. But by the 1960s, advances in the Soviet Union's air-defense technologies made high-altitude aircraft obsolete—a point emphasized in April 1960, when Gary Powers' U-2, flying at an altitude of some 65,000 feet, was shot down by the Soviets.

In the 1970s, the Air Force's strategy shifted to developing bombers that could deliver cruise missiles—including nuclear-armed cruise missiles—launched far enough from targets to keep the bombers from being detected by enemy air-defense systems. The B-52, which entered service in the 1950s, fulfilled this function. However, the Air Force argued that a supersonic jet bomber designed to fly at low altitudes and high speeds would be still less vulnerable to air-defense systems than the relatively slow B-52. For this reason, the Air Force continued to push for the B-1's development.

During the late 1960s and early 1970s, the B-1 program ran into mixed political headwinds. After the Nixon administration reinstated the B-1 program, the Carter administration unceremoniously canceled the bomber's development in 1977. It wasn't until January 1982, after the Reagan administration revived the B-1 program, that the Air Force awarded a $2.2 billion contract to Rockwell International for 100 B-1s. The last plane was delivered to the Air Force in May 1988.

Of the three bombers in the Air Force's arsenal today—the B-1 Lancer, B-2 Spirit, and B-52 Stratofortress—the B-1 is the fastest, with a max speed of Mach 1.2, or around 900 miles per hour. The B-1 can carry up to 75,000 pounds of ordnance—more than either the B-52 or the B-2—and fly at altitudes greater than 30,000 feet.

Although the B-1 was designed to carry nuclear weapons, the aircraft's portfolio began to change when, in 1991, President George H. W. Bush and Mikhail Gorbachev, president of the Soviet Union, signed the Strategic Arms Reduction Treaty (now known as START I). In keeping with the treaty, which limited the number of nuclear-armed bombers that each country could operate, the Bush administration decided that the B-1 would become a conventionally armed aircraft.

> **"The B-1 is a super complicated aircraft, and it's America's workhorse."**
>
> —CHANDLER ANDERSON

Beginning in 1994, the Air Force stopped maintaining the arming and fuzing systems that made the B-1 nuclear capable, and the bomber ceased carrying nuclear weapons. However, it wasn't until 2007 that the Air Force began to remove the wiring and mounting points that had allowed the B-1 to carry nuclear bombs and nuclear-armed missiles, rendering the bombers permanently incapable of deploying those weapons. The conversion process was completed in 2011, under the New START treaty.

With this change, the responsibility for delivering nuclear weapons was left to the B-52 and the stealth B-2. The shift also meant that the B-1 wouldn't end up replacing the B-52 after all. Instead, in the next five years, the B-21 Raider will replace both the B-1 and the B-2.


Photo: U.S. Air Force


Photo: U.S. Air Force


Photo: U.S. Air Force


Photo: Northrop Grumman

■ From top: a B-52H Stratofortress, a B-1B Lancer, a B-2A Spirit, and a rendering of a B-21 Raider.

The Air Force has decided to retire the B-1 and B-2 in part because these bombers have proven expensive to maintain and upgrade. Although younger than the B-52, the United States' B-1s suffered significant wear and tear over the course of two decades of service in the Middle East, necessitating overhauls that could cost as much as $30 million per aircraft. Phasing out the B-1s in favor of the B-21 and B-52 will be more cost effective than upgrading all the planes, while still allowing the Air Force to meet its objectives.

Although the B-1 won't end up replacing the B-52 as planned, the B-1 will go out on something of a high note, having belatedly found its niche not as a nuclear-armed bomber, but as a conventionally armed bomber that supported U.S. and allied military operations against groups such as the Islamic State. Anderson is well qualified to speak about the Bone's capabilities in such missions, having flown more than 800 combat hours in a B-1 above the Middle East.

An airman's progress

Anderson is a third-generation member of the United States' armed forces, going back to his grandfather, who flew planes and served for more than two decades in the Air Force. While Anderson was a college student at Georgia Institute of Technology—he was admitted on a football scholarship and specialized in punting—he decided to follow his brother's example by joining the Reserve Officers' Training Corps (ROTC).

From the beginning, Anderson felt that his path in the military would lead to the sky. "I decided I wanted to fly airplanes, and that was it," he says. In 2011, Anderson completed ROTC and received a commission to the Air Force. At the beginning of 2012, he relocated to Pensacola, Florida, for flight school.

After earning his wings in 2013, Anderson was assigned to be a B-1 weapons systems officer—tasked with operating the sensors and weapons of an aircraft—in the 34th Bomb Squadron at Ellsworth Air Force Base in South Dakota. The 34th Bomb Squadron, nicknamed the "World Famous Thunderbirds," is the fourth-oldest active squadron in the Air Force, having been founded shortly after the United States joined World War I in 1917. While with the

■ In collaboration with the South Korean air force, U.S. Air Force and Marine Corps aircraft—led by a B-1 bomber—conducted a continuous bomber presence mission over the Korean Peninsula on September 18, 2017. The mission was carried out in response to North Korea's test of an intermediate-range ballistic missile on September 14.
Photo: U.S. Army/Steven Schneider

The B-1 is one of the U.S. Air Force's three heavy bombers. Photo: U.S. Air Force

Thunderbirds, Anderson completed two tours of duty, first at Al Udeid Air Base in Qatar and then at Andersen Air Force Base in Guam.

This latter tour involved what is known as "continuous bomber presence" missions. These missions are conducted to deter potential adversaries of the United States by demonstrating America's ability to strike targets around the world. For example, in 2017, after North Korea conducted an ICBM test, two B-1 bombers, escorted by Japanese and South Korean fighter jets, flew from Guam and over the Korean peninsula in what was intended as a show of force to the North Korean regime.

Anderson's first tour of duty with the 34th Bomb Squadron to Al Udeid involved active combat. The United States began conducting military operations at Al Udeid in the early 2000s. Throughout the 21st century, the air base has served as a center of operations for American and allied forces in the Middle East, including during Operation Enduring Freedom in Afghanistan. More recently, Al Udeid served as the center of U.S. operations for the American-led coalition against the Islamic State.

It was at Al Udeid that the B-1, now outfitted for conventional combat, came into its own. "For roughly 20 years, from the time that the United States started conducting operations out of Al Udeid Air Base, there was a B-1 in the sky 24/7," Anderson says.

A B-1's four-person crew comprises two pilots and two weapons systems officers, or "wizzos," in Air Force slang. As a weapons systems officer, Anderson is qualified to sit in both the left and right rear seats, whose occupants operate the aircraft's defensive systems (which protect the bomber from air- or ground-based threats) and offensive systems (which enable the crew to target and drop weapons), respectively.

When Anderson arrived at Al Udeid in 2015, the United States was still conducting regular bombing operations in the Middle East. For Anderson, a typical week would involve two sorties, or missions, with an average duration of 12 to 17 hours each. His longest sortie lasted some 20 hours.

That duration doesn't include the several hours of preparation that precede each mission. Sorties would typically begin four hours before takeoff with an intelligence briefing and a review of the air tasking order that dictated the mission's objectives. Two hours prior to takeoff, the flight crew would dress and gather its gear, arriving at its B-1 about an hour before flight time. Then the B-1 would take to the skies, remaining aloft until, after 12-plus hours, the plane would land and its crew would debrief.

"It felt like a time warp," Anderson says. "You're leaving at breakfast, flying, and coming back, and then the people you saw the day prior are eating breakfast again."

