LOS ALAMOS NATIONAL LABORATORY ◇ SUMMER 2020

NATIONAL ★ SECURITY SCIENCE

THE HISTORY ISSUE

The Trinity test: 75 years ago, scientists detonated the world's first atomic bomb

The mission that changed the world: On August 6, 1945, the Enola Gay dropped Little Boy on Hiroshima, Japan

Cold War watchmen: Project Vela satellites could detect nuclear explosions in space

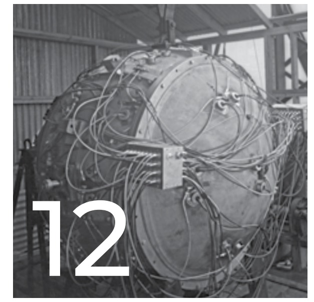
Behind the bamboo curtain: An inside look at the Chinese Nuclear Test Site at Lop Nur

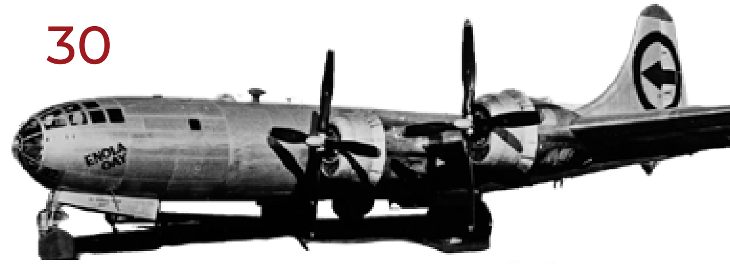
+PLUS:

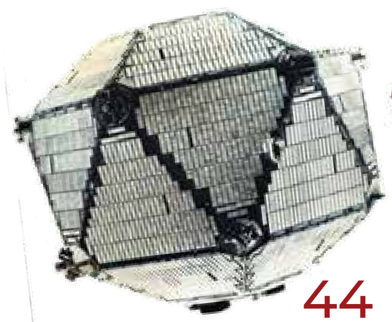
Q&A with Brigadier General Paul Tibbets IV	Relocating the Rocky Flats archive to Los Alamos	Doomed to cooperate: The United States and Russia

PHOTOBOMB

Because even a drop of a concentrated nerve agent can endanger the health of passengers on an airplane, the Transportation Security Administration (TSA) worked with Los Alamos National Laboratory to develop a screening device for nerve agents. The device (the silver canister pictured here) uses nuclear magnetic resonance (NMR) to screen passengers' carry-on items (such as the bottle pictured here) in fewer than eight seconds—perfect for fast-paced airport environments. NMR is a common technique that allows the molecular structure of a material to be analyzed when the material is placed in a powerful magnetic field. The technology typically requires very large magnets, but Los Alamos scientists were able to essentially shrink the magnet for use in this small, portable device, which fits seamlessly into TSA's airport security lines. ★







About the cover: The B-29 Superfortress was a four-engine propeller-driven bomber and was the most sophisticated aircraft of its kind during World War II. In this photo, taken by Harold Agnew on Tinian Island, electrical engineer Walter Goodman stands in front of the Great Artiste, a B-29 that made history in August 1945 as the only aircraft to participate in the bombings of both Hiroshima and Nagasaki, Japan. Read more about the Hiroshima mission on p. 30.

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THE HISTORY ISSUE

Building on its storied past, our Laboratory continues to push the envelope of what's possible, making history every single day.

BY BOB WEBSTER DEPUTY DIRECTOR, WEAPONS

We think "history," and we gravitate toward dusty technical reports, dog-eared notebooks, and black and white photographs. Many such documents are archived in the Laboratory's new National Security Research Center (NSRC), a largely classified library that allows scientists and engineers to access long-forgotten materials to aid their research. The NSRC was also a great resource for creating this issue of *National Security Science* magazine. The NSRC staff patiently answered questions from our writers and unearthed documents that support many of the articles you'll read here.

In addition to the treasure trove of items in the NSRC, history is being made every day at the Laboratory. Earlier this spring, nearly all Laboratory staff began telecommuting in an effort to reduce opportunities for COVID-19 transmission. This situation is a first for everyone. It involves not only working remotely but also considering what a global health pandemic means for each of us individually as well as for the Laboratory's national security mission.

Our IT and communications teams are working efficiently and effectively to get our 12,000 employees on the same page and connected from afar. As the majority of employees work from home, a handful of employees do come in to the Laboratory every day to support key mission-essential activities that cannot be done offsite.

In the midst of all this, President Donald Trump announced a new initiative to use America's supercomputing resources to combat COVID-19. "The launch of the COVID-19 High Performance Computing Consortium will provide COVID-19 researchers with access to the world's most powerful high performance computing resources that can significantly advance the pace of scientific discovery in the fight to stop the virus," the White House said in a press release.

Well, guess where some of the world's most powerful high-performance computing resources are located?

That's right. Right here at Los Alamos. As a National Nuclear Security Administration (NNSA) laboratory, Los Alamos "is eagerly lending out its world-class supercomputing resources to combat COVID-19 in collaboration with other agencies," said NNSA Administrator Lisa Gordon-Hagerty. "NNSA supercomputers will be available, empowering researchers to understand the COVID-19 virus, develop treatments and vaccines, and ultimately bring an end to this pandemic."

In other words, we are making history. ★

MASTHEAD

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NSS STAFF SPOTLIGHT

Much of this issue was created during the coronavirus pandemic, which challenged Lab employees to find creative solutions for getting their work done while social distancing. Here, writer Clay Dillingham (right) interviews retired weapons physicist John Hopkins through a window at Hopkins' house. To read the resulting article, flip to p. 56.

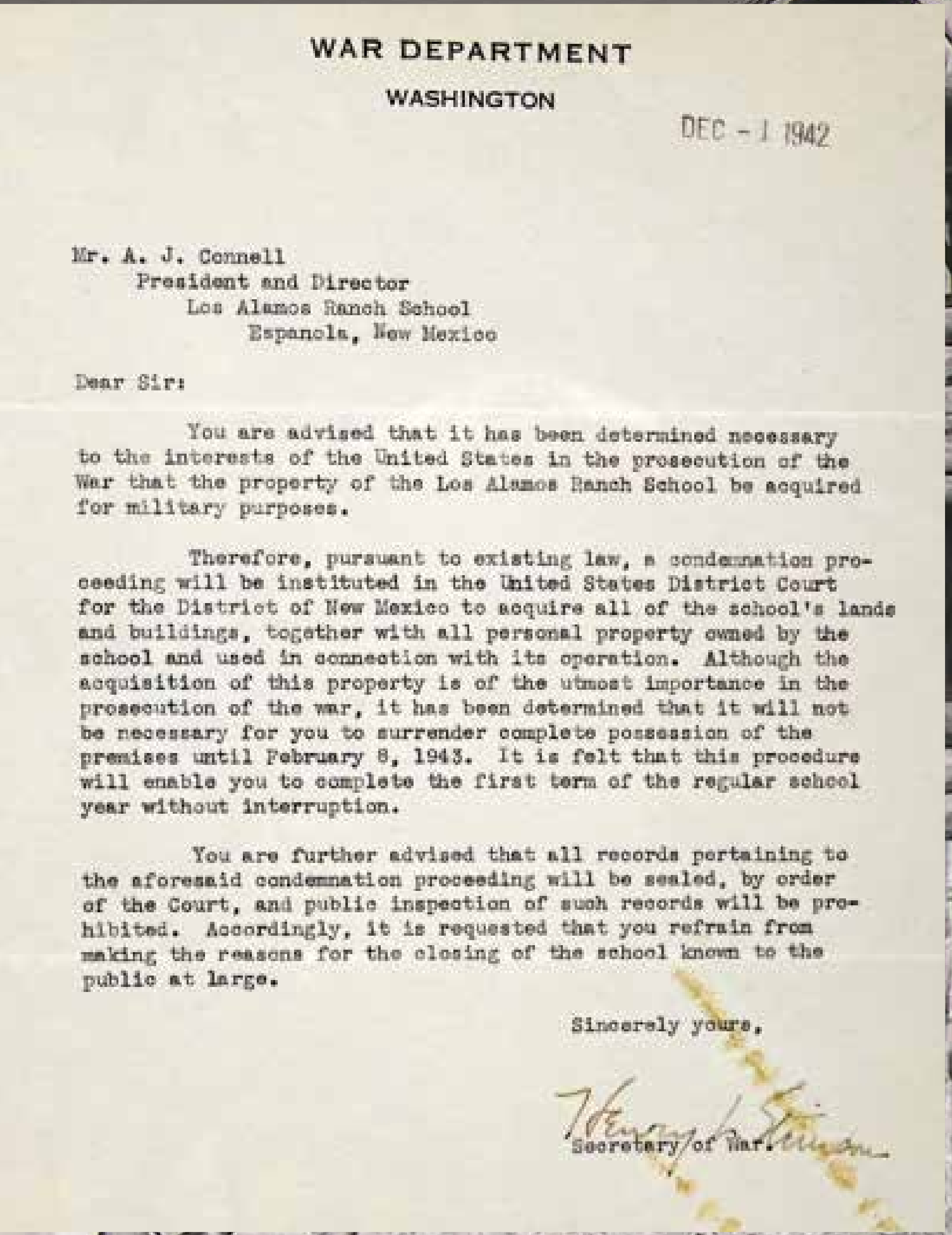
FROM THE ARCHIVES

A LETTER FROM WASHINGTON

The Los Alamos Ranch School is acquired for "military purposes."

In 1914, Detroit businessman Ashley Pond constructed a log cabin on the Pajarito Plateau in north-central New Mexico. The one-room structure served as the office for the Pajarito Club, a guest ranch for well-heeled city folk looking for a little Wild West adventure. Although the Pajarito Club was short-lived (it disbanded in 1916), Pond remained in the area and went on to found the Los Alamos Ranch School in 1917. The elite prep school offered classical education and rigorous outdoor activity for boys ages 12–18. But once more, Pond's business venture was fleeting. In 1943, the U.S. government acquired the school and launched Project Y of the Manhattan Project in its stead.

Here, Henry Stimson, U.S. Secretary of War, explains the acquisition to the Ranch School's director. ★



WAR DEPARTMENT
WASHINGTON

DEC - 1 1942

Mr. A. J. Connell
President and Director
Los Alamos Ranch School
Espanola, New Mexico

Dear Sir:

You are advised that it has been determined necessary to the interests of the United States in the prosecution of the War that the property of the Los Alamos Ranch School be acquired for military purposes.

Therefore, pursuant to existing law, a condemnation proceeding will be instituted in the United States District Court for the District of New Mexico to acquire all of the school's lands and buildings, together with all personal property owned by the school and used in connection with its operation. Although the acquisition of this property is of the utmost importance in the prosecution of the war, it has been determined that it will not be necessary for you to surrender complete possession of the premises until February 8, 1943. It is felt that this procedure will enable you to complete the first term of the regular school year without interruption.

You are further advised that all records pertaining to the aforesaid condemnation proceeding will be sealed, by order of the Court, and public inspection of such records will be prohibited. Accordingly, it is requested that you refrain from making the reasons for the closing of the school known to the public at large.

Sincerely yours,

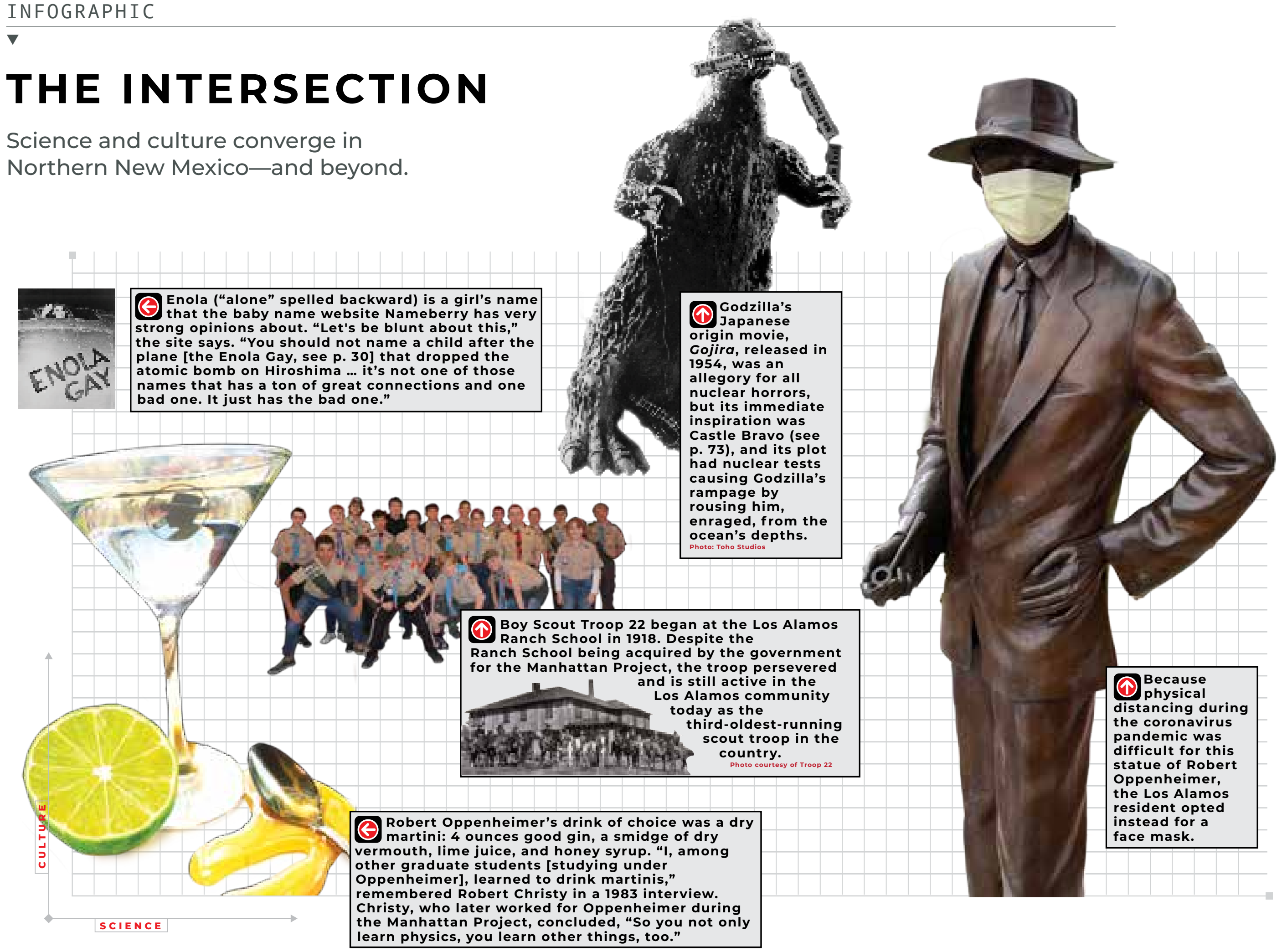
Henry L. Stimson
Secretary of War.

◆ Fuller Lodge was one of the main buildings at the Los Alamos Ranch School and remains a cornerstone of downtown Los Alamos today.

INFOGRAPHIC

THE INTERSECTION

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



QUOTED

MY CONFIDENCE STEMS FROM OUR HISTORY…

At the outset of World War II, America faced an unprecedented set of threats that produced fears for our physical security and our economy, and caused significant disruptions to Americans daily lives. Yet through prudent leadership, the application of science to practical problems, and above all, thanks to the fortitude and the determination of the American people, our nation overcame these trials and emerged from that world crisis stronger than ever.”

— National Nuclear Security Administration Administrator **Lisa Gordon-Hagerty** in a March 30 message to members of her “NNSA family” regarding the coronavirus pandemic. “I am confident that we have the same ability to not only survive this pandemic,” she wrote, “but that we will become a wiser and more resilient enterprise as a result.”

HISTORY

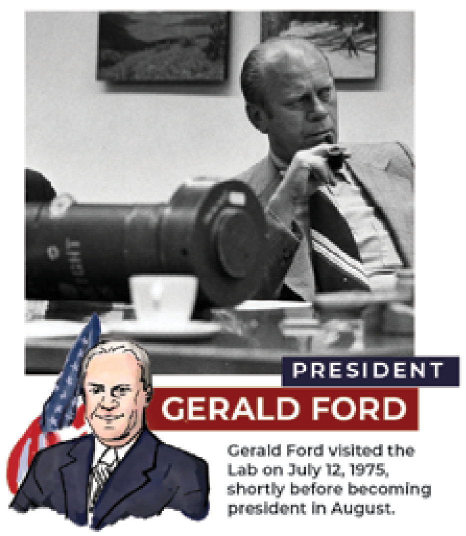
PRESIDENTIAL VISITS

Many public figures have toured the Lab, including several senior government officials.

BY JOHN MOORE

On December 7, 1962, President John Kennedy along with **Vice President Lyndon Johnson** traveled to Los Alamos for a briefing on the details of Project Rover, the Lab’s program to develop nuclear rocket engines for space travel. After visiting the Lab, Kennedy addressed Los Alamos residents at the high school football field and then rode down Central Avenue in a motorcade.

Former Hollywood movie star and future president Ronald Reagan visited Los Alamos in April 1967, when he was governor of California. At that time, the Laboratory was managed entirely by the University of California system.



Gerald Ford visited the Lab on July 12, 1975, shortly before becoming president in August.

Bill Clinton visited twice during his presidency—once on May 13, 1993, and again on February 4, 1998. Here he is with then-Lab Director Sig Hecker (second from right) and others.

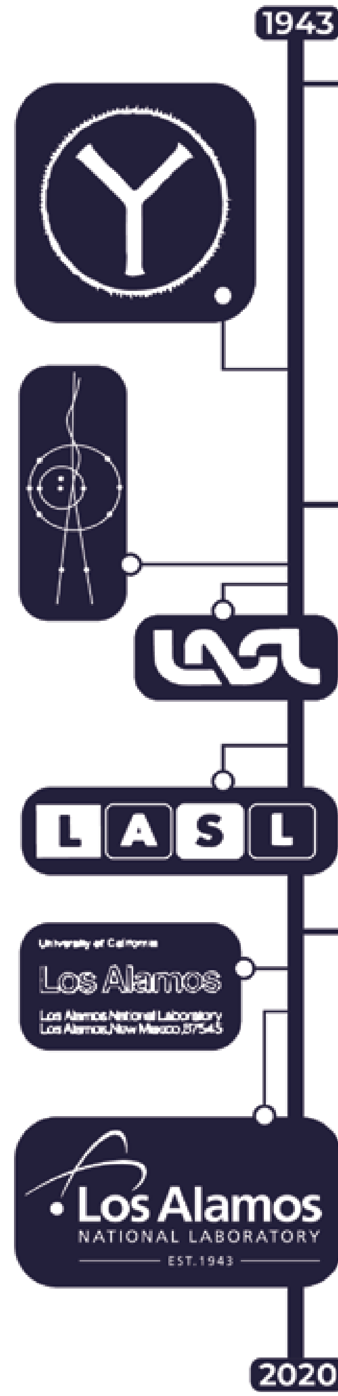
HISTORY

WHAT’S IN A NAME?

Los Alamos National Laboratory has had three names in 77 years.

BY MADELINE WHITACRE

Though the Lab’s mission of ensuring national security through scientific excellence has endured, the Lab has had three different monikers in its lifetime. Here’s a quick look at each:



Project Y

1943 TO 1945 When the Laboratory was first established in 1943, it was officially known as Project Y and was just one of many Manhattan Project sites across the country. The name was meant to help keep the actual location and purpose of the Laboratory secret. However, most people working there simply referred to the Lab as “the Hill” because of its mesa-top location.

Los Alamos Scientific Laboratory

1945 TO 1980 After the Lab developed the world’s first two atomic bombs, which helped end World War II, its location no longer needed to be a secret. Project Y became known as the Los Alamos Scientific Laboratory. The first known reference to this name change is in the October 1945 program for the Army-Navy “E” award ceremony for excellence in the production of war equipment.

Los Alamos National Laboratory

1981 TO TODAY In 1981, the Lab became Los Alamos National Laboratory. This change was prompted by Congress’s decision that the Department of Energy’s laboratories would all have “national” in their official names to emphasize the breadth of the work they perform on behalf of our nation’s interests. At the time, many employees didn’t like that “scientific” wasn’t in the name anymore.

HISTORY

THE MAN WHO WAS NEARLY OPPENHEIMER

Nobel Laureate Carl David Anderson was the first person tapped to lead Project Y.

BY JOHN MOORE

In 1936, 31-year-old physicist Carl David Anderson was the youngest person at that time to receive the Nobel Prize for his discovery of the positron years earlier. (A positron is a subatomic particle with the same mass as an electron and a numerically equal positive charge.)

About six years later, he was approached by fellow physicist and Nobel Laureate Arthur Compton. Compton had three telegraphs; two asked Anderson to head the government's top-secret project that would eventually produce the world's first atomic bombs. The third telegraph was a request that none other than Robert Oppenheimer join Anderson's ongoing scientific work—as Anderson's assistant—to discuss the "theorical aspects" of the project.

While at the California Institute of Technology (Caltech), where Anderson studied, taught, and researched, Anderson often interacted with Oppenheimer. Anderson recalled that Oppenheimer believed he (Oppenheimer) would never be able to work on Project Y due to his past affiliation with the Communist Party.

Anderson never pursued the job offer that ultimately helped end World War II and made "Oppenheimer" a household name. In his autobiography, *The Discovery of Anti-Matter: The Autobiography of Carl David Anderson, the Youngest Man to Win the Nobel Prize*, Anderson said that his inability to head Project Y was out of his control, citing economic and family issues.

He wrote, "I believe my greatest contribution to the World War II effort was my inability to take part in the development of the atomic bomb." In a 1990 *Los Angeles Times* interview, Anderson said he had no regrets about his decision not to lead Project Y because of the burden it had placed on his friend "Oppie."

During World War II, however, Anderson played a major role in the ability of Allied aircraft to fire a variety of rockets that were developed at Caltech. He would also continue to interact with famed Manhattan Project scientists, such as Seth Neddermeyer, who championed the implosion-style nuclear weapon called Fat Man. (In the pre-war years, Anderson had worked with Neddermeyer to discover the muon in 1936.)

Anderson's discovery of the positron is still significant for various types of sciences, including particle accelerator experiments and what are commonly called PET scans, which help diagnose diseases.

