Los Alamos National Laboratory

April 2016

NATIONAL SECURITY SCIENCE

In this issue

Welcome to this issue of

NATIONAL SECURITY SCIENCE

Los Alamos National Laboratory has been at the forefront of high-explosives research since the Manhattan Project in 1943. The science of high-explosive performance is central to stockpile stewardship.

Yet, explosives science at the Laboratory isn't simply about maintaining and certifying the aging U.S. nuclear deterrent; it's also about developing novel applications of that science to other national security challenges. In 2015, Los Alamos executed more than 400 high-explosive-driven experiments (averaging more than one a day). The tests were conducted in support of a diverse number of projects, such as rocket propellant science. (See "Explosive Results," page 11.)

Understanding explosives is more than a scientific curiosity; this research has urgent and global impacts. The nation's Explosive Ordnance Disposal (EOD) experts—the men and women who have the dangerous responsibility to seek out and destroy hostile munitions, improvised explosive devices, and the laboratories that produce them—must also understand the science behind their job. Thus, every six weeks, Los Alamos offers an Advanced Homemade Explosives Course to educate EOD techs about the nature of the raw materials commonly found in explosives and how to safely defeat them. (See "The Hurt-Locker School," page 3.)

In 2016, the EOD courses will continue alongside a host of other vital projects and explosives-science research. The year is already off to an explosive start, as Lab scientists work to characterize the "hydrogen bomb" detonated on January 6 by North Korea. (See "Shake, Rattle, and Roll," page 20).

The Laboratory is also working with the Department of Energy to grant public access to several 1940s-era Laboratory facilities within the new Manhattan Project National Historical Park. The challenge is provide safe access without compromising the ongoing national security work at the Lab. (See "Manhattan Project National Historical Park," page 22.)

The Manhattan Project led to a surprising partnership between Los Alamos and an unlikely affiliate: the United States Navy. After the war, the Lab designed the first nuclear weapon to enter the Navy's stockpile, and Los Alamos designed every nuclear weapon the Navy currently deploys. Today, the relationship between the two remains as strong as ever. (See "Charting a Parallel Course," page 30.)

The Laboratory's nuclear weapons work remains vital to U.S. Strategic Command, which is led by U.S. Navy Admiral Cecil D. Haney. Los Alamos staff are among those who support the "chess players" that Admiral Haney says the nation needs to play "in a multi-dimensional environment" on a board "where they may not fully understand the rules by which our adversaries are playing." (See "Strategic Deterrent Forces," page 26.)

Making sense of this "board"—and being proactive about the findings—is why the Laboratory exists. Here's to another year of noteworthy accomplishments and continued excellence in 2016.

Bob Webster
Principal Associate Director, Weapons Programs

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In February 2014, the U.S. Department of Homeland Security got wind of a potential bomb threat: explosives packed into a travel-sized toothpaste tube. Could such a bomb bring down an airliner? Find out on page 11.

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Scenes such as this explosion in Iraq have been typical in recent wars as insurgents and terrorists create homemade explosives that are often deployed as roadside improvised explosive devices (IEDs). Explosive Ordnance Disposal (EOD) technicians in the U.S. Air Force, Army, Marine Corps, and Navy tackle the tough job of detecting, rendering harmless, and disposing of a wide range of explosive materials. Los Alamos teaches EOD techs how to save lives by recognizing homemade bomb labs and the raw ingredients commonly used to make IEDs and other bombs. EOD techs also learn safety measures, get hands-on experience synthesizing the materials, and study the sensitivity and performance characteristics of those materials. The Los Alamos National Laboratory Advanced Homemade Explosives Course uses science and hands-on training to keep EOD techs out of the "hurt locker." *(Photo: U.S. Army)*

THE HURT-LOCKER SCHOOL

Los Alamos's Advanced Homemade Explosives Course puts world-class science to work keeping military Explosive Ordnance Disposal techs safe.

Under an exhaust hood shielded by safety glass in a research laboratory, a U.S. Marine Corps sergeant named Alvin puts three white crystals, each the size of a sea-salt grain, into a piece of foil crimped like a cupcake liner. It's Day 2 of the Los Alamos National Laboratory Advanced Homemade Explosives Course. Two other marines and an airman, all Explosive Ordnance Disposal (EOD) technicians, crowd around. Alvin clicks-on a disposable gas lighter and waves the flame back and forth below the foil for a few seconds…

Bang!

A bright blue flame flashes off the sample. Everybody jumps, except instructor Virginia Manner, a Los Alamos staff scientist in the High Explosives Science and Technology group. Manner runs the course with co-leader Margo Greenfield of the Shock and Detonation Physics group. None of the EOD techs—all experienced with explosives—expected this batch to go off like that.

"Whoa!" says Devin, another Marine sergeant. "I wasn't ready for that!"

"That was freaking *awesome*!" Alvin says.

The energy in the room ratchets up several notches. So does the techs' respect for this powdery homemade explosive that behaves similarly to a conventional high explosive (pentaerythritol tetranitrate) that Laboratory scientists have been researching to better understand its performance and sensitivity characteristics.

> **If you've seen the movie The Hurt Locker, which many techs say exaggerated their work for the sake of drama, you have some sense of how tough that job is.**

"This type of explosive material has interesting properties," Manner tells the group. "You may be tricked into thinking it is safe to handle." She pauses slightly for emphasis: "It isn't."

That's a lesson crafted particularly for the 20 or so EOD techs attending the course designed for them by Los Alamos. EOD techs have a tough job. Their lives—and others' lives, too—depend on how much they know. From all branches of the service, these techs routinely get the call to dismantle homemade explosives (HMEs) along dusty roads, for instance, or neutralize HME factories in war zones. If you've seen the movie *The Hurt Locker* (which many EOD techs say exaggerated their work for the sake of drama), you have some sense of how tough that job is.

EOD techs learn to test the sensitivity of a small quantity of an unknown explosive material by hitting it with a hammer in progressively harder strikes, eventually producing a flash and a pop. *(Photo: Los Alamos)*

Hammer Time

The label "explosives" covers a wide range of substances that are characterized by liberating energy and producing heat under a stimulus, "like an impact or spark," which sets them off, according to a standard text in the field, *The Chemistry of Powder & Explosives*. The EOD techs at the Los Alamos course are experimenting with the homemade kind, defined loosely as any improvised concoction of readily available material that can blow up, often in an improvised explosive device (IED). One dangerous task facing an EOD tech is determining whether a material—a white powder, for example—is, in fact, an explosive.