Contributing to the "time warp" experience was the tempo of the sorties themselves. On a typical sortie, Anderson's B-1 might fly east from Al Udeid over Pakistan and into Afghanistan, or north over Bahrain and through Kuwait into Iraq or Syria. At that point, the B-1 would need to refuel, accepting some 80,000 pounds of fuel in the air from a Boeing Stratotanker hovering above. Then there might be several hours "on station"—during which the B-1's crew would drop ordnance onto targets—followed by another break for refueling, several more hours on station, and the journey back to base.

The B-1 no longer carries nuclear weapons, but it continues to play a vital role in deterring the United States' potential adversaries. Photo: U.S. Air Force

"After that, you'd get off, eat, and rest," Anderson says. "Then, before you knew it, it'd been three days, and we'd go do it again."

The B-1 has the largest internal payload of any Air Force bomber. In addition to 24 air-launched cruise missiles or 24 2,000-pound Joint Direct Attack Munitions (JDAM), the B-1 can carry up to 84 500-pound bombs. That capacity is why the six B-1s that flew as a part of Operation Allied Force—a 1999 bombing campaign by North Atlantic Treaty Organization forces against the Republic of Yugoslavia during the Kosovo War—delivered more than 20 percent of the operation's total ordnance while flying less than 2 percent of sorties.

"The B-1 is a super complicated aircraft, and it's America's workhorse," Anderson says. "Over the course of two combat deployments, I stopped counting after I dropped my 400th bomb."

One of Anderson's most memorable missions was in 2015. On that sortie, his B-1 flew in support of a group of A-10 Thunderbolts, or "Warthogs"—fighter jets that often provide close air support to friendly ground troops.

Having discovered a pocket of 30 to 40 enemy fighters, Anderson says, the A-10s were well poised to drop munitions onto, and deploy guns against, targets. But due to a mechanical malfunction, the A-10s couldn't use their laser targeting systems. Fortunately, Anderson was able to carry out what is called a "buddy lase," targeting the weapons that the A-10s would then drop.

"We were able to get rid of every target that was nominated for us," Anderson says. "On that particular sortie, I flew with two colonels, and both of them said that it was the most dynamic sortie they'd ever been on. Everything that the joint tactical air controller requested of us, we did."

Air Force bomber crews pride themselves on achieving a "Winchester," which involves attaining a mission's objectives to such a degree that a bomber returns to base without any munitions left onboard. That Anderson's aircraft achieved a Winchester on that mission was icing on the cake.

Integrated deterrence

Although the B-1 no longer carries nuclear weapons, Anderson says that its dependability in combat and on Bomber Task Force missions

At Los Alamos, Chandler Anderson is studying science-based stockpile stewardship, nuclear weapons effects, and counterproliferation, among other topics.

means that the aircraft still plays an important role in deterring the United States' potential adversaries. (Bomber Task Force missions are training and deterrence missions that ensure the Air Force's ability to operate around the world and in collaboration with the United States' allies and partners.)

In particular, Anderson says, the B-1 helps ensure the nation's ability to achieve strategic deterrence, which involves coordinating a breadth of combatant commands, government organizations, and allied support to deter potential adversaries.

"The B-1 has a role in strategic deterrence because it is credible," Anderson says. "The B-1 shows that the United States can strike any target, anywhere in the world, at the time of our choosing."

In 2022, the Biden administration released its National Security Strategy (NSS) report. A key concept in the 2022 NSS is integrated deterrence, which seeks the "seamless combination of capabilities to convince potential adversaries that the costs of their hostile activities outweigh their benefits." According to the 2022 NSS, by integrating its capabilities in this way, the United States will be better poised to achieve its aim of achieving strategic deterrence. (For more on different types of deterrence, see p. 18.)

Among other things, integrated deterrence involves leveraging the United States' conventional and nuclear warfighting capabilities in tandem, according to the Biden administration's National Defense Strategy (NDS), which was also published in 2022.

"A pragmatic approach to integrated deterrence will seek to determine how the Joint Force can combine nuclear and non-nuclear capabilities in complementary ways," the NDS says. "Our goal is to strengthen deterrence and raise the nuclear threshold of our potential adversaries in regional conflict by undermining adversary confidence in strategies for limited war that rely on the threat of nuclear escalation."

"The B-1 shows that the United States can strike any target anywhere in the world, at the time of our choosing."

—CHANDLER ANDERSON

Anderson's career began on bombers armed with conventional weapons. But as a budding expert in nuclear strategy, he is well poised to take a holistic view of deterrence and to consider how the United States can leverage both conventional and nuclear weapons to ensure the nation's security.

In 2020, after a deployment to the 9th Bomb Squadron that involved a second combat tour at Al Udeid, Anderson decided it was time to take his career in a different direction. He applied for, and was accepted to, a highly selective Air Force Global Strike Command (AFGSC) internship program at Barksdale Air Force Base in Louisiana.

AFGSC oversees the Air Force's nuclear weapons portfolio. The command is one of nine major commands in the Air Force and is a successor to Strategic Air Command, which oversaw the Air Force's strategic bomber and ICBM fleet throughout the Cold War.

The AFGSC internship program marked a change in emphasis in Anderson's career. "As an aviator, you're very operational," Anderson says. "The primary thing is to be an expert in the jet. That's what instructors always preach, and then when I became an instructor, that's what I preached. Once I got picked up for the internship program, I got to see things at a strategic level—to see what four-, three-, and two-star generals think about bombers and everything deterrence-related. I really gained valuable insight from those leaders."

After finishing the AFGSC internship in 2021, Anderson spent two years working for the Eighth Air Force commander as an executive officer. The Eighth Air Force, which is part of AFGSC, is also headquartered at Barksdale and controls fleets of B-1s, B-2s, and B-52s, many of which are assigned elsewhere in the United States and deployed around the world.

In 2023, Anderson jumped at the opportunity to come to Los Alamos, the better to round out his education in nuclear weaponry. At the Laboratory, Anderson is working in the Weapons Engineering associate directorate, where he is "trying to get my arms around everything the Lab cares about," he says.

Among other topics, Anderson is learning about science-based stockpile stewardship, nuclear weapons effects, and counterproliferation. "The Lab participates in, and is expert on, a bunch of different areas," Anderson says. "I want to be immersed in that and continue to get educated."

Much as the United States is leveraging its varied capabilities in the name of strategic and integrated deterrence, the Laboratory is a place where Anderson can draw on the full breadth of his career, ranging from his time as a B-1 "wizzo" to the years he has spent preparing to become one of tomorrow's nuclear strategy-makers.

"Los Alamos is where it all started," Anderson says. "If I were a B-52 air crew member or a B-2 pilot and a nuclear weapon was loaded onto my aircraft, it's the national laboratories that make that happen. We can talk about strategic deterrence today because of Los Alamos." ★

Chandler Anderson stands in front of a B-1 at Dyess Air Force Base, Texas, with his wife Katelyn, son John, and daughter Rylee.
Photo: Chandler Anderson

On August 1, 1946, President Harry Truman signed the Atomic Energy Act, creating the Atomic Energy Commission.

WHY DOESN'T LOS ALAMOS BELONG TO THE U.S. DEPARTMENT OF DEFENSE?

Decisions made at the dawn of the atomic age help ensure that nuclear weapons remain under civilian control.