Meanwhile, Oppenheimer was nominated for the Nobel Prize for physics three times—in 1945, 1951, and 1967—but never won. ★

Physicist Carl David Anderson had no regrets about turning down the top scientific leadership role at Project Y.

Photo: Archives, California Institute of Technology

BY THE NUMBERS

NOBEL PRIZES

Twenty scientists with ties to Los Alamos have won Nobel Prizes.

Established by Alfred Nobel in 1895, the Nobel Prize is the most prestigious award offered in the fields of chemistry, peace, physics, literature, physiology or medicine, and economics. Nobel Prizes have been bestowed upon more than 900 individuals. More than a dozen of these Nobel Laureates contributed to research at Los Alamos during some point of their careers. ★

The 1965 Nobel Prize in Physics was awarded jointly to Sin-Itiro Tomonaga, Julian Schwinger, and Richard Feynman (pictured) "for their fundamental work in quantum electrodynamics."

Feynman, who worked at Los Alamos during the Manhattan Project, is remembered for his creative problem solving, unconventional perspective, and ability to communicate with a flair. Today, the Richard P. Feynman Center for Innovation at the Lab is guided by the Feynman legacy.

Photo: Archives, California Institute of Technology

SCIENCE

SWITCHABLE EXPLOSIVES

What if an explosive could be switched on and off like a light?

BY KATHARINE COGGESHALL

▲ Thuy-Ai Nguyen readies for explosives testing at the Lab's High Explosives Science and Technology site.

Traditional explosives have just one state, which is determined by their outermost electrons. Electrons (little balls of charged energy) arrange themselves in orbitals (regions) around the atoms of an explosive compound. Although the orbitals are finite and unchanging, how the electrons decide to disperse among the orbitals determines the compound's state and therefore its properties, such as its sensitivity (how likely it is to explode). Most compounds settle on a state that requires the least amount of energy to maintain.

But what if explosives could have two states—an insensitive state (not likely to accidentally explode) and a sensitive state (ready to boom)? By exploiting a property called "spin crossover"—a phenomenon that supports two different electron dispersion states—Lab researchers are honing two-state "switchable" explosives, which are safer to handle because they can essentially be turned on and off.

"Spin crossover has been studied for some time in other materials," says Jackie Veauthier, deputy group leader of Inorganic Isotope and Actinide Chemistry, "but until now, no one had reported it in an explosive."

Veauthier, with collaborators from the Lab's Explosive Science and Shock Physics Division and the Theoretical Division, were the first to realize that $[Fe(Htrz)_3]_n[ClO_4]_{2n}$, an explosive material, also possesses spin crossover. $[Fe(Htrz)_3]_n[ClO_4]_{2n}$ is not new, but Veauthier and her colleagues only recently discovered its versatility.

Although $[Fe(Htrz)_3]_n[ClO_4]_{2n}$ is providing a framework for what a switchable explosive might look like, the material isn't the most ideal in terms of switchability. The gap between the less-sensitive and more-sensitive states isn't as large as the researchers would like. A larger gap would offer more of an on-off control mechanism, one that could be triggered by a specific stimulus, such as a magnetic field or irradiation with light.

"There are definitely other compounds out there that could be switchable explosives," says Thuy-Ai Nguyen, an Agnew National Security Postdoctoral Fellow in the Lab's High Explosives Science and Technology group. "New spin-crossover materials are being made all the time for applications in electronic devices, and some of those compounds have energy-dense, nitrogen-rich sections that can be optimized to have explosive properties."

As they tweak these new compounds, researchers will also be testing known explosives for spin-crossover properties. Slowly, they are building a new class of explosives—one that is safer for military personnel, miners, construction workers, and others to use. ★

QUOTED

"Since the era of the Manhattan Project, it has been essential to underwrite the performance of nuclear weapons using the most powerful computing available."

—Bob Webster, Deputy Laboratory Director for Weapons, in a press release announcing that Hewlett Packard Enterprise (HPE) was awarded the contract for the new Crossroads supercomputer, which will eventually replace the Laboratory's current supercomputer, Trinity. Crossroads is projected to be installed at Los Alamos in early 2022 and will offer groundbreaking 3D simulation capabilities.

■ The Restartable Rocket Engine, developed at Los Alamos, will help prevent satellites from colliding, which will reduce the amount of debris in space.

Photo: Dreamstime Illustration 119686378 © Planetfelicity

SPACE

THE SPACE-CLUTTER DILEMMA

A revolutionary update to the solid rocket engine will help solve a fast-growing satellite problem.

BY J. WESTON PHIPPEN

The history of the solid rocket engine reaches back to 13th-century China, when soldiers fired gunpowder-filled "fire arrows" at invading Mongols. After many advancements, solid rocket engines—called that because they use a solid, granular fuel—have powered U.S. intercontinental ballistic missiles, launched astronauts into space, and delivered the nation's most sophisticated satellites into orbit.

Yet the technology always suffered a major drawback: a solid rocket engine can fire only once. This has had special consequences for satellites because, although solid rocket engines can launch them into orbit, once there, satellites must rely on small, liquid-fuel engines for trajectory adjustments.

Liquid-fuel engines can fire as many times as needed. But their compression chambers and volatile fuel make for a higher risk of accidental ignition, especially during the strain of launch. Although that risk is tolerable for larger satellites delivered individually into space, the most ubiquitous satellites are smaller communication or imaging devices that often share one launch to reduce costs. If a single liquid-fuel engine explodes, it jeopardizes the rest. So these small satellites are often sent into orbit without a way to be maneuvered or to be deorbited once they've completed their missions.

Once in low Earth orbit (typically below an altitude of 1,200 miles), about 5,000 satellites contend for room, along with 20,000 softball-size or larger pieces of space debris—everything from dropped payloads to spent rockets. Collisions are infrequent (the last was in 2009), but near-collisions pose a constant threat.

In January, two defunct satellites missed each other by 154 feet. If they'd collided, the debris could have crashed into other satellites, possibly causing more collisions. This problem grows exponentially as satellites become increasingly affordable and more are placed into orbit.

At Los Alamos National Laboratory, the work of research engineer Nicholas Dallmann and his team has finally solved this problem. Their Restartable Rocket Engine can start, stop, and start again as many times as necessary to help small satellites maneuver safely through space. The Restartable Rocket Engine, which is safe, reliable, and cheap to build, was made possible by three major breakthroughs.

The first concerned the fuel grains. The typical solid rocket combines both a fuel and an oxidizer in its body to use as propellant, but the Restartable Rocket Engine physically separates these two, which reduces the chance of accidental combustion to almost zero.

Next, to ignite the fuel, the Los Alamos team developed an electrolyzer similar to those used on submarines but modified for low-gravity space. This electrolyzer separates water into hydrogen and oxygen gas and lights them with a spark.

The biggest innovation was the ability of the rocket engine to switch on and off. Dallmann's team knew that a rapid change in pressure in the engine body could do this. So they reinvented an aerospike and cowl, the small opening at the end of a rocket body that focuses escaping gasses combusted in the engine that create thrust. The cowl on the Restartable Rocket Engine can expand and contract, like a camera's shutter, to rapidly drop the pressure in the body and stop combustion. Then it resets with a magnet so the process can begin again.

With those three developments, the Restartable Rocket Engine is safe enough to be mounted on small satellites piggybacking on a shared payload, and durable enough to survive years in space. With this technology, Los Alamos hopes to help society conserve low Earth orbit as a resource for future generations for centuries to come. ★

◆ The Rocky Flats archive is not unlike the warehouse in the last scene of *Raiders of the Lost Ark*, shown here.
Photo: Lucasfilm/Paramount

RAIDERS OF THE LOST ARCHIVE

Relocating the Rocky Flats archive to Los Alamos ensures we will learn from history, not repeat it.

BY KATHARINE COGGESHALL

Hundreds of boxes sit in a vault in the Denver Federal Center, each filled with hard copies of data, reports, laboratory notebooks, welding procedures, and technical illustrations. The boxes came from the Rocky Flats Plant in Golden, Colorado—a behemoth manufacturing hub that churned out the majority of the nuclear weapon pits (plutonium cores) that still exist in our nation's nuclear weapons stockpile. From 1952 to 1989, Rocky Flats produced those fissile cores and documented everything along the way. But when Rocky Flats shut down in 1989, following a dramatic raid by the Federal Bureau of Investigation and the Environmental Protection Agency, all of that pit-production knowledge was boxed up, sent to a vault, and nearly forgotten.

"It's like that last scene of *Raiders of the Lost Ark*," explains Joe Watts, a technical project manager at Los Alamos National Laboratory, referencing the 1981 film that ends with the prized Ark of the Covenant being sealed in a wooden crate and stored in a giant government warehouse.

About 20 years ago, Frank Gibbs, who oversaw the closure of the Rocky Flats site, remembered the cumulative value of those boxes. Gibbs (who is now the Lab's director of Actinide Operations) tasked Watts with retrieving the archive and relocating it to Los Alamos. "I went to Colorado to scan and digitize a portion of the technical reports," Watts remembers. Watts took what he could, but the bulk of the archive had to be left behind.

The effort to relocate the entire archive was revived in 2019. This effort involved not just physically moving hundreds of boxes but also digitizing their contents and making them easily searchable. "Now that we have restarted work on fleshing out the archive library, we are working as fast as we can to provide access to the entire collection," Watts says. "Today, we can quickly access around 25 percent of the technical reports electronically."

The timing is good, if not a little late. Los Alamos has been tasked by the National Nuclear Security Administration to produce 30 nuclear weapon pits per year by 2026. "Standing up pit production at Los Alamos from the Rocky Flats archive is like being asked to recreate the Sistine Chapel from da Vinci's drawings," says Bob Putnam, former program director (2006–2011) for Pit Manufacturing at Los Alamos and now an executive advisor to Gibbs. "We want to learn from the rich production history of Rocky Flats." In other words, the archive provides a solid knowledge foundation, but making pits still requires skill, experience, and finesse.

"Even if we don't follow their techniques exactly, the archive still offers us a well-worn path for how things were done in a facility known for efficient production," Watts says. Reaping that expertise from Rocky Flats is especially important as swaths of the Los Alamos workforce retire and are replaced by a new generation with limited experience building pits. The archive helps fill the knowledge gap, even if its contents don't bridge it completely.

▲ "Rocky Flats didn't just make pits," says Bob Putnam, "it was also home to premier actinide research and development, and all of that data is still relevant today."

"If you're a 20-something, you've never been taught to write procedures for a nuclear facility; it's nice to see how it's been done before," Watts says. "The Rocky Flats technical reports will certainly be an enduring resource to help maintain our national defense and lay the groundwork for future weapon production."

In addition to providing baseline knowledge for pit production, the archive contains experimental test data from hundreds of nuclear weapons tests—data that can't be replicated today because the United States no longer tests nuclear weapons. But that data is important because scientists can still incorporate it into their current research to help determine if a weapon is safe, secure, and effective. "That information is something both our adversaries and our allies would love to get their hands on," Putnam says. "The data is irreplaceable and invaluable."

But maybe "invaluable" isn't quite the right word, given that Rocky Flats data was recently used to save the National Nuclear Security Administration $2.5 million. In this instance, a set of experiments were planned that—unbeknownst to many—had been performed at Rocky Flats years ago. When former Rocky Flats employees at Los Alamos recalled the experiments, the archival data was retrieved. "Within 20 minutes, we had 29 documents that were helpful on a question," Putnam remembers. "A test that would have been $2.5 million has been redirected to something more valuable."

Putnam and Watts, who are based at the Lab's Plutonium Facility, are working with the Laboratory's Weapons Research Services Division (home to the National Security Research Center, the Lab's classified library) to build a searchable database that indexes the Rocky Flats archive with thorough metadata. The process will take several years, but the cost savings are already being realized.

Watts is quick to give his colleague credit for the progress so far: "That's Bob—he's the raider of the lost archive." ★

BETTER SCIENCE = BETTER SECURITY

Creating the world's first nuclear explosion was a science problem—**one that Los Alamos scientists and engineers solved in just 27 months.**

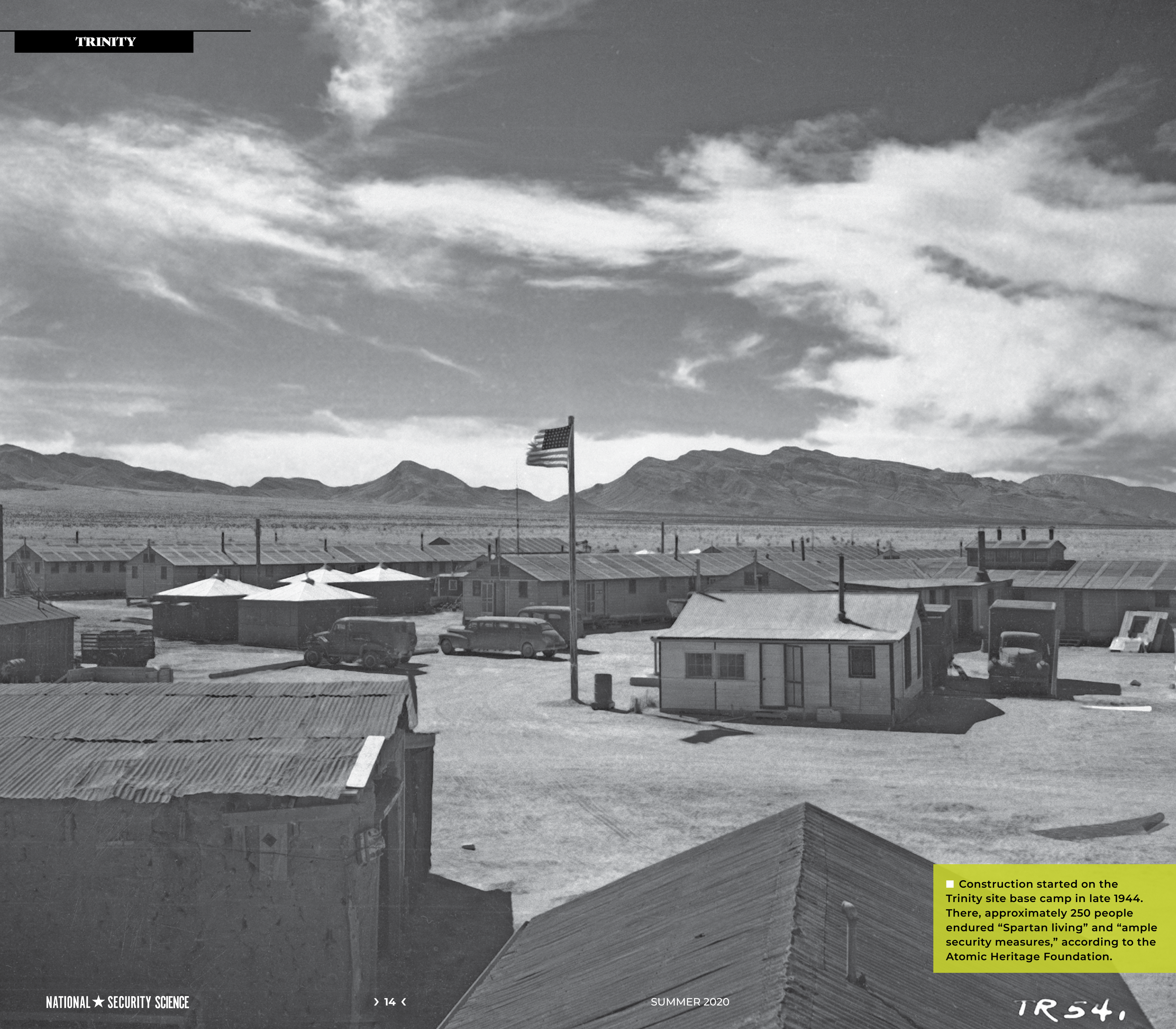
THE TRINITY TEST

Seventy-five years ago, Los Alamos scientists detonated the Gadget—the world's first atomic bomb.

BY VIRGINIA GRANT

■ In preparation for the Trinity test, an experiment using ordinary high explosives took place on May 7, 1945. The experiment, which detonated more than 100 tons of TNT stacked on a tower, allowed scientists to practice timing and calibrate instruments that would detect energy release, thermal radiation, and other factors.

NATIONAL ★ SECURITY SCIENCE



■ Construction started on the Trinity site base camp in late 1944. There, approximately 250 people endured "Spartan living" and "ample security measures," according to the Atomic Heritage Foundation.

On July 16, 1945, a predawn thunderstorm moved through the desert near Alamogordo, New Mexico, about 120 miles south of Albuquerque. After it passed, at 5:29:45 a.m., detonators ignited explosives around a large, steel, globe-shaped device on a 100-foot tower. The explosion prompted a fission chain reaction in the plutonium inside the globe. The resulting nuclear blast from the Gadget, as the device was called, released an explosive force of 21 kilotons (equivalent to 21 thousand tons of TNT), more than had been predicted. It created a blinding flash of light, a thunderous sound, and a mushroom cloud 38,000 feet tall. "Some people claim to have wondered at the time about the future of mankind," remembered physicist Norris Bradbury of witnessing the event. "I didn't. We were at war, and the damned thing worked." This was the Trinity test, the culmination of 27 months of work at Project Y—a secret laboratory in Los Alamos—to create the world's first atomic bomb.

THE NECESSITY OF TESTING

Project Y covertly developed two types of nuclear weapons. The first type—exemplified by Little Boy, the bomb eventually dropped over Hiroshima, Japan—achieved detonation by firing a subcritical piece of uranium at another subcritical piece of uranium, thus starting a supercritical reaction. Scientists were so certain that this gun-type design would work (see p. 43) that full-scale testing was deemed unnecessary.

The Gadget and Fat Man (the bomb dropped over Nagasaki) were of a different type; they were implosion bombs, with cores of subcritical plutonium that reached a supercritical mass because of pressure from the explosives surrounding them. Scientists weren't quite as confident in this design and felt the need to test the technology before its use in war.

"The set of problems connected with implosion was the most difficult," said Laboratory Director

Herb Lehr (left), a member of the Army's Special Engineer Detachment, and physicist Harry Daghlian unload the Gadget's plutonium core at the Trinity site. The core was driven to the site from Los Alamos in the pictured Army sedan.

Robert Oppenheimer of the development of the Gadget. "It required very new experimental techniques, and it was not a branch of physics which anyone was very familiar with."

PREPARING TO (HOPEFULLY) MAKE HISTORY

The Trinity test, directed by physicist Kenneth Bainbridge, would take place at the Alamogordo Bombing and Gunnery Range in the Jornada del Muerto ("Journey of Death") desert of New Mexico. The site, which was selected in September 1944, provided isolation and also proximity to Los Alamos, which was about 210 miles away. The area was flat, with little wind, providing better conditions for studying the explosion and its aftermath.

A great deal of construction commenced that fall. A base camp was built for the approximately 250 people who worked on preparations, roads were paved for the transport of materials to the site, and electricity was run to the test tower for the detonators. Three shelters—one each at 10,000 yards north, west, and south of ground zero—were constructed to protect people (scientists and soldiers) and equipment (for observation and radiation detection) during the test. More than 52 cameras were used to photograph and video record the test, including special high-speed cameras developed by members of the Weapons Physics Division for the purpose of recording nuclear explosions.

To prevent the waste of the plutonium in the Gadget's core, scientists considered building a giant concrete bowl filled with water to catch plutonium. This idea never materialized at the Trinity site, although a smaller version was built at Los Alamos. Scientists also contemplated detonating the Gadget inside Jumbo, a 216-ton steel cylinder that would contain plutonium if the detonation failed. Jumbo was built but

■ Herb Lehr carries the Gadget's plutonium core. From 1943 to 1946, Lehr served in the U.S. Army as part of the Special Engineer Detachment.

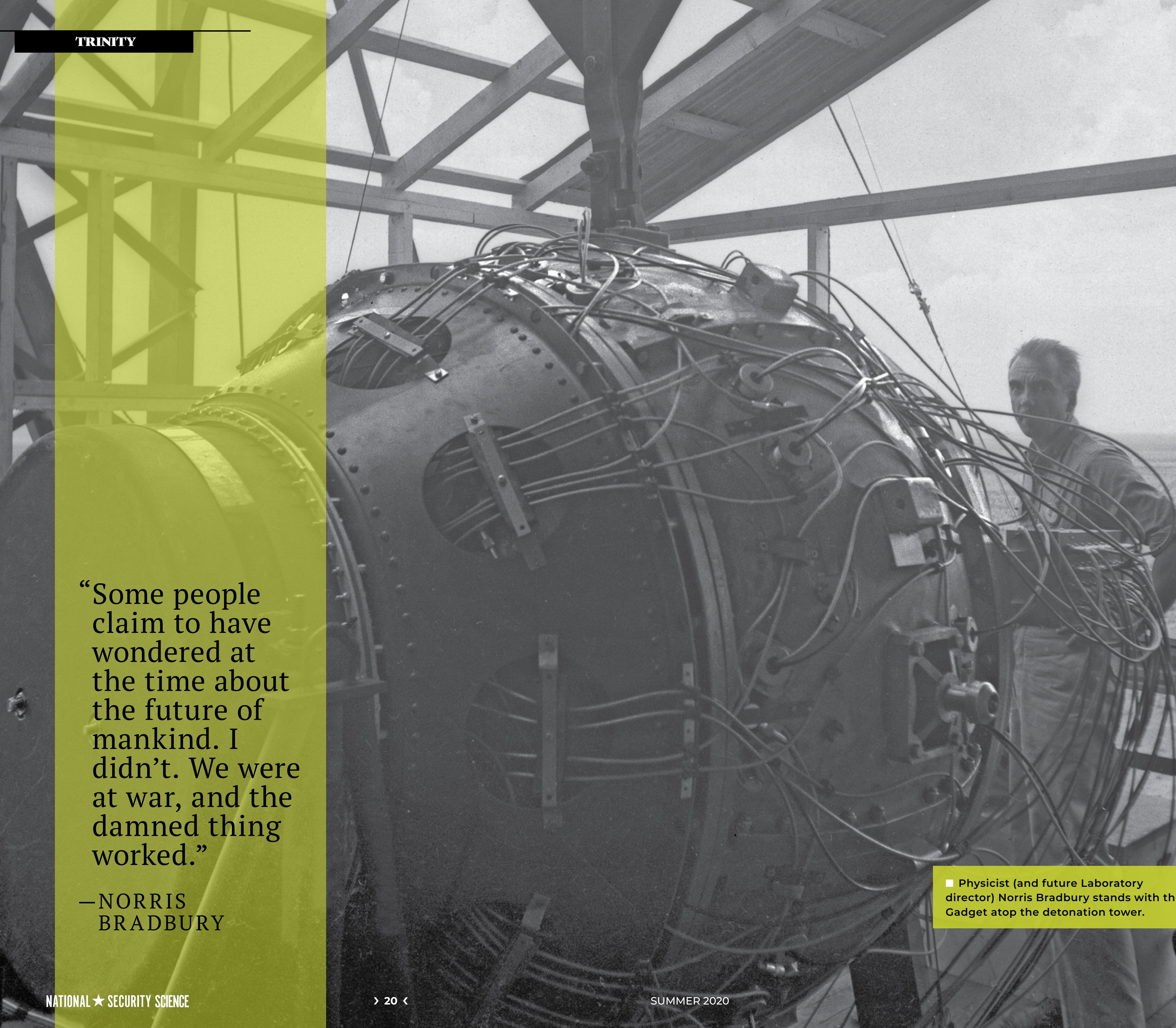
never used. Placed a quarter mile from ground zero, the vessel was unharmed by the blast. After World War II, eight 500-pound bombs were exploded inside Jumbo, but much of the cylinder stayed intact and remains today at the Trinity site.