> **One dangerous task facing an EOD tech is determining whether a material—a white powder, for example—is, in fact, an explosive.**

Manner started this lesson by guiding the team through preparing a batch of improvised homemade explosive using common off-the-shelf ingredients that you might find at a local hardware or grocery store, so the techs can see how it's made and how it reacts to a stimulus.

What will set it off?

The team works in Manner's lab, a narrow room with floor-to-ceiling steel cabinets, glass-fronted ventilated hood areas for handling chemicals, a sink, plenty of counter space, and a pull-chain shower for an emergency rinse. An army captain, currently on assignment at Los Alamos for a year as a Department of Defense (DoD) liaison, observes from the side. Wearing safety glasses, ear plugs, and white lab coats over their camouflage uniform pants, the EOD techs joke with Manner and then focus on mixing the improvised explosive. Alvin reads the printed instructions aloud while the others measure the precursors into various beakers. A Teflon-coated piece of steel the size and shape of a vitamin pill agitates the mixture on a magnet-driven stir-plate behind safety glass. Next comes the slow process of precipitating the explosive to form a sludge that will dry into a powder.

After rinsing the explosive, Manner nudges it out of a funnel. Dampness makes the explosive relatively safe to handle. Now Richard, an EOD tech in the Air Force, picks up a pair of hammers, sets the head of one over a few grains of the explosive on a small anvil, and starts tapping with the other hammer: once gently, once hard, and once really hard. Nothing happens. Too much water. Eventually, a swift strike triggers a pop.

> **We want EOD techs to have respect for the explosives but not be so afraid they can't walk into an HME lab.**

The "Aha" Moment

The techs talk about "getting left of the boom," which means working before the bomb goes off. "Right of the boom" means it's already blown up. The Los Alamos course is all about working on that left side, *safely*. To that end, every six weeks for five days, about 24 techs come from the Air Force, Marines, and Navy to learn more about how the bad guys whip up explosives in makeshift labs.

"Currently, we're enhancing the EOD techs' understanding of HME threats and the labs that they might encounter when deployed," Manner says. "The course teaches them how to safely go through a lab, for instance, and understand what's being made and how to handle it."

Everything the EOD techs learn this week will apply to combat. They can safely conduct a hammer test with common tools in a Humvee and a flame test with a pocket lighter to determine the sensitivity of a questionable material. They are also learning how to identify explosive ingredients, how to desensitize explosives (for example, by spraying them with a special liquid), and how to transport them.

The course also aims to develop critical thinking skills. Later, when the techs find themselves in a hostile situation, "they can apply logical thought processes and critical reasoning because they understand the fundamentals behind how the explosives work," explains Clinton, an army captain and a qualified EOD instructor who once ran a team of instructors. Clinton was also a DoD liaison at Los Alamos.

"This course doesn't pretend to be tactical," he says. "It's very cerebral, very academic in getting across the basic chemistry and physics principles to explain why things work. I see a lot of connections being made by the students. The first two days are a deep dive into what an explosion is at a fundamental level. The EOD techs understand it in an intuitive sense. They get how all these things work, but understanding why—that's the 'aha' moment."

The techs explore simulated labs in a mock village tucked into one of the Laboratory's remote canyons.

Days 1 through 3 of the course provide an overview of general HME characteristics, the hazards, and related safety precautions. Forty-five-minute lectures are balanced by two-hour labs, when the EOD techs formulate and test explosives. The lab ratio is one instructor to four or five students, with lots of interaction among them.

"The labs show them how, starting from very simple precursors, we make this thing that's very dangerous," Manner says. By understanding its characteristics, they can safely handle it. "We want them to have respect for the explosives but not be so afraid they can't walk into an HME lab."

Later in the week, the students work with unidentified explosives on the outdoor range. By relying on high-speed video of the explosions, detection equipment, and observations of effects such as the color of smoke, the EOD techs identify the materials. On another day, the techs explore simulated labs

Los Alamos explosives scientist Bryce Tappan of the High Explosives Science and Technology group demonstrates the flame test for a class of EOD techs. The class had just made a small batch of an explosive often used in improvised detonators. Exposing a few grams to flame and observing how the substance ignites helps the techs identify it and determine its sensitivity. (Photo: Los Alamos)

An Afghan border police commander stands by as two EOD techs photograph a pressure plate. Pressure plate components are used in conjunction with improvised explosive devices. *(Photo: U.S. Army)*

in a mock village tucked into one of the Laboratory's remote canyons. In ramshackle huts representing scenarios around the world where EOD techs might find explosives, students investigate rough chemistry labs containing beakers, burners, and unlabeled materials—a white powder, a jar of liquid, and so on. Working in groups in this realistic setting, the students must find, identify, and analyze the materials, then handle them appropriately.

"Many of the starting materials are used for legitimate industrial applications, but they can also be used to make homemade explosives," Greenfield explains. "We teach them what to watch for. When they walk into a lab in theater, they might not know, without going through the course, how to safely deal with those materials."

Flexible Course Puts Safety First

Becky Olinger, associate director of the Los Alamos National Laboratory's Explosives Center and program manager of the Los Alamos Collaboration for Explosives Detection, played a key role in launching the HME course. In 2009, the Lab first offered an HME situational awareness course for the DoD; lectures focused on awareness of HME types, "sights and smells," and equipment used to make HMEs. It also included "shot demos" of explosions and mock village search scenarios. This course lacked hands-on lab work in synthesizing explosives. That important educational component was added to create the advanced course.

The EOD techs want to know, can the enemy do this? Is it possible? Would it work?

"Due to several previous HME training accidents that occurred with private companies who did not understand the hazards and safety requirements associated with explosives, the DoD asked Los Alamos to take the lead on the advanced HME training course," Olinger says. "These other courses offered by private companies who have had accidents have been 'banned' by the DoD. They called us and said, 'You have a record of solid safety practices, and we trust you'll come up with the safe training we need.' So we ended up taking it over."

Los Alamos began offering the advanced course in June 2009. The July 2015 course was the 23rd session.