BY JAKE BARTMAN

Los Alamos National Laboratory was founded as a part of the Manhattan Project, the World War II–era endeavor to develop the world's first nuclear weapons. Today, as one of two U.S. Department of Energy (DOE) national laboratories tasked with designing nuclear weapons—Lawrence Livermore National Laboratory is the other—much of Los Alamos' work involves ensuring that the nation's nuclear deterrent remains safe, reliable, and effective.

Given the Laboratory's nuclear weapons work, one might wonder: Why is Los Alamos administered by DOE rather than the U.S. Department of Defense (DOD)?

"The primary reason is to ensure civilian control and authority over the research, development, and production of nuclear weapons," explains Sean Mcdonald. Mcdonald has a unique perspective on the Laboratory's role in the national security enterprise. Having worked over the course of decades at Los Alamos, Mcdonald has received assignments to DOD, the National Nuclear Security Administration (NNSA), and the House Armed Services Committee. He recently accepted another position at NNSA.

Civilian control of the military is enshrined in the U.S. Constitution. The Constitution gives Congress the power to declare war, while the president is commander-in-chief of the armed forces. But Mcdonald notes that in the months following World War II—which ended after the United States detonated two Los Alamos-designed nuclear weapons over Japan—U.S. scientists, military leaders, and elected officials debated who would have authority over these powerful new weapons.

During World War II, the U.S. departments of War and the Navy (predecessors to today's DOD) oversaw—on the president's behalf—the development and use of conventional and nuclear weapons alike. However, after the war's end, scientists and civilian leaders argued that nuclear weapons' tremendous destructive power made them different in kind from conventional weapons, and that the weapons should fall more directly under civilian control.

"The fear was that nuclear weapons might be used as just another tool, which could lead to incredibly destructive wars," Mcdonald says.

To confirm the president's status as the one person authorized to direct the development and use of nuclear weapons, Congress passed the Atomic Energy Act in 1946. Central to the Atomic Energy Act was the creation of the Atomic Energy Commission (AEC). Composed of five presidentially appointed civilian commissioners, the AEC was tasked, among other things, with ensuring the "continued conduct of research and development activities" related to the United States' nascent nuclear enterprise. A separate committee, the Military Liaison Committee, was created to ensure that the War and Navy departments had a say in AEC deliberations.

Upon its creation, AEC assumed custody of the nuclear weapons and material produced during the Manhattan Project. The United States' nuclear stockpile remained under AEC's purview until the agency was disbanded in 1974, and, in 1977, AEC's functions became part of the newly created DOE. Then, in 2000, Congress created NNSA—a semi-autonomous agency within DOE—to manage the United States' nuclear weapons enterprise.

Throughout these administrative transitions, civilians have remained responsible for designing, developing, and maintaining the United States' nuclear stockpile. For the past two decades, policymakers have decided that responsibility means ensuring NNSA remains part of DOE, rather than DOD.

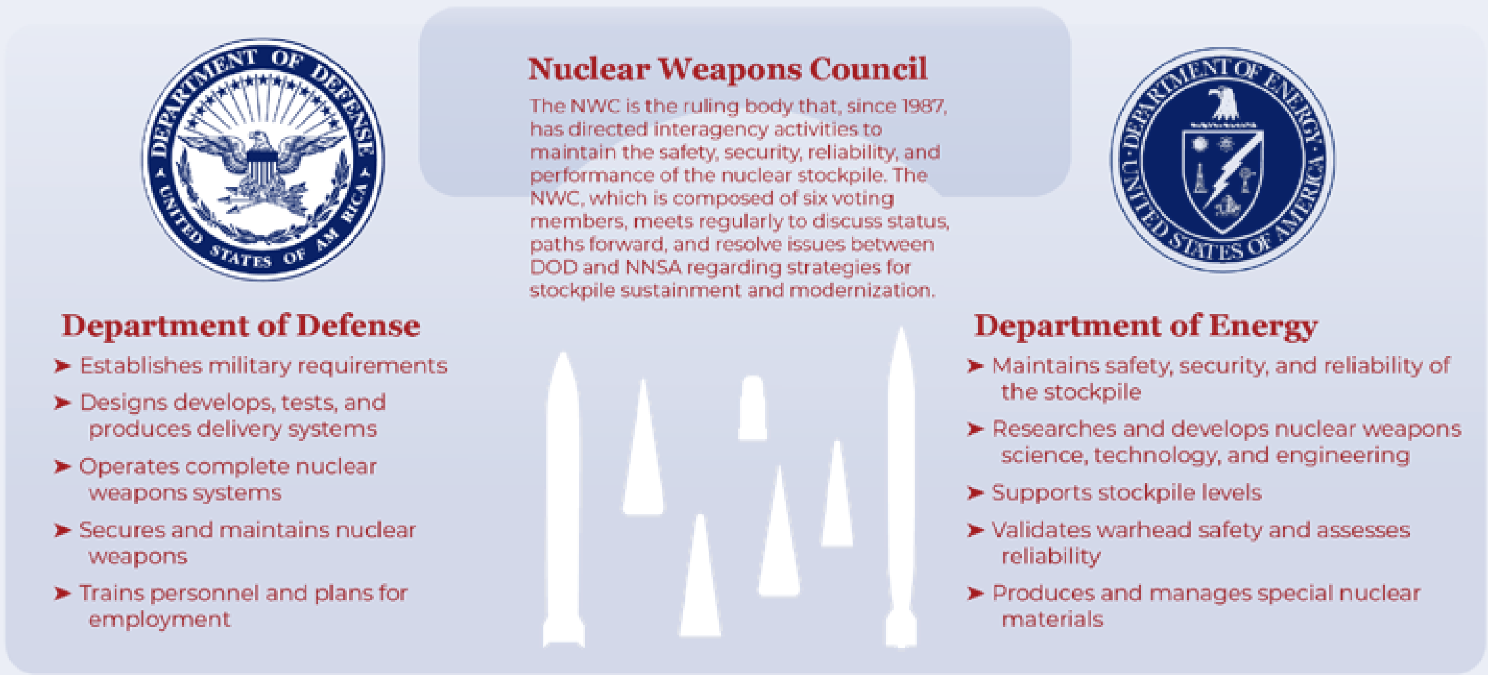
"Over the decades, there have been debates about whether NNSA should be part of DOD," Mcdonald says. "But those debates have always been decided in favor of having nuclear weapon design, development, and production remain part of a separate agency."

Although NNSA isn't part of DOD, the two entities collaborate as a matter of course. For one thing, DOD develops, deploys, and operates the delivery systems—the aircraft, submarines, and missiles—that make nuclear weapons an effective deterrent. Los Alamos works closely with DOD to ensure that weapons designed at the Laboratory meet DOD specifications.

Moreover, DOD is responsible for setting the nation's high-level nuclear policy, which is based on each presidential administration's nuclear posture review. DOD policy is also informed by the capabilities of NNSA facilities like Los Alamos, whose leaders provide technical input on policy objectives.

The relationship between DOD and NNSA is complicated by the fact that NNSA has its own budget. That means that while DOD can request research and development programs from NNSA, DOD doesn't necessarily pay for the programs that NNSA administers, which leads to a certain amount of wrangling between the two organizations. The Nuclear Weapons Council, which Congress created in 1987, serves as an arbiter between DOD and NNSA, helping to translate the former's policy into the latter's programs.