Another important construction project was the 100-foot steel tower atop which the Gadget was detonated. The tower was used to get good images of the early fireball expanding and to reduce fallout—the radioactive dust and ash created when a nuclear weapon explodes. (Ultimately the tower was too short for a 21-kiloton test, and the blast produced a lot of fallout.)

The Gadget was hauled up the tower by an electric winch. During the process, part of the device became unhinged. For just this circumstance, a truckload of mattresses had been brought in and placed around the tower. Despite some onlooker panic, the Gadget was stabilized before it could fall.

In another mishap, Kenneth Greisen, whose group was in charge of the Trinity detonators, was pulled over for speeding in Albuquerque just a few days before the test. Luckily, the officers didn't check his trunk, as it contained the detonators themselves, which he was delivering to the site. Such delivery methods were the norm for Trinity—the plutonium core of the Gadget was delivered to the site in an Army sedan.

Preparations also included two explosives tests. The first, on May 7, was a 100-ton shot of TNT, used to make sure the test timing was right and to calibrate the detection instruments. The second took place near Los Alamos just two days before the Trinity test. The plan was to practice for Trinity using a model Gadget that did not contain plutonium. Although the faux Gadget did detonate, the initial interpretation of the data indicated the implosion of the actual Gadget would not be fast enough to initiate a full-scale nuclear detonation. However, physicist and Nobel Laureate Hans Bethe recalculated the data and concluded there would be adequate force for a successful implosion and that the Trinity test would be successful.



> "Some people claim to have wondered at the time about the future of mankind. I didn't. We were at war, and the damned thing worked."
>
> —NORRIS BRADBURY

■ Physicist (and future Laboratory director) Norris Bradbury stands with the Gadget atop the detonation tower.

■ The Gadget makes its way up the test tower.

The Gadget was "from a theoretical, from an observational, and from a practical point of view quite an adventure," Oppenheimer explained in a 1965 interview with journalist Stephane Groueff. "It was still a very reasonable opinion that one of the many things that we needed to make it work was not completely in order on July 16."

Perhaps that's why, among the numerous provisions made to protect the test's secrecy, false press releases were created for distribution after the blast. For example, one New Mexico paper, the *Clovis News-Journal*, would later report that "a remotely located ammunition magazine containing a considerable amount of high explosive and pyrotechnics exploded" at the Alamogordo Army Air Base. "There was no loss of life or injury to anyone, and the property damage outside of the explosive magazine itself was negligible."

"WE KNEW THE WORLD WOULD NOT BE THE SAME"

The Trinity test was originally scheduled to take place at 4 a.m. on Monday, July 16, but a thunderstorm caused a delay. Meteorologist Jack Hubbard predicted a narrow window of favorable weather between 5 and 6 a.m.; the rain stopped at 4, and the test was conducted seconds before 5:30.

The first visible product of the blast was an incredibly intense flash of light that

■ Workers prepare to hoist the Gadget to the top of the detonation tower. Not pictured is the truckload of mattresses placed below the tower in case the Gadget fell.

could be seen for 160 miles. After the light came the fireball, then a column of smoke that flattened into a mushroom cloud. The Trinity test created a crater a half-mile wide and melted the asphalt and sand around ground zero, leaving behind a green glassy substance now called trinitite.

Greisen recalled that "between the appearance of light and the arrival of the sound, there was loud cheering in the group around us. After the noise was over, we all went about congratulating each other and shaking hands."

Years later, Oppenheimer would remember about Trinity, "We knew the world would not be the same. A few people laughed, a few people cried, most people were silent." But at the time of the test, according to his brother, he simply said, "It worked."

THE CULMINATION OF A "HERCULEAN PROJECT"

After the detonation of the Gadget, General Leslie Groves, director of the Manhattan Project, was "struck by [a] feeling that the faith of those who had been responsible for the initiation and the carrying on of this Herculean project had been justified."

The Trinity test was important not only for its world-changing historical significance, but also because of the confidence it gave the United States that the Fat Man device would work and could help end World War II. Less than a month after Trinity, Fat Man was detonated over Nagasaki, Japan; less than a week after that, Emperor Hirohito announced Japan's surrender.

In the decades since the Trinity test, Los Alamos has continued the work of nuclear weapons design and stewardship, with the added responsibility of nonproliferation. When scientists waited in the desert before dawn 75 years ago, they knew the significance of what might be accomplished, just as current Los Alamos personnel know how important it is to continue and guard that work in the 21st century. ★

"A NEW THING HAD JUST BEEN BORN"

Witnesses of the Trinity test recount the world's first nuclear explosion.

"Although I did not look directly towards the object, I had the impression that suddenly the countryside became brighter than in full daylight. I subsequently looked in the direction of the explosion … and could see something that looked like a conglomeration of flames that promptly started rising. After a few seconds, the rising flames lost their brightness and appeared as a huge pillar of smoke with an expanded head like a gigantic mushroom that rose rapidly beyond the clouds."

—Physicist and Nobel Laureate Enrico Fermi

"It was like being at the bottom of an ocean of light. We were bathed in it from all directions."

—Joan Hinton, graduate student in physics

"The effects could well be called unprecedented, magnificent, beautiful, stupendous, and terrifying. … The whole country was lighted by a searing light with the intensity many times that of the midday sun. It was golden, purple, violet, gray, and blue. It lighted every peak, crevasse, and ridge of the nearby mountain range with a clarity and beauty that cannot be described but must be seen to be imagined."

—Brigadier General Thomas Farrell

"The whole spectacle was so tremendous—and one might almost say fantastic—that the immediate reaction of the watchers was one of awe rather than excitement. After some minutes of silence, a few people made remarks like, 'Well, it worked,' and then conversation and discussion became general. I am sure that all who witnessed this test went away with a profound feeling that they had seen one of the great events of history."

—Edwin McMillan, physicist

"We looked to the place where the bomb had been; there was an enormous ball of fire which grew and grew and it rolled as it grew; it went up into the air, in yellow flashes and into scarlet and green. It looked menacing. … A new thing had just been born; a new control; a new understanding of man, which man had acquired over nature."

—Isidor Rabi, physicist

"As I was not actively concerned with the problems of [Project] Y, I had on occasions asked my colleagues there what the event would be like, and their predicted picture of the event was borne out completely. I am amazed that the whole business went off so exactly as their calculations had predicted."

—Ernest Lawrence, scientist

"Oppie, you owe me ten dollars."

—George Kistiakowsky, physical chemist, to Oppenheimer directly after the test. Kistiakowsky won a bet—a month of his salary against Oppenheimer's ten dollars—that the Gadget would work.

■ Trinity test director Kenneth Bainbridge chose part of the Alamogordo Bombing and Gunnery Range for the test. Located in the Jornada del Muerto valley, the range was already owned by the government and was near Los Alamos—but not so close that people would suspect the two were connected.

To see color video footage of the Trinity test, find this article online at lanl.gov/magazine.

POIGNANT POETRY

The test of the Gadget was named "Trinity" by Robert Oppenheimer, who was most likely inspired by John Donne's 17th-century Holy Sonnet XIV.

Batter my heart, three-person'd God, for you
As yet but knock, breathe, shine, and seek to mend;
That I may rise and stand, o'erthrow me, and bend
Your force to break, blow, burn, and make me new.
I, like an usurp'd town to another due,
Labor to admit you, but oh, to no end;
Reason, your viceroy in me, me should defend,
But is captiv'd, and proves weak or untrue.
Yet dearly I love you, and would be lov'd fain,
But am betroth'd unto your enemy;
Divorce me, untie or break that knot again,
Take me to you, imprison me, for I,
Except you enthrall me, never shall be free,
Nor ever chaste, except you ravish me.

—JOHN DONNE

FROM THE ARCHIVES

Documents now housed in the Lab's National Security Research Center recount the preparation for the Trinity test.

THIS DOCUMENT CONSISTS OF ___ PAGES, ___ OF ___ COPIES, SERIES ___

Directions for Personnel at Hill Camp at Time of Shot

U up

PL 6-20-86

UNCLASSIFIED

1. Do not leave main group at camp where there will be monitoring and evacuation facilities. There will also be contact with planes, shelters, and area monitors over the radioreceivers.

PUBLICLY RELEASABLE
Classification Group
7/23/98

2. All personnel at Hill Camp will conform with the following Safety Regulations:

a) At a short signal of the siren at minus 5 minutes all personnel whose duties do not specifically require otherwise will prepare a suitable place to lie down on.

b) At a long signal of the siren at minus 2 minutes all personnel whose duties do not specifically require otherwise, will immediately lie prone on the ground, the face and eyes directed toward the ground and with the head away from "zero". Do not watch for the flash directly, but turn over after it has occurred and watch the cloud. Stay on the ground until the blast wave has passed (2 minutes).

c) At two short blasts of the siren, indicating the passing of all hazard from light and blast, all personnel will prepare to leave as soon as possible.

3. The hazard from blast is reduced by lying on the ground in such a manner that flying rocks, glass, and other objects do not intervene between the source of blast and the individual. Open all car windows.

4. The hazard from light injury to the eyes is reduced by shielding the closed eyes with the bended arms and lying face down on the ground. If the first flash is viewed a "blind spot" may prevent your seeing the rest of the show.

5. The hazard from ultraviolet light injuries to the skin is best overcome by wearing long trousers and shirts with long sleeves.

CLASSIFICATION CANCELLED
Per memo dated 6/29/77
By

UNCLASSIFIED

OCT 24, 1980
P. Lang 6-20-86

~~This document contains information affecting the national ... the meaning of ... Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

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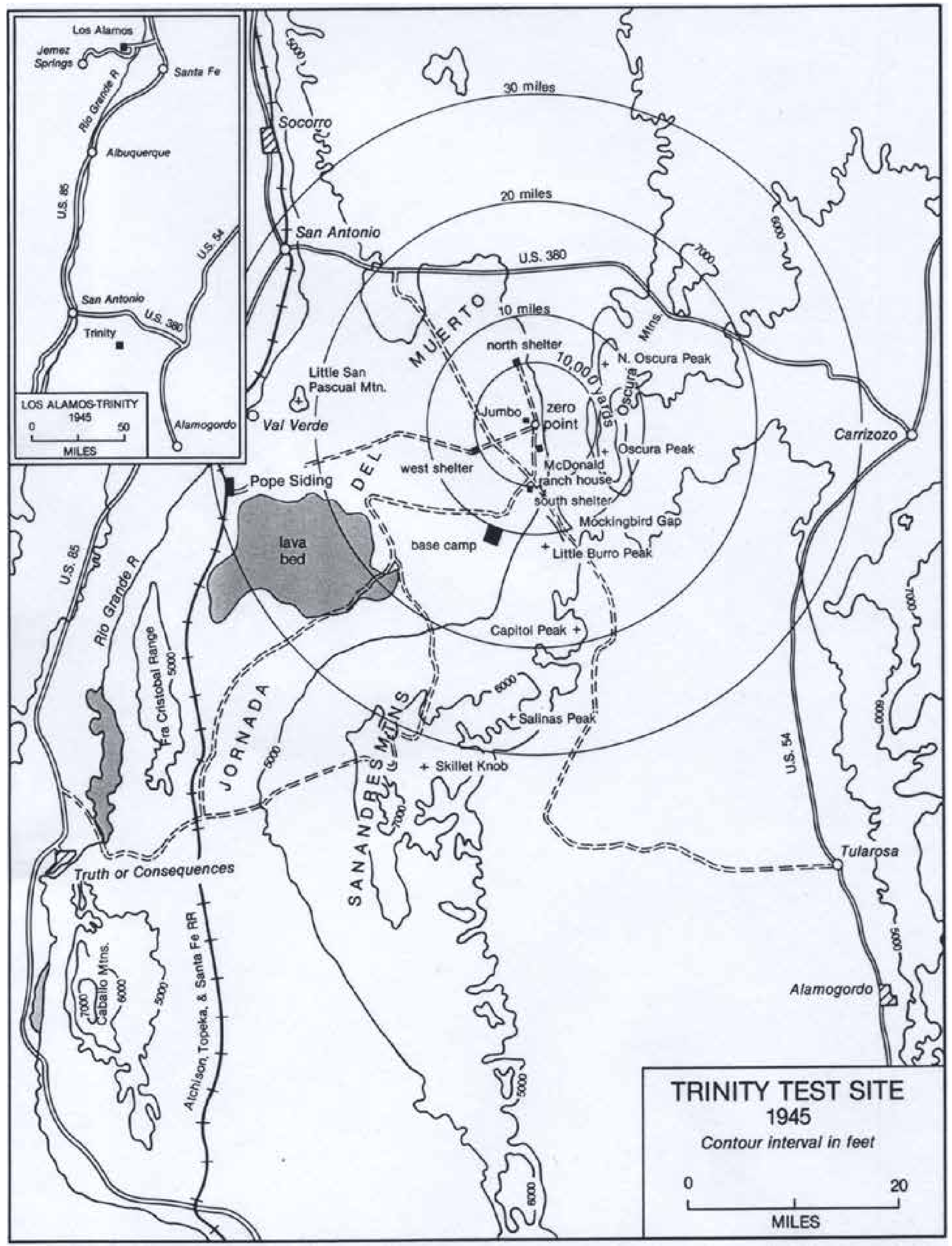


BETTER SCIENCE = BETTER SECURITY

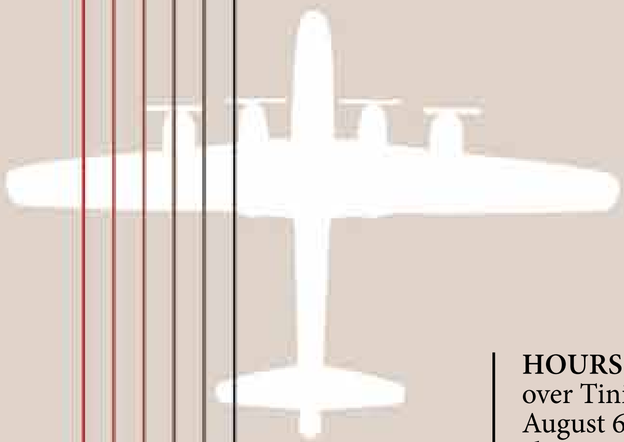
By thoroughly testing its components, **scientists were confident that Little Boy—the nuclear weapon dropped by the Enola Gay—would detonate**, thus establishing the United States as a credible nuclear power.

THE MISSION THAT CHANGED THE WORLD

BY BRYE STEEVES

Pilot Paul Tibbets Jr. named his B-29 bomber the "Enola Gay" after his mother, who long supported his dream of becoming a pilot.

On August 6, 1945, the crew of the Enola Gay dropped an atomic bomb designed at Los Alamos on the Japanese city of Hiroshima. As pilot Paul Tibbets Jr. and others explain, delivering a 10,000-pound bomb to southern Japan was a years-long endeavor that required patience, practice, and precision.



HOURS BEFORE THE SUN WOULD RISE over Tinian island on the morning of August 6, 1945, a B-29 airplane was positioned above a specially built bomb-loading pit, as crews readied the aircraft with cargo unlike anything the world had ever known.

Preparations on the tiny Pacific island—about 1,500 miles southeast of the plane's intended target in Japan—had begun months before on April 3. And months before that, pilot Paul Tibbets Jr. and his crew had practiced dropping dummy concrete bombs on targets in Wendover, Utah. Even years before that, development of this revolutionary cargo began in secrecy under the direction of a physicist and an Army general in the mountains of Northern New Mexico.

It was all leading to one day that would help end years of bloodshed and change the world forever.

In the early-morning darkness of that historic day 75 years ago, Colonel Tibbets and his 11-man crew boarded the plane and began their preflight preparations. As the plane's engines roared and its propellers spun, Tibbets looked out an open window at the crowd amassed on the runway. Sticking his head out just above the plane's painted name—Enola Gay, after his mother—the 30-year-old husband and father gave a wave and a slight smile and began to taxi.

At 2:45 a.m., the plane took off, and at 8:15 a.m., the crew of the Enola Gay released Little Boy, the world's first nuclear weapon, over the city of Hiroshima, Japan.

▶ The B-29 Superfortress, Colonel Paul Tibbets Jr., and an 11-man crew were chosen to deliver Little Boy, the first atomic bomb released in combat, above Hiroshima, Japan. The bomb's yield was 15 kilotons.

"You can't fly straight ahead because you'd be right over the top when it blows up and NOBODY WOULD EVER KNOW YOU WERE THERE"

—ROBERT OPPENHEIMER TO PAUL TIBBETS JR.

ENOLA GAY

"I had to go fly airplanes"

About a year earlier, in September 1944, Tibbets was chosen to lead the mission to deliver the world's first atomic bomb used in combat. But the man who would fly perhaps the world's most important sortie almost wasn't a pilot.

Tibbets was born to Paul and Enola Gay Tibbets on February 23, 1915, in Quincy, Illinois, and spent most of his childhood in Miami, Florida. He was drawn to flying at an early age, never forgetting a summer day at the local racetrack. A stunt pilot let a 12-year-old Tibbets climb aboard his small plane and toss Baby Ruth candy bars to the crowd below, according to *The New York Times*.

Tibbets later attended a private military preparatory school in Illinois and began taking flying lessons, despite his father's wish for him to pursue a medical career. His mother, though, encouraged her son to follow his dream.

"He [my father] said, 'You're going to be a doctor,' and I just nodded my head and that was it. And I started out that way. But about a year before, I was able to get into an airplane, fly it—I soloed—and I knew then that I had to go fly airplanes," Tibbets said, according to a 2002 interview in *The Guardian*.

In 1937, Tibbets withdrew from the University of Cincinnati's medical school and joined the U.S. Army Air Corps (which became the U.S. Air Force in 1947).

Training for a secret mission

Tibbets piloted various observation aircraft and bombers, including the B-17, which he flew in bombing raids above German-occupied Europe in the summer of 1942. By mid-1943, Tibbets began flying a new, innovative bomber: the B-29.

The aircraft would prove a game changer for the U.S. military, says Kirk Otterson, from the Office of Nuclear and Military Affairs at Los Alamos National Laboratory. It was larger and faster than a B-17 and could fly higher and farther. And, he adds, the B-29 could carry a larger bomb.

Nicknamed the Superfortress, the B-29 was a four-engine, propeller-driven bomber. First flown in 1942, it was the most sophisticated aircraft of its kind during World War II, Otterson says, and it was also the first bomber to house its crew in pressurized compartments. According to the Smithsonian's National Air and Space Museum, the B-29 was designed by Boeing to fight in the European theater, but it also proved valuable in the Pacific theater, with as many as 500 planes operating there in a two-year period. When production of the B-29s ended in 1946, about 3,970 had been built.

Tibbets established himself as an adept B-29 pilot as well as a skilled military officer and leader. So upon landing a routine B-29 test sortie in Nebraska in September 1944, he found a man waiting for him with a message from a general in Colorado Springs. Tibbets was told to pack his bags and be in the general's office at 9 a.m. the next day. He had no idea what the meeting was about or why he had been ordered to attend.

There, Tibbets was told the U.S. government's most closely guarded secret—scientists in Los Alamos, New Mexico, were harnessing atomic energy to create the world's first nuclear weapons, and Tibbets was being tapped to deliver an atomic bomb to help end World War II.

"When I got the assignment, [I knew] it was going to be an emotional thing," Tibbets told *The Columbus Dispatch* in 2005. "We had feelings, but we had to put them in the background. We knew it was going to kill people right and left. But my one driving interest was to do the best job I could so that we could end the killing [of World War II] as quickly as possible."

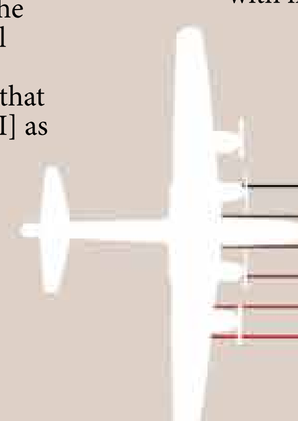
> "My one driving interest was to do the best job I could so that we could **END THE KILLING AS QUICKLY AS POSSIBLE.**"
> — PAUL TIBBETS JR.

Tibbets was told by his superiors that if he was successful, he would be a hero. He was also told that he was the first choice of just three names considered to lead the mission.

Lieutenant General Leslie Groves, the Army officer who oversaw the Manhattan Project, wrote in his memoir that Tibbets was chosen because "he was a superb pilot of heavy planes, with years of military flying experience, and was probably as familiar with the B-29 as anyone in the service."

Shortly after the meeting in Colorado, Tibbets took command of the newly created unit of 1,800 men who trained under extraordinary secrecy and security in an isolated, mostly uninhabited location in Utah at Wendover Airfield. Most of the airmen knew only as much as they needed to know to perform their duties. Tibbets himself handpicked the B-29 unit that would drop the atomic bombs and the Enola Gay's crew, including the bombardier, navigator, and flight engineer—Thomas Ferebee, Theodore "Dutch" Van Kirk, and Wyatt Duzenbury—all of whom he'd flown with in Europe.