"An EOD tech put together the initial curriculum," Greenfield says. "He knew the threats, and he said, 'We want this, that, and the other.' " She says Los Alamos is flexible enough to adapt the course on the fly to address new, previously unknown threats. "We're flexible."

The course has flexed already. Intelligence analysts contribute to the course's content, as do DoD liaisons and students in the course who were recently deployed as EOD techs in theater. As one army captain put it, this adaptability is "a huge strength" of the Lab course. "It's incredibly dynamic," he says. "We have our finger on the pulse of the intelligence."

The course is a rare and valuable opportunity to work directly with the materials in a safe environment.

Manner recalls a recent example: "We had been talking about a homemade explosive that we believe could decompose in the presence of humidity, which could create a dangerous situation if it decomposed quickly and violently," she says. "During a lecture, we talked about how it would form ammonia gas when it decomposes, so that smell, coupled to the presence of that particular HME, would be indicative of a dangerous situation. Several students said they had encountered that exact HME in Afghanistan and smelled ammonia. Now they know it was in the process of what could become a potentially violent decomposition."

An EOD tech participates in the Lab's Advanced Homemade Explosives Course. Inside a structure in the Lab's mock Afghan village, course instructors stage materials and equipment to simulate an explosives laboratory. Students must safely identify the bomb ingredients. *(Photo: Los Alamos)*

Manner says the curriculum also incorporates pictures and videos that EOD techs provide from war zones. In all these cases, the EOD techs "provide validation for us," she continues, "because they either reinforce the subject matter we teach or confirm it through personal experiences. Or sometimes they even tell us that what we are teaching needs to be updated."

Hands-On Learning "Stays with You Longer"

The HME course would not be possible without the contributions of the many scientists, engineers, and technicians in multiple divisions throughout the Laboratory. The diverse team of practicing bench scientists who teach the course at Los Alamos distinguishes it from other courses—a fact not lost on these students. The Lab currently has more than 20 instructors with expertise in explosives.

A marine master sergeant vouched for the instructors' top-rank expertise: "You can't find smarter people. They're not just regurgitating what they remember. They're easy to understand, and the course really fits our level."

"Having true subject-matter experts in the field means there isn't a question they can't answer," says marine staff sergeant Tom, an EOD tech who was deployed in Afghanistan and a veteran of other explosives courses. "That's different from several previous courses I've taken. They're giving us information all the way from basic theories and the properties of explosives to how to produce them in the lab. Then we go to the range and see if they work."

For Tom, the hands-on laboratory instruction in the Los Alamos course is a rare and valuable opportunity to work directly with the materials in a safe environment. "You can

A coalition trooper in Afghanistan uncovers a Taliban cache of explosive materials, including ammonium nitrate and detonation triggers, that can be used to synthesize homemade explosives. In caches and ad hoc bomb labs, EOD techs must determine the nature of materials they find and safely dispose of them. *(Photo: Department of Defense)*

A female member of the 630th Explosive Ordnance Disposal Company prepares to clear a known explosives cache site in Afghanistan. Many female EODs participate in Los Alamos's Advanced Homemade Explosives Course. *(Photo: U.S. Army)*

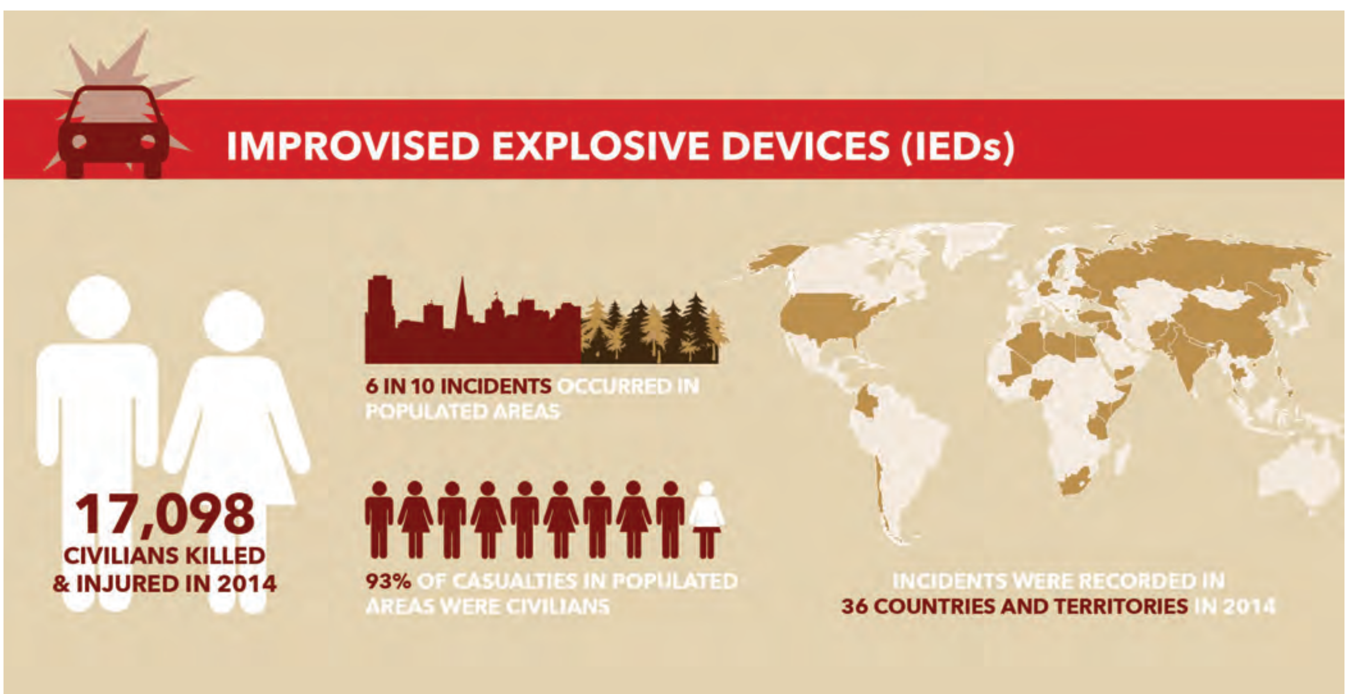
look at pictures all day, but when you learn in the lab like this and you make the explosive yourself, you have the sights and smells, too, and it stays with you longer."

