Los Alamos National Laboratory

July 2015

NATIONAL SECURITY SCIENCE

In this issue

Welcome to this issue of

NATIONAL SECURITY SCIENCE

The world remains a dangerous and unstable place. Russia is loudly rattling its conventional and nuclear sabers. North Korea appears to be striving to build its own nuclear-armed intercontinental ballistic missiles. Every declared nuclear-armed nation is increasing and/or modernizing its nuclear stockpile. More nations are debating whether to acquire their own nuclear weapons.

The continuing need for the U.S. nuclear deterrent grows in direct proportion to these growing threats to U.S. national security and to the security of its allies.

But the nuclear deterrent faces a challenge. The United States used to regularly shake the earth testing its nuclear weapons. These weren't just tests, of course—they were also demonstrations for U.S. adversaries and allies alike that U.S. nuclear weapons packed a seismic punch. We have not sent that awe-inspiring message in 23 years.

Since the last U.S. nuclear test in 1992, the world's population has grown by two billion people. These generations were born after U.S. nuclear testing ceased and probably have never even seen a photograph of a test. (See "Atomic Photography—Blasts From the Past," page 16.)

So, while the importance of the U.S. nuclear deterrent is more relevant now than ever, the nation does not overtly demonstrate to the world (or to itself), consistent with Presidents Bill Clinton's and George W. Bush's decisions to halt nuclear testing, that its aging nuclear weapons still work. The nation's mightiest message is muted at this most dangerous moment.

How then does the nation continue to convey to its adversaries and allies—and even to its own military—that two decades later its nuclear deterrent still packs its punch?

The United States promises that its warheads are safe, are secure, and will work, based upon the expertise of the scientists and engineers at the Laboratory (and other nuclear weapons labs) *doing stockpile stewardship. In 2014 alone, Los Alamos conducted more than 1,000 experiments to more fully understand the nation's nuclear deterrent. But that largely secret science cannot be made public.*

Yet without testing—or demonstrating much of the science that has replaced testing—what is it that makes this promise credible?

Because the United States can't "show the money," we are compelled to show something else. The nation is betting that demonstrating major scientific excellence in other areas will build trust in the science that stewards the stockpile. If the nation continues to demonstrate its worldwide scientific superiority in nonnuclear weapons science, our scientists and engineers, like those at Los Alamos, can promise that the U.S. stockpile is still good to go, and our adversaries and allies, along with our own warfighters, will have faith in that promise.

A startling truth now emerges: In the absence of the direct empirical evidence of testing, the nation's scientific credibility is now a key element of successful nuclear deterrence and, thus, a pillar of U.S. national security.

This is why Los Alamos is so important to the nation—now more than ever; it not only stewards the stockpile, but also demonstrates the scientific excellence required to maintain the scientific credibility that has become a stanchion of U.S. national security. Clearly, Los Alamos must continue to protect and enhance its scientific credibility; the nation's security depends on it.

Deterrence is based on what your adversaries believe you have. In the absence of testing a warhead that shakes the earth, the Laboratory keeps the faith in the nuclear deterrent by doing science that shakes the earth.

The question now is how long will the nation's adversaries, allies, and its own warfighters continue to keep a faith that's based on indirect evidence?

Craig Leasure
Principal Associate Director, Weapons Program (acting)

INSIDE THIS ISSUE

About the Cover

Atmospheric nuclear tests were always photographed from a safe distance using unique equipment designed specifically for the job. The film captured key data needed to estimate the amount of energy the weapon released. *(Photo: Open Source)*

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◀ Left: Trinity Test, July 16, 1945. Although color movies were taken of the Trinity Test, they were of poor quality, overexposed, damaged by the intense light of the blast, or have since deteriorated. This photograph, also showing the ravages of time, is the only existing color shot of the test. It was taken by Jack Aeby using his personal camera. Aeby was working at the Trinity site with (future Nobel Prize winner) Emilio Segre. Segre secured permission for Aeby to carry his own camera to the site to record their work. The test came and, as Aeby once said, “It was there so I shot it.” Aeby’s photograph provided the basis for the Laboratory’s earliest calculations of the Trinity Test’s yield. Aeby worked at the Lab until he retired. He died in June 2015. (Photo: Los Alamos)

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


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MERIT

Some of the photographs used in this issue are the newly digitized ones from the Film Scanning and Reanalysis Project (page 10). Others were generously donated by Pete Kuran, one of the project's consultants.

COLD WAR FILMS YIELD NEW EFFECTS-DATA FOR U.S. NUCLEAR WEAPONS

Films of the U.S. atmospheric nuclear tests provide breathtaking reminders of the power of nuclear weapons. Now a new project is salvaging and mining these deteriorating films for fresh—and crucial—scientific data about the weapons' yields.

To understand why Lawrence Livermore National Laboratory nuclear weapons physicist Greg Spriggs is spearheading, in partnership with Los Alamos, an urgent search-and-rescue mission to salvage several thousand films documenting U.S. atmospheric testing before they crumble into celluloid dust, you have to appreciate the importance of the information they contain. These deteriorating, often hard-to-find filmstrips and still-photo negatives provide the hard data on key nuclear blast effects that scientists use to determine a weapon's yield.

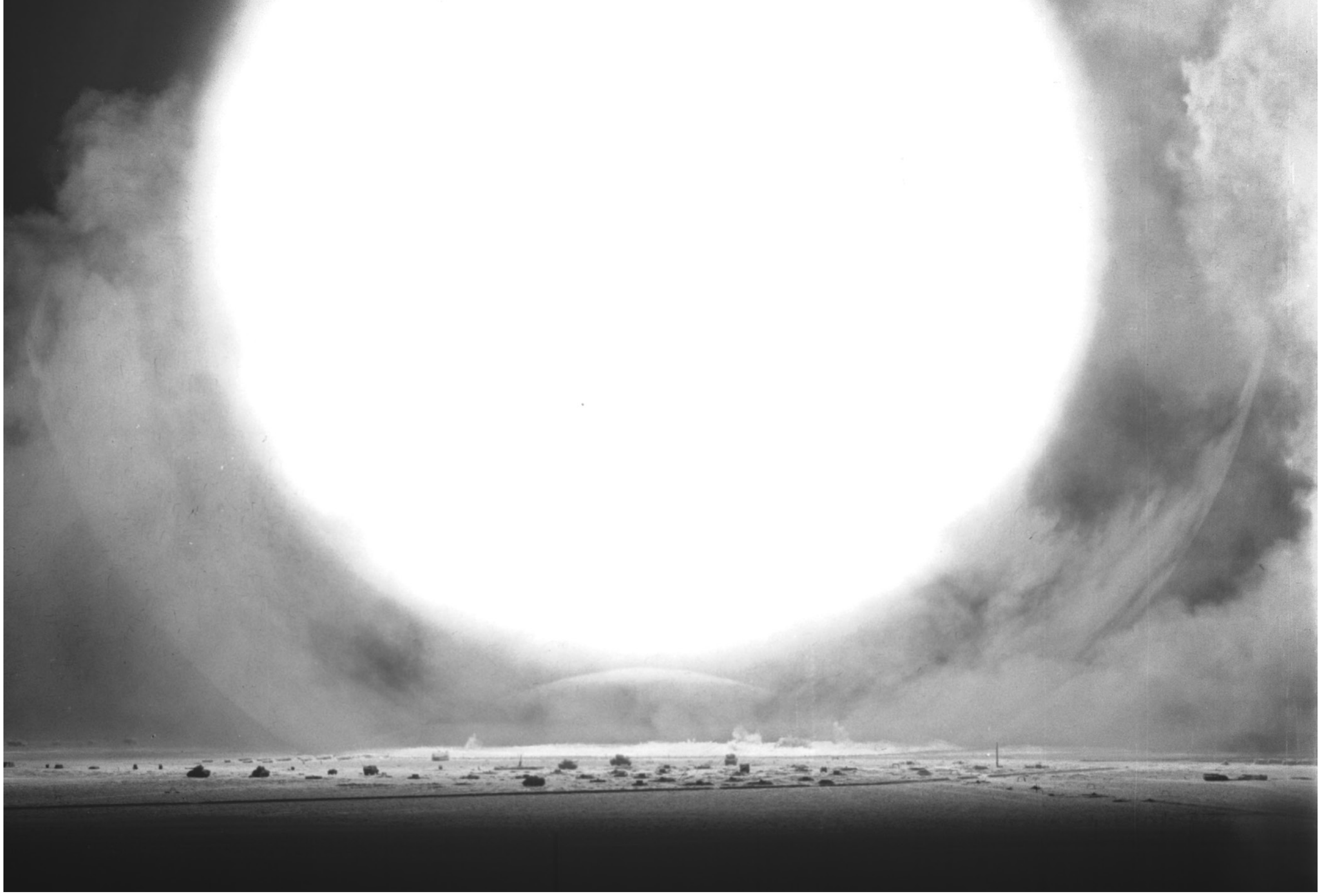
Knowing the yield helps weapons scientists and Department of Defense (DoD) strategists predict whether a given weapon will successfully destroy a specific target. Yield estimates also help forecast the extent of damage an adversary's missile or a terrorist's improvised weapon might cause in the United States or an allied country—knowledge vital to effective planning for mitigation and recovery. Yield, in other words, is the name of the game in both nuclear weapons science and national security. (See "Bigger's Not Always Better," page 9.)