Of course, none of the negotiations between NNSA and DOD happen in a vacuum. World events continually shape the United States' nuclear posture in a way that flows from high-level policymaking down to the national laboratories' day-to-day work. But while the specifics of Los Alamos' work might change, the Laboratory's larger goal remains the same: to ensure that the nation's nuclear deterrent remains safe, reliable, and effective. ★

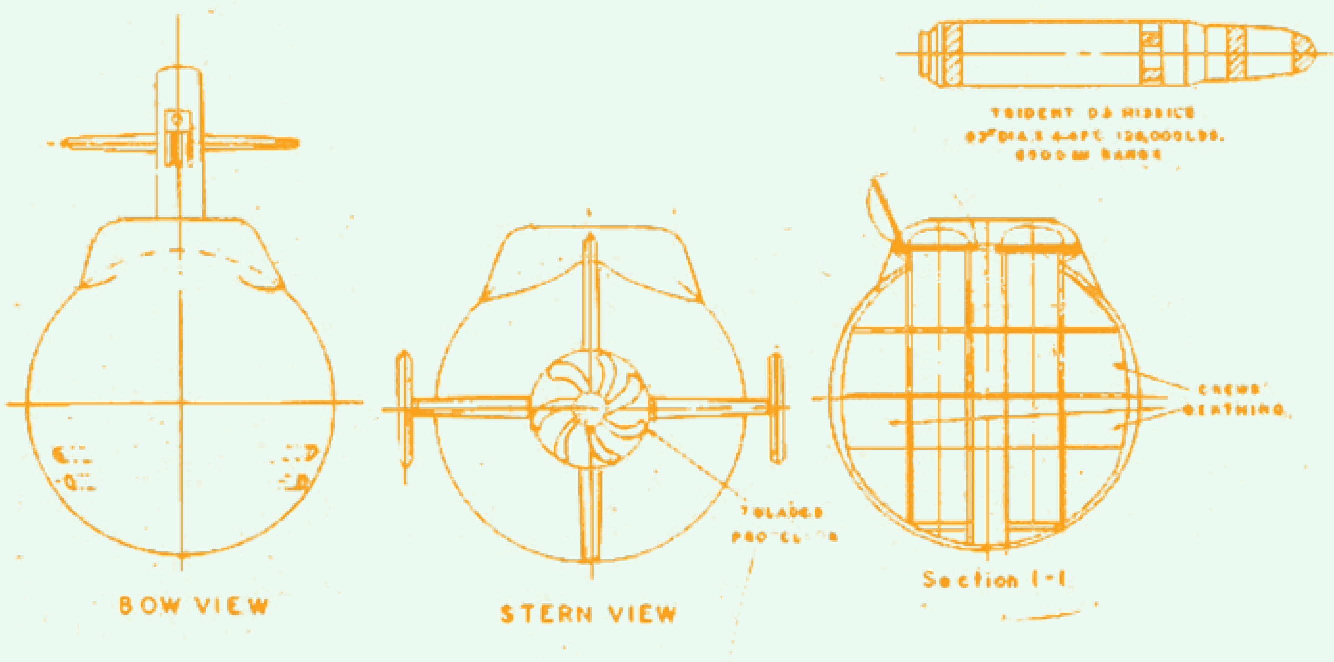


◆ The USS *Tennessee* (foreground) participates in a training exercise.
Photo: U.S. Navy/Aaron Abbott

A Los Alamos employee remembers his time onboard a nuclear-armed submarine.

BY IAN LAIRD

DETERRENCE AT SEA



The USS *Tennessee* was in a precarious situation.

"We were somewhere deep in the middle of the Atlantic Ocean, gearing up to take on the role of the alert boat—the submarine that would launch nuclear warheads if called upon by the president to do so—when things took an unexpected turn," recalls David Flores, who was an ensign in the U.S. Navy at that time. "A fellow sailor had suffered a severe injury; his potential for internal bleeding was high."

The sailor needed urgent medical attention that would require the *Tennessee* to navigate to meet a rescue vessel, surface, and then transfer the sailor into the rescue vessel's care. But as the upcoming on-alert submarine, the *Tennessee* had to hold its course. Breaking from that position would jeopardize the nuclear posture of the United States.

Communication went back to Kings Bay—the homebase for nuclear-armed submarines in the Atlantic Ocean. Almost immediately, another submarine was ordered to assume alert status. The *Tennessee* was ordered to alter course and meet a rescue vessel.

"At that moment, I started to grasp the communication, coordination, and time necessary to redirect a submarine," says Flores, who now works as a manufacturing manager at Los Alamos National Laboratory. "In less than 48 hours, the *Tennessee* reached the waypoint, surfaced, and transferred the injured sailor to receive medical care. It was then that I truly appreciated the operational capability and flexibility of nuclear submarines."

Getting his sea legs

As a high school student in Riverside, California, Flores was looking for a way to pay for college. A military recruiter encouraged Flores to apply for an ROTC scholarship, which would allow him to attend college and then commission into the U.S. Navy as an officer. Flores qualified for the scholarship and enrolled at the University of California, Los Angeles, intent on becoming a submarine officer.

After graduation, Flores was sent to the Naval Nuclear Power School in Charleston, South Carolina. There, officers are taught how to operate the nuclear reactors that power some of the Navy's submarines. After a year of training, Flores was certified to operate the nuclear propulsion system used by Ohio-class submarines and was assigned to the gold crew aboard the USS *Tennessee*. (Each submarine has two crews—gold and blue—that alternate operating submarine patrols.) Flores started as a chemical and radiological controls officer, monitoring the nuclear reactor plant chemistry to ensure the nuclear propulsion system was operating properly. He also performed radiological work, including taking the dosimetry (radiation levels) of every sailor onboard.

During his seven years of active duty, Flores went on to work as a damage control assistant, a tactical systems officer, and a quality assurance officer. "Of those positions, I really enjoyed being a tactical systems officer," Flores says. "In that role, I trained junior officers to drive the ship, read the combat control system, and navigate while submerged." In fact, Flores enjoyed teaching so much that, after his active deployments ended, he worked at Kings Bay for two years as an instructor, training sailors and junior officers.

Boomers

Nuclear-armed Ohio-class submarines, which are often called boomers, currently serve as the sea-based arm of the nuclear triad, the three-pronged structure of U.S. nuclear armaments composed of land-launched intercontinental ballistic missiles, air-delivered bombs and missiles, and submarine-launched ballistic missiles. Submarines are considered the most survivable arm of the triad, meaning that if a nuclear strike is ever launched against the United States, submarines will likely be unharmed and capable of striking back.

Of the nation's 18 Ohio-class submarines, 14 are denoted as SSBNs (SS for submarine, N for nuclear propulsion, and B for ballistic missiles), which means they are nuclear-armed. Six of these SSBNs submarines are based out of Kings Bay, in Georgia, and eight are based out of Naval Base Kitsap, in Washington state. Each boat carries 20 missiles topped with Los Alamos–designed W76 or W88 warheads.

Ohio-class submarines were designed to last 30 years. The first one—the USS *Ohio*—entered service in 1981. The newest boat—the USS *Louisiana*—entered service in 1997. Through maintenance and upgrades, the lifetimes of all boats have been extended to 42 years, but some submarines are already up against that limit. Flores' boat, the *Tennessee*, will turn 36 years old in 2024. "The Ohio-class submarines, having been extended in life, have longer maintenance periods," he says. "Things break a lot more often."