Staff sergeant Tom also appreciates the ability to quiz practicing scientists: "I came in with questions about detonation speed propagating from one explosion to another, from the primary to the booster to the main charge. I can go to reference books for answers, but they require a level of knowledge that I don't have. It's nice to have someone who can translate that for you."

Army captain Clinton joked about EOD techs sitting around their hotel rooms at night thinking up tough questions to ask their scientist-teachers the next day. Good luck. He explains: "These scientists have done the work with these explosives—and they did it yesterday." Such intimacy with the material means they can provide rich answers to students' questions. "The EOD techs want to know, can the enemy do this? Is it possible? Would it work? A vast majority of the time, the instructors can give them a definitive answer because they have tested that same thing."

The Adrenaline Advantage

Some of the HME course students have forged their skills on the battlegrounds of Iraq and Afghanistan. Some are just starting their careers. Others have risen to supervisory and administrative positions. Although all the students in the July class were men, women also serve as EOD techs and often take the course. Students' education levels range from high



Explosive violence harm caused by IEDs in 2014. (Infographic courtesy of Action on Armed Violence) school to graduate school, but everyone has been through military training on explosives, including the Naval School's Explosive Ordnance Disposal course, which techs from every service branch attend. They all need to know more about how to combat the ever-varied and unpredictable threats of HMEs.

They go through demanding testing to ensure they can handle high-stress situations while dismantling a bomb.

The instructors are unanimous in their appreciation of the students' knowledge. "They're all smart and all inquisitive," Manner says. Greenfield adds, "It's a very rigorous process to become an EOD tech. They go through demanding testing to ensure they can handle high-stress situations while dismantling a bomb."

Clinton agrees: "The EOD tech is a higher caliber of service member. It takes good test scores and passing stringent physical requirements to get into the Naval School's EOD course, and a lot of people wash out. These guys are confident and like the excitement. That's true for anyone in the service, but it takes an extra leap to be an EOD tech and to approach these dangers."

"They're eager to learn and get the practical application," he continues, "because every bit of training, every bit of knowledge is going to keep them safer."

"I'm definitely grateful to be here," Tom says, noting he and his comrades-in-arms will benefit from their study time at Los Alamos. "We'll take it back and apply it to operations."

For Manner, that practicality makes the course worthwhile. "Research can sometimes be isolated from current real-world applications," she says. "During this one week every six weeks, we get to do something real, when we're actually helping somebody. It's the most valuable thing I've ever done."

Greenfield agrees: "All the instructors feel that way, and that's why it's so successful. We know we're increasing the EOD techs' overall safety. We're using world-class science to save lives on today's battlefields." ✦

~Charles C. Poling

Virginia Manner (left) of the High Explosives Science and Technology group and Margo Greenfield (right) of the Shock and Detonation Physics group co-lead the Los Alamos National Laboratory Advanced Homemade Explosives Course. Like all the instructors, Manner and Greenfield conduct research in explosives science, providing a level of expertise that students cite as a distinguishing trait of the Laboratory's course. (Photo: Los Alamos)

For more on the Advanced Homemade Explosives Course: *youtube.com/watch?v=GEnrLviSeBE*

EXPLOSION (N.):

A LOUD NOISE AND THE SUDDEN GOING AWAY OF THINGS FROM THE PLACE WHERE THEY HAVE BEEN

~*The Chemistry of Powder & Explosives*
by Tenney L. Davis

To test whether a travel-toothpaste-tube-sized bomb could bring down an airliner, Los Alamos scientists tried to blow a hole through half-inch-thick aircraft-grade aluminum using an explosive they developed. As seen by the approximately 5-inch hole in the blast plate pictured at left, their efforts were successful. (Photo: Los Alamos)

EXPLOSIVE RESULTS

LOS ALAMOS LEADS EXPLOSIVES-SCIENCE RESEARCH

Scientists at Los Alamos are solving national security challenges, from the threat of toothpaste bombs on airliners to ensuring the safety of our nuclear stockpile.

In February 2014, the U.S. Department of Homeland Security (DHS) got wind of a potential new bomb threat: explosives packed into a toothpaste tube that a terrorist planned to smuggle onto an airplane headed for the Winter Olympics at Sochi, Russia.

Could someone make such a small bomb and blow an airliner full of passengers out of the sky?

With no time to waste, scientists in the Explosive Science and Shock Physics division at Los Alamos National Laboratory leapt into action. In approximately 24 hours they tested an explosive they developed and called back with the answer: Yes, a toothpaste bomb was possible—"very possible," in the words of Lab explosives researcher Bryce Tappan, who responded to the inquiry. And it could bring down an airliner.

Ever since the Manhattan Project, maintaining the safety, security, and reliability of the nation's nuclear stockpile has driven multidisciplinary explosives research at Los Alamos.

Understanding the nature of the toothpaste-bomb threat was a "how-do-you-make-it?" problem. That kind of explosives research is just one piece of the Lab's A-to-Z range of capabilities, most of them interrelated and synergistic and necessary to solve challenges to U.S. national security. As Tappan points out, Los Alamos has more scientists studying things that go *kaboom!* than anyplace in America and quite possibly the world.

That's why national security and defense experts turn to Los Alamos. The Laboratory has been blowing up materials and studying the results for a long time. Los Alamos burst into the public consciousness 70 years ago with the biggest explosion known to humanity—the world's first atomic bomb. That breakthrough required Manhattan Project scientists to understand the behavior of the conventional explosives that detonated a nuclear weapon, particularly in developing the uniquely shaped charges necessary to create a critical mass of plutonium in the implosion bomb design. Ever since the Manhattan Project, maintaining the safety, security, and reliability of the nation's nuclear stockpile has driven multidisciplinary explosives research at Los Alamos.

Not the Sensitive Type

Through the decades, much of the Lab's Department of Defense (DoD)-related research has centered on high explosives. This work includes synthesizing thermally stable, hard-to-accidentally-detonate (insensitive) explosives, which make for safer military munitions. (See “” on page 18.) In fact, in 1952 Los Alamos developed the first plastic-bonded explosives, which bind explosive powder with plastic to enable better control over the safety and performance characteristics of explosives. After a number of accidents involving nuclear weapons in the 1950s and 1960s (see “Learning from (Near) Disaster,” page 16), the call to improve their safety led Los Alamos to develop insensitive high explosives and to patent the manufacturing technique for TATB (triaminotrinitrobenzene), the key ingredient in the insensitive high-explosive charges used to set off nuclear weapons.