The trouble is, outside of those old films, yield data are very hard to come by.

No New Data

Here's why. Beginning with the Trinity Test in 1945, nuclear explosions lit the skies, churned the seas, and rocked isolated deserts during the U.S. atmospheric nuclear weapon testing program. Scientists filmed every one of the 210 atmospheric tests and manually measured two key effects—thermal radiation (heat and light) and the massive shock wave (the blast)—that had been recorded on film. (The third effect, nuclear radiation, was not recorded on film.) From these, scientists derived crucial, irreplaceable data about the yields of the weapons.

Then in 1963, the Limited Test Ban Treaty ended atmospheric testing—and scientific filming with it. The tests went underground. Finally, when the United States halted all testing in 1992, real-world test data dried up completely.



Test shot Grable was fired from the 11-inch-bore atomic cannon, "Atomic Annie," at the Nevada Test Site (May 25, 1953). The only nuclear cannon shell to be test fired, it weighed 803 pounds and had an estimated yield of 15 kilotons, which exceeded the yield of the 10,000-pound Little Boy bomb that destroyed Hiroshima just eight years earlier. The size of Grable's fireball miniaturizes military trucks and tanks staged near the detonation as targets. The transparent curves in the air beyond both sides of the fireball (lower right and left) are the shock wave. Photographing and then measuring the peak growth of the main shock wave over time provides an estimate of the yield of the weapon. (Photo: Open Source)

Since then, scientists at Los Alamos (and the other nuclear weapons labs) have tested weapons *virtually* by running computer codes on supercomputers (supported by extensive experimental data) to simulate detonations and measure weapon performance. The computer simulations depend on the estimated yields derived from the one-of-a-kind blast-effects data collected from those atmospheric-test films.

> **Computer simulations of weapons depend on yields estimated from data collected from Cold War atmospheric-test films.**

Unfortunately, a few problems cloud these yield estimates. Recently, Spriggs and others realized that scientists were often rushed in analyzing the films, and the techniques used more than 50 years ago produced inconsistent and relatively crude results. Modern techniques, using computers to digitize and analyze the blast effects on the film, can fix those problems.

Unfortunately, to further complicate matters, time is ravaging this film data trove. Film is made from organic material that naturally decomposes over time. Eastman Kodak Company, a major manufacturer of film, estimates that a black and white film has a useful life of about 100 years and color film about half that. With the oldest films now at 70 years and the youngest of the atmospheric test color films already at 53 years, some films are already crumbling into celluloid dust.

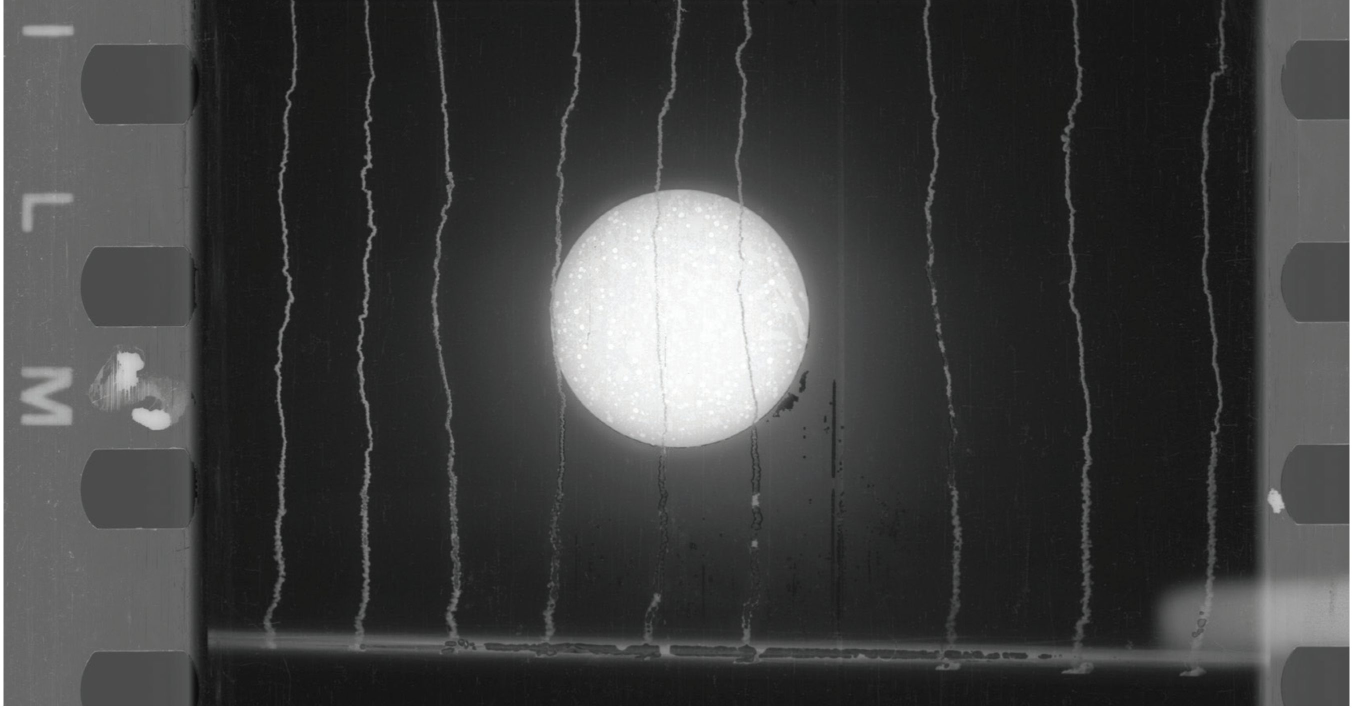
Once these data are gone, they're gone, and there's no place else to get new real-world test data.