◀ Colonel Paul Tibbets Jr. stands in front of his plane, a B-29 bomber named the Enola Gay.



The bombs, Los Alamos

Meanwhile, work to design and build the first atomic bombs at Project Y—the code name for the secret laboratory in Los Alamos—continued as part of the Manhattan Project, says Alan Carr, senior historian at Los Alamos National Laboratory. This effort to beat the enemy in developing nuclear technology eventually resulted in Little Boy, the gun-type uranium bomb that would be released by Tibbets and his crew during the Hiroshima mission. Los Alamos scientists also developed Fat Man, the implosion-type plutonium bomb that another pilot, Major Charles Sweeney, and his crew delivered to Nagasaki three days later in a B-29 named Bockscar. It was the world's second nuclear mission—and the last to date.

At 9,700 pounds, 10 feet long, and just over 2 feet in diameter, Little Boy was bigger than any bomb Tibbets had ever seen. The Enola Gay had to be specially modified to successfully carry and deploy it, Carr says. In the end, the bomb was released from the plane's front bomb bay at an altitude of 31,000 feet. Little Boy exploded less than one minute later, about 1,500 feet above Hiroshima.

During the development of the two nuclear bombs, Tibbets recalled visiting Los Alamos three times to meet with scientists and military officials—including Robert Oppenheimer, Project Y's lead scientist; General Groves; and others as the clandestine work on Little Boy and Fat Man progressed.

Initially, Tibbets didn't understand the full depth of the bombs' destructive nature, he said in the 2002 *Guardian* interview. One of the physicists explained it to Tibbets, who remembered thinking, "This was gonna be one hell of a big bang."

Tibbets asked Oppenheimer how to get away from the bomb after it was released.

"[Oppenheimer] said, 'You can't fly straight ahead because you'd be right over the top when it blows up and nobody would ever know you were there,'" Tibbets recalled in 2002. "'Turn 159 degrees as fast as you can and you'll be able to put yourself the greatest distance from where the bomb exploded.' I had dropped enough practice bombs to realize … I would have 40 to 42 seconds to turn 159 degrees. I went back to Wendover [Airfield, Utah] as quick as I could and took the airplane up. I got myself to 25,000 feet, and I practiced turning, steeper, steeper, steeper and I got it where I could pull it round in 40 seconds. The tail was shaking dramatically and I was afraid of it breaking off, but I didn't quit. That was my goal. And I practiced and practiced until, without even thinking about it, I could do it in between 40 and 42 [seconds] all the time."

The unique shapes of Little Boy and Fat Man meant the crews had to learn new techniques of releasing the bombs from the aircraft, Carr says. For nearly a year, hundreds of practice bombs were dropped from B-29s on targets surrounding the Utah airfield, while scientists and engineers in Los Alamos worked to determine the correct weight distribution and shape of the aerodynamically unique bombs. Meanwhile, special pits were constructed with hydraulic lifts to hoist the bombs into the B-29s' bomb bays.

▲ Little Boy was 9,700 pounds, 10-feet long, and just over 2 feet in diameter. Today, a full-scale replica can be seen in the Bradbury Science Museum in downtown Los Alamos.

▲ The Enola Gay had to be positioned above a specially built bomb-loading pit to allow crews to transfer Little Boy into the aircraft's bomb bay.

▶ Navy Captain William "Deak" Parsons (center) flew as the weaponeer on the Enola Gay, piloted by Colonel Paul Tibbets Jr. (right, standing). Parsons also helped prepare for the atomic bomb's delivery by modifying the aircraft and conducting field tests.

Los Alamos to "Destination"

In late May 1945, Tibbets and his unit transferred for additional training on Tinian island, where the Enola Gay would launch its mission several months later.

"One of three islands in the Northern Marianas, Tinian was chosen as the launching point for both the Hiroshima and Nagasaki missions based on its proximity to Japan and easy sea access for supplies," Carr says. "The island's code name was Destination."

Meanwhile, U.S. bombings on different targets in Japan continued, making the B-29s an already familiar site in the skies above the country.

On July 14, 1945, completed bomb components and about half of the United States' supply of uranium were taken by train from New Mexico to San Francisco, where they were loaded aboard a Navy heavy cruiser, the USS *Indianapolis*, and delivered to Tinian island less than two weeks later. Meanwhile, the other half of the uranium was flown to Tinian. Little Boy was then readied for the Hiroshima mission.

Around this same time, on July 16, 1945, Los Alamos scientists conducted the Trinity test, detonating a plutonium device, code-named the Gadget, in the New Mexico desert to verify the success of Fat Man in war.

By August, the plans for the first atomic mission were in place. In addition to the Enola Gay, many B-29s would participate, including a standby plane, a plane to take pictures, and another to collect data for scientific purposes. Weather planes also flew over the target cities before the missions.

Tibbets and his crew received notice that the sixth of August would be the day with the best weather for the mission above Hiroshima, and they began preparing. Around 4 p.m. on August 5, Tibbets got word that President Harry Truman had authorized the mission, according to the *Guardian*.

The Enola Gay was airborne less than 12 hours later.

The Hiroshima mission

As the Enola Gay drew nearer to its target on the morning of August 6, Tibbets recalled addressing his crew. "I said, 'You know what we're doing today?' They said, 'Well, yeah, we're going on a bombing mission.' I said, 'Yeah, we're going on a bombing mission, but it's a little bit special.' My tail gunner, Bob Caron, was pretty alert. He said, 'Colonel, we wouldn't be playing with atoms today, would we?' I said, 'Bob, you've got it just exactly right.' So, I went back up in the front end [of the airplane] and I told the navigator, bombardier, flight engineer, in turn. I said, 'OK, this is an atom bomb we're dropping.' They listened intently, but I didn't see any change in their faces or anything else. Those guys were no idiots. We'd been fiddling round with the most peculiar-shaped things we'd ever seen."

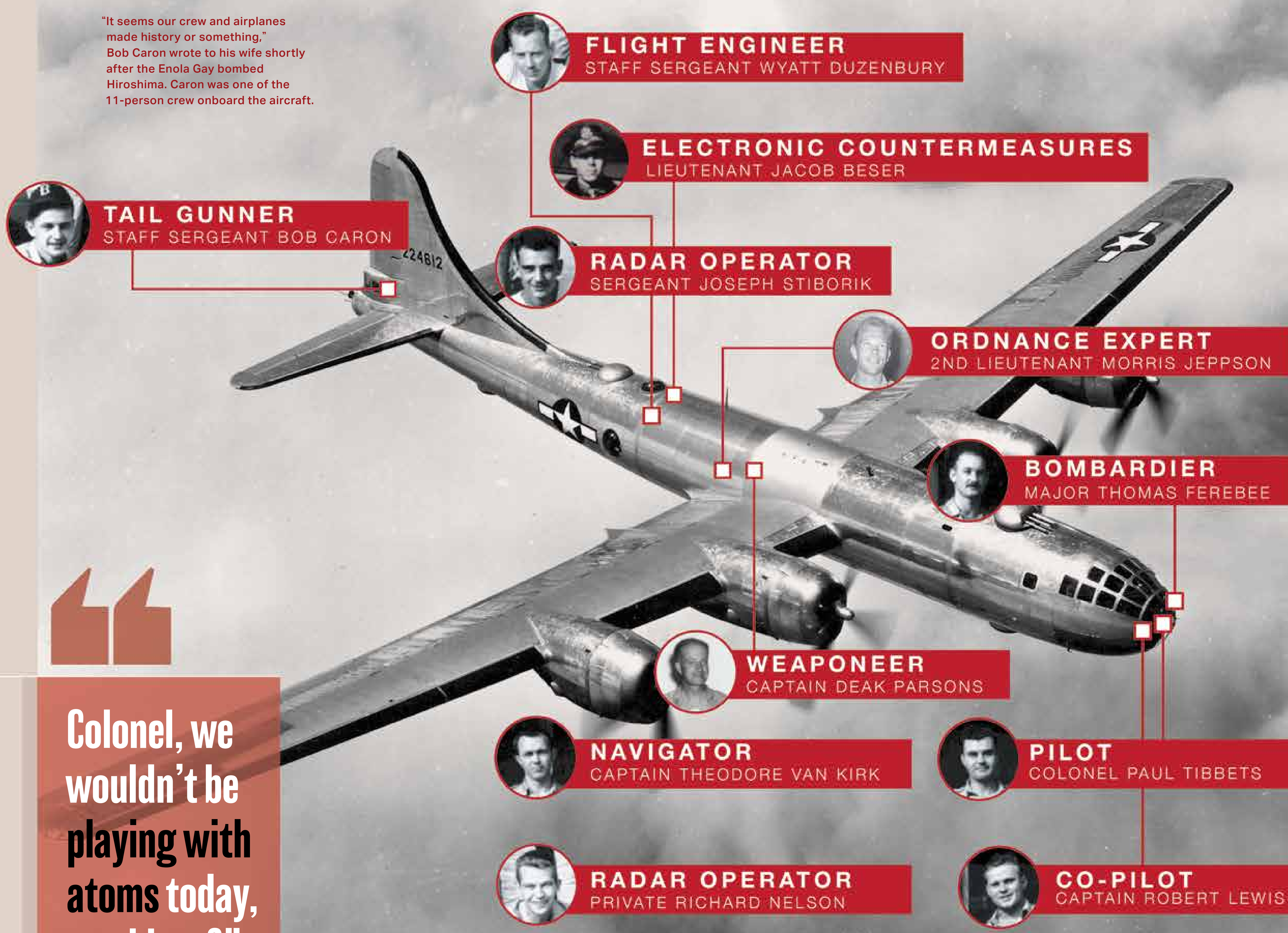
About six and a half hours after takeoff from Tinian, the Enola Gay was nearing Hiroshima. The skies were clear, and Little Boy was to be aimed at the distinctive T-shaped Aioi Bridge—an aim point that was chosen, Otterson says, because it was in the center of the city and could be easily seen from the air. Hiroshima itself was strategically significant because it headquartered the Japanese Army responsible for defending southern Japan and was a communications center and assembly area for troops.

With the target in sight, Tibbets counted down the seconds aloud for the crew … three, two, one … until the release of Little Boy. There was no doubt when the atomic bomb left the airplane.

"The [plane's] nose lurched up—I mean it lurched dramatically—because if you immediately let 10,000 pounds out of the front, the nose has got to fly up. We made our turn, we leveled out, and at the time that that happened I saw the sky in front of me light up brilliantly with all kinds of colors," Tibbets recalled. "At the same time, I felt the taste of lead in my mouth. And where we had seen the city on the way in, I [now] saw nothing but a bunch of boiling debris with fire and smoke and all of that kind of stuff. It was devastating to take a look at it."

The Enola Gay and its crew had carried out a flawless mission with no opposition from Japanese fighters and delivered the first nuclear bomb used in war, Carr says.

> **"Colonel, we wouldn't be playing with atoms today, would we?"**
> — BOB CARON



"It seems our crew and airplanes made history or something," Bob Caron wrote to his wife shortly after the Enola Gay bombed Hiroshima. Caron was one of the 11-person crew onboard the aircraft.

After World War II, Tibbets and his fellow crew members received various military honors for their roles in the Hiroshima mission. Tibbets continued to serve in the Air Force until he retired in 1966 as a brigadier general. He went on to help start and run an air taxi service in Ohio until he retired from the business in 1985. Tibbets died at the age of 92 in 2007.

The blast from Little Boy destroyed five square miles of the city, killed about 64,500 people, and injured countless others, according to a 1954 Army pathological study. Many more died in the ensuing months and years from injuries and radiation. (The blast from Fat Man, released above Nagasaki, is estimated to have killed about 39,214, according to the study.)

"I have been convinced that we saved more lives than we took," Tibbets said. "It would have been morally wrong if we'd have had that weapon and not used it and let a million more people die," he told an interviewer for the documentary *The Men Who Brought the Dawn*.

A few days after another crew dropped the second nuclear bomb during the Nagasaki mission, the Japanese government surrendered, ending World War II. As many as 50 million to 80 million (or more) people are estimated to have died during the war's six years, Carr says.

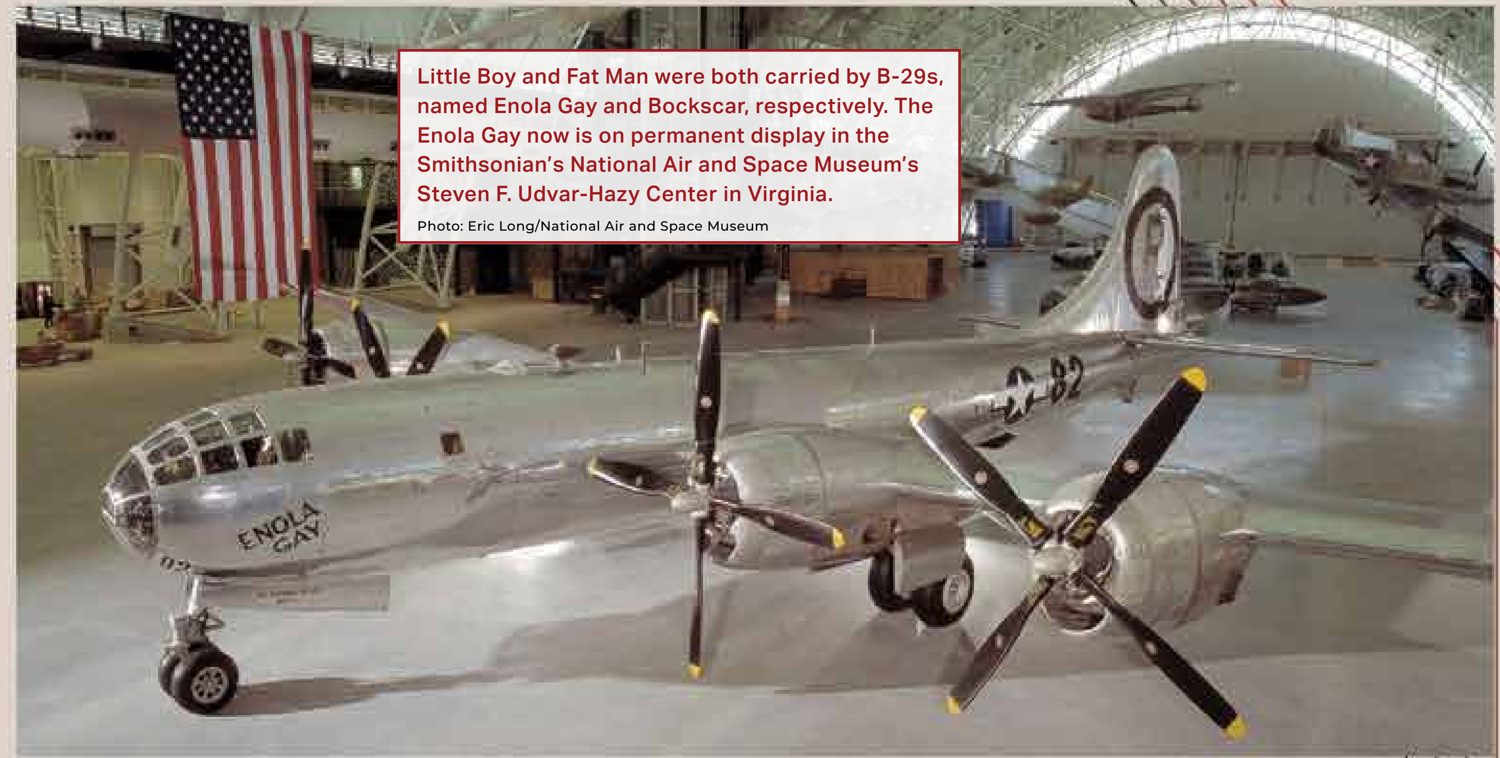
Aftermath

No one has used nuclear weapons in combat since 1945, though the United States uses them every day as a deterrent.

Since creating the world's first nuclear device 75 years ago, the Lab has been ensuring nuclear weapons are more effective, safe, and specific to the military's needs, Otterson says.

"The work here at Los Alamos and our other national labs gives the warfighter—whether he or she is pulling the trigger, planning the targets, or maintaining the weapons system—the knowledge and, more importantly, the confidence essential to mission success," Otterson says. He adds that as a retired Air Force officer who now works for the Lab, he believes that the partnership between the Department of Defense and Department of Energy is what secures our country's nuclear-deterrent capability.

Carr concurs, adding, "Today at Los Alamos National Laboratory, we're in the business of making sure another world war never happens. The Lab's weapons work makes sure the world is a safer, more secure place. Nuclear weapons, as a deterrent, do that. Thus far, this transformative technology has helped render world wars obsolete."



Little Boy and Fat Man were both carried by B-29s, named Enola Gay and Bockscar, respectively. The Enola Gay now is on permanent display in the Smithsonian's National Air and Space Museum's Steven F. Udvar-Hazy Center in Virginia.

Photo: Eric Long/National Air and Space Museum

As just one reminder of its role as a means to the end of World War II, the Enola Gay now is on permanent display in the Smithsonian's National Air and Space Museum's Steven F. Udvar-Hazy Center.

None of the 12 crew members of the Enola Gay are alive today. Tibbets died at the age of 92 on November 1, 2007, in Columbus, Ohio. The last surviving crew member, Theodore "Dutch" Van Kirk, died in 2014 at 93.

After World War II, Tibbets and his fellow crew members received various military honors for their roles in the Hiroshima mission. Tibbets' awards included the Distinguished Service Cross, the Legion of Merit, and the Distinguished Flying Cross. He was also part of a small group invited to meet with President Truman at the White House. According to Tibbets' 2002 *Guardian* interview, Truman asked Tibbets, "What do you think?" Tibbets responded, "'Mr. President, I think I did what I was told.' He [the president] slapped his hand on the table and said, 'You're damn right you did, and I'm the guy who sent you. If anybody gives you a hard time about it, refer them to me.'"

After World War II, Tibbets continued to serve in the Air Force until he retired in 1966 as a brigadier general. He went on to help start an air taxi service in Ohio, and he helped run it until he retired from the business in 1985.

Before his death, Tibbets requested that his remains be cremated and that he not have a physical memorial, fearing it would become a gathering spot for nuclear weapons protests. His ashes were scattered by family members over the English Channel, where he'd flown many times in combat.

In various interviews in the decades after delivering the world's first nuclear bomb, Tibbets never once expressed regret. Piloting the Hiroshima mission was his patriotic duty, Tibbets said time and again.

"I knew we did the right thing. … I thought, yes, we're going to kill a lot of people, but by God we're going to save a lot of lives," he said.

But he also realized that once Little Boy was released, nothing would ever be the same. Albert Einstein famously said the world became a different place after the atom was split, referring to nuclear fission, the source of the atomic bomb's explosive power.

Tibbets concurred. "That's right. It has changed."

He and the crew of the Enola Gay were there to see it the moment it happened. ★

GENERATIONS OF TRADITION

Brigadier General (retired) Paul Tibbets IV reflects on his family's legacy of military service.

BY BRYE STEEVES


Photo: U.S. Air Force

Paul Tibbets Jr., the Enola Gay pilot, was father to Paul Tibbets III, who served in the military as an Army reservist pharmacist and hospital administrator and eventually retired as a colonel. His son—grandson of Tibbets Jr.—is also Paul Tibbets.

Paul Tibbets IV is a retired Air Force brigadier general and decorated bomber pilot, and his legacy is not lost on his fellow airmen. They gave Tibbets IV the callsign "Nuke" early in his flying career.

Tibbets IV flew the B-1 bomber and then the B-2 stealth bomber, a nuclear-capable, long-range strike aircraft. His 29 years of military service include combat missions in the Middle East, Afghanistan, and the Balkans—and a flight in a restored B-29 with his grandfather.

In commemoration of the 75th anniversary of the atomic bomb and his grandfather's historic role, Tibbets IV spoke with *National Security Science* magazine.

The atomic bomb made history and changed the world but also must be very personal to you. What are your thoughts as we recognize the 75th anniversary?

I am honored to be a Paul Tibbets. When my wife was pregnant with our son, I asked my grandfather what he thought of us naming him Paul W. Tibbets V. He chuckled, so I was certain he and my father had the same conversation when my mother was pregnant with me. Granddad was excited that the family name was alive for another generation. But he was also cognizant of the potential pressure from others on our son with this name recognition.

I am so proud of Granddad and those he served with during World War II. Those were challenging times, requiring bold action. President Truman recognized this and, after careful consideration and deliberation, made the decision to use these special weapons to end the bloodshed on both sides. Millions of lives were saved, as were generations of people. Now, 75 years later, we still have these weapons underpinning our national security.

Many people will say they wish nuclear weapons were never invented, but I disagree. Although I fear these weapons and honestly don't like them, we know what a world without them looks like. We lived in a world without them before August 1945, and what did that world look like? In the six years of World War II, an estimated 50 to 80 million people died. And that doesn't include the wounded. That's more than 30,000 people killed every day for six years.

Since August 1945, we've had regional but not global wars. In the Korean War, an estimated 52,000 Americans were killed. In the Vietnam War, about 58,000 Americans were killed. Each of those wars equaled close to just two days of killing in World War II. That's what a world without nuclear weapons looks like.

Success is avoiding war and loss of life. So I'm grateful for the nuclear deterrent. Although we must be prepared for conflict, I truly believe deterrence is the highest calling of any military person.

What do you think your grandfather would say about the bombings 75 years later?

He said many times that, on order from the president, they were given a mission that was expected to accelerate the end of World War II and save countless lives. It was their job to ensure its success. That type of mission had never been done before, and it required an enormous amount of teamwork—the military and political leadership, scientists, weapons experts, and the airmen who would ultimately maintain, load, and fly the aircraft. On this significant anniversary, I think he would say how proud he is of our men and women serving in the military today, who are carrying on the legacy of all who have served before them.


Paul Tibbets Jr. and Paul Tibbets IV piloted a restored B-29 in 1998. It was the only time the two flew together. Photo: U.S. Air Force

Your grandfather named his B-29 "Enola Gay" after his mother. What was she—your great grandmother—like?

My grandfather was very close to his mother. He described her as very kind, loving, and supportive. When he dropped out of college to pursue aviation, his mom encouraged him, while his father did not. Granddad knew the missions they were training for would be remembered throughout history, and he wanted his B-29 to have a meaningful and unique name. When he told his mom, he said she giggled with great appreciation.

What did your grandfather think about you becoming a bomber pilot, too?