The increased need for explosives in the wars following 9/11 and a focus on increased safety prompted the DoD to ramp up its demand for TATB.

Los Alamos has been in the explosive science business since the 1940s. The men on this test tower pose in front of the mountain of TNT used in the May 7, 1945, 100-Ton Test—which held the record as the world's largest blast until the Trinity test two months later. (Photo: Los Alamos)

Today, TATB is the only insensitive high-explosive molecule approved by the Department of Energy (DOE) for nuclear weapons. Conventional munitions use TATB, as well. By the late 1980s, decreased nuclear weapons production and the end of the Cold War led to a halt in TATB production, but the increased need for explosives in the wars following 9/11 and an ever-present focus on increased explosives safety recently prompted the DoD to ramp up its demand for TATB. Given the Lab's deep background with the material, Los Alamos played a critical role in a nationwide project to start making TATB again over the past 10 years.

In related work, Laboratory scientists are exploring revolutionary new methods of fabricating insensitive high explosives using 3D printing. Also called additive manufacturing, 3D printing allows for the rapid production of insensitive high explosives into complex shapes that would be impossible to make using traditional machining techniques. This technique will also give Los Alamos scientists increased control over the explosives' safety and performance.

Meanwhile, the DOE's Stockpile Stewardship Program has been refurbishing the nation's aging nuclear weapons and the DOE has consistently emphasized continuous safety improvements for explosives used in the stockpile. Using TATB has a big impact on increasing overall nuclear weapons safety.

Lab scientists also tackle practical battlefield challenges, such as researching and testing explosives used in the deadly improvised explosive devices (IEDs) that characterize recent wars. Understanding the nature of these homemade explosives (HMEs) helps the military (and law enforcement) detect, handle, and mitigate them. The Lab also communicates that understanding directly to military Explosive Ordnance Disposal technicians at its Advanced Homemade Explosives Course. (See “The Hurt-Locker School,” page 3.)

Emerging Threats and Detecting Explosives

The Laboratory focuses much of its explosive science research on emerging threats and explosive detection. To highlight that focus, in 2015 the Lab established its Explosives Center and also rolled out the Los Alamos Collaboration for Explosives Detection (LACED). Becky Olinger, the center's associate director and program manager at LACED, says new threats cover a broad spectrum beyond countering IEDs. For example, as with the toothpaste bomb threat, the Lab analyzes intelligence information to evaluate the plausibility of potential threat scenarios. "We look at whether these scenarios are a concern and, if so, how do we deal with them?" she says. Threats could include nuclear weapons, HMEs, or conventional explosives. If one seems legitimate, the Laboratory develops a countermeasure.

> **We are end-to-end, from design and synthesis to supercomputer modeling and testing.**

Countermeasures include improving explosives detection. Los Alamos scientists and engineers are doing basic research on new technologies for detecting every conceivable type of explosive in a range of scenarios and then engineering new mitigation technologies for them. That research involves determining the chemical signatures of materials—necessary for developing a detection method—and inventing new methods to neutralize them.

In one example, David Moore of the Laboratory's Explosive Science and Shock Physics division recently led a team that created a radically new technology for detecting explosives from a safe distance. Called ODD-Ex (optimal dynamic detection of explosives), it zaps a suspicious material with a laser and then identifies it by analyzing the reflected light spectrum. Every material has a unique identifying signature of absorbed and reflected light. ODD-Ex combines greater sensitivity than other related techniques with the ability to filter out interference from dust in the atmosphere, say, or other materials mingled with the explosives that can conceal the material's identity. The high sensitivity enables greater—and thus safer—standoff distance for interrogating a target such as a roadside bomb.

What's Next? The Future of Explosives Science at Los Alamos

No place else can match Los Alamos's suite of capabilities in explosives science and decades of experience: a deep roster of scientists doing research in the field, wide-ranging experience

Los Alamos explosives scientists are developing 3D-printing techniques to rapidly produce insensitive explosives in a wide range of shapes that cannot otherwise be created. Three-dimensional printing also gives increased control over the explosives' safety and performance. (Photo: Los Alamos)

Researchers at Los Alamos heat an explosive compound past its melting point, then pour it from the kettle into an apparatus to do experimental work. Explosives that melt at temperatures well below their ignition points—the temperature at which they blow up—can be safely poured into containers or molds without risk of detonation. (Photos: Los Alamos)

in explosive materials and every kind of detonation, facilities for developing and testing explosives, and expertise in detecting them.

To back up that claim, Explosives Center director Dan Hooks cites metrics such as the larger numbers of explosive tests conducted, papers published, and patents received. He also points to the Lab's exclusive facilities, such as its one-of-a-kind outdoor firing range. (See "Questing for the Holy Grail of High Explosives," page 15.)

"What's unique about Los Alamos in explosives science and research is that we are end-to-end, from design and synthesis to supercomputer modeling and testing, and from detection to characterization," says Olinger. "We cover the full gamut of explosives types, with all the experts on site, and bring real ingenuity to the problem."

We have the tools to see things now that we've only been speculating about for 70 years.

Even with the Laboratory's long, celebrated history of explosives research, Hooks thinks the best work is yet to come. "In explosives, we're in a time of major transition," he says. "We have the tools to see things now that we've only been speculating about for 70 years, so there will be a generational shift in making new materials, knowing how they will respond, and understanding what drives that response."

Advances in basic science—the theories underpinning research—fundamental diagnostic tools, and computing platforms will enable Lab scientists "to see what's going on in a material—the physics and chemistry—almost in real time," Hooks says. "We'll be able to take a snapshot of picoseconds [millionths of a second] resolved to microns [millionths of a meter] or less. Once we can see something happening, that changes the theory and that changes the model. We'll have a new ability to make things and predict things. These breakthroughs will lead to a fundamental improvement in the safety of rockets and weapons. We're developing the future right now. In 15 to 20 years, it will be a whole new world of explosives science."

Of course, global events will also shape that future. Although the nuclear mission will remain central at Los Alamos and a driver of explosives science, Hooks says, threats such as IEDs and HMEs "will continue to be a challenge in any theater."

No one really knows what the next new threat will look like—or where it will come from. But Los Alamos will be ready to help fend it off.