Enter Spriggs's Film Scanning and Reanalysis Project, which aims to salvage this visual record and digitally analyze the images, extracting much more reliable yield data than ever before. (See "The Film Scanning and Reanalysis Project," page 10.)

What Films Yield about Yield

Scientists cannot measure nuclear weapon yield directly. They infer it from indirect evidence, such as radiochemical analysis, in which scientists measure the ratios of isotopes (products of the nuclear reactions inside the detonation) that are a function of yield. These isotopes are found in air and soil samples collected after a nuclear explosion. The accuracy of this yield estimate, therefore, depends upon the quantity and quality of the samples.

> **Some films are already crumbling into celluloid dust.**



This photograph of the Climax test (1953) at the Nevada Test Site shows the trails of the smoke rockets that created a grid to help track the speed and size of the shock wave's expansion. These data were then used to estimate the yield of the test: 61 kilotons. (Photo: Open Source)

And there is another way, inferring yield by measuring its effects: the fireball's gigantic pulse of light and heat and the massive shock wave. Working backwards, measuring a weapon's blast effects provides an estimate of its yield as the amount of energy a weapon releases at detonation, expressed as the equivalent in kilotons (thousands of tons) or megatons (millions of tons) of TNT.

But to measure these effects, you first have to pin them down, and a nuclear explosion's effects may last only milliseconds. That's quicker than the blink of an eye, so even if eyewitnesses don't blink, they cannot see them. During the atmospheric tests, the effects were pinned down on film. Using still and motion pictures, in black and white and in color, photographers captured the detonation in its full evolution, the shock wave in its flight, and the thermal radiation of the fireball.

Thermal Radiation: The Double Flash of Light

A double flash of light is the signature of a nuclear explosion, the light's characteristics distinguishing it from anything else. This double flash is really a single flash briefly divided into two when the atmosphere becomes so hot it turns opaque and blocks the light. As the atmosphere cools, the light can escape again, creating the second flash.

The time it takes for this process to run its course depends upon the yield—the bigger the yield, the greater the heat and the longer it takes to see both flashes.

The first flash emerges less than a millisecond after detonation and lasts less than a tenth of a second. Depending on the yield, the second flash can last anywhere from just a few tenths of a second for low-yield detonations to several minutes for high-yield detonations.

> **The films also provided surprising information about the destructive consequences of the effects.**

Using high-speed cameras and films, photographers captured this double-flash phenomenon so analysts could measure it to estimate the yield. (See "The Double Flash Meets the Bhangmeter," page 12.)

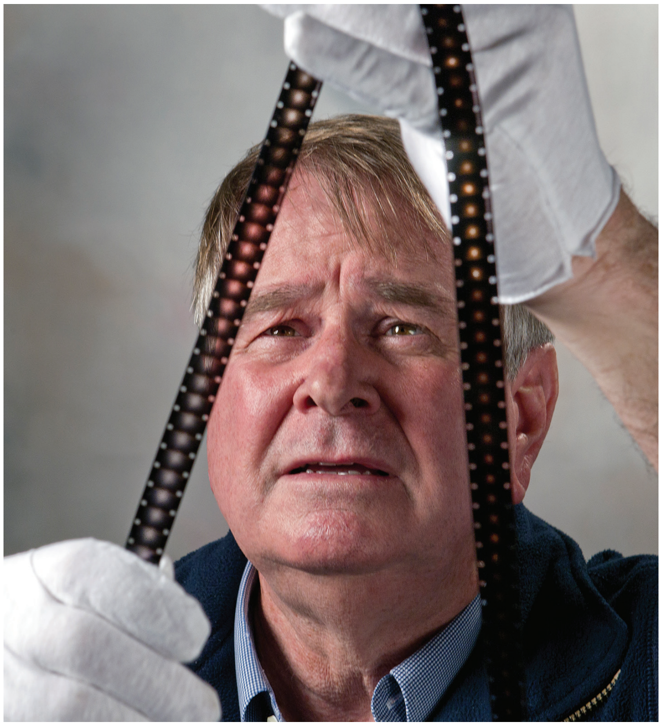
Thermal Radiation: The Fireball

Detonation instantaneously releases the energy from the weapon's nuclear reactions (fission and fusion) and within a millisecond produces what amounts to a small sun, its temperature reaching over 100 million degrees. This is the fireball—a glowing sphere of vaporized weapon debris and superheated air.

The fireball expands, and because it is buoyant (lighter than the relatively cool air around it, like a hot-air balloon), it rises. The amount of energy that created it determines how far it expands, how rapidly it rises, and how long it glows. Like the double flash, these phenomena were captured on film and used to estimate yield.

The Shock Wave

The shock wave's expansion over time also indicates yield. Researchers could photograph the wave's expansion because the dense air compressed at the wave's front refracted the light passing through it. The trails of smoke rockets created a grid that could be photographed to help track the speed and size of the shock wave's expansion.



Lawrence Livermore National Laboratory's Greg Spriggs examines a filmstrip from the Los Alamos National Laboratory archives. *(Photo: Open Source)*

These test films not only allowed researchers to measure effects, then estimate yields from them, but the films also provided surprising information about the destructive consequences of the effects. For example, shock wave photos revealed critical information that influenced U.S. policymakers during debates in the 1970s and 1980s about where *not* to stage the nation's newest intercontinental ballistic missile, the Peacekeeper, also called the MX missile. (See "The MX Factor," page 14.)

Back to the Past

Los Alamos, Lawrence Livermore National Laboratory, and several Department of Defense organizations are now searching for and retrieving a large portion of the test films from storage as they collaborate on the Film Scanning and Reanalysis Project. Project leader Spriggs is interested in finding the scientific films (approximately 10,000 motion pictures and still photographs), defined as such because professional photographers (with top secret clearances) made them, using unique cameras and films and focusing tightly on the detonations and the effects emanating from them. Another approximately 6,500 films were made as documentaries, covering all the activities that surrounded a test, from preparation to wrap-up. (See "From Glimmer to Fireball: Photographing Nuclear Detonations," page 13.)

As Spriggs finds the films, he uses a high-resolution film scanner to convert them frame-by-frame into digital images. He then analyzes them with sophisticated image-processing software—a far cry from the relatively crude manual analysis techniques of the 1950s and 1960s.

> **The original analyses were prone to inaccuracies that make today's weapon physicists scratch their heads.**

Although Spriggs is only at the mid-point of the work, he has already made some important discoveries. First of all, he has found that the films are indeed rapidly deteriorating; so the project (if adequately funded) is just in time to digitally preserve them.