Although I knew about my grandfather's historic role, it didn't really hit home until he visited the U.S. Air Force Academy in 1987, where I was a cadet, and spoke to my class. It was the first time I heard his experiences from him, in depth. He attended my pilot training graduation and, years later, shared a discussion he had with the commander. My follow-on assignment was to fly the B-1, and my grandfather wondered if he inadvertently had anything to do with my bomber assignment. The commander told him I earned that assignment, having finished in the top of my class. That made Granddad happy.

You've flown two restored B-29s, one in a 2017 celebration of the Air Force's 70th birthday and another in 1998 with your grandfather—the only time you'd ever flown with him. What was that flight like?

My grandfather had given up flying due to his hearing loss. At the Commemorative Air Force airshow in Midland, Texas, we were given the opportunity to fly in the B-29 named Fifi, which Granddad flew back in the '70s. It was a once-in-a-lifetime offer for the two of us, but due to his hearing difficulty, my grandfather was not particularly excited, though with a little encouragement from some friends, he agreed. It was one of the most memorable moments of my life. The look of pride on his face was priceless.

How does the B-29 compare to today's modern-day nuclear-capable bomber, the B-2?

The B-29 was very advanced for its day, like the B-2 is today. The B-2 carries on the legacy of the B-29 with its conventional and nuclear roles.

In addition to creating the world's first nuclear device, Los Alamos has made nuclear weapons more effective, safe, and specific to military needs. Can you comment on what this means to those who would be asked to deliver the weapons, if needed?

Our military men and women rely on the skill and expertise of the talented experts at Los Alamos and our other national labs, who make "safe, secure, and reliable" the cornerstones of our nuclear weapon mission. We are deeply grateful to the labs for all the technological advancements that ensure the public's trust and keep our aircraft maintainers and operators safe. We are inextricably linked with our brothers and sisters in the labs, who are true patriots, who love their country and make a difference every day.

You've visited Los Alamos several times and have even signed the replica of the B61 nuclear bomb displayed in one of the main buildings. How do you see the Lab's impact on our national security?

Los Alamos is a national treasure. Because we operate the weapons systems provided by the Department of Energy, those of us in the Department of Defense are indebted to all the men and women at the national labs. Together we are part of what I would call the highest calling of our nation. The Air Force cannot fly, fight, and win if we fail at our first and most important mission: to deter. And successful deterrence is defined through the work we do together. ★

WHY WASN'T LITTLE BOY TESTED?

The bomb's components *were* tested, and Lab scientists were certain of its success.

BY ALAN CARR, LABORATORY HISTORIAN

It's often said that Little Boy, the uranium gun–type atomic bomb developed at the Laboratory during World War II, was not tested before it was dropped above Hiroshima, Japan, on August 6, 1945. Well, that's not exactly correct.

Although a full-scale nuclear explosive test was not conducted, every component of Little Boy was rigorously tested right here at Los Alamos.

In my lectures, I often say, "Little Boy was going to work; it was a matter of math." Beyond that, no one's ever asked me to provide any further explanation—until just recently, when a member of the public sent me this inquiry:

"I find it amazing that the United States would use this device untested after the incredible amount of testing—including the Trinity test—that went on with the plutonium bomb (Fat Man, which was dropped on Nagasaki, Japan, on August 9, 1945). Wasn't anyone concerned that Americans could be delivering secrets for an atomic bomb to the Japanese if it failed to explode? Was it just mathematical theory that gave scientists the confidence to use this device untested?"

I have to admit, that's something I couldn't entirely answer off the top of my head. The plutonium implosion device, Fat Man, was indeed more complicated and thus required more testing. And it's true there was a genuine concern the enemy might be able to recover the fissile material (albeit with tremendous difficulty) if a Fat Man–type bomb was not a successful nuclear explosion. In fact, the Trinity test director, Kenneth Bainbridge, stated in a report from 1945, "No one was content that the first trial of a Fat Man gadget should be over enemy territory, where, if the gadget failed, the surprise factor would be lost and the enemy might be presented with a large amount of active material in recoverable form."

But why were scientists certain Little Boy would work? I asked my friend Dick Malenfant, a retired physicist who spent decades working at the Lab.

Malenfant directed me to a report titled "Experiments with the Dragon Machine," which includes a complete transcription of the original handwritten notes on the experiments that gave scientists confidence that Little Boy would work. "Those experiments were crucial to the proof that an explosive reaction could be produced," Malenfant says. "This provided the final verification that Little Boy would function as designed."

Notice Malenfant uses the word "proof." These experiments proved Little Boy would work. The scientists were not simply confident Little Boy would work, they knew Little Boy would work—it was a mathematical certainty. Thus, the weapon went into combat without a full-scale nuclear explosive test. ★

Sophisticated technology is necessary to determine if a nuclear explosion happens in outer space. That technology—in the form of Vela satellites—was first developed at Los Alamos.

COLD WAR WATCHMEN

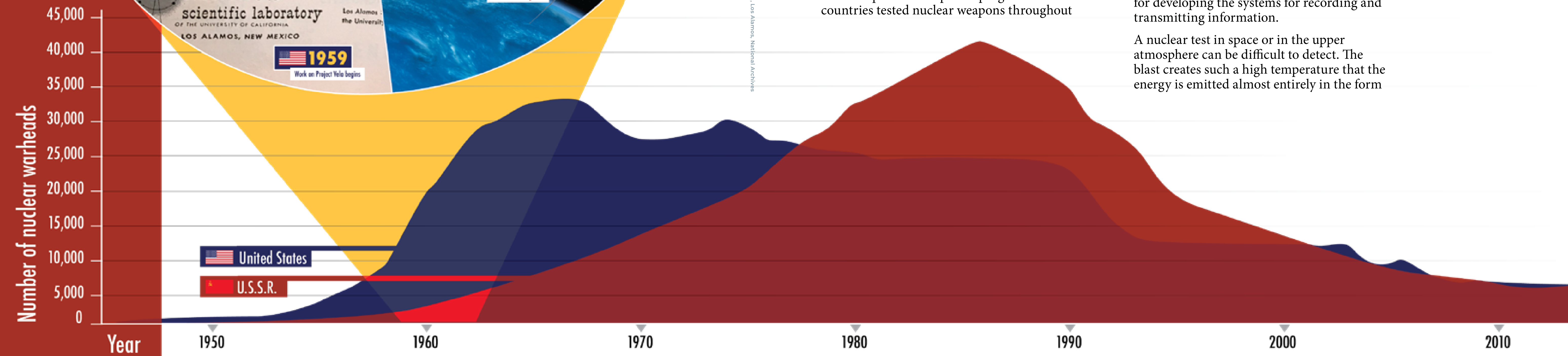
In the 1960s, Los Alamos scientists changed the landscape of national security with Project Vela—satellite instruments that could detect nuclear explosions in space.

BY VIRGINIA GRANT

✦ **Because mid-century spacecraft could not be photographed in outer space (the technology did not yet exist), Lab artists were tasked with rendering how the spacecraft might look in orbit. In this illustration, the twin Vela satellites detach from each other to move into orbit.**

SPIRALING TOWARD VELA

✦ Cold War events intensify, leading to the need to detect nuclear explosions in space and the Limited Test Ban Treaty.



Photos: Wuka/Dreamstime, Los Alamos, Smithsonian, Time Magazine, Wikipedia, Wikipedia, Wikipedia, Los Alamos, National Archives

IN DECEMBER 1961, PHYSICIST IAN STRONG moved to New Mexico to work at Los Alamos Scientific Laboratory (LASL). To work on what project? He had no idea. "I didn't know what I was going to be working on when I came here," he says. "They didn't tell people what they would be doing when they got hired." Upon arrival in Los Alamos, he had to wait for his security clearance so he could go into a secure area. There he was told he was being added to a team of scientists already at work on Project Vela, a program to develop satellite instruments that could detect nuclear detonations in the upper atmosphere and outer space.

The eye in the sky

On October 4, 1957, the Soviet Union launched the first satellite into outer space. For many Americans, Sputnik, whose name translates to "fellow traveler [with the Earth]," was simultaneously a source of awe and fear, excitement and anxiety. Although the idea of a human-made creation circling Earth was thrilling, Sputnik was also a frightening reminder that the U.S.S.R. had achieved something the United States had not. Even more troubling was the fact that the Soviets could use the same technology that shot Sputnik into space to launch an intercontinental ballistic missile that could carry a nuclear weapon to American soil. Sputnik therefore played a major role in America's decision to advance in the space race and to maintain superiority in weapons development.

As technology continued to advance during the Cold War, the United States also began to launch satellites, and America and the U.S.S.R. continued their weapons-development programs. Both countries tested nuclear weapons throughout most of the 1950s and early 1960s by way of underground, surface, and atmospheric tests (including some that were high-altitude), though each nation would at times announce periodic halts in testing. But when one country began testing again, the other would also resume. (This period included the American Argus tests, the first nuclear tests in outer space.) Each country felt compelled to answer the other's tests, and each round of tests pushed the technology further, forcing the countries to keep up with each other. Although a treaty would have relieved some of this tension, this was the Cold War, and the United States could not take the risk that the Soviets would continue testing even after a treaty was signed.

In early 1959, during a period when neither the Americans nor the Soviets were testing, a group called the Buzzer Committee was formed by LASL and Sandia National Laboratories to determine whether satellites might be used to detect nuclear explosions at high altitude or in outer space. Also interested in test-monitoring technology, the Department of Defense funded the Advanced Research Projects Agency (ARPA) to back detection research; ARPA funds set Los Alamos physicists in the P-4 group to work creating instruments that would change the battleground of the Cold War. This was the beginning of Project Vela.

The P-4 physicists designed sensors that would detect the radiation produced by a nuclear blast: x-rays, gamma rays, and neutrons. P-4 then flew prototypes aboard Sandia-built Deacon-Arrow rockets in 1959, and in 1960, the Air Force started allowing LASL to test detection instruments on Air Force Atlas missiles. Sandia was responsible for developing the systems for recording and transmitting information.

A nuclear test in space or in the upper atmosphere can be difficult to detect. The blast creates such a high temperature that the energy is emitted almost entirely in the form

President John Kennedy views a skeletal mockup of a Vela satellite during a 1962 visit to Sandia National Laboratories. Kennedy visited both Sandia and Los Alamos before the first Project Vela launch.

of x-rays, which are invisible to the human eye. The emitted x-rays, gamma rays, and neutrons quickly disperse, so distant blasts can be dim. Furthermore, these emissions can't penetrate Earth's atmosphere—ruling out ground-based detection. Conducting a test behind the moon is another way to conceal an explosion.

As the *LASL News* explained in 1963, "LASL, knowing more about nuclear weapons than any other laboratory, was the logical research center to set the pace" for the development of sensors. With a history of diagnostic equipment dating all the way back to the Trinity test (see p. 12), Los Alamos was prepared to take on this next important role for national security.

Tensions build

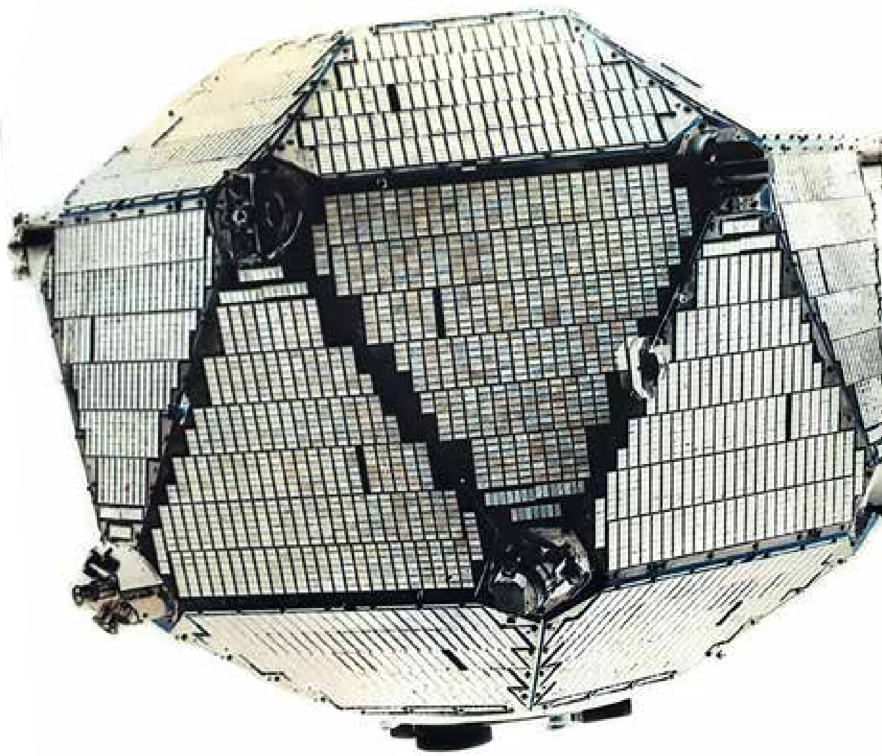
As Los Alamos physicists worked furiously to develop instruments that would safeguard a test ban treaty, the Cold War intensified. On May 1, 1960, CIA U-2 pilot Francis Gary Powers was shot down by a Soviet surface-to-air missile near the city of Sverdlovsk Oblast in the U.S.S.R. Powers was able to safely parachute from the plane, but he was captured by the KGB. As events unfolded, the United States was unable to provide a feasible alternative to the truth—that Powers was flying a spy plane. This resulted in heightened tensions between Soviet Premier Nikita Khrushchev and President Dwight Eisenhower. (Powers returned home after being traded for a Soviet spy in 1962.)

On April 12, 1961, the Soviets pulled into the lead in the space race when Yuri Gagarin became the first human to travel into space. Just two months later, ARPA approved funding for five Vela launches (in the end, there were six). That same year, the Soviets began a series of huge atmospheric nuclear tests, including the October 30 test of Tsar Bomba, the most powerful nuclear weapon ever detonated, with a yield of 50 megatons—the equivalent of about 2,380 Fat Mans or more than 3,300 Little Boys. At the time, the United States was conducting underground nuclear tests, but in 1962, America resumed atmospheric nuclear testing with Operation Dominic. This included Project Fishbowl, a series of space tests meant to apply more scientific rigor than the Argus tests. The biggest test of the series, Starfish Prime, yielded 1.4 megatons and an electromagnetic pulse (EMP) so intense that it knocked out streetlights and telephones in Hawaii, about 900 miles from the site of the launch. It is also estimated that at least six satellites were damaged in that blast (one of which was worked on by Ian Strong before he joined P-4).

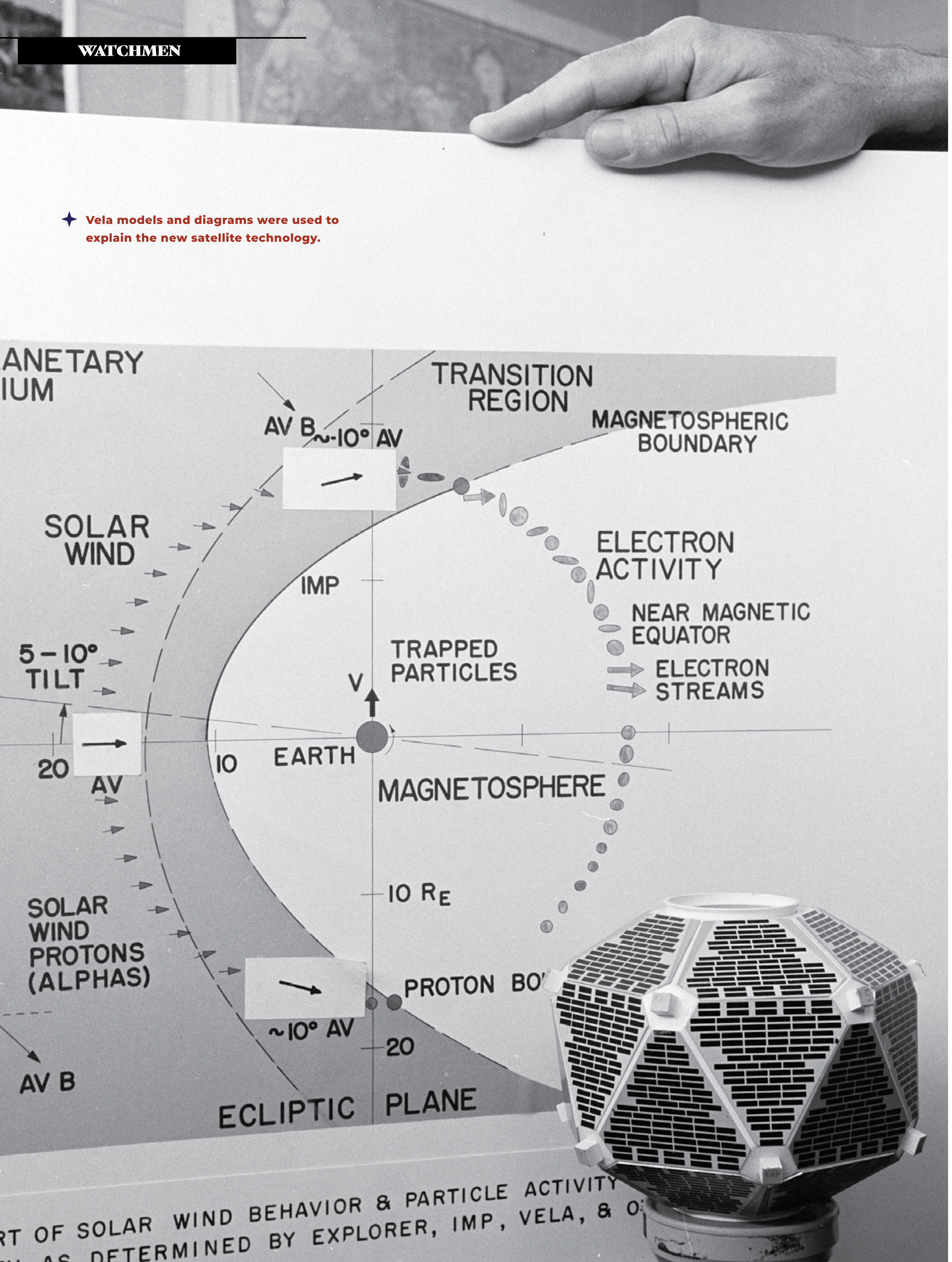
Then, in October 1962, the Cuban Missile Crisis brought the two superpowers as close as they ever came to nuclear war.

This series of escalating Cold War events further emphasized the tenuous nature of a signature-only test ban treaty, but it also stressed the need for one. If the United States could verify a treaty, it could enhance global security and help prevent nuclear war.

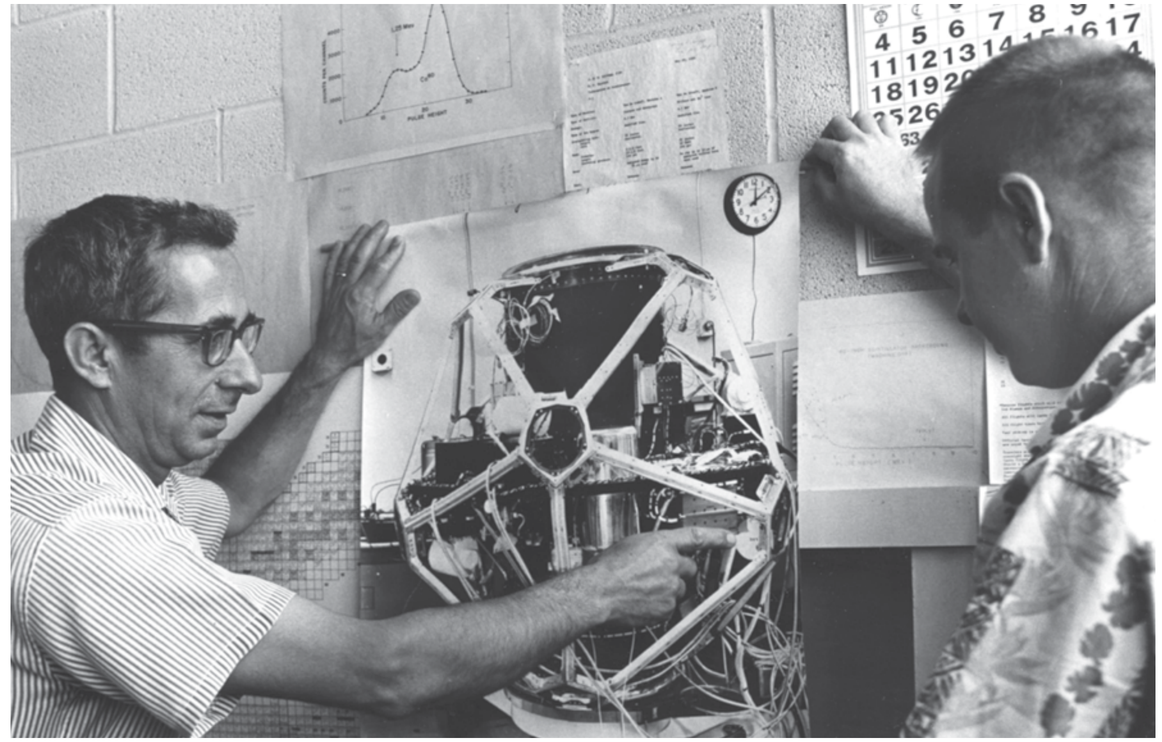
Although the United States didn't know it at the time, its last atmospheric test was Clean Slate III, a safety test conducted jointly with the United Kingdom in Nevada on June 9, 1963. The Soviets' last atmospheric test took place a few months earlier, in December of 1962, the same month that John Kennedy became the first president to visit Los Alamos. He also went to Sandia, where he viewed a skeletal mockup of a Vela satellite. (Sandia and Los Alamos partnered on the detection sensors and electronics, while the satellites were developed and produced by TRW Inc. for the U.S. Air Force.) "Kennedy wanted a test ban treaty," says Doyle Evans, a retired Los Alamos physicist who worked the entire span of the Vela project. "And he had a lot of trouble getting agreement on that until he had



An artist's mid-century rendering depicts a Vela satellite in orbit.



Vela models and diagrams were used to explain the new satellite technology.



Los Alamos physicists Richard Taschek (left) and Jerry Conner look at a photo of a first-generation Vela satellite's interior instruments.

assurances that it could be monitored. So it was very important to get the Vela satellites in place and operating."