Life on patrol

Patrols—the periods of time when a boat is at sea—are often planned out years in advance, creating predictable and routine cycles for sailors. Typically, each patrol is three months, but as Ohio-class submarines show more and more signs of aging, patrol lengths have started to vary. Some ships are forced into port early when things break, while others have their patrols extended if ships in port require longer maintenance periods.

According to Flores, the first week of a patrol is chaotic. The crew is getting reacquainted with snug living conditions while also wrapping up maintenance tasks left over from the previous patrol. All the while, the ship's navigators are steering farther from shore to deeper water.

After the first week, a routine takes hold, and sailors get as comfortable as they can be in a 560-foot-long submerged metal tube. The ultimate source of comfort is a sailor's bed, or rack. "It is very, very important to customize your rack and create whatever you need to make your piece of home," Flores says. "I would bring in half of a queen memory foam topper, 900-count sheets, a memory foam pillow, and I thought I had a really comfortable rack until I found out that other people get even more creative. People were installing televisions and video games, fitting things in every crevice and corner of their racks."

Flores explains that "your rack is your sanctuary. Disturbing people is called racking someone out, and we try to avoid racking out as much as possible because it can potentially ruin the only alone time the sailor may have that day."

Without any windows and very limited contact with the outside world, the passage of time is largely dictated by routines. On submarines, everything is built around a 24-hour schedule where submariners have 8 hours on watch, 8 hours for administrative duties, and 8 hours to sleep. The 24-hour schedule was implemented in 2014.

"Extended patrols are creating more proficient warfighters."

—DAVID FLORES

◆ The USS *Ohio*, the namesake and first SSBN of the Ohio-class, went into service in 1976.
Photo: General Dynamics Electric Boat Division

◆ After completing his undergraduate studies and pre-deployment training, Flores was assigned to Naval Submarine Base Kings Bay, which would become his home on land for the duration of his time in the Navy. Photo: David Flores

Submarines used to operate on an 18-hour schedule where each shift lasted 6 hours instead of 8. "That was terrible for sleep," Flores admits.

Another facet of life that is vital on submarines is what Flores calls a culture of quiet. So much of a submarine's stealth, survivability, and threat capability is reliant on silence.

"From the very beginning, the moment we step on a submarine, sound silencing is the number one thing we do," Flores says. "We do everything we can to keep our own ship noise at a low level." This means gently closing doors and not dropping toilet seats.

Silence isn't just a protective shield for submarines, though. It can be crucial for locating and identifying enemy ships. "We take sound analysis underwater; we look at the environment and at our own ship noise," Flores explains. "Once we know the trends in the water of how sound propagates, we try to position ourselves in the best place to take advantage of the environment to amplify what we can hear."

Another factor in stealth is visibility. To reduce visibility, submarines rarely surface during a patrol. Instead, they will come up to periscope depth—just high enough that a periscope can be used to help assess their surroundings. Coming up to periscope depth also allows the submarine to recirculate its atmosphere, release pressure, and get fresh oxygen into the ship before diving deeper again. Flores says the time between coming up to periscope depth typically ranges from several hours to several days, although the ships are capable of enduring longer stretches.

One drawback of maintaining stealth is that submarines are unable to restock supplies without giving away their location. This means the food the crew is eating three months into their patrol is the same food that was loaded onto the ship the day they left port. But Flores says he never had any complaints.

"We had great cooks on the ship; I never had a bad meal," Flores says. "My favorite was chicken and waffles with Chick-fil-A sauces."

When a boat returns to port, the crews swap over, and the departing crew relinquishes all authority of the submarine. The departing crew has about a week to relax (and eat whatever they want) before getting back to work. Flores explains that a lot is demanded of sailors while on land. "You're wearing three hats," Flores says. "You're trying to maintain your training, you're trying to proceed in qualifications and still actively learn, and then you're trying to also plan maintenance and meetings, so once you take back the ship, you can see what can get done in the time before you go out to sea."

Ready to act

During patrols, the 24-hour schedule is only interrupted by drills and maintenance that requires immediate attention. Sometimes these drills are missile launch drills. These "Wardays" are a way for the crew to test its readiness and response to likely launch scenarios.

When a message is received initiating a launch sequence, Flores says it becomes priority number one. The encrypted messages require two specially trained officers to work together to decode the incoming order. If the order is valid, it is then relayed to the captain who gives concurrence to follow the order.

"It could happen anytime," Flores says. "So there were times where I'd be asleep, and I'd wake up to an alert going off saying that there was a receipt of a message. I would immediately have to get out of my rack."

◆ A payload is delivered to the USS *Henry M. Jackson* in the Pacific Ocean. Mid-deployment supply drops are sometimes necessary to ensure crews stay fed and equipped for any situations that might arise. Photo: U.S. Marine Corps/Jacob Wilson

He continues. "The way that these scenarios go is you get one message that briefs a potential issue, then it escalates. You get another message that says to start navigating toward an area. Then you get another message saying this is a potential launch and then a final message to launch. And each of those messages comes throughout the day over a long period of time."

At any given time, at least three ships are in the Pacific Ocean and three ships are in the Atlantic Ocean. In each hemisphere, one is on-alert and ready to launch. Another ship is mod-alert, meaning if the alert ship is unable to act on launch orders, the mod-alert ship can replace it within 24 hours. The final ship is non-alert and is in standby mode.

During Flores' time on submarines, he never patrolled beyond the Atlantic Ocean, but he says now, things are starting to change.

"We are seeing kind of a show of force in response to the situation in Ukraine, and we're also seeing China's movements around Taiwan," Flores explains. "We're showing the capabilities and endurance of our submarines and an ability to not only execute strategic missions, but also show that the crews are proficient, experienced, and able to execute those missions."

Flores says submarines are traveling to places they haven't been in a long time—or ever. In October 2022, for example, the USS *West Virginia* embarked from Kings Bay to Diego Garcia in the Indian Ocean. In May 2023, the USS *Maine* resurfaced in the Philippine Sea after deploying out of Naval Base Kitsap, a journey of nearly 6,000 miles. In July 2023, the USS *Kentucky* made a port call to Busan, South Korea.

Flores says all crews have been trained to swap over at sea or at these distant bases. This allows the Navy to enact long-range patrols without requiring the crews to overexert themselves. And although much of the reasoning behind the extended patrols is the current geopolitical climate, Flores believes there is another factor. "Longer deployments do create a toll on the personnel, but crews are coming back a lot more proficient," he says. "When a submarine's back in port, you really can't do much besides go to simulators and try to emulate what you see out at sea, so these extended patrols are creating more proficient warfighters."

Building a more secure future

For decades, the United States Navy has maintained technological superiority over foreign countries with its Ohio-class submarines. Flores says in recent years, that gap has shrunk.

"Foreign countries are improving their combat control systems, their knowledge of the environment, their

> "We're showing the capabilities and endurance of our submarines."
>
> —DAVID FLORES

After spending months at sea, Flores says returning to port was always exciting. "You'd have some time to maybe take a vacation and really de-stress," he says.
Photo: David Flores

underwater acoustics, and their ability to operate submarines," Flores says.

However, starting in 2031, the aging Ohio-class submarines will be replaced with new Columbia-class submarines, which are designed to be in service for 42 years. These boats will each carry 16 missiles topped with W76, W88, and perhaps eventually, W93 warheads. The W93, which is still in the early design phase, is slated for delivery in the mid-2030s, meaning that it will need to be compatible with both Ohio- and Columbia-class submarines.