That Was Then—This is Now

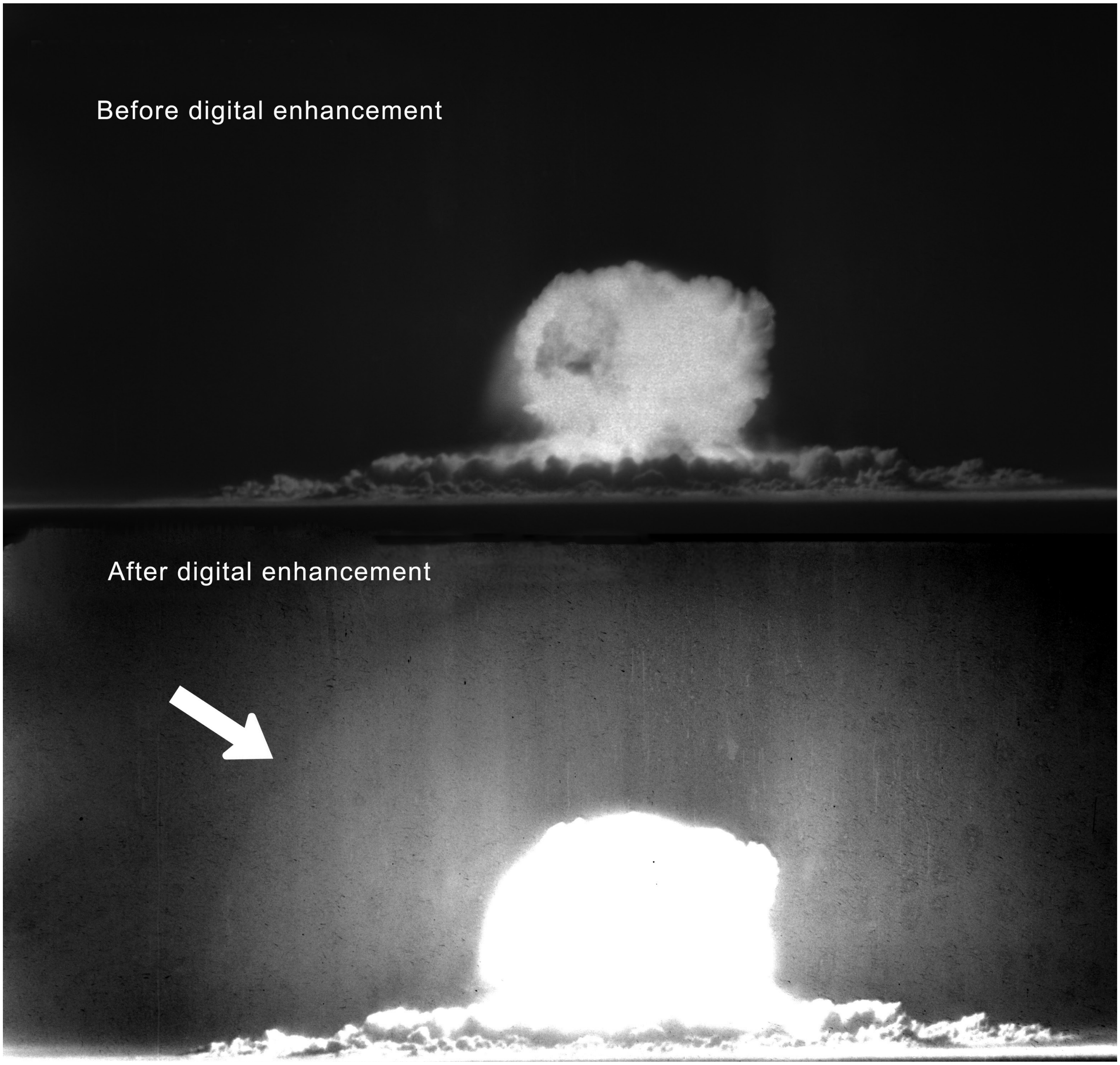
Second and more important, Spriggs has discovered that the original analyses were prone to inaccuracies. The technology of the day prevented more precise estimates of the yields. Measurements were inconsistent and subject to an individual's interpretation and judgment. As such, the results showed relatively large uncertainties and inconsistencies that make today's weapon physicists scratch their heads.

For example, the analysts would place a film of, say, a fireball into a sprocketed, hand-fed system, enlarge it, and project it onto a calibrated grid. Next they would advance the film one frame at a time to measure the size of the fireball as a function of time—the growth rate—looking for what they believed to be the edge of the fireball's peak growth. (These specialized films came with built-in timing marks for this purpose.) One or two people (two would be used to compare each other's results for consistency) would decide where the edge of the fireball stopped on the grid and write those numbers down on an analysis sheet. Then they measured the radius: fireball center to edge.

> **Spriggs has found these analyses were rushed and incomplete but this means lots of fresh data remains to be mined and analyzed.**

This process was slow and had the potential for lots of human error; different people might report different fireball-edge estimates from the same film. Analysts might then calculate two different yields for the same detonation. Sure enough, the yield numbers are sometimes oddly inconsistent across multiple tests of the same weapon design, something that doesn't make scientific sense.

In addition, Spriggs has found these analyses were rushed and incomplete: only a fraction of the films was analyzed.



The digitized image of the Badger test (top) of Operation Upshot-Knothole (1953), Nevada Test Site, has been enhanced (bottom) for a stronger contrast between the shock front (indicated by the arrow) and the sky behind it. Badger was originally estimated to yield 23 kilotons. With the shock wave now clearly visible, the yield can be estimated with far greater precision. (Photo: Open Source)

That's understandable, considering the hectic schedules and stressful deadlines of the Cold War. But this means lots of fresh data remains to be mined and analyzed.

Size Matters

Digitizing these films allows much more rigorous analysis. For example, digital images of the shock wave's position enable researchers to see its terminal edges with finer precision, thus providing higher accuracy in measuring its radius and allowing more exact yield estimates. Based on some preliminary results, Spriggs believes that by digitizing the films he can reduce the uncertainty of some measurements, like those of a fireball radius, from about 20 percent to about 2 percent.

> **Could a megaton-class weapon actually have an extra five Hiroshima-size yields lurking inside?**

Improving the accuracy of this measurement by as little as 1 percent has an outsized impact on the yield estimate. A 1-percent difference in the measured radius of a fireball, for example, would produce a 5-percent difference in the yield estimate. Suppose the original estimate predicted a yield in the 1-megaton range, but the radius measurement was off by 1 percent; that translates to a 5-percent difference in the actual yield estimate, which in this case equals 50 kilotons. The yield of the Little Boy bomb that destroyed Hiroshima was about 10 kilotons. So could that megaton-class weapon actually have an *extra five* Hiroshima-size yields lurking inside?

> **Spriggs believes he can sharpen the official yield numbers used by DoD strategists and emergency responders.**

To Form a More Perfect Number

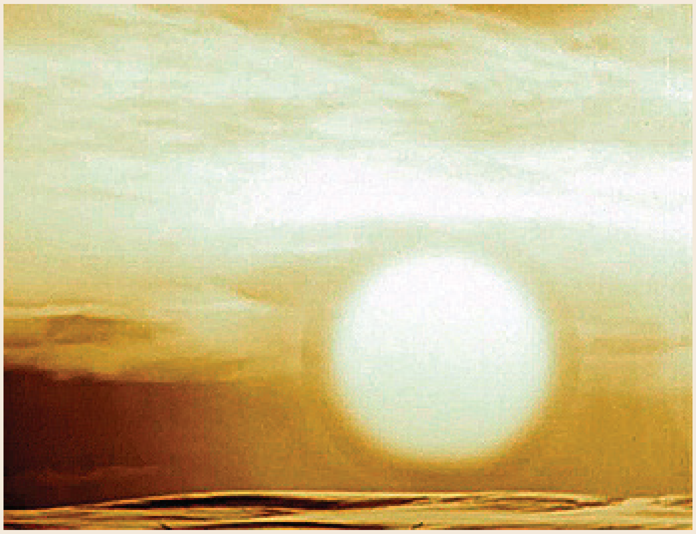
Because yield numbers are estimates based on inferences, they have inherent margins of error. Spriggs is targeting that uncertainty as he digitizes the test films and gets new, computer-generated measurements from their images. With modern technology, Spriggs believes he can “sharpen” each estimate—bring it as close to perfect as an inference can be—and put a finer point on the official yield numbers used by weapons scientists, DoD strategists, emergency responders, and other stakeholders.