~Charles C. Poling

Los Alamos conducted more than 400 high-explosive-driven experiments in 2015. (Photo: Los Alamos)

Questing for the Holy Grail of High Explosives

Explosives chemist David Chavez has developed new explosives molecules that offer high energy with enhanced safety—they cannot be detonated by spark, friction, or impact. (Photo: Los Alamos)

The perfect material for detonating nuclear weapons, arming a conventional bomb, mining ore, and even propelling a rocket into space has two seemingly paradoxical characteristics: releasing tremendous energy on demand while resisting accidental detonation and remaining stable for its intended life cycle.

That combination of qualities is the Holy Grail in explosives research, according to Los Alamos scientist David Chavez of the High Explosives Science and Technology group—and he's on a promising quest to find it.

In a recent breakthrough, Chavez invented a molecule that could herald the arrival of a new class of insensitive high explosives. The new compound performs nearly as well as conventional explosives but can't be detonated by a spark, friction, or impact.

Chavez's work exemplifies the sometimes-trying trial-and-error progress of scientific research. Chavez was pursuing his idea for uniquely arranging carbon, hydrogen, nitrogen, and oxygen—the basic building blocks of all explosives—into a novel molecule. Along the way, he stumbled through several failures before hitting on the right configuration of atoms. He found that extensive hydrogen bonding among the molecules created a "glue" strong enough to bind them but weak enough that an unwanted striking force, spark, or friction can separate the molecules without triggering a detonation. That quality makes them safer to handle and use than conventional explosive materials.

As Chavez's work shows, Los Alamos researchers are constantly deepening their understanding of the basic science underpinning the performance and behavior of explosives (and propellants, too). Those research results then guide new problem solving to support the national security mission of the Laboratory. Developing new explosives with tailored properties, including enhanced safety, has been a primary focus of the Lab's science and engineering efforts since the days of the Manhattan Project. Today, these efforts continue to ensure the viability of the nuclear stockpile, improve conventional explosive weapons, and better position the United States to assess threats from foreign-made explosive materials, according to Chavez.

On a personal note, Chavez adds, the Laboratory environment gives him the opportunity to explore his ideas about explosives: "One of the great things about Los Alamos is having the ability to push the frontiers, to do the new thing that no one's been able to do before."

~Charles C. Poling

EXPLOSIVE RESULTS

Learning from (Near) Disaster

In 1966, a B-52 collided with a tanker over Palomares, Spain, while refueling. Three of its four hydrogen bombs fell on land, and the fourth fell into the sea, where it was recovered after a lengthy search (see photo on page 17). Two bombs were destroyed when their conventional high explosives detonated; the surviving two bomb casings are on display at the National Atomic Museum in Albuquerque, New Mexico. The incident helped prompt the initiative at Los Alamos to develop insensitive high explosives to prevent future accidental explosions of nuclear weapons. (Photo: Sandia National Laboratories)

Just short of high noon on May 22, 1957, an Air Force B-36 bomber was powering down on its final approach to Kirtland Air Force Base in Albuquerque, New Mexico, completing what should have been a routine flight ferrying a nuclear weapon from a base in Texas. In an instant, all hell broke loose.

A few miles south of the control tower and 1,700 feet off the deck, the bomb bay doors of the huge plane sprang open. In a blink the nuclear bomb plunged earthward, smashing into the ground seconds later with an impact that detonated the high-explosive charges designed to trigger the weapon's nuclear material. The ensuing explosion destroyed the weapon and blasted a crater 12 feet deep and 25 feet wide, hurling debris and bomb fragments a mile away.

As awful as that accident sounds, a nuclear detonation was impossible. For safety, bomb designs in those days centered on a removable capsule of nuclear material carried separately on the plane. The crew would only insert the capsule to arm the weapon in an actual combat operation. This bomb was not armed.

The Kirtland calamity was just one of 32 cited in a 1981 Department of Defense (DoD) report covering the history of the nuclear program. In a dozen cases, the conventional high explosives unintentionally detonated, and although none tripped a nuclear explosion, they sometimes wreaked destruction and injured or killed crew members and rescuers alike. A 1950 B-29 crash in California claimed 19 lives.

Two tragic, high-profile incidents spewed radioactive material around the landscape and elevated awareness of the risks involved. In January 1966, a B-52 carrying four nuclear weapons collided with its refueling tanker plane at high altitude above Palomares, Spain, knocking both from the air and killing several crew members. The high explosives of two nuclear weapons exploded when they slammed into the ground, scattering plutonium and other nuclear materials up to 500 yards away and contaminating about 650 acres. One bomb whose descent was slowed by a parachute did not detonate, and another disappeared into the Mediterranean Sea; it was recovered more than two months later after the most expensive salvage operation in U.S. Naval history.

Workers hauled off 1,400 tons of soil and vegetation, which were shipped to the United States for disposal, and burned or buried nearby tomato crops that were a key agricultural

In the Palomares incident, a hydrogen bomb vanished into the sea. Sailors recovered the weapon two months later in the most expensive U.S. Navy salvage operation in history. The casing is currently displayed at the National Atomic Museum. (Photo: Open Source)

product in Palomares. But traces of nuclear material remained, as tests starting in the 1990s revealed. After years of wrangling between the two allies over new cleanup details, in October 2015, U.S. Secretary of State John Kerry signed an agreement with Spain to remove, almost 50 years after the accident, additional contaminated soil to an as-yet-unspecified location in the United States.

If the high explosives inside these weapons could be rendered incapable of accidently detonating, many lives could be saved, property protected, and expensive environmental cleanups prevented.

Two years after the accident over Palomares, a bomber carrying four nuclear weapons crash-landed seven miles short of the runway at Thule Air Base, Greenland, several hundred miles north of the Arctic Circle. The ensuing fire destroyed all the weapons and scattered plutonium and uranium. Although intense cold and the total darkness of Arctic winter hampered the cleanup, crews ultimately removed 237,000 cubic feet of contaminated ice and debris.

If the high explosives inside these weapons could be rendered incapable of accidently detonating, many lives could be saved, property protected, and expensive environmental cleanups prevented. As weapons designers looked for ways to increase the safety of nuclear weapons, they turned to developing safer high explosives for triggering the implosion of a nuclear blast.