Flores explains that the reduction in the number of submarines and missiles isn't necessarily a reduction in force. "There's not really a concern in terms of strategic readiness because the advancements in the Columbia boats—such as improved combat control systems—means they will still meet the intent of strategic deterrence."

Fewer boats means fewer crews. Twelve Columbia submarines require a total of 24 crews—that's compared to 14 Ohio-class SSBNs with 28 crews. The extra crews will be spread across the other SSBNs or shifted to new nonnuclear-armed fast-attack submarines that are in development. Flores also says the condensation of personnel may help crews that might've stretched thin previously.

"The Navy has a problem with retention on submarines," Flores says. "I think having the extra personnel will actually satisfy and help meet some of the staffing requirements we have because right now we are understaffed."

The personnel shortage is also a result of the Navy working with a limited talent pool for decades. That's because until

> "I've fallen in love with the mission and what we're doing."
>
> —DAVID FLORES

2010, women were banned from serving on submarines. The Navy started incorporating female officers into crews in 2011, but it took more than a decade before enlisted women served on SSBNs. In 2022, 15 female enlistees completed a strategic patrol aboard the USS *Wyoming*. That number will likely increase in the coming years, which Flores says can only benefit the entire fleet.

"We are doubling the amount of talent that we can tap into for these submarines," Flores says. "We were limiting ourselves before, and in a couple of years we'll be able to have the first female commanding officer of a submarine."

The inclusion of women on SSBN crews is also shaping the design process of the Columbia-class submarines. Previous iterations were designed with only male sailors in mind, meaning things like dimensions and the placement of controls and operating equipment were based on average male height. The Columbia-class submarines will be the first SSBNs with gender-neutral and more accessible operating systems.

"Now, when you go out on an SSBN, you have to have a step stool for shorter sailors to see on the periscope," Flores says. "They wouldn't be able to reach valves or use emergency equipment. The Columbia-class submarines won't have these issues."

Beyond integrating the operational systems on the submarines for all people, improvements will also be made to propulsion and combat control systems. According to a 2023 Congressional report, "The Columbia class is to be equipped with an electric-drive propulsion train, as opposed to the mechanical-drive propulsion train used on other Navy submarines. The electric-drive system is expected to be quieter (i.e., stealthier) than a mechanical-drive system."

A 2022 news release from the U.S. Navy explained that the boat "will feature superior acoustic performance and state-of-the-art sensors to make it the most capable and quiet submarine ever built."

In short, Flores says, "The Columbia is going to be a game changer."

Extension of the mission

After leaving the Navy in 2023, Flores began looking for jobs that had a similar national security mission. "It was surprisingly very difficult," he says. "I wasn't having any luck, and it got to the point where I was debating going back to school or even staying in the Navy."

That's when he met a Los Alamos recruiter at King's Bay. After one conversation, Flores thought perhaps a career at the Laboratory would allow him to continue serving the nation. In January 2023, he was hired into the Lab's Power Supply Production group as a manufacturing manager where he helps develop power sources made with plutonium. These radioactive "heat sources" are used in everything from defense programs to NASA spacecraft, such as the Dragonfly rotorcraft that will attempt to land on Titan, Saturn's largest moon.

"One of my biggest concerns when I left the Navy was leaving that collaborative work environment," Flores says. "I feel I have that here. I've fallen in love with the mission and what we're doing."

But Flores can't tear himself away from the Navy completely. He continues to serve his country as a reserve officer. ★

HOLDING THE LINE

Major General John Weidner recalls how his time at Los Alamos shaped his views of deterrence.

BY J. WESTON PHIPPEN

In 2008, Major General John Weidner—then a lieutenant colonel in the U.S. Army—was stationed at Los Alamos National Laboratory. As a nuclear forensics and countering weapons of mass destruction (WMD) officer, also known as an FA52, Weidner was at Los Alamos to learn from the scientists and engineers who design nuclear weapons. (For more on FA52s, see p. 16.)

While at the Lab, Weidner recalls a conversation with a physicist who worked down the hall. “He was complaining about something at Los Alamos, and after several minutes, I interrupted him to ask why, given his frustration, he was still working at the Lab. Without missing a beat, he looked me dead in the eye and said he wanted to be of service to the nation and that working at Los Alamos was the best way he knew how to contribute.”

Weider says this type of patriotism is common across the nuclear security enterprise. “I have no doubt, none whatsoever, that this workforce will create and deliver the capabilities our nation needs to defend itself and our allies,” he says. “My nearly four years at Los Alamos provided me with an understanding of what it takes to create, sustain, and dismantle the nuclear stockpile—an incredible investment. Moreover, working at Los Alamos gave me the technical knowledge and practical experience to be successful in every one of my follow-on assignments.”

Today, Weidner is the chief of staff for the United Nations Command (UNC) and United States Forces Korea (USFK). *National Security Science* spoke to Weidner about how his time at Los Alamos informed his current position and helped shape his views on deterrence.

This conversation has been edited for clarity and brevity. The views expressed are those of Major General Weidner and do not necessarily represent those of the U.S. Department of Defense.

You are stationed at U.S. Army Garrison Humphreys in South Korea, where you are the UNC and USFK chief of staff. What are your responsibilities?

The primary mission of the UNC is to support and enforce the armistice agreement that ended the hostilities of the Korean War. As the UNC chief of staff, I am the senior U.S. member on the UNC Military Armistice Commission (UNCMAC). I provide oversight of the process the UNCMAC uses to determine if an activity by either side violates the armistice agreement.

My other primary duty is to coordinate efforts across our personnel, intelligence, operations, logistics, plans, policy, information technology, and resource directorates within and between both commands.

How has the current geopolitical environment impacted your mission?

Russia, China, North Korea, Iran, and other state powers wish to overturn the rules-based international order that has served the free world so well for so long. For example, China is making claims to almost the entire South China Sea. Russia invaded Ukraine in complete disregard of the sovereignty of nations. North Korea is threatening war with the Republic of Korea and the United States.

China has reportedly constructed more than 300 intercontinental ballistic missile silos in the past few years. Russia claims to have modernized more than 90 percent of its nuclear forces, and North Korea has enshrined nuclear weapons into its constitution and its leader has directed an exponential increase in nuclear warhead production.

For the first time, the United States will be challenged by two near-peer nuclear nations, as well as a third nuclear power that says it is increasing its nuclear capabilities and stockpile size. This is all occurring at a time when our nuclear forces are at their lowest level since the early 1950s, and all legacy nuclear weapons and delivery platforms have long outlived their design lifetimes.

The importance of the U.S. nuclear stockpile is to demonstrate that an adversary cannot escalate its way out of a failing conflict and that efforts to do so would cause its demise. Our nation must communicate and demonstrate this through well-trained, well-equipped conventional and strategic forces every day.

How do you define deterrence?

Deterrence is the process of convincing someone not to do something. More specifically, it is decisively influencing perceptions regarding the costs and benefits of taking an action and not taking an action to convince someone that restraint is the best course.

I believe the nature of deterrence endures. The character of deterrence, however, has evolved. For example, there are no widely agreed upon norms for behavior in space or cyberspace, and that is driving us to evolve our approach to strategic deterrence.

How should the United States best prepare itself for the future?