Assurances in place, the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water—more commonly called the Limited Test Ban Treaty (LTBT)—was signed in Moscow on August 5, 1963, by U.S. Secretary of State Dean Rusk, Soviet foreign minister Andrei Gromyko, and British Foreign Secretary Alec Douglas-Home. The LTBT banned the testing of nuclear weapons anywhere except underground. It was a watershed treaty that changed the course of nuclear testing, but it wouldn't have happened without Project Vela. After the Senate was convinced not only of the merit of the treaty but also of the scientific ability to enforce it, the treaty was approved, and it was signed by President Kennedy on October 7, 1963. It went into effect three days later, and one week after that, the first pair of Vela satellites was launched.

First watch

On the morning of October 17, 1963, an Atlas-Agena-D rocket was launched from Cape Canaveral Air Force Station in Florida carrying the twin satellites Vela 1A and Vela 1B.

"We knocked ourselves out there for a while getting ready and getting our instruments constructed," remembers Jerry Conner, a retired Los Alamos physicist who worked on Project Vela from the beginning. "We spent a few days in Florida, running checkouts of the instruments mounted on the satellites, which were on the rocket in the big NASA assembly building."

Doyle Evans remembers being nervous. "We knew the instruments had to be working perfectly when they left the ground," he says, "and hopefully they would still be working when they got into orbit."

"The biggest thrill," Evans says, "was to go up on the tower where the rocket was sitting and do the last-minute adjustments to the satellites."

Ray Klebasadel, another member of P-4 from the beginning of the project, also remembers the last-minute preparations. "Although I wasn't directly involved, I recall that during one prelaunch preparation, part of the logic system was dissembled to correct a problem just before the satellite was mounted on the rocket. So the team had electronic boxes and modules scattered on the workbench, working on them actively, when we were in final testing. That was a stressful situation, but it all worked well."

After the launch, the scientists climbed into an Air Force plane and flew straight to an Air Force data processing center in Sunnyvale, California. Once there, in a windowless building called the Blue Cube, they studied large reels of Vela data on magnetic tape. Initially, they made sure everything was operating correctly and determined whether the project would yield a workable series of detection systems. The first Velas were not intended to function as detection satellites, but rather to establish if such a system was feasible. Velas 1A and 1B were such a success, in fact, that for years after, scientists studied those initial tapes looking for evidence of nuclear detonation. "The launch was very successful," Conner remembers. "The instruments worked correctly. There was a lot of excitement in seeing the instruments we made functioning up in space, doing their jobs."

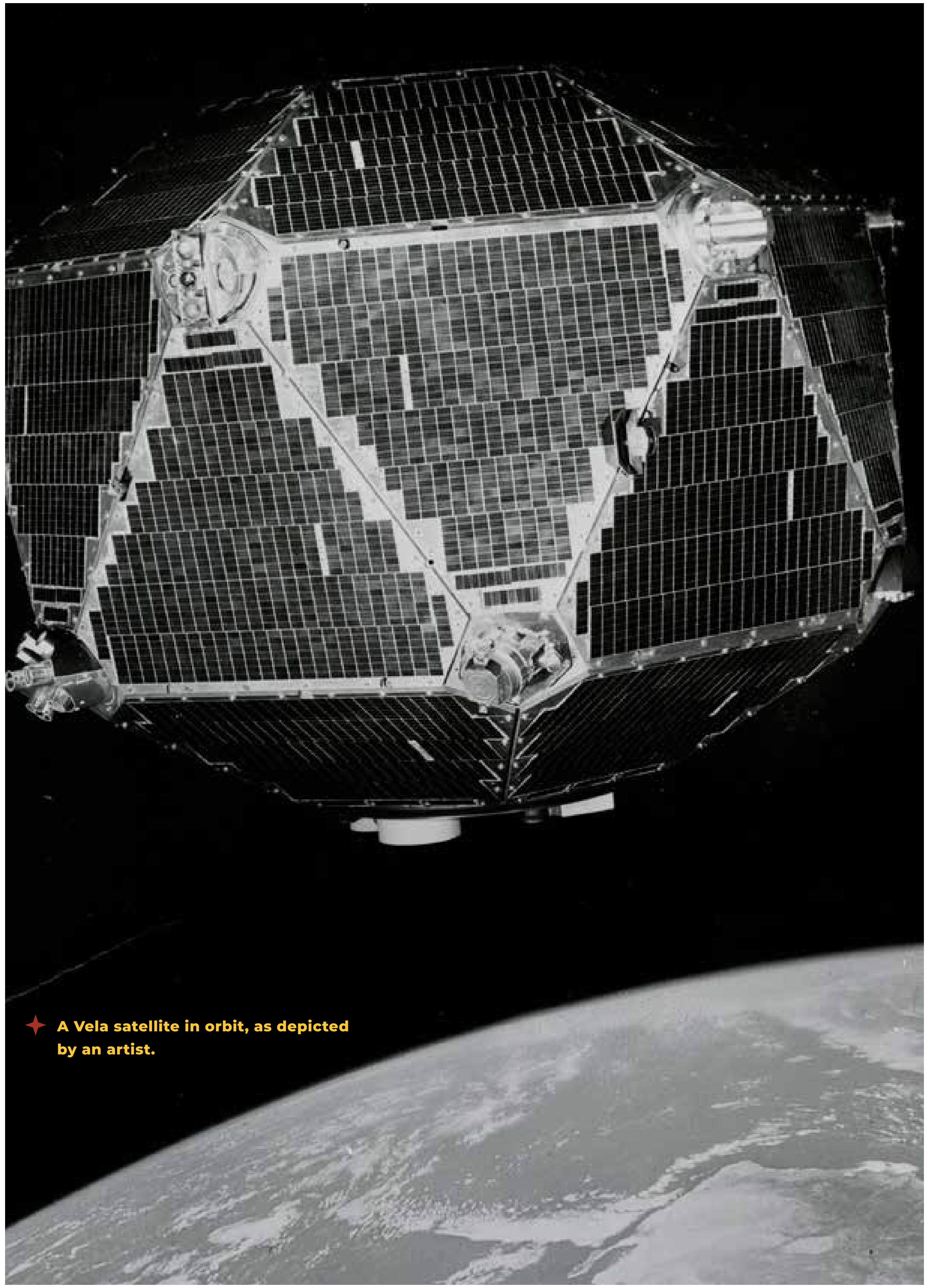
A news release from LASL lauded this monumental contribution to national, and global, security. "The unblinking eye in the nuclear blast detection satellites now in orbit some 60,000 miles in space are products of the Los Alamos Scientific Laboratory, where the nuclear weapons age was born during World War II."

Part of what made Project Vela so remarkable was the speed at which Los Alamos scientists were able to figure out how to make such important instruments work in outer space. "The Vela satellite program was revolutionary at the time," says Marc Kippen, Nuclear Detonation and Test Detection program manager. "In retrospect, it continues to be astonishing how much was accomplished in such a short time with extremely limited prior knowledge of the space environment."

Dave Smith, a project leader in the Intelligence and Space Research (ISR) Division, agrees. "Today we still find it very challenging to build high-performance sensors that can survive a rocket launch and then withstand the space environment for a long-duration, on-orbit mission," he says. "That our predecessors were able to do the same thing in the 1960s without modern-day tools and without our current understanding of the space environment is impressive."

How to spot a space bomb

From Spanish, "vela" loosely translates to "watchman." Referred to in the press as "sentries," the Vela satellites were launched in pairs so they could view the whole Earth at once—one satellite per half the globe. The Vela satellites orbited about 60,000 miles from Earth, each with a sensing range of 200 million miles. Each satellite had 20 sides (an icosahedron), with x-ray detectors mounted on each of its 12 points. More instruments were stowed inside the satellite for detecting x-rays, gamma rays, and neutrons.



A Vela satellite in orbit, as depicted by an artist.

"If there was a bomb," Strong explains, "then they could see that the radioactive products that came out of the bomb decayed in a specific way." Some of the instruments were developed specifically to recognize detonation emissions, but some were developed to gather information about the background of outer space so nuclear detonations would stand out.

The satellites were capable of real-time data transmission, and they could transmit their collected data when signaled to do so by radio transmission from Earth. The data was collected at an Air Force processing center in Sunnyvale. There, LASL scientists studied the data on giant printouts, looking for information about what was happening thousands of miles above Earth.

At the time, so little was known about the space environment that preparing the Vela instruments was in many ways a series of trial-and-error experiments, and LASL scientists made some of the instruments adjustable from Earth after the satellites were in orbit. The technology used on the Vela satellites wasn't new, but getting this technology to work in space was, and many factors required experimentation and creativity.

"Scientific principles involved in the instruments were old in terms of radiation measuring," a 1963 LASL press release explained, "but the degree of sensitivity desired and the durability required to withstand launch acceleration and continual operation in orbit were problems for which there was no experience to draw upon." The innovation of these instruments continued throughout the project, and nuclear detection technology used today is built on these designs. The Vela instruments, Strong says, "improved each time, right through the end."

Academic cold warfare

The instruments built for Project Vela had significant impact not only on national security but also on scientific discovery. "Vela was the prototypical project that made Los Alamos the premier scientific national security laboratory in the world," says Ed Fenimore, an Emeritus Fellow at Los Alamos, who has used Vela data in a great deal of his work. Los Alamos' scientific prowess is a major reason the LTBT was so successful. In the mid-century Cold War, displays of military and technological superiority were often demonstrated through nuclear weapons testing. But in 1965, the scientists working on Project Vela exhibited the United States' scientific superiority without firing a single detonator. By publishing the details of what the Vela satellites were detecting at every moment and how they were accomplishing it, the scientists demonstrated that the United States had the technology to detect nuclear explosions at high altitude or in space.

The publication was a special "Nuclear Test Detection Issue" of *Proceedings of the IEEE* (Institute of Electrical and Electronics Engineers) in December 1965. By this time, three pairs of Velas had been launched, and the publication included unclassified data from all six satellites, providing evidence that the technology was operational.

In the introduction, the journal notes that "the dearth of published material on some aspects of nuclear test detonation has, in part, been the result of the security blanket under which much of the work has understandably been conducted." To this day, a paper with this level of detail about a national security project is an anomaly.

Ian Strong remembers that his colleagues thought that publishing the Vela papers was a good plan. "The Russians had good scientists; we knew that," he says. "They would be able to tell that those instruments would be able to detect a bomb." And the plan worked. "The Russians never did cheat," he says. "Never tested above ground after they said they wouldn't."

According to Eric Dors, program director for Intelligence and Emerging Threats, "There is an additional benefit that Vela and its science-based approach have delivered to the mission, which is science-based deterrence." The concept of scientific superiority as deterrence is a major component of the Los Alamos mission.

"Part of the Laboratory is seen outside the fence (by the public)," says William Priedhorsky, program director of Laboratory Directed Research and Development, "and we want to be very clear about the excellence that is communicated that way, so that potential adversaries say, 'Whatever they're doing behind the fence (in secure areas) must be just as good, so let's not mess with them.'"

These ties between research and national security continue to be integral to the culture of Los Alamos. "Over my 41 years at the Lab," Priedhorsky says, "I have come to understand the great scientific breadth and strength of the Lab and how it contributes to the nation in so many ways. It has been the greatest honor of my lifetime to contribute a small piece to that."

Descendants of Vela

The legacy of Vela continues at Los Alamos today. Data from Project Vela is still used for national security work at the Laboratory, and sensors continue to be an important part of nuclear detonation detection. "We've got basically a whole division of people working every day on designing, building, testing, and analyzing data from newer sensing payloads that go on satellites," Kippen says.

Tess Light, who works on EMP sensor development and is chief scientist for space-based nuclear detonation detection, calls Vela "the mother, or perhaps grandmother" of her work. "We still list the Vela sensors in any timeline describing the evolution of our capabilities," she says.

The history that began with Vela has been built upon over the years, resulting in "expertise in nuclear weapons, detector technologies, and the natural radiation background of space," says Ben Norman, a project leader in the Space Science and Applications group. Such expertise makes Los Alamos "the perfect place to continue space-based treaty monitoring."

Los Alamos continues to be the premier lab for the development of these types of instruments. "The threat of what we're searching for and monitoring is changing," Kippen explains, "and it takes a nuclear weapons development lab to understand that, which is another example of why Los Alamos is the place to do this."

Currently, Los Alamos has seven satellite instruments for varying purposes in various stages of production, and usually one or two Laboratory instruments are launched each year. For example, nuclear detonation detection sensors go on every single GPS satellite and a number of geostationary satellites.

Nuclear detonation detection, Kippen says, "is still our biggest footprint in the space business. We do other things now in space, but 60 percent of the space activities at the Lab are still on this program that began with Vela." Just as the science of weapons evolves, so does the science of detection. Who is testing and where is still vitally important to U.S. national security. That work still requires advanced research, and the need to be accurate and reliable is of paramount importance. "We need to be able to say, yes, absolutely, it was a nuclear explosion" so the United States can "act accordingly," says Brian Dougherty, a project leader in ISR Division.

Los Alamos and Sandia are currently preparing a set of experiments for the next generation of nuclear detonation detection sensors. "In many ways, these experiments hearken back to Vela," Kippen says. "It's putting things in space that have never been done before. It's our most ambitious experimental program in many years." SENSER (Space and Endoatmospheric NuDet [Nuclear Detonation] Surveillance Experimentation and Risk Reduction) is an experimental testbed for many new sensing technologies and modalities that are being considered for future use. Set for launch in 2021, the experiment will put sensing modalities for x-rays, gamma rays, neutrons, and radio frequency and optical signals all on the same satellite for the first time since the launch of the last six Vela satellites.

Between 1963 and 1970, Project Vela yielded six launches, each with twin satellites. In addition to the data they provided for nuclear detonation detection, the satellites enabled a host of other scientific research projects, including Ray Klebasadel's historic discovery of gamma-ray bursts, a phenomenon that sparked decades of astrophysics debates among scientists, including Edward Teller and Stephen Hawking. "Vela's impact," says Light, "caused Los Alamos to become a major player in space research and engineering."

Project Vela continues to inspire not only technical accomplishments, but also a continuation of the spirit of discovery, ingenuity, and national pride that sparked its development. "The treaty monitoring mission imparts a real sense of importance," says Caleb Roecker, an early-career scientist in ISR. "I truly believe what we do in ISR affects the nation and keeps us safe."

Katherine Mesick, also an early-career ISR scientist, agrees. "Vela demonstrates the Laboratory's abilities to rapidly provide technical solutions to challenging problems," she says. "This is an extremely important mission, and I am excited to be a part of continuing the Vela legacy."

In September of 1984, though it was still functioning, the last Vela satellite was turned off. And though they no longer gather data, all 12 Vela satellites are still in orbit as, below them, Los Alamos carries on the work they began. ★

THE MYSTERY FLASH THAT CHANGED ASTROPHYSICS

Project Vela made one of the biggest space discoveries of the 20th century—cosmic gamma-ray bursts.

BY VIRGINIA GRANT

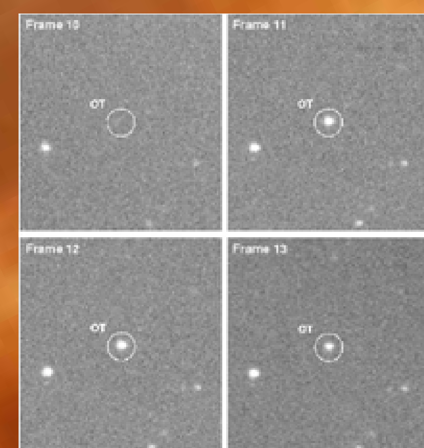
✦ Gamma-ray bursts, such as the one illustrated here, are the most powerful explosions in the universe. They emit most of their energy in gamma rays, a form of light more energetic than visible light.

Photo: NASA

In 1967, Los Alamos scientist Ray Klebesadel saw, in data from two Vela satellites, evidence that something extraordinary had happened in outer space. "The instruments on the two satellites had responded to the same event," Klebesadel says. "It was an electromagnetic phenomenon, but it wasn't a nuclear event," which was what the Velas were built to detect. "It was something remarkable."

Klebesadel had discovered the most powerful explosions in the universe—gamma-ray bursts (GRBs). GRBs are essentially massive space explosions that produce gamma rays, which are a form of radiation. In order to monitor space for nuclear explosions, the detection instruments on the Vela satellites measure x-rays, neutrons, and gamma rays, all byproducts of nuclear explosions. Scientists expected that there would be some naturally occurring gamma rays in outer space; what they didn't expect were enormous bursts of them that are about a trillion times brighter than the sun.

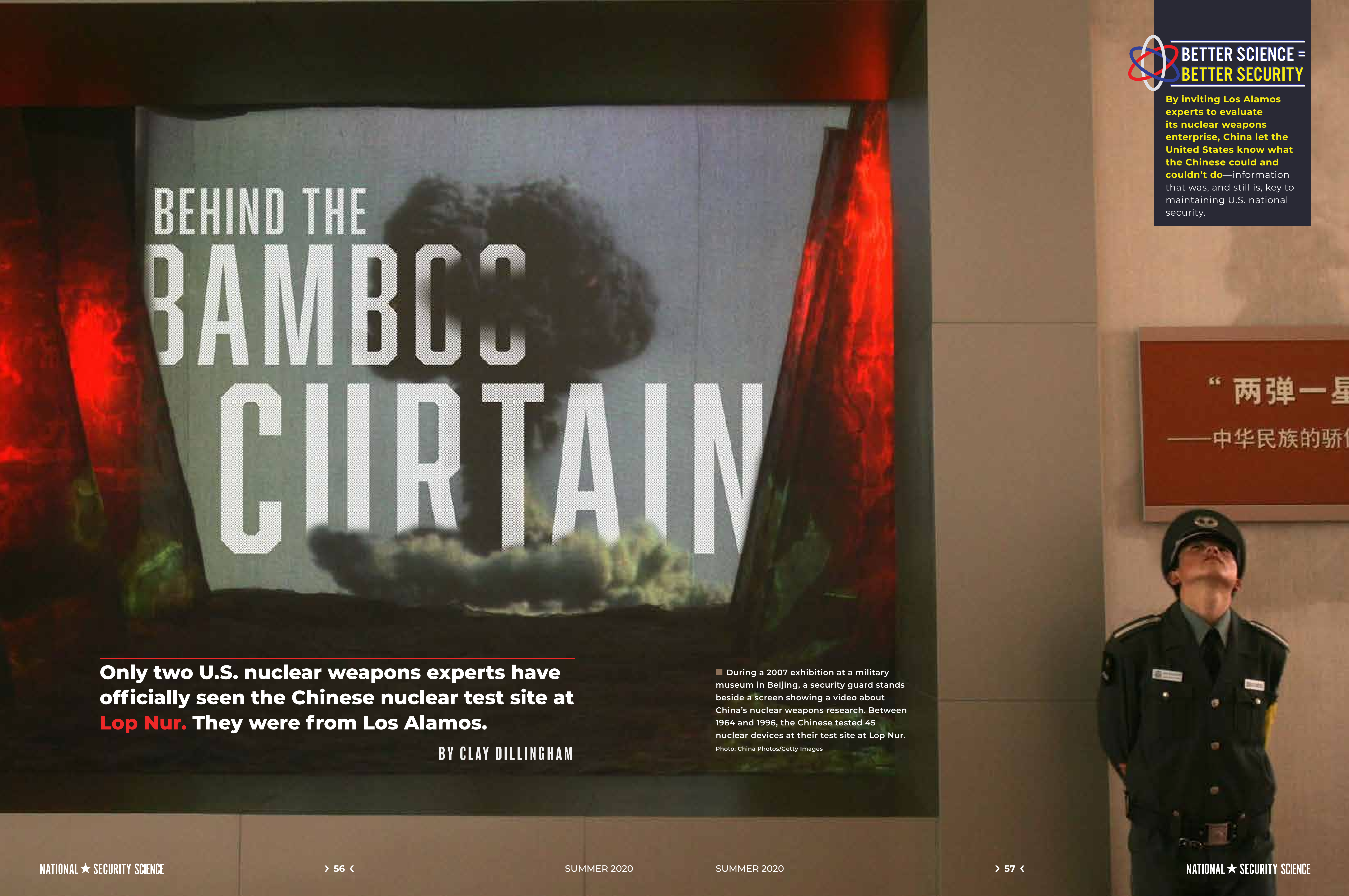
Declassified, the Vela detection of GRBs was published in 1973, launching a flurry of debates about their origin and nature. We now know that a GRB is produced by the collapse of matter at the formation of a new black hole, but scientists at the time could only speculate about what was causing them. Los Alamos scientist Ian Strong gave a 1973 lecture about gamma-ray bursts, after which he found physicist Stephen Hawking waiting to talk with him. Hawking, like many other scientists of the time, was interested in discussing the mysterious nature of GRBs.



✦ This gamma-ray burst was recorded on August 20, 2005, by the RAPTOR telescope system located at the Fenton Hill Observatory, near Los Alamos.

Los Alamos scientists continue to build on the foundational work of Project Vela in studying GRBs with tools such as Los Alamos' RAPTOR (Rapid Telescopes for Optical Response) robotic observatory system. Recent discoveries about GRBs have come about because of GRB-focused instruments such as the Swift Gamma-ray Burst Explorer, which uses Los Alamos–developed Burst Alert software to find GRBs, and the Fermi Gamma-ray Space Telescope, which was partially developed by Los Alamos scientists. Recently, the Swift and Fermi spacecraft detected GRB 190114C, the first, and so far only, GRB that emits ultra-high-energy photons—teraelectronvolt (TeV) photons. Discoveries like this will help scientists learn even more about GRBs.

Vela's monumental discovery "generated an enormous amount of excitement, fostering whole new areas of research," says Richard Belian, a retired Los Alamos physicist who worked on Project Vela. With the continued development of detection instruments for outer space, those areas of research are still being explored at Los Alamos. ★



BEHIND THE BAMBOO CURTAIN

Only two U.S. nuclear weapons experts have officially seen the Chinese nuclear test site at Lop Nur. They were from Los Alamos.

BY CLAY DILLINGHAM

During a 2007 exhibition at a military museum in Beijing, a security guard stands beside a screen showing a video about China's nuclear weapons research. Between 1964 and 1996, the Chinese tested 45 nuclear devices at their test site at Lop Nur.
Photo: China Photos/Getty Images

BETTER SCIENCE = BETTER SECURITY

By inviting Los Alamos experts to evaluate its nuclear weapons enterprise, China let the United States know what the Chinese could and couldn't do—information that was, and still is, key to maintaining U.S. national security.