> **Everything goes back to the yield estimates originally developed during the atmospheric tests.**

Everything goes back to yield,” he says, “and all the correlations between effects and estimates of yield were originally developed during the atmospheric tests. If we’re to more accurately estimate yields and their destructive consequences, and reduce the uncertainties in our weapons codes, we need the best data available. That’s what took me back to the films. We need to reanalyze them now that we can, and we need to preserve them so future scientists can analyze them with future technologies.”

~Eileen Patterson

Bigger's Not Always Better



The largest human-made explosion in history was the Soviet Union's detonation (October 30, 1961) of its 50-megaton Tsar Bomba (the "King of Bombs"), the most powerful nuclear weapon ever designed (about 10 times the combined power of all the conventional explosives used in World War II). It had a designed yield of 100 megatons but was tested at half that yield, in part so that the plane that dropped it would have time to fly to safety. Due to its size and yield the Tsar made a huge, international political and military splash, but in reality it was impractical for military use. No more were built. (Photo: Open Source)

This may come as a surprise, but bigger yields are not always better. Nuclear weapons were generally designed not to be as powerful as possible—but to be as precise as possible.

For example, the Department of Defense (DoD) typically tasked Los Alamos to design and build nuclear weapons that produced the specific yield required to destroy one or several types of specific targets. Too little yield and the weapon would fail to destroy the target; too much and the blast would cause unanticipated, unintended, and/or undesirable consequences.

The weapon should, for example, have a yield whose subsequent effects would destroy the enemy's missile base but not harm the nearby town. From the U.S. perspective, the goal was to eliminate an adversary's ability to fight, not wipe them out. So the yield of U.S. nuclear weapons needed to be like Baby Bear's porridge: not too cold and not too hot, but just right.

The destruction caused by a nuclear weapon is also determined by the conditions under which it is detonated: on the ground, at different heights above the ground, underground, on the water, at different depths underwater, in the desert, in the Arctic, in the mountains, in a city, above a city, up in space, etc. The same-yield weapon—capable of releasing the same amount of energy—detonated in each of these environments will result in very different kinds and degrees of destruction. Sometimes a lower-yield weapon causes greater destruction than one with higher yield detonated in different circumstances. (See "The MX Factor," page 14.)

Solid Gold

It is a sobering fact that nuclear weapons designers, DoD strategists, policy makers, and disaster relief planners have derived much of what they know, or theorize, about the results of atmospheric detonations of modern nuclear weapons from the data taken from Hiroshima and Nagasaki and from the 210 atmospheric tests conducted between 1945 and 1963. Several factors make using those data problematic. For example, Hiroshima and Nagasaki did not resemble today's modern, concrete-dense, high-rise cities. And many weapons and yields were never tested in different environments against different types of targets.

The United States conducted approximately 800 underground tests after 1963, but the analysis of their destructive capabilities on real-world targets was limited.

Atmospheric tests provide the only "real world" test data for today's nuclear weapons scientists and national security stakeholders to work with. It may not be much data, but it is solid gold. ✦

~Clay Dillingham

The Film Scanning and Reanalysis Project

For Lawrence Livermore National Laboratory's weapon-physicist Greg Spriggs, leader of the Film Scanning and Reanalysis Project, the work has become a search-and-rescue mission. He has to find thousands of scientific test films and digitize them before they deteriorate beyond usefulness.

Lost and Found

Old and imprecise records told Spriggs how many original films there were, but not where they were. In fact, they were stored in several different archives. He has now found most of them at Livermore; the Defense Threat Reduction Information Analysis Center on Kirtland Air Force Base in Albuquerque, New Mexico; and Los Alamos National Laboratory. Los Alamos had the most, about 7,000. About 2,500 remain missing.

Spriggs had to not just hunt them down but also verify that they were, indeed, the original negatives as opposed to the plethora of duplicates, called prints. To scientifically reanalyze the films he needed the original negatives that were in the cameras on test day to capture the original, undistorted data.

Near Perfect

To digitize the films, Spriggs is using a high-resolution, sprocketless scanner that moves the film through the scanner without gripping the holes on a filmstrip's edges. Running one of the old films, now shrunken and buckled, through a sprocket-type scanner would just rip it up.

He also worked with the manufacturer to ratchet up the scanner's ability to capture a wider range of optical density—a measure of the film's capacity to respond to extremely dim and bright light. A nuclear detonation's light output is important data for measuring yield, especially the double flash of light, one of a nuclear explosion's most significant effects.

No film stock can capture the full range light emitted by a nuclear explosion—12 orders of magnitude. The film normally used by Hollywood can only capture two orders of magnitude of light variation. But the film stock, especially designed for the atmospheric tests, was capable of capturing four orders of magnitude. The scanner used by Spriggs now matches that number, producing near-perfect copies.

Critical Analysis . . .

Spriggs is doing computer analyses on the newly digitized films—a good thing because the original analyses were cursory at best, partly because the work had to be done quickly. Yield estimates were required in as little as an hour after a test, so a few films were developed in on-location film-lab trailers and analyzed immediately.

. . . and Reanalysis

Computers with image-processing software have eliminated guesswork. "For measuring the radius of the fireball," says Spriggs, "we don't have to look at a grid and hope we read it right. We can detect the exact edge now. And we can sample optical density on millions of points on every frame."

In addition, on the newly digitized images, the shock wave is traceable much longer—over hundreds of frames—because the contrast between shock-wave front and background can be greatly enhanced.

A Team Effort

Spriggs is not alone. He has scientists at Los Alamos, Livermore, Sandia National Laboratories, and Britain's Atomic Weapons Establishment supplying theoretical fireball calculations, against which Spriggs checks his own analyses. In addition, students from the Air Force Institute of Technology and the military academies are helping reanalyze the digitized films either as summer-student projects or as part of their graduate studies.

The project also boasts two film consultants with Hollywood credentials: Peter Kuran and Jim Moye. Kuran is a film historian, filmmaker, and technical film expert who won an Academy Award for his film preservation technology. Kuran produced the movie *Trinity and Beyond*, about the atmospheric tests, and wrote *How to Photograph an Atomic Bomb*, about how the tests were filmed. (See atomcentral.com.)

The National Archives entrusted Moye, a film expert with 40 years of experience in the film industry, to perform full preservation work of the famous "Zapruder film" that captured the assassination of President Kennedy.

Spriggs says, "Because these films represent a unique set of important data that are irreplaceable, they are being handled and preserved with great care by film professionals like these. They know the importance of their work and are dedicated to ensuring these data will be there for future use in national security science." ✦

~Eileen Patterson

Lawrence Livermore's Greg Spriggs (foreground) and Alan Carr, Los Alamos National Laboratory historian, dig through boxes of films in the vast Los Alamos archives. Each box may hold up to 50 films that may or may not be test films. All must be checked. (Photo: Los Alamos)

The Double Flash Meets the Bhangmeter

The U.S. Nuclear Detonation Detection System (NDS), which uses satellite-borne sensors to watch for nuclear explosions, can spot a nuclear attack anywhere in the world.