Fire and impact cannot start a nuclear explosion—only the high explosives precisely detonating in their carefully designed configuration within the warhead can do that. But as the DoD's report reveals, accidentally detonating high explosives caused tremendous problems all on their own.

The solution was achieved at Los Alamos through development of less sensitive high explosives. Los Alamos developed manufacturing and formulation methods for the explosive TATB (triaminotrinitrobenzene) for triggering nuclear weapons (and for use in conventional ordnance). TATB burns but does not explode when it's heated, and does not react even when struck by bullets or shrapnel. Deliberately detonating this unique material requires a well-engineered initiation system.

Los Alamos began researching insensitive high explosives in the 1950s. Based on that expertise, the Laboratory played a key role in refining TATB, patenting the TATB manufacturing process, and becoming the first national lab to use a TATB composition in nuclear weapons.

From the beginning, the skills of Los Alamos weapons designers at making sure their nuclear weapons were safe meant that none of these weapons unintentionally detonated, even after the most horrific accidents. Even so, servicemen lost their lives in these accidents. The advances in explosives science at the Lab means that today, the risk of accidental detonation and death is more remote than ever.

~Charles C. Poling

A Safer Liftoff

An innovative rocket-fuel system taps a novel source of power and breakthrough engineering to deliver high-energy thrust with improved safety.

On a broad mesquite plain in central New Mexico, a small crew fits a metal cylinder into a rocket the size of a baseball bat, then slips the rocket onto guide rods on a platform. A "Los Alamos" logo on the fuselage certifies this launch as official science by the world-famous national laboratory, not a weekend outing with the kids.

Bryce Tappan and a handful of scientists, engineers, and students from Los Alamos National Laboratory and New Mexico Tech stand back as another crew member handles a control box set on a folding table. He counts down, "Three, two, one, zero!" The rocket issues a loud *pssshhhhhewwwweeee!* and whisks into the cobalt sky, the cylinder trailing a stream of gases and tilting toward horizontal as it soars to its apogee.

The small group cheers, perhaps a little more vigorously than one might expect, but that's because this 41-inch rocket just proved that a novel fuel invented by Tappan and others at the Lab actually works.

Powerful, safe, and potentially powerful enough to launch a full-sized spacecraft, the breakthrough segregated-fuel-oxidizer system, called IsoFOX, enables a new era in propellants. For rockets, missiles, and satellites the fuel is a "humongous safety improvement," according to Dan Hooks, director of the Los Alamos Explosives Center. Hooks explains that missiles carry "a huge tonnage of propellant," which multiplies the risk of their detonable fuels exploding accidentally, "so any safety improvement is tremendous."

From Failure to Breakthrough

Ironically, Tappan, who came to the Lab first as an undergraduate in 1996, then returned as a postdoctoral researcher in 2003, stumbled onto this propellant in the wake of a disappointment. He was studying an energetic material called TAGzT (triaminoguanidinium azotetrazolate) and related compounds. (Energetic materials store chemical energy, which is a useful characteristic for making explosives, propellants, or fuels.) It had failed miserably as an explosive.

"For more than 20 years, Los Alamos had been experimenting with synthesizing high-nitrogen materials for use in energetic materials," Tappan explains. "High nitrogen content is interesting in explosives because it can reduce the amount of oxygen needed to burn the fuel atoms in the molecule, making an oxygen balance easier to achieve." Managing the amount of oxygen in a fuel helps tune its safety characteristics. The nitrogen makes for a higher-energy-density system that works much like an automobile efficiently burning gasoline. Tappan was experimenting with these high-nitrogen/high-hydrogen materials, which contain little or no oxygen, for their applications to explosives.

In his first large-scale test with TAGzT, the material didn't detonate.

"I thought, this sucks," Tappan recalls with a laugh. "Then I thought, wow, this could be an important discovery as a propellant ingredient. Non-detonable materials that combust well are good for propellants and bad for explosives." TAGzT—and the novel fuel that Tappan would later develop from it—"doesn't detonate at all. It just burns." That property opened up the potential for a new kind of rocket fuel several years later, when a collaborator from Penn State University came to Tappan for oxidizer pellets to use with a liquid fuel. Tappan had a better idea, based on his research: use a high-nitrogen/high-hydrogen energetic material.

"There was nothing else out there like it in the research literature," he says.

Actually, It Is Rocket Science

In a slow-motion video of the test showing the simultaneous launch of Tappan's rocket beside a conventionally fueled twin, Tappan's rocket ignites and vanishes from the frame as the other lumbers up. It's a jackrabbit leaving a tortoise in the dust.

The next-generation rocket? Los Alamos scientists recently tested a powerful new rocket fuel and motor that are safer because the fuel is kept separate from its oxidizer. The new rocket motor and fuel outperformed commercial rockets in thrust with at least twice the velocity. (Photo: Los Alamos)

"The actual rocket launch was definitely tense," Tappan says. "If you go to YouTube and search 'rocket motor failure,' you'll get thousands of videos, and these are rockets that had who-knows-how-many millions of dollars poured into them. It's never a given the rocket is going to work because the tests in a laboratory don't necessarily translate to an actual successful launch. So it was a very exciting moment to demonstrate something we had been working on for a couple years." The flight data showed the Los Alamos rocket motors outperformed the commercial rocket motors in thrust with at least twice the velocity.

"The main goal of this project is to get something that offers very high safety in a completely non-detonable system without an energy penalty," Tappan explains, meaning the material would still provide plenty of propulsion. "Typically, when you look at something that's high performance, it's not a safe a material. We're trying to break that performance versus sensitivity curve and make a rocket propellant that's high-energy and high-performance as well as very safe."

Tappan explains that the "enabling technology" involves "physically separating the energetic fuel material and a solid oxidizer." A typical solid rocket propellant keeps the fuel and oxidizer together, with potentially dangerous and explosive results. The Lab's segregated-fuel-oxidizer system, IsoFOX, keeps the fuel and oxidizer apart because the initial stage of ignition does not require oxygen. The high-nitrogen/high-hydrogen energetic material decomposes when ignited, creating a fuel that flows into the separate secondary section of the rocket containing the solid oxidizer. There the fuel combusts with oxygen released from a reaction with the oxidizer, and full propulsion is achieved—fast! This design dramatically reduces the chance of accidental detonation. It's also completely insensitive to shock, meaning a sharp impact won't blow up the rocket.