Russia, China, and North Korea appear to be increasing the role of nuclear weapons in their national security strategies. Moreover, all those countries have used forms of nuclear coercion to obtain their national security objectives. In my opinion, the United States must evolve our nuclear stockpile to convince potential adversaries not to engage in conflict with the United States or our allies. First, we should move away from nuclear weapon life extension programs and begin the design of completely new nuclear weapons purpose-built for the threats, environments, and likely targets of the 21st century. Second, we should complete the planned modernization program of record and in doing so explore and incorporate smart, micro-, and nano-technologies into new nuclear weapon designs that provide real-time measurements that enable nuclear weapons with longer design lifetimes and reduced surveillance costs. These options would plug gaps that an adversary may see in our nuclear capabilities. They would also reassure our allies of our extended deterrence commitments.

> “THE LABS CAN OFFER OPTIONS AND CAPABILITIES AT THE BEST POSSIBLE VALUE.”
>
> —Major General John Weidner

A nation can have a reasoned debate on whether to develop a nuclear deterrent, but once the decision is made to develop that capability, there must be no debate on building, growing, and sustaining the capabilities and staff necessary to maintain that stockpile. The nation must also plan for and exercise strategic deterrence while in conventional conflict because the greatest risk of nuclear use will almost certainly stem from a regional conventional war. The conventional fight is unlikely to end with an adversary’s first use of a nuclear weapon. It will continue, and during that fight, the United States and our alliance must continue to deter the adversary from using nuclear weapons.

How does Los Alamos help in this mission?

Los Alamos and the other labs, plants, and sites of the National Nuclear Security Administration are foundational to the vision I described. We need to unleash the talent, creativity, ingenuity, and dedication of our workforce on the problem.

The national labs are helping leaders within the Department of Defense understand the threats we currently and are likely to face in the near-term. The labs can offer options and capabilities at the best possible value. This has been invaluable and educational. For example, the labs have some of the best nuclear weapon effects models. Those models are helping military and civilian leaders understand the outputs and effects of nuclear weapons.

Tell us about your assignment at Los Alamos.

Los Alamos was the longest assignment of my career—nearly four years from fall 2008 to summer 2012—and one of my most enjoyable. I supported weapon physics studies on the W78 warhead and did medical isotope production experiments to complete my PhD. I also helped create an electronic database of U.S. nuclear tests, participated in many national technical nuclear forensic analyses and exercises, and made several cooperative threat reduction trips to the former Soviet nuclear test site at Semipalatinsk, Kazakhstan.

I cannot overstate the importance of my assignment at Los Alamos. In my current role, I have been involved in the Nuclear Consultative Group meetings between senior Republic of Korea and U.S. national security members. My Los Alamos experience has informed my discussions with both the Republic of Korea government and military and helped me articulate the outputs and effects of nuclear weapons as well as options to manage the consequences of nuclear use.

Given the increasing role of nuclear weapons in the nuclear security strategies of North Korea and other countries, how do you see the role of the FA52 evolving?

Among other things, FA52s will play key roles in advising military and civilian leaders about the effects of nuclear weapons and nuclear-related policy. In my experience, most leaders overestimate the effects of nuclear weapons, which may cause them to underestimate the likelihood of adversary nuclear use.

I believe the most likely scenario for adversary first use of a nuclear weapon is in a conventional conflict they are losing. Should an adversary use a nuclear weapon in that case, the conventional war would continue. Therefore, it is important for U.S. military forces to understand how to operate in and through a nuclear environment created by an adversary.

That may seem like an obvious statement, but almost all our leaders have lived their entire professional careers in an environment where adversary nuclear use was almost unthinkable. The United States has not been in a conflict where it had to worry about being out-escalated since World War II.

With that in mind, it’s imperative that the United States and our allies develop a vision for how to go to war against a near-peer adversary. This includes an approach for how to mobilize a nation for war and how to integrate all elements of national power. In this way, our nation and our network of allies and partners will be best prepared to deter conflict and, if necessary, prevail in conflict. FA52s will be central to all of this. ★

Brock atop North Eolus (elevation 14,039 feet above sea level) in July 2006. "Every climb provided a new perspective on the Colorado Rockies," he says.

Brock and his 9-year-old daughter descend from Buckskin Mountain (elevation 13,865 feet above sea level) in August 2009.

While stationed in Washington, D.C., Brock, a lifelong Dodgers fan, attended many baseball games at Nationals Park. In October 2022, he caught a game ball and posed with the team's mascots.

PEAK PERFORMANCE

Over a quarter century, Jerry Brock escaped to the Colorado Rockies to climb the state's 116 tallest mountains—every peak higher than 13,800 feet above sea level.

BY WHITNEY SPIVEY

"This is the most precious piece of paper in my possession that cannot be replaced." Jerry Brock flips to a page in the back of *Colorado's High Thirteeners: A Climbing and Hiking Guide* by Mike Garratt and Bob Martin. He traces an index finger down a list of the tallest mountains in Colorado. To the right of the first 116 names, dates are penciled in tiny numbers: month-day-year.

"I wrote the day I climbed each peak in the book," he explains. "The recording was most often made on summit day."

Brock started exploring Colorado's Rocky Mountains when he began work at Los Alamos National Laboratory in March of 1995. During the week, he worked on computational fluid dynamics in the Lab's Theoretical division, and on many weekends he'd head north with a group of local mountaineers. "Early on, I took advantage of climbing opportunities with people who had more experience," Brock remembers. "In August 1995, I climbed my first fourteener [mountain at least 14,000 feet above sea level] because my roommate was going."

Before long though, Brock was often summiting peaks solo, sometimes embarking on multiday backpacking trips to reach the top of a mountain—or several mountains. "I bought a 1998 4x4 Toyota Tacoma with a 6-foot bed," he says. "I'd often leave work on Fridays around noon, drive to Colorado, sleep in the bed of the truck, and get up very early to climb."

Brock still has that Tacoma, in which he slept in October 2020, the night before he summited Mount Elbert, Colorado's highest peak—14,433 feet above sea level. That climb was also the last in his quest to summit every peak above 13,800 feet in Colorado. "My wife carried a bottle of champagne to the top for us to celebrate," says Brock, noting that his wife and daughter accompanied him on a handful of hikes. "I could not have accomplished this goal without their support."

Brock says he had summited around 75 peaks when he realized that all 116 above 13,800 feet might be attainable. But he never put himself on any sort of schedule. He says the few times he had to bail on a summit attempt due to poor conditions and then try again were "just part of the process." Mount Elbert, however, was the exception. "I knew I was moving to Washington, D.C. for an assignment on the Defense Programs Science Council," Brock remembers. "I knew I had to do Elbert—and a few others—before I left New Mexico."

Brock ended up spending three years in the nation's capital; one as a senior technical advisor on the Defense Programs Science Council (part of the National Nuclear Security Administration) and two as a senior technical advisor supporting the Joint Staff Strategic Stability Directorate in the Department of Defense.

In July 2023, Brock returned to Los Alamos, where he now leads the Office of Stockpile Assessment and Strategy. In this role, Brock is responsible for orchestrating the annual assessment reporting process—one of the Lab's most important deliverables—that is mandated by Title 50 U.S. Code Section 2525. Every year, the process culminates in a letter from the Laboratory director to the secretary of energy, the secretary of defense, and the chair of the Nuclear Weapons Council that describes the Lab's confidence in the safety, reliability, and performance of four nuclear weapons systems: the B61 family of bombs, the W76 family of warheads, and the W78 and W88 warheads. Los Alamos is responsible for maintaining these weapons systems without nuclear testing. Instead, the Laboratory relies on nonnuclear and subcritical experiments coupled with advanced computer modeling and simulations to assess the status of these weapons. This science-based approach is called stockpile stewardship.