One of the NDS sensors is a "bhangmeter" (pronounced BANG-meter), developed by Edgerton, Germeshausen, and Grier, Inc. (now EG&G) in 1948 at the request of Los Alamos scientists. The bhangmeter's job is to detect a nuclear explosion's telltale double flash of light and send a signal to NDS ground stations manned by the Air Force. The explosion's yield can be estimated from that signal, which appears as two humps on an oscilloscope.

William Ogle, one-time head of the Los Alamos's field-testing division, reported that the bhangmeter was named during an afternoon-long meeting held for just that purpose. Bhang is a form of cannabis consumed in India. The group chose the name as a joke, implying that you had to be "on something" to believe such a simple instrument could determine yield.

But the bhangmeter is no joke. U.S. scientists deployed the instrument when observing this country's atmospheric tests, and the Department of Defense has installed it on satellites since the 1960s, initially on the Advanced Vela satellites, launched in 1967, 1969, and 1970, and now on the NDS satellites. Vela-borne bhangmeters detected 41 confirmed nuclear tests, but they may be most famous for the one detection never definitively confirmed: the "Vela Incident," September 22, 1979.

On that date, the two bhangmeters on Vela satellite 6911 detected a double flash over the Indian Ocean between Antarctica and the southern tip of South Africa. Many believe it was a joint Israel-South Africa nuclear test, but the scarcity of corroborating evidence persuaded others that a sensor malfunction or meteor strike caused a false positive. The incident remains controversial. ✦

~Eileen Patterson

A bhang shop in Jaisalmer, Rajasthan, India. *(Photo: Tom Maisey - Flickr. Licensed under CC BY-SA 2.0 via Wikimedia Commons)*

Dressed for the job. While EG&G was responsible for scientific photography, a secret Hollywood studio, Lookout Mountain Laboratory, made documentaries for military and government briefings and then for public consumption. This Lookout Mountain photographer (1956) is outfitted to protect himself from radiation.
(Photo: Open Source)

From Glimmer to Fireball: Photographing Nuclear Detonations

Photographing nuclear explosions was not for the faint hearted. Some of the cameras were manned, but those close to a detonation were remotely controlled and placed in bunkers or outfitted with armor-like housings. To retrieve the film, photographers donned breathing masks and radiation-protection clothing, with wrists and ankles taped against leaks.

The technology had to be cutting edge. EG&G (Edgerton, Germeshausen, and Grier), the defense contractor that made the scientific films, used a wide variety of cameras and film stocks, some radiation resistant. Much of the equipment was developed just for the tests. Hollywood and the commercial and scientific photographic industries later adapted many of these advancements in photography.

Capturing the yield-signifying phenomena occurring in the thousandths of a second after time zero (the instant of detonation) required extremely high-speed cameras. Exotic “rapatronic” cameras (rapid-action electronic cameras) had exposure times of 4 to 5 millionths of a second. And one camera, the “teletronic,” had an exposure time of a single billionth of a second. It could record a detonation’s first glimmer—almost time zero itself.

The rapatronics photographed the fireball and the double flash representing the bomb’s pulse of thermal radiation. Each camera took only a single photograph, exposed on a glass plate, so cameras were arranged in groups of 12 to 15 and triggered one right after the other to document the effects’ evolution through time. An equal number of movie cameras, running at up to 3,000 frames per second, filmed alongside the rapatronics. ✦

~Eileen Patterson

The MX Factor

A Peacekeeper missile being test-launched from Vandenberg Air Force Base, CA. The Peacekeeper, also known as the MX missile (for Missile-eXperimental), was a land-based, intercontinental ballistic missile deployed starting in 1986. The Peacekeeper carried up to 10 re-entry vehicles, each armed with a nuclear warhead. The last of the Peacekeeper missiles was decommissioned in 2005.

(Photo: U.S. Air Force.)

Test films played a strategic-planning role in the debates of the late 1970s and early 1980s about where and how to deploy the MX intercontinental ballistic missile (LGM-118 Peacekeeper). The deployment would have to ensure that the missiles could survive a first strike by an adversary. Military planners were considering placing the missiles in clusters of hardened concrete shelters in the hot, dry Great Basin Desert of Nevada and Utah.

Films of atmospheric tests at the Nevada Test Site had something important to show about such a location. That something is called a "thermal" precursor, an additional shock wave that can race ahead of the main shock wave, battering objects in its path with highly destructive pressures exceeding those of the main wave. A precursor is far more likely in a hot, dry environment.

Rod Whitaker, Los Alamos physicist participating in the film project, explains: "In a desert or arid environment, vegetation is sparse, so a nuclear explosion heats the ground and the air just above the ground, creating a thermal layer, which can then generate this precursor. The only data we have on thermal layers, precursors, and the damage they can cause came from films of aboveground nuclear testing in Nevada."

A Peacekeeper test missile re-entering the atmosphere at the Kwajalein Atoll in the Marshall Islands. This long exposure photo shows the paths of the multiple re-entry vehicles deployed by the missile. Each of the missile's 10 nuclear warheads could be aimed to destroy a different target and packed a yield that was many times greater than Fat Man or Little Boy. (Photo: U.S. Army.)

The Nevada films also showed that a precursor was even more likely as detonations occurred closer to the ground. The May 25, 1953, Grable test is a case in point. Grable's 15-kiloton explosion surprisingly produced greater destruction than did the higher-yield (27 kilotons), higher-altitude Encore test held earlier the same month in the same place. Objects that Encore left untouched, Grable destroyed. Film revealed the reason: Grable produced a precursor, while Encore did not. Both tests took place in the same hot, dry environment, but Grable was detonated closer to the ground.

Because the precursor phenomena would increase the uncertainties of how destructive a Soviet air-burst-detonation against the MX base might be, there were problems with engineering adequate defenses and, even if they could be engineered, the economic costs of putting them in place would certainly be steep.

Information like that revealed in the atmospheric test films ultimately meant that the MX missiles would not be based in the Great Basin Desert. ✦

~Eileen Patterson

ATOMIC PHOTOGRAPHY

BLASTS FROM THE PAST

Twenty-five U.S. atmospheric nuclear weapons operations (each a series of tests) were conducted from 1945 to 1963, primarily at the Pacific Proving Grounds and at the Nevada Test Site, southeastern Nevada.

Below, observers witness Operation Greenhouse, Eniwetok Atoll, spring 1951. Greenhouse was a series of four tests.

Proof of principle for thermonuclear weapons, the 225-kiloton George test, May 8, 1951, of Operation Greenhouse, Eniwetok Atoll, Marshall Islands. Greenhouse George was an 8-foot by 2-foot disk, detonated on a tower on Eniwetok Atoll. George led to the development of thermonuclear weapons.