American visitors have accessed the Lop Nur test site by flying into Ürümqi, China. Ürümqi (population 3.5 million) claims to be the most remote big city from any sea in the world.

LOCATED IN HOT AND ARID NORTHWEST China, Lop Nur was once the country's largest inland lake. As the water dried up over the first half of the 20th century, it left behind a salt-covered, windswept, largely uninhabitable landscape. In other words, a landscape ideal for testing nuclear weapons.

China established the Lop Nur Nuclear Test Base on October 16, 1959. The first Chinese nuclear bomb was detonated there exactly five years later, on October 16, 1964, making China the world's fifth nuclear power. Between 1964 and 1996, 45 nuclear tests (atmospheric and underground) were conducted at Lop Nur, including China's first hydrogen bomb test in June 1967. China issued a formal moratorium on nuclear testing in 1996, but low-level testing may still be conducted there today.

Only two U.S. nuclear weapons experts have ever officially visited Lop Nur. They were both from Los Alamos National Laboratory. The first was former Lab director Harold Agnew, who visited in 1982 when he was working as the chief executive officer of General Atomics. Then, in June 1990, weapons physicist John Hopkins traveled to China. He was joined by his wife, Adele (a plutonium chemist), Terry Hawkins (then a Laboratory intelligence analyst), Danny Stillman (then the head of Laboratory intelligence), and Bob Daniels (then head of intelligence at the Department of Energy [DOE]).

"When we went into the town near the test site, the children wanted to touch my face, feel my skin, look into my round eyes," Hawkins remembers. "They'd never seen a person who looked like me."

Hopkins agrees. "More Americans have walked on the moon than have visited Lop Nur!"

In this interview, Hopkins and Hawkins—both now in their 80s (and the only two of the six Americans who officially visited Lop Nur who are still living)—share their memories of what it was like peering behind the bamboo curtain and seeing the secret China protected the most—its nuclear weapons program.

China has always been secretive about its nuclear weapons programs. Why were you invited to Lop Nur?

Hopkins: In 1989, Yang Fuchai, who was the head of physics at Fudon University in Shanghai, met with Jay Keyworth at the Lab. Jay was the head of the Lab's Physics Division. [Keyworth later became President Reagan's scientific advisor.] The physics program at Fudon University was a major source of physicists for the Chinese nuclear weapons program. Yang was very closely associated with China's nuclear weapons program. I met Yang when he met with Jay, and Yang invited me to visit Fudon, but the trip didn't happen due to the Tiananmen Square massacre [when the Chinese government forcibly shut down a series of pro-democracy protests in Tiananmen Square in Beijing].

So, the next year, Yang invited me again. Sig Hecker (see p. 68) was the Laboratory director at that point. I talked to Sig about this invitation, and I said that I thought someone from the Lab's intelligence group ought to go. That's how Danny Stillman made the list, and he brought Terry along. I also thought getting permission to go from the DOE would be easier if someone from DOE intelligence could go with us, and that's how Bob Daniels joined us.

When it came to working out the trip's itinerary, the Chinese said they were going to take us out to their nuclear test site at Lop Nur. They told me to "tell your wife she won't want to come because it's very primitive out there." But she said, "Absolutely no! I want to go, and I'm going." So, that was that. Adele was the first, maybe the last, non-Chinese woman to visit the Lop Nur test site.

The Chinese must have been aware of your positions in the national security world. What do you think they knew about you?

Hawkins: As an analyst, I had been studying the Chinese nuclear test program before I came to Los Alamos. I knew what they were doing, and I knew that the Chinese knew me.

Hopkins: Yes, the Chinese knew an enormous amount about us. Our Chinese hosts liked to tease poor Bob Daniels. When they were having dinner with us, our Chinese hosts would sometimes ask, "Oh, Mr. Daniels, we don't understand what you do. Could you please tell us what you do?" Well, they knew he was head of DOE intelligence. They didn't tease us this way, but they did tease Daniels. These guys knew everything about what we did—probably what dry cleaners we used.

Hawkins: Daniels thought he knew how to impress people. He presented the Chinese with little gifts: pens with Department of Energy logos. He gave five or six to some very senior Chinese people. But the next day, they came in, and they had big blue spots on their shirts. These pens that he'd given them had leaked like sieves!

Hopkins: One evening at dinner they asked my wife about a paper she had written 20 years before. I'd forgotten that she'd even written it. They were just telling us that they knew all about us. The Chinese knew everything there was to know about us from the open literature. They'd done their homework.

But why would they want you to know they'd done the homework?

Hopkins: I think they wanted to show us how good they were, how smart they were. Our trip was made during the summer, in June. It was

> MORE AMERICANS HAVE WALKED ON THE MOON THAN HAVE VISITED LOP NUR!
>
> —John Hopkins

very hot, dry, and dusty at the Chinese site. The first day, when we got back to the hotel, my wife said, "I wish I could have a glass of ice water." Well, two minutes later, there was a knock on the door, and a guy with a tray said, "We thought you might like a glass of ice water." Well, that immediately tipped us off that our room was bugged.

Not long after that, one afternoon after we got back to the hotel, I made use of our discovery. I said to my wife, "Gosh, I wish we could eat a dinner at a Chinese restaurant." You see, each night for dinner, the Chinese had been feeding our little group of five at a table right in the middle of a big, empty ballroom. Well, no surprise, about an hour or so later, when we went downstairs for dinner, the host said, "We thought maybe tonight you'd like to eat at a Chinese restaurant!"

But we managed to surprise them, too. They'd asked me to give a talk about Los Alamos testing while we were out at their test site, and I did. At the end of my talk one of the Chinese guys asked a question, in English, but I didn't understand exactly what he was getting at. So, they began animatedly chatting amongst themselves, in Chinese, how to better explain the question to this American. But then Adele, who apparently was much more perceptive than I was, said, "I think what they're interested in is blah, blah, blah."

Suddenly, they all stopped talking. You could hear a pin drop. They were absolutely thunderstruck. The Chinese looked at each other, then they looked at her, and one of them said, "Oh, you understand Chinese."

Well, she didn't. But it was clear they were convinced she'd been listening to their conversation and understood everything they said. They were shocked that she knew Chinese, and, in addition, were embarrassed they hadn't found this incredibly important fact about her during their research.

As we were leaving, I said to her, "Don't admit a thing." And she didn't. For years afterwards, we got Christmas cards from them. And, each one had a little paragraph in Chinese, just for her. It might say, "We hope your family is well…" or something similar.

China's Dongfeng-2 (DF-2) nuclear missile was first tested at Lop Nur in the 1960s and was an active part of the Chinese stockpile until the 1980s. Pictured in 2007, this one is on display at a military museum in Beijing.

Photo: TEH ENG KOON/AFP via Getty Image

> **THEIR TUNNELS LOOKED AS IF A GROUP OF CHINESE MINERS WITH PICKS AND SHOVELS DUG THEM OUT.**
>
> —Terry Hawkins

Talk about your journey to the test site.

Hawkins: We flew into Ürümqi, the capital of the Xinjiang region and the city that is farthest away from any sea in the world. It's a huge city. It's also in the news frequently because it's in the center of the disputes between the ethnic Han Chinese and Muslim Uyghurs. Currently, the ruling Chinese Communist Party is putting tens of thousands of the Uyghurs into huge detention and concentration camps.

Hopkins: One of the more surreal images I recall was at one of their truck stops along the major highway (really just a dirt road) to the test site. It was late at night when we pulled in, and very hot. We drove up to a simple, small, cinderblock building painted blue. I could see inside. There was a single, naked light bulb hanging down, revealing these Chinese truck drivers sitting around a color TV … and they were intently watching an episode of *Little House on the Prairie* that was dubbed into Chinese. I couldn't imagine how Communist Chinese TV got a hold of it or what was going through the minds of those tough-looking truck drivers as they watched a show about life in 1870s Minnesota.

What is the Lop Nur test site like?

Hopkins: The morning we arrived, the buildings smelled like fresh paint. They'd been busy into the night painting the walls and installing new carpeting.

Hawkins: It's an enormous area—nearly 39,000 square miles [for comparison, America's Nevada National Security Site, formerly the Nevada Test Site, is 1,351 square miles]. They showed us a series of vertical shafts for testing nuclear devices, similar to the ones we used in Nevada.

Hopkins: I asked their designers if they needed to test nuclear weapons. And they told me, "As long as we need nuclear weapons, we need to test them."

I counted the diagnostic cables coming out of one or two of their shafts. Their cabling was about the same number as ours. And they appeared to be high-quality fiber optic cables.

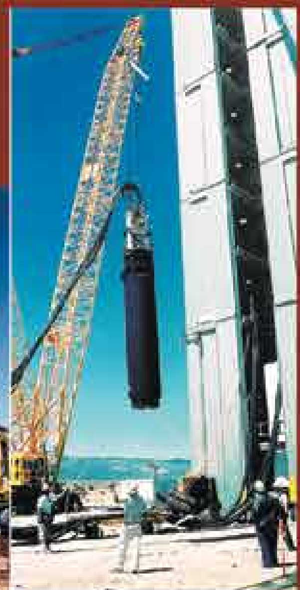
They had much harder rock than we have in Nevada. Everything for them seemed to be harder. It took them about a year to drill a shaft. It took us a month or so, maybe a few months, depending on the depth of it. They just had less equipment. If the scientists out at the Nevada Test Site wanted three bulldozers at ground zero tomorrow at 8 o'clock, three bulldozers would be there at 8 o'clock. I didn't think the Chinese could do that.

In Nevada, we were shooting in rock that was like Styrofoam. They had granite. Also, their water table was about 12 or 15 feet down. So, they had to either pump out the hole or make waterproof canisters to contain their nuclear explosions. Mostly, they did the latter. We were always fortunate in that, in Nevada, we had a deep water table.

Hawkins: They were very concerned about their tests breaching. Before they moved into testing in granite, they had one shot in dolomite, which is a carbonaceous material. It generated so much carbon dioxide when the test went off that the detonation blew the shaft apart, spreading contamination all over. That was a major surprise for them and a big disaster.

So, they were concerned about the environment?

Hawkins: No, I think it was a programmatic concern. When you blow out a shaft like that, it contaminates your whole testing area, which ruins it. The mistake is costly and puts your testing program behind.



The Lop Nur test site is the equivalent of the Nevada National Security Site (formerly the Nevada Test Site) north of Las Vegas, Nevada. Between 1951 and 1992, the U.S. tested 928 nuclear devices at Nevada using more advanced and efficient techniques and equipment (shown here) than the Chinese.

Did you see the inside of their testing tunnels? [Testing in horizontal tunnels is often done to investigate weapons effects on items placed inside the tunnel.]

Hawkins: Yes. And although I tried to be careful, the general who was escorting me noticed I was pacing off the distance from the entrance. He smiled and said, "You don't have to do that. I'll tell you how many meters it is."

Hopkins: It turns out, without coordinating, both Danny and I were also pacing it. It is interesting to finally see the things that you've been studying the satellite photographs of for years.

Hawkins: It's really incredible that they actually let us go inside and told us the length. We went all the way up to the shot point, the detonation point. That was significant. The distance from there to the tunnel entrance relates to a weapon's yield. So they were, in effect, letting us know about their yields.

It also gave us an idea of their mining prowess, and, along with other insights, it told us how they went about engineering their tunnels for nuclear tests.

Hopkins: They mined their tunnels with a sort of 1920s technology. When we drilled a tunnel in Nevada, we had a huge powered cylindrical drill bit, 15 feet across, that drilled into the tunnel.

Hawkins: Our tunnels looked like beautifully engineered, large, smooth highway road tunnels. Their tunnels looked more like railroad tunnels, as if a group of Chinese miners with picks and shovels dug them out, leaving rough unfinished walls.

Hopkins: Anything that required specialized equipment, like our drills, well, they were never as far along as we were.

Hawkins: And their process for loading vertical shafts? They always used the Livermore way of doing things, not the Los Alamos way.

Hopkins: Yes, I asked one of them, "How do you put your bombs down the hole?

"We put them down with a drill pipe like Livermore does, not on a cable harness like you do." Again, just to show us that they were paying attention. How they knew the details of how the different labs tested underground is anybody's guess. But they knew it.

Besides being remote, what were advantages to Lop Nur's location?

Hawkins: The Chinese were really frightened by the Soviets possibly taking out their facilities. So, to avoid a total wipeout from a single attack, they dispersed their facilities across very great distances. It would be like having a computer division here and a physics division miles away over there, not buildings next door to one another the way they are at Los Alamos.

Hopkins: So many of their experimental areas were spread to the four winds that it took a long time to get from one place to another. This meant they couldn't easily meet up with their colleagues to share information or ask questions. They stationed facilities of 60 to 100 people all over the place. We also learned about some facilities that our intelligence folks were totally unaware of. For example, they took us to a small hydrodynamic testing facility, like the Lab's, only in miniature. They wanted us to know they were pursuing everything we would pursue in weapons science, but they didn't have the huge facilities or equipment we had.

Hawkins: They were also trying to emulate what Livermore was doing at its National Ignition Facility, researching the use of laser beams to ignite fusion. But theirs was basically half the size of Livermore's design. I asked the head of their program, "Why are you so small in comparison to Livermore in fusion research?" He replied, "We don't have the money. But we'll do all the same research. And in the end, we'll not have achieved ignition—and neither will Livermore. Yet, we will have done it for half the price." I thought that was very insightful, powerful.

Hopkins: The Chinese can afford to do anything. But they can't afford to do everything. So, they had to pick and choose across the engineering and scientific horizon whether they wanted to support this or that. Higher-priority things were in defense: rocket research, ballistic missiles, etc. These had much higher priority, for example, than an apartment building for workers. The accommodations for their workers were really primitive by our standards.

We saw a lot of their equipment, and it looked sort of like miniatures of ours. That is, where we would have a box of electronics the size of a big table, they would have one about one-quarter the size. Generally, their hardware looked much more primitive than ours. It looked like it was made by a college student.

Hawkins: That extreme separation of staff and facilities was one of the major impediments to the advancement of the Chinese weapons program. They told me they understood that was the problem. Sure enough, after the fall of the Soviet Union, they began to consolidate their facilities.

China officially stopped testing nuclear devices in 1996 but is suspected of containing low-level nuclear testing in giant steel vessels, called Kolbas, such as the one pictured here.

Photo: Terry Hawkins

At a military museum in Beijing, visitors walk past China's Dongfeng 1 nuclear missile. Limited numbers of the DF-1 were produced in the 1960s and have since been retired.
Photo: TEH ENG KOON/AFP via Getty Images

> THAT'S A KEY PART OF DETERRENCE: LETTING THE OTHER PERSON KNOW WHAT YOU'VE GOT AND JUST HOW DANGEROUS YOU ARE.
>
> —John Hopkins

What was your impression of the people you met at the test site?

Hawkins: During the trip we took to some of their more remote places, one of the things they said was, "We have to apologize for some of the people you meet." They said, "They are some of the most brilliant people in China when it comes to physics and chemistry. They are the smartest people you will possibly meet in the world. But because of the way they're dressed, their language, their awareness of international affairs, you will go away with the idea that these are peasants." And I thought, You should see and meet some of our folks who work at Los Alamos!

Hopkins: The Chinese had lots and lots and lots of very smart people. Their theoretical design capability was larger than Livermore's plus

■ A recent satellite image shows activity at Lop Nur. Photo: Satellite image ©2020 Maxar Technologies

Los Alamos'—about 600 people. One of their guys told me, "Well, you know why we're so much better than you are is that we don't have the big computers; we really have to do this on the back of an envelope. We try harder." And I was, indeed, very impressed with the quality of their scientists and engineers.

They wanted to show us what they were doing. In fact, if we didn't ask the right questions, they'd give us hints about what we should ask. That's a key part of deterrence: letting the other person know what you've got and just how dangerous you are.

Hawkins: That's the message they wanted us to bring back.

Was the whole point of your visit to intimidate you?

Hawkins: They were looking for opportunities to collaborate with us. We were so far ahead of them, back then, that any kind of collaboration would have been much more to their benefit than to ours.

Hopkins: We weren't interested in any collaboration with the Chinese. But they would have welcomed it. For instance, among the things they told us is that they had done some experiments on the electromagnetic pulse from nuclear explosions. And, if we were interested in that, maybe together we could pursue researching it. We weren't, so we didn't. But it was clear to me that collaboration was something they really wanted us to do.

What were some of the key takeaways from your trip, the points the Chinese wanted to make sure you took back home?

Hawkins: This was their visit. They were going to exploit it to the fullest to serve their purposes, not ours. One of their purposes was to convince us how well they knew nuclear weapons technology.

Hopkins: And they surprised us every once in a while; some details of their nuclear weapons program really astounded us. I think they pretty well gave us an idea of everything they were working on.

Hawkins: I think so, too.

Hopkins: It was essentially everything that we were working on. It was clear that their physics of nuclear weapons was not all that far behind us. Their engineering was not so far along. In trying to make the nuclear weapons in the smallest size with the largest yield, using the smallest amount of materials—these were very difficult things that often took the best numerically controlled machines. The Chinese, in the 1990s, couldn't do it. Today they can.

Hawkins: When they stopped atmospheric tests in 1980, where we could see what they were doing, and went underground, it became necessary to invite us to see what they were doing underground.

Hopkins: Certainly, that was their agenda, to let us report back that we were looking at a competent adversary who was developing weapons very similar to what we were doing. That was their agenda. They accomplished it.

Hawkins: Since our visit, one of the things that they've done—that we haven't done—is build modern production facilities. We know from things like satellite imagery that their plutonium pit production facilities are incredibly modern. They still want us to know, at least generally, how far along they are.

So, they were happy to let you go home?

Hawkins: When we were at the airport getting ready to leave, gathering our belongings to board the plane, we suddenly noticed our plane, a big commercial jet, had moved out onto the runway and was taxiing away. This was not good. The person at the desk said that, unfortunately, we'd have to wait, maybe three or four days, because they didn't have another plane.

General Chen—he was a major general who ran the nuclear weapons program for China—he saw the plane leaving, too. General Chen pulled a little red card from his jacket, held it up, and barked some order in Chinese. I don't know what he said, but the result was like a break in billiards: uniformed Chinese sprinted off in all directions. Suddenly, we saw the plane stop on the runway. It stopped so fast that it rocked. Then, a half a dozen Chinese suddenly got off the plane … and the half a dozen of us got on.

Before we climbed aboard, General Chen asked, "Is there anything else I can do for you?"

I said, "Yes sir!"

"What?"

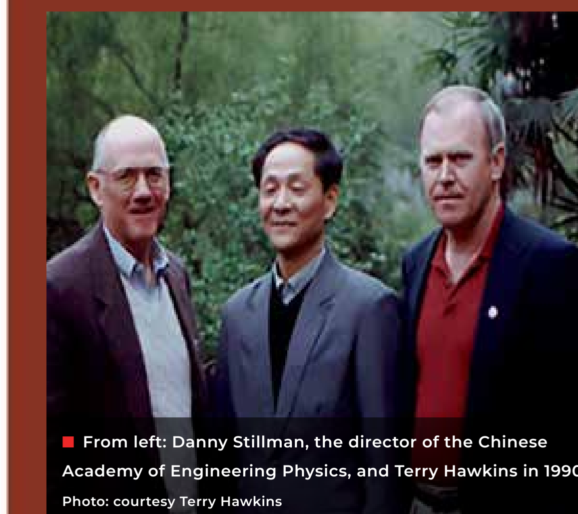
"Can you get me one of those little red cards you showed these guys?"

His eyes twinkled, and he said, "I won't be able to do that." ★

■ From left: John Hopkins, the director of the Lop Nur test site, and Adele Hopkins in 1990. Photo: courtesy Terry Hawkins

ABOUT JOHN HOPKINS

John Hopkins was the Laboratory's nuclear test division leader and later the Laboratory's associate director for the Nuclear Weapons Program. He participated in five atmospheric nuclear tests in the Pacific and some 170 tests at the Nevada Test Site. He has worked with the nuclear weapons programs of Britain, France, China, and Russia.



■ From left: Danny Stillman, the director of the Chinese Academy of Engineering Physics, and Terry Hawkins in 1990. Photo: courtesy Terry Hawkins

ABOUT TERRY HAWKINS

Houston T. "Terry" Hawkins is a retired Air Force colonel and a Los Alamos National Laboratory Senior Fellow currently assigned to the Associate Laboratory Directorate for Global Security. He is an internationally recognized intelligence expert on Chinese and Russian nuclear programs.

DOOMED TO COOPERATE

Former Laboratory Director Siegfried Hecker recalls the relationship between the United States and Russia at the end of the Cold War.

BY J. WESTON PHIPPEN

▲ Russian theoretical physicist Evgeny Avrorin (right) congratulates Hecker on Los Alamos National Laboratory's 50th anniversary. Photo: courtesy Siegfried Hecker

It was 1965. Siegfried Hecker, a student at Case Western Reserve University in Cleveland, Ohio, was looking for a summer job. "I picked up this brochure that said Los Alamos Scientific Laboratory," Hecker remembers. "Of course, I knew the fame of Los Alamos, but what really got my attention was a photo of the Pajarito ski mountain."

Hecker, who'd grown up skiing in Austria, ended up coming to Los Alamos, where he "probably put in more vertical feet skiing on Pajarito than anyone else at the Lab at the time." He went on to serve as the president of the Los Alamos Ski Club, and more important, as the fifth director of the Laboratory.

When Hecker took the helm at Los Alamos in January 1986, the space shuttle Challenger exploded. In April, the FBI informed him it was investigating a spy at the Lab. That same month, the Chernobyl Nuclear Power Plant suffered a catastrophic explosion and fire. But the most trying times were still to come.

When the Soviet Union collapsed in late 1991, no one knew what would happen to the hundreds of thousands of kilograms of nuclear material the Soviet Union had controlled. The United States feared that Soviet researchers, who'd spent decades advancing nuclear science, might now sell their knowledge to other countries. So, for the first time since the Cold War began, America began to pivot from competing with the Soviets to working with them.