"I work with staff and leaders from across the Laboratory to help communicate their assessments," Brock says. "This important work underpins Los Alamos' and the nation's confidence in the nuclear stockpile."

Looking back over his 29-year career at Los Alamos, Brock says that "I've tried to fully commit to whatever job I'm doing." He explains that for 25 of those years, climbing mountains was a "release" that took him away from his desk and into the wilderness. These days, Brock's hiking is much more casual and he recalls his quarter-century of Colorado summits with a mix of enthusiasm and nostalgia. "It was so mentally and physically tough—it required me to completely pivot away from work," he says. "And I just really enjoyed the challenge and reward of climbing each peak." ★

THE DISTINGUISHED ACHIEVEMENTS OF LOS ALAMOS EMPLOYEES

BETTER SCIENCE = BETTER SECURITY

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

The United States Army recognized Tim Goorley, chief scientist for weapons effects, for outstanding performance of duty while serving as an Army Science Board consultant from June 2022 to September 2023. Goorley received the Army's Civilian Service Commendation Medal for his work. As a consultant, Goorley supported the study "An Independent Assessment of the Army's Readiness to Fight, Survive, and Win on a Limited Nuclear Use Battlefield." During the study, he shared his expertise on nuclear weapons and nuclear weapons effects and gathered the latest threat data from the intelligence community. For more on weapons effects, see p. 28.

Physicists Leslie Sherrill and Manolo Sherrill, who are married, were awarded the 2023 Samuel Abraham Goudsmit Medal by the University of Nevada, Reno (UNR). The medal is the College of Science Distinguished Alumni of the Year award and recognizes graduates with outstanding career accomplishments. Leslie is the X Theoretical Design deputy division leader. Manolo was the program manager for physics and engineering models in the Advanced Simulation and Computing program.

The Institute of Electrical and Electronics Engineers (IEEE) Visualization and Graphics Technical Committee's Visualization Academy inducted James Ahrens at the IEEE VIS 2023 conference in Melbourne, Australia. Ahrens is the founder and design lead of ParaView, a widely used open-source visualization package that has been downloaded more than two million times.

Retired scientist and Laboratory Fellow John Pedicini received the 2023 Outstanding Mechanical Engineer Award from his alma mater, Purdue University. Pedicini joined the Lab in 1981 and worked in nuclear weapons design and testing, nuclear intelligence, nuclear counterintelligence, nuclear counterproliferation, and nuclear counterterrorism.

Juan Duque and Kevin Mitchell were awarded the 2023 Los Alamos Global Security Medal for their work in growing the Laboratory's remote sensing capabilities.

Barbara Lynn and Ralph Martinez received the Laboratory's 2023 Community Relations Medal, which recognizes individuals who have made significant contributions to the Lab's goal of excellence in community relations.

Physicist Christopher Ticknor was selected as a Fellow of the American Physical Society. The recognition cites Ticknor "for theoretical and computational advances in the properties of matter under extreme conditions, and for leadership in guiding new research in these fields."

Evelyn Mullen, special advisor to the Texas A&M University System Vice Chancellor for Research, was honored with the Texas A&M University Department of Nuclear Engineering Distinguished Alumni Award. Before her joint Texas A&M University System appointment, Mullen was the executive officer for Weapons and the chief operating officer of the Laboratory's Global Security associate directorate.

Bobbi Riedel, a researcher in the Lab's Materials and Physical Data group, received the 2023 American Nuclear Society Landis Public Communication and Education Award, which honors outstanding efforts, dedication, and accomplishment in furthering public education and understanding of the peaceful applications of nuclear technology. "Nuclear science and the issues that surround it are often misunderstood, and education ensures that there is accurate information driving policy and decision-making," says Riedel, whose colleagues nominated her for the award.

Marianne Francois, Jimmy Fung, and Elizabeth Hong-Geller completed the National Laboratory Directors Council's Oppenheimer Science and Energy Leadership Program (OSELP). The program cultivates leaders to explore the complexities, challenges, and opportunities facing the national labs and the Department of Energy. Kane Fisher and Jolante van Wijk were accepted as members of the next OSELP cohort. Read about Fisher using the QR code below.

SCAN QR CODE WITH A SMARTPHONE CAMERA
Kane Fisher, a Yupik Eskimo, has made a name for himself as a commercial fisherman, athletic coach, mechanical engineer, and mentor.

IN MEMORIAM

After working as a scientist and engineer at Los Alamos, Kevin Greenaugh worked for the National Nuclear Security Administration, where he served as the assistant deputy administrator for Strategic Partnership Programs and a senior policy advisor on nuclear matters. In an interview for the spring 2019 issue of this magazine, Greenaugh explained, "there's an intersection between science and policy. For example, there's a policy that established a moratorium on underground nuclear testing. So, what does that mean technically? What do you need to do in weapon programs to be able to certify that weapons will work as a result of that policy decision?... You need scientific understanding to determine how policy can change technology." Greenaugh passed away on December 17, 2023, after a 9-month battle with pancreatic cancer.

Laboratory historian Alan Carr received a Department of Energy Achievement Award for his work on the Atmospheric-Test Film Scanning and Analysis project team, a collaborative effort started by Lawrence Livermore National Laboratory in 2011. The project involved making digital scans of historical nuclear detonation test films, most of which are stored at Los Alamos. From identifying, selecting, and handling the films, to shipping them to Livermore for digitization, Carr jokes that he "played the parts of mailman, lobbyist, janitor, and junkyard dog."

Brian Haines, Nels Hoffman, John Kline, Rick Olson, and Doug Wilson, all of the Weapons Physics associate directorate, received the 2023 Director's Science and Technology Award from Lawrence Livermore National Laboratory. The scientists were recognized for their role in achieving ignition at the National Ignition Facility.

U.S. Acting Secretary of Labor Julie Su recognized the Laboratory as one of 859 recipients of the 2023 Hire Vets Medallion Award during a virtual ceremony in November 2023. The Lab has received this annual award since inception in 2018. ★

62 YEARS AGO

Detonated on July 14, 1962, at the Nevada Test Site (now the Nevada National Security Site), Small Boy was the second-to-last aboveground nuclear test in the continental United States (Little Feller I, conducted three days later, was the final such detonation). Researchers from Los Alamos Scientific Laboratory (now Los Alamos National Laboratory) detonated the Small Boy device atop a 10-foot tower, hoping to learn more about the electromagnetic pulse created by nuclear explosions. (For more on nuclear weapons effects, see p. 28.) ★

Photo: Nevada National Security Sites, Nuclear Testing Archive

Los Alamos
NATIONAL LABORATORY

NATIONAL ★ SECURITY SCIENCE

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THEN & NOW

Los Alamos National Laboratory's national security mission helps deter aggression against the United States and its allies. But who deters aggression against the Lab? Since its inception, guards—many of them active military or veterans—have protected the Laboratory. These guards are perhaps most visible at entrances to the Lab, where they check the identification of every driver passing through. Here, guards check IDs in the 1940s (above) and in 2024 . ★