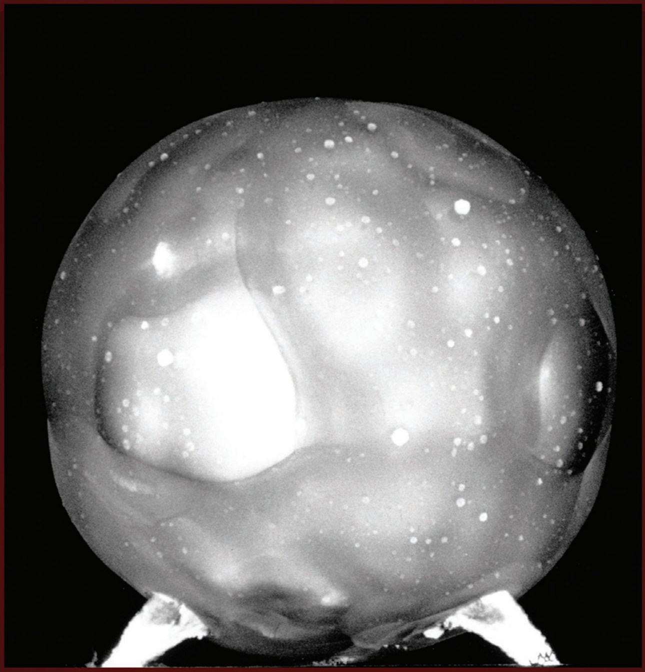
The world's first full-scale thermonuclear device, the 10.4-megaton Mike shot of Operation Ivy, October 31, 1952, Eniwetok Atoll. Ivy Mike was a 54-ton cylinder, almost 19 feet tall, in an aluminum building—essentially, an exploding house.

The first U.S. airdropped thermonuclear bomb, the 3.8-megaton Cherokee test of Operation Redwing, May 20, 1956, Bikini Atoll. Redwing Cherokee, one of 17 Redwing tests, was a true bomb. . . and a big one—about 3 feet wide, 11 feet long, and 6,867 pounds. It was dropped from a B-52.

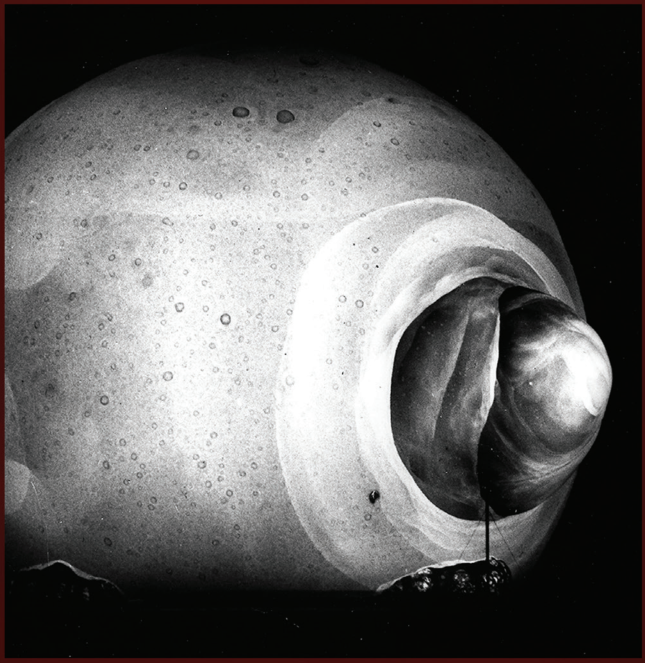
The first underwater test of a nuclear weapon, the 21-kiloton Baker test, July 24, 1946, Bikini Atoll. One of two tests for Operation Crossroads, Baker raised a huge pillar of irradiated water. The bikini swimsuit was named for the Crossroads test site, the swimsuit's designer explaining that it, like a nuclear bomb, was "small, but devastating."

The Grable test of Operation Upshot-Knothole, May 25, 1953, Nevada Test Site. The 11-inch diameter nuclear cannon, "Atomic Annie," fired an 803-pound nuclear shell, with a yield of 15 kilotons, almost 20 miles. The nuclear shell was the same general design as the Hiroshima bomb, whose yield it exceeded. Atomic cannons were fielded in 1953 in both Europe and Korea and retired in 1963.

The 210-kiloton Truckee test of Operation Dominic, June 9, 1962, Christmas Island, Pacific Ocean. The Dominic test series of 36 tests was the final U.S. atmospheric test series. The airdropped Truckee test device, a missile warhead, produced a spectacular mushroom cloud that exhibited "skirts," the bell-like shapes seen here descending the mushroom's stalk.



Nuclear fireball of the 14-kiloton, tower-supported How test, Operation Tumbler-Snapper, June 5, 1952, Nevada Test Site. Captured by a “rapatronic” camera in an exposure of just 4–5 millionths of a second. The fireball is shown here just thousandths of a second after detonation. The fireball seems to stand on glowing stalks—the tower’s guy-wires being consumed in a phenomenon called a “rope trick.”



Rapatronic photo of the 360-kiloton Mohawk test’s fireball, Operation Redwing, July 2, 1956, Eniwetok Atoll. Most test detonations included side experiments, detonated by the radiation from the main test. One such side test produced the secondary explosion seen here protruding from the fireball’s right side.

Another rapatronic image, the 19-kiloton Whitney shot, Operation Plumbbob, September 23, 1957, Nevada Test Site. X-rays generated by the detonation strip electrons off atoms in the air. The electrons then rejoin the atoms, producing a flash of electrical discharge that creates the feathery light seen here.

Smokey, a 44-kiloton shot, Operation Plumbbob, August 31, 1957, detonated atop a 700-foot tower, Nevada Test Site. The U.S. military needed to know how well soldiers would physically and mentally handle fighting on a nuclear battlefield. Approximately 18,000 soldiers, representing each branch of the military, participated in military exercises during Operation Plumbbob.

Military maneuvers during Operation Tumbler-Snapper, May 1, 1952, Nevada Test Site. RKO-Pathe produced a short documentary motion picture about Marines in action at the test site. The film was titled "Operation A-Bomb."

Operation Tumbler-Snapper, Nevada Test Site. Marines exhibit a decidedly lighthearted attitude toward nuclear weapons.

Photographic cargo for a nuclear test. Each atmospheric nuclear test was photographed by 40 to 50 cameras, although one test series required 200. One million still photos were taken during the two-shot 1946 series, Operation Crossroads. Here, a B-29 stands ready to be loaded with the staggering amount of photographic equipment needed for one series of tests.

In the path of the shock wave. Several miles from ground zero at the Nevada Test Site, photographers brace themselves against the arrival of the shock wave, 30 seconds after detonation. Photographers were first blinded by the explosion's flash of light. The shock wave arrived seconds after the flash.

Film disintegration. Age is the enemy of film. This decomposing original film of the July 16, 1945, Trinity Test, the world's first nuclear explosion, was destroyed by a form of decay called vinegar syndrome, named for its odor. When Spriggs and his associates opened this film's metal container, he says, "the vinegar odor almost keeled us over."