Fortunately, the Lab had built a relationship with many of the Soviet Union's top nuclear scientists. It had started in 1988 with the Joint Verification Experiment (JVE), during which U.S. and Soviet nuclear weapons scientists worked together at each other's nuclear testing sites. The JVE was actually two experiments done to evaluate methods of measuring the yields of nuclear tests. Those methods, when proven accurate, would enable the 1990 ratification of the Threshold Test Ban Treaty, which limited nuclear tests to 150 kilotons. From that experience, Hecker says, "We learned that if things are going to turn out well in the nuclear sciences you have to cooperate."

NSS spoke with Hecker about this momentous period in history.

The foundation for cooperation was laid in the late 1980s. How did it develop?

The Soviet Union was changing dramatically during Mikhail Gorbachev's time. Gorbachev and President Ronald Reagan met at the Reykjavik Summit in 1986, and they initially thought they might be able to get rid of nuclear weapons. Well, it turns out they didn't get there. But they did decide the two countries would work together more, and they ended up ratifying a treaty four years later.

This was the so-called Threshold Test Ban Treaty [signed in 1974 but unratified until 1990], and as a result it was decided that the U.S. and Soviet nuclear labs were going to conduct joint tests at their respective sites. Our test in Nevada was scheduled for August 1988, and the Soviets would be onsite to measure yield. The device that would be tested was a Los Alamos device, so to a degree, I was responsible.

The treaty limited tests to 150-kiloton yields; were you nervous you'd be over?

We picked a device that would be very close to 150 kilotons. So moments before detonation, I'm sitting there in the control room, and across from me were the Soviets. I think to myself, We're going to push this button, and I hope to God our guys are right. How embarrassing would it be if it went off at 200 kilotons? But then I think what would be even worse is if nothing happened—with the world watching, and the Soviets seeing that our test didn't work. What that would have done to the faith in our entire nuclear arsenal would have been devastating.

Well, eventually we detonated the device, and it was pretty close to 150 kilotons. But the other significant moment happened afterward at a steakhouse.

What happened there?

We'd often gone to this steakhouse to eat after a test, so we were sitting down having a steak and beer. This time, of course, the Soviets are sitting across from us. So I said to one of the Russian scientists sitting by me, "It worked, you guys made all your measurements, and it all went great, don't you think?" He seemed unimpressed, then said what we should be doing in the future is not these joint verification experiments but joint science experiments. Essentially, joining our research together. That moment really stuck in my mind. It was a moment when both sides realized the world was changing dramatically, and it really did benefit us to cooperate.

How evenly were we and the Soviets matched, as far as nuclear technology? Were you able to tell?

In 1992, we visited the Russian nuclear laboratories. This is when we could best assess how good these guys were. In the first half of the 20th century, they had some of the best scientists in the world, so we knew they were good. It wasn't until these meetings, though, that we realized they were just good as we were.

The United States had a major advantage over the Russians in electronics and computers, particularly computers. The Russians didn't have a private computer industry. So we thought that, for example, we would be significantly ahead of them in modeling and simulation. Then during that first visit in 1992, they showed us some of the three-dimensional calculations they'd done related to implosions, and they were exquisite. I asked them, "How can you do this? Your computers are 1,000 times worse than ours." They said, "In America, you have these big, powerful computers. You got lazy. We didn't have them, so we had to think better than you."

In 1991, the Soviet Union collapsed. As the director of Los Alamos, were you concerned about Soviet nuclear weapons?

The greatest concern was what we called loose nukes—loose fissile material [material that can sustain a nuclear chain reaction], loose people, and loose exports of this knowledge. Before that moment, we'd focused mostly on what weapons the Russian government had in its hands. When the Soviet Union collapsed, suddenly we were concerned that the weapons might leave Russia. Its nuclear program's collapse coincided with economic collapse, so the U.S. worried about not only the physical nuclear material leaving the country but also a massive brain drain, with all these scientists going elsewhere to work on nuclear programs.

You led an unprecedented effort to work with these Russian scientists at their nuclear labs, some of which didn't even appear on maps. What was it like trying to set up these meetings?

From that initial meeting in Russia we'd developed a list of things that we could work on together. This list included a lot of fundamental research and some things like nuclear safeguards [ensuring the peaceful use of nuclear materials]. I went to Washington, D.C., and the main response was, "No way are we going to do all those things." They said they were mostly concerned about brain drain and about Russian nuclear scientists selling their knowledge to other countries. And the Russian government was very concerned about the Americans learning too much. So the governmental discussions weren't getting anywhere.

By 1994, it grew easier, and gradually the governments opened up. The Department of Energy's deputy secretary at the time, Charles Curtis, finally gave me the go-ahead to start working more closely with the Russians. That's when we began working with them to do a better job of securing and safeguarding their nuclear materials.

How did you overcome that kind of political opposition?

These political systems couldn't just turn on a dime. Of course, there were risks—risks that the other side would learn something you didn't want them to know. But we tried to focus on the scientific areas where we could work together.

As scientists and engineers, we spoke the same language. We were able to demonstrate how much of an advantage it would be to work toward our common interests. And in that way, we brought the politicians along. If you go back to the book [*Doomed to Cooperate*, edited by Hecker in 2016] and look at the foreword by Charles Curtis, he wrote that we, the scientists, helped build trust where there was none.

If you want to avoid a world of nuclear war, nuclear proliferation, and nuclear accidents, you need cooperation. The title for the book came from a Russian who said, "We all arrived in the 20th century in the same nuclear boat. A movement by one of us will affect all of us, so therefore we are doomed to cooperate."

What would have happened if we didn't cooperate?

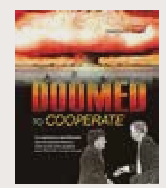
After the dissolution of the Soviet Union, it looked like a perfect storm. They had more nuclear weapons coming back to be disassembled than ever in history. The most dangerous part of a nuclear weapon's life is when it's being disassembled, and I was almost certain there'd be an accident.

It takes about six kilograms of plutonium or a few tens of kilograms of highly enriched uranium to build a bomb. The best we knew, the Russians had somewhere close to 150,000 kilograms of plutonium and somewhere around 1.3 kilograms of highly enriched uranium. The thought that none of it would get into the hands of another country was … well, I never thought it would be possible. And the Russian scientists didn't go anywhere either. The brain drain never materialized. These were incredibly patriotic people who were willing to weather horrible economic conditions. So I attribute the success to them, and to the relationships we were able to build.

You capture these relationships in *Doomed to Cooperate*. How did the book come to be?

We started work on the book with the idea that our colleagues in the Russian labs would be co-editors of the book. As 2014 arrived, after the invasion of Crimea, they said they could no longer work on the book. But they told us, "Look, you have our articles. They've already been cleared through classification, so use them." All that did was make me more determined than ever to finish the book.

A good part of the book demonstrates how important cooperation is in the nuclear world. I've taken this as a mantra, so to speak. ★



Siegfried Hecker is the author of Doomed to Cooperate. *The two-volume book tells the story of nuclear scientists from two former enemy nations, Russia and the United States, who reached across political, geographic, and cultural divides to confront, together, the nuclear threats that resulted from the collapse of the Soviet Union.*

■ On February 23, 1992, Hecker (right) greets physicist Yuli Khariton (left), who oversaw the creation of the Soviet Union's first atomic bomb. Photo: courtesy Siegfried Hecker

FORGED IN FIRE

Engineer and bladesmith Boyd Ritter intertwines art and science to create custom knives.

BY OCTAVIO RAMOS

Standing in his garage-turned-blacksmith-hovel, Boyd Ritter of the Laboratory's Weapon Systems Safety Analysis (W-10) group clasps a bright-red steel bar called a billet. He takes it out of a blazing hot forge and places it onto an anvil that's secured to a tree stump by a rusted chain. With his other hand, he uses a hammer to strike at the steel to sculpt what will become a custom blade for culinary use.

"There's a ton of detail when it comes to forging knives," Ritter says, eyebrows raised. "It really appeals to me at an engineering level. I just love how the art intertwines with the science of it."

A CAREER DEDICATED TO THE WEAPONS COMPLEX

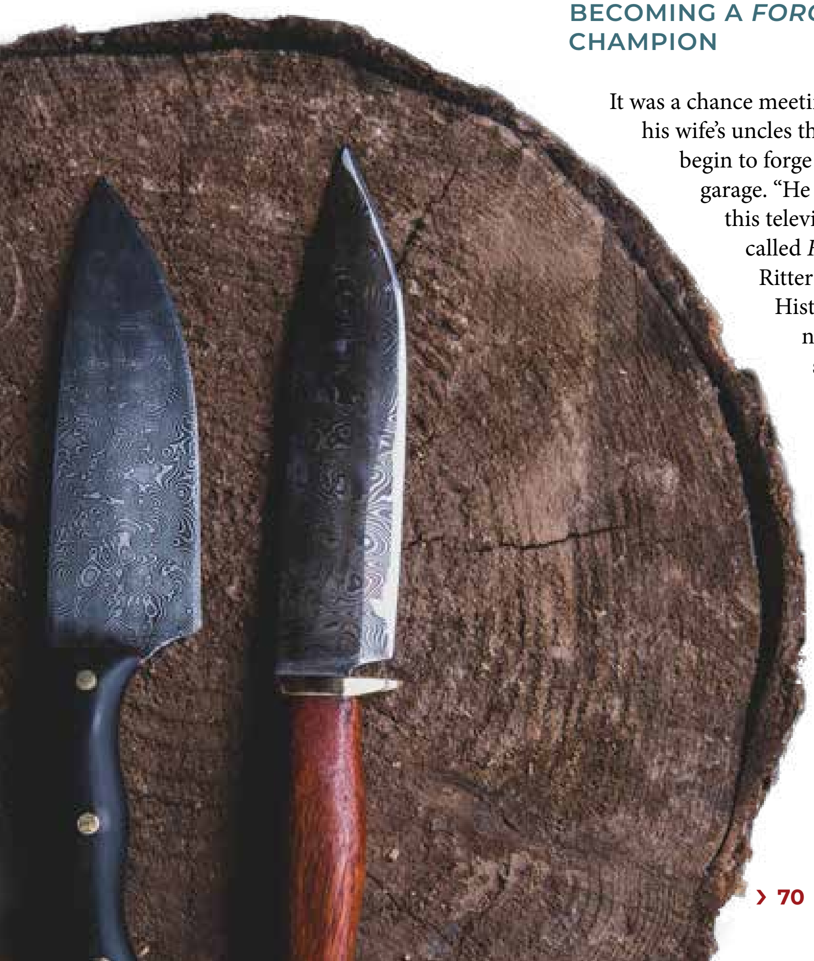
After graduating from New Mexico State University with a degree in mechanical engineering, Ritter joined B&W Pantex, where he worked for the next 15 years. After a short stint as a facility nuclear safety manager at Bechtel Corporation, he came to Los Alamos, where for the past four years he has worked as an R&D engineer for W-10.

"I've been part of the weapons complex for pretty much my entire career," Ritter explains. "It's interesting—while at Pantex, I worked on the other end of what we do at the Laboratory, so I had many opportunities to collaborate with the technical staff here."

Ritter says that W-10 is one of the key interface groups with Pantex. "We deal with the safety characteristics of working with nuclear weapons. Weapons are our primary focus—although Pantex carries out the hands-on work, we provide guidance on how to carry out that work as safely as possible. You could say we're the 'answer site' to all questions related to hazard analysis."

BECOMING A *FORGED IN FIRE* CHAMPION

It was a chance meeting with one of his wife's uncles that led Ritter to begin to forge blades in his garage. "He described to me this television program called *Forged in Fire*," Ritter remembers. The History Channel show, now in its seventh season, features bladesmiths competing in a three-round elimination contest to recreate some of history's most iconic bladed weapons. The overall winner of each episode receives $10,000.



After binge watching as many episodes as he could, Ritter wanted to give blade forging a try. Encouraged by his wife, Ritter began to acquire the basic tools and to experiment. Using his engineering background, he began to sculpt blades for friends and family. He quickly gained prowess and decided to try out for a *Forged in Fire* competition.

To his surprise, Ritter found himself competing on the show's December 18, 2019, episode, titled, "A Very Forged Christmas." He beat out finalist Jamie Chandler by crafting a British light-cavalry sword to become a *Forged in Fire* champion.

"The competition is very real," Ritter says with a laugh. "I mean, it feels like 1,000 degrees in there. There's a cameraman assigned to you, and he follows you wherever you go. The hardest part about the competition is succumbing to tunnel vision—next thing you know, time's up!"

Although the judges are intense onscreen, Ritter notes that offscreen they are really helpful. "The judges did a great job of putting us at ease before the filming got started," he notes. "What was most surreal was when the host, Wil Willis, announced that I was the champion. I didn't believe it until I saw Jamie leaving the forge. I looked around and whispered, 'I must've just won.'"

THE MISSION REMAINS HIS CALLING

Although he continues to make knives and even swords for family and friends, Ritter remains dedicated to his stockpile stewardship mission at the Laboratory.

"Making knives and other cutting tools will remain a hobby of mine for a while yet," he says with a smile. "I have an awesome job where what I do matters to the security of the nation, so for now I'm more than content just to keep my forging a hobby." ★

✦ Boyd Ritter inspects a completed blade. Look closely, and you can see the beautiful Damascus pattern on the steel.

ACCOLADES

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.**

On May 4, **Charlie Nakhleh** started a new role as Associate Laboratory Director for Weapons Physics at Los Alamos. Nakhleh, who has been at the Lab since 1996 in various roles, is an internationally recognized technical expert in weapons performance and design. Since November 2018, Nakhleh served as the executive officer for Weapons Programs. In this role he ensured that Weapons Programs effectively delivered on commitments, was internally coordinated, and was aligned with the Laboratory's strategic objectives.

Xiaokun Yang won the 2019 Postdoctoral Publication Prize in Engineering Sciences for her paper, "Hydrodeoxygenation (HDO) of Biomass Derived Ketones Using Supported Transition Metals in a Continuous Reactor." Yang describes the development and optimization of novel chemical catalysts for use in flower reactors to convert biomass, which is typically over-functionalized with oxygen atoms, to hydrocarbons, which are suitable for fuels used as renewable hydrocarbons. Yang's work has the potential to increase the economic viability of future commercial bio-refinery operations, and this in turn allows us to increase our domestic energy security.

Mike Steinzig of the W88 Alteration and Refresh Programs group was elected a Fellow in the American Society of Mechanical Engineers, an honor bestowed on fewer than 3 percent of the membership. Steinzig was recognized for his pioneering work in electronic speckle pattern interferometry for residual stress measurement.

Kary Myers was selected as a Fellow of the American Statistical Association. Myers was recognized for her leadership, innovative development and application of statistical methods for high-impact collaborations, statistical outreach to the broader statistical community, and service to the statistics profession.

Six Lab employees received Fellows Prizes for Outstanding Research in Science or Engineering and in Leadership, which are prestigious awards recognizing individuals for their full breadth of Laboratory accomplishment—from basic research to applied mission deliverables. **David Chavez**, **Baolian Chen**, and **Han Htoon** received prizes for outstanding research in science or engineering. **Alina Deshpande**, **George Guthrie**, and **Warren Oldham** received prizes for leadership.

Two winners and two honorable mention recipients of the Postdoctoral Distinguished Performance Award were recognized at a ceremony on March 2. **Conrad Goodwin** (winner) was recognized for outstanding contributions to the field of actinide chemistry. **Christina Steadman** (winner) was recognized for pioneering studies of algae epigenetics. **Oleg Kozlov** (honorable mention) was recognized for achievements in the broad and technologically important field of quantum-dot lasing. **Xiocan Li** (honorable mention) was recognized for research in the fundamental physics of particle energization during magnetic reconnection.

The Advanced Photon Source Users Organization (APSUO) awarded **Hsinhan (Dave) Tsai** of Materials Synthesis and Integrated Devices the 2020 APSUO Rosalind Franklin Young Investigator Award for groundbreaking scientific and technical achievements using the grazing incidence wide angle x-ray scattering technique.

Brenda Fleming, a graphic designer in the Communications Arts and Services group, won the Visual Science Communication award from the Southwest Science Writers Association (SWSWA) for her work art directing *National Security Science* magazine. Fleming submitted the summer 2019 issue as an example of how she's redesigned the publication. "Each page jumps out as a very successful visual presentation of science," according to SWSWA founder Martha Heil. We couldn't agree more! ★

IN MEMORIAM

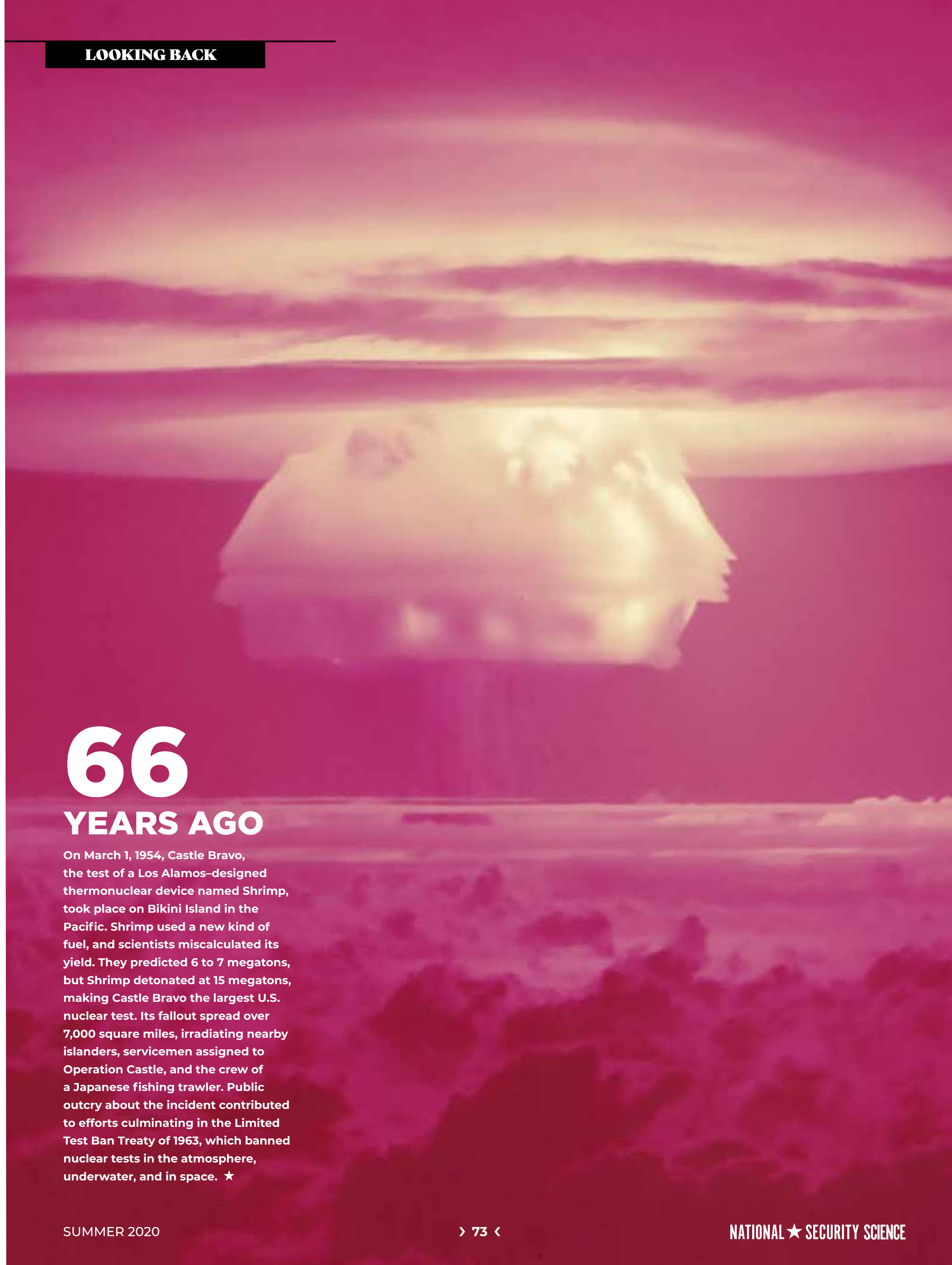
Laboratory Fellow Donald Barr

Donald Barr spent his entire professional career at Los Alamos, arriving in 1957. He retired in 1990 as the leader of the Isotope and Nuclear Chemistry Division. He returned as a Lab associate immediately after his retirement and continued as an active researcher and mentor until 2011.

Barr was the archetype of the national security scientist: technically brilliant, able to move with facility in all disciplines of weapons science, and completely committed to and focused on the Lab mission. He had a nearly encyclopedic memory and an ability to see through myriad information to recognize and extract that which was truly important for understanding weapons performance.

Barr passed away on February 23 at his home in Jemez Springs, New Mexico. ★

LOOKING BACK



66 YEARS AGO

On March 1, 1954, Castle Bravo, the test of a Los Alamos–designed thermonuclear device named Shrimp, took place on Bikini Island in the Pacific. Shrimp used a new kind of fuel, and scientists miscalculated its yield. They predicted 6 to 7 megatons, but Shrimp detonated at 15 megatons, making Castle Bravo the largest U.S. nuclear test. Its fallout spread over 7,000 square miles, irradiating nearby islanders, servicemen assigned to Operation Castle, and the crew of a Japanese fishing trawler. Public outcry about the incident contributed to efforts culminating in the Limited Test Ban Treaty of 1963, which banned nuclear tests in the atmosphere, underwater, and in space. ★

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NATIONAL LABORATORY
EST. 1943

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NNSA
National Nuclear Security Administration

THEN + NOW

In 1943, the U.S. government took over the Los Alamos Ranch School and turned it into a secret laboratory to develop an atomic bomb. One of the school buildings was an ice house that'd been used to store ice blocks cut from the adjacent Ashley Pond. During the Manhattan Project, scientists used the ice house (pictured above) to assemble the nuclear components of the Gadget, the world's first nuclear device, which was detonated during the Trinity test on July 16, 1945 (see p. 12).

In the early 1950s, Los Alamos National Laboratory used the ice house as a museum. In 1957, the ice house was torn down, and an open-air memorial—using some of the original ice house stones—was later constructed in its place. The memorial recognizes Los Alamos as a Registered National Historic Landmark that "possesses exceptional value in commemorating or illustrating the history of the United States."

Today, the ice house memorial is part of the Manhattan Project National Historical Park and, even more specifically, part of the Los Alamos Historic District Walking Tour. Stop by and see it next time you're in downtown Los Alamos! ★