~Eileen Patterson

TRINITY TO TRINITY

The journey from Trinity to Trinity begins with the New Mexico desert night sky turning instantly to day at 05:29 am on July 16, 1945. An eyewitness recalled,

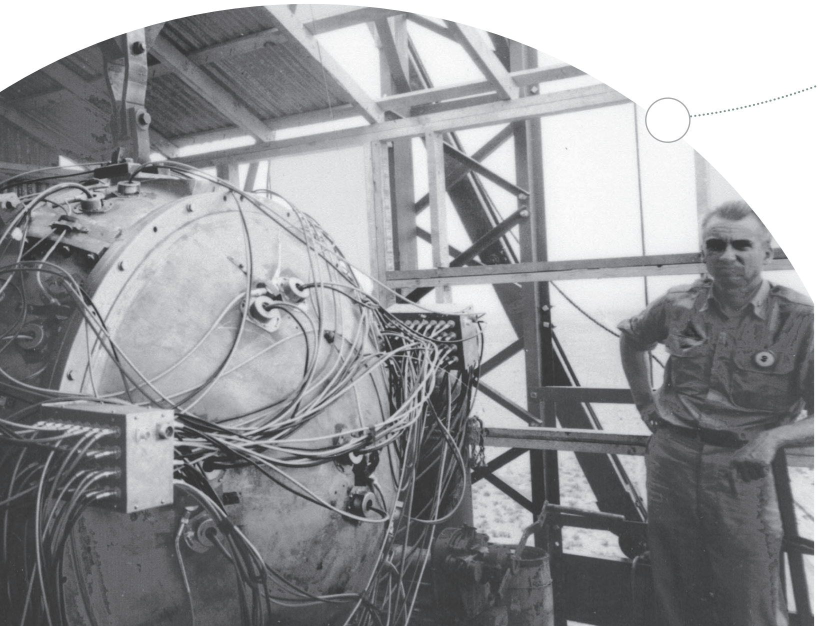
“The effects could well be called unprecedented, magnificent, beautiful, stupendous, and terrifying. The lighting effects beggared description. The whole country was lighted by a searing light with the intensity many times that of the midday sun. It was golden, purple, violet, gray, and blue.”

It was the Trinity Test: the world’s first nuclear detonation.

This year, the Laboratory is marking the 70th anniversary of the Trinity Test because it not only ushered in the Nuclear Age, but with it the origin of today’s advanced supercomputing—the Age of Supercomputers largely began with weapons science at Los Alamos.

The evolution of computers is directly tied to the evolution of nuclear weapons. Simple computers were key to the design and development of the first nuclear bombs, like the one detonated during the Trinity Test. Throughout the Cold War, ever more powerful computers were designed and built specifically to aid the design and build cycle that led to today’s U.S. nuclear deterrent.

Just as it was 70 years ago, the key mission of Los Alamos is to provide the nation with a safe, secure, and effective nuclear deterrent. From 1945 to 1992 the Lab designed, tested, and built many different types of weapons. Today, the Lab uses its science and engineering capabilities to ensure that the few thousand weapons that remain in the deterrent are safe, secure, and effective.



The weapons in the stockpile are built of thousands of components; some of these components are now beyond their expected lifespan. These aging components must be continuously evaluated, replaced, repaired, or redesigned—and then tested where possible, and the findings reported to the President of the United States.

Without supercomputing this would not be possible. This brings the journey to the new Trinity supercomputer. At 40 petaflops (40 quadrillion [10^{15}] floating point operations per second) and with 2 petabytes of memory, Trinity will be the second or third fastest computer in the world.

But its speed is not as significant as what it will do with its speed *and* revolutionary new programming; Trinity will make complex, 3D simulations of nuclear detonations practical with increased fidelity and resolution.

Highly accurate 3D computing is a Holy Grail of the Stockpile Stewardship Program’s supercomputing efforts. As the weapons age, issues may arise that require highly accurate 3D modeling to understand and resolve. This is a great challenge reminiscent of the one faced by the Manhattan Project: building the first nuclear weapon that works. Now our challenge is to understand how and why a weapon works well enough to confidently predict its performance without requiring an additional nuclear test.

The Trinity Test of 1945 was the first full-scale, real-world test of a nuclear weapon; with the new Trinity supercomputer our goal is to do this virtually, in 3D.

Because stewarding these weapons depends on an in-depth understanding of mind-bogglingly complicated physics, which we are still unraveling, and because warhead components continue to age—and thus change their characteristics—there is no foreseeable end to the challenges of stockpile stewardship. Highly accurate 3D computing is a critical part of this journey, but not its destination. ✦

~Clay Dillingham

Norris Bradbury, who became the Laboratory’s second director, stands beside the Gadget just hours before the Trinity Test. Above: A supercomputer simulation. (Photos: Los Alamos)

A TRADITION OF WELCOMING FOREIGN SCIENTISTS AND ENGINEERS

It is ironic: many immigrants fleeing Adolf Hitler's and Benito Mussolini's fascist governments in the 1930s and 1940s played critical roles in the development of Los Alamos National Laboratory and of the nuclear weapons that helped bring an end to World War II.

In fact, many immigrants served as senior leaders at the Laboratory. Originally, there were four technical divisions at the Laboratory. (Today there are over 40.) The legendary Nobel Prize–winning physicist Hans Bethe, a German-born immigrant, led the Theoretical Division. Bethe's mother was Jewish, and this had cost him his university position in Hitler's Nazi Germany.

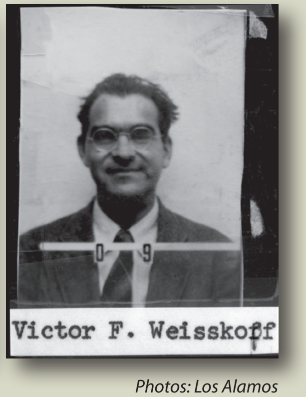
Two of Bethe's group leaders in the Theoretical Division were also refugees. Victor Weisskopf, a gifted Jewish physicist from Vienna, had made valuable contributions to understanding quantum mechanics. At Los Alamos, his group calculated the efficiency of the atomic bombs. Edward Teller, who was also Jewish, lived under communist and fascist dictatorships in his native Hungary. Teller became known as "the father of the hydrogen bomb" and would go on to help create Lawrence Livermore National Laboratory in California. Teller also contributed to writing the famous Einstein-Szilard letter, sent to President Franklin Roosevelt in early August 1939, which provided the initial spark for what would ultimately evolve into the Manhattan Project.

Emilio Segre and Bruno Rossi, both Italian experimental physicists who had escaped Italy's fascist, anti-Semitic government, became group leaders in the Experimental Physics Division. Rossi's work was vital in the development of Fat Man, the first implosion bomb. Segre's work at Los Alamos revealed that plutonium would not work in a gun-assembled nuclear weapon, like Little Boy. This discovery saved valuable time and resources and led to plutonium's use in implosion weapons.

Enrico Fermi, also Italian, was one of the most important physicists at Los Alamos. Fermi was not Jewish but his wife was. He was awarded the Nobel Prize in 1938 and was given permission to travel to Stockholm to receive the prize. He was also permitted to take his wife along but given orders to return to Italy with her immediately afterward. They never did. Once in the United States, Fermi built the world's first nuclear reactor, led the team that initiated the world's first self-sustaining chain reaction, and went on to become a division leader and associate director at Los Alamos.

Thus, from its inception Los Alamos has always welcomed scientists and engineers from foreign countries.

~Alan Carr



Photos: Los Alamos

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The 21-kiloton Baker test of Operation Crossroads (July 24, 1946), Bikini Atoll, was an underwater explosion. The bomb was suspended beneath a surplus landing ship, the LSM-60, in a shallow (180-foot deep) lagoon and detonated amid 71 expendable ships staged at various distances from the detonation point. In this famous photograph, a wide condensation cloud ("Wilson cloud") surrounds the actual mushroom cloud.

The dark patch on the right side of the huge (2,000 feet wide) hollow water column raised by the explosion is the 562- foot, 26,000-ton dreadnought battleship, U.S.S. Arkansas*, which was upended by the explosion. It actually got stuck nose down in the bottom of the lagoon, with 350 feet of its hull in the air. The* Arkansas *was longer than the lagoon was deep. The water column then pushed it over. It lies today upside down at the bottom of Bikini Lagoon. No sign of the LSM-60 was ever found; it was vaporized.* *(Photo: Los Alamos)*

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