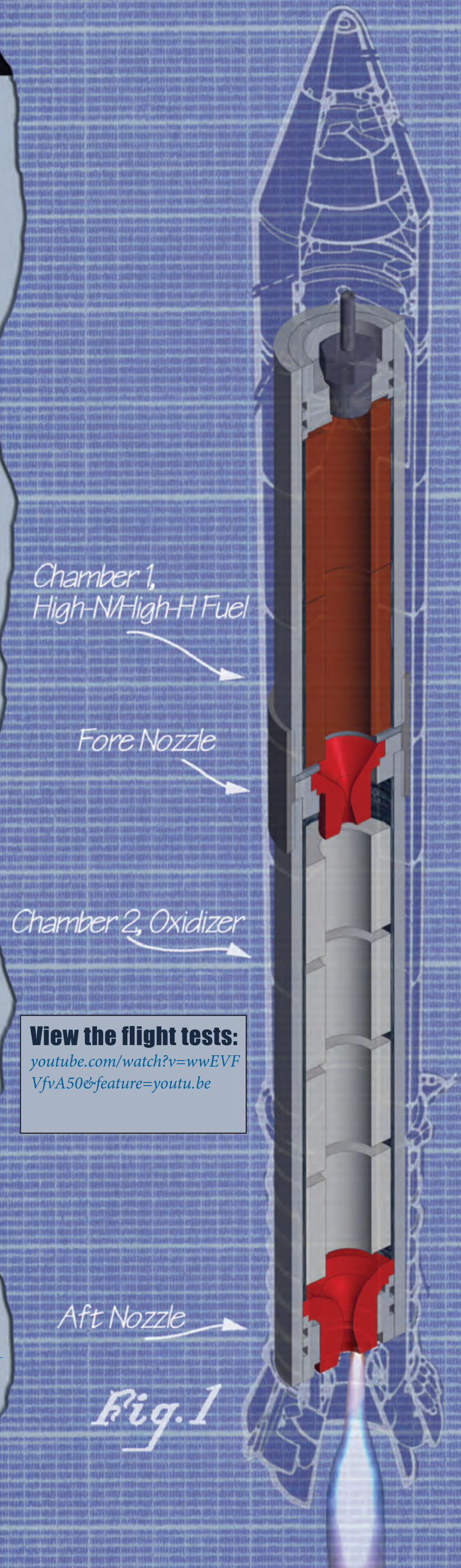
What's Next

Becky Olinger, associate director of the Los Alamos Explosives Center, sums up Tappan's breakthrough: "Tappan's rocket technology provides a safer alternative to propellants without compromising performance." The project began under Laboratory Directed Research and Development funding, which supports high-risk, potentially high-payoff research in promising directions. The next steps are refining the fuel system and exploring industrial partnerships to commercialize it.

Tappan intends to follow two tracks: scaling up the system to larger motors and miniaturizing it for use on satellites. As an on-board satellite fuel system, IsoFOX addresses concerns about the risk of an explosion destroying the craft in space. Such a system could shift a satellite between orbital planes or bring it back into Earth's atmosphere when its mission is complete.

One day, Tappan suggests, IsoFOX might even power a small satellite to the moon. That's a lofty target for a material that once fizzled in a lab test.

~Charles C. Poling



View the flight tests:
youtube.com/watch?v=wwEVFVfvA50&feature=youtu.be

Shake, Rattle, and Roll

Los Alamos scientists analyze North Korea's recent "hydrogen bomb" test to determine the details—location, yield, and type—of the explosion.

Around 10 a.m. Pyongyang Time on Wednesday, January 6, 2016, seismic analysts around the world picked up something unusual—a 5.1-magnitude seismic event in the northeast corner of North Korea. Earthquakes of this size aren't common on the Korean Peninsula, which likely meant the violent shaking was caused by something else: an explosion.

Enter Los Alamos National Laboratory.

Los Alamos isn't just in the business of developing, testing, and maintaining explosives. A significant part of the Laboratory's mission is to evaluate global seismic data to identify and locate possible nuclear explosions. For example, a country might hope its underground containment of a nuclear test goes unnoticed because the rest of the world thinks the resulting seismic event is an earthquake. In the interest of national security and global nuclear threat monitoring, Los Alamos scientists have developed the tools to differentiate between the two.

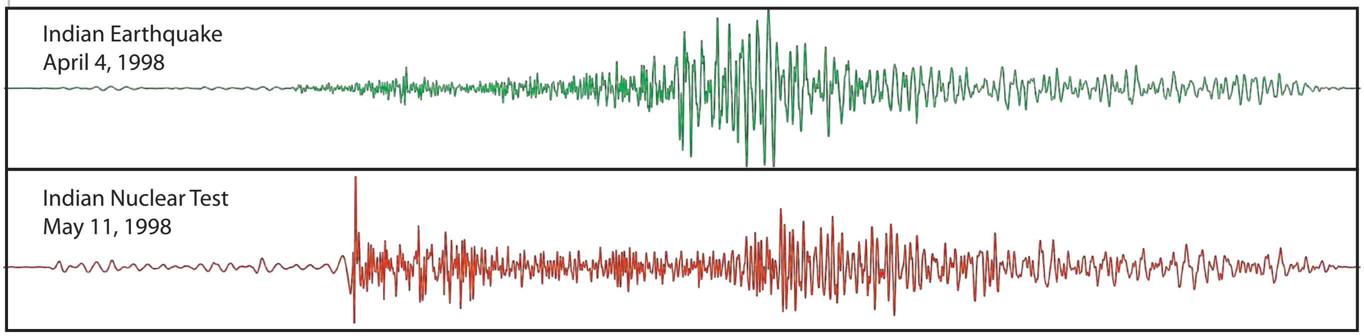
But what happens when there's no need to differentiate? What happens when a country blatantly declares it tested a nuclear weapon? In the case of the January 6 seismic event, North Korea immediately attributed the tremors to a subterranean hydrogen bomb test. H-bombs, which use nuclear fusion to release explosive energy, are potentially more than 500 times more powerful than the atomic bombs the United States dropped on Japan during World War II.

Does North Korea really have the capabilities to develop and test such a powerful weapon? Is its claim valid? Immediately upon receiving news of the explosion, Los Alamos scientists began working—and they continue to work—to determine information about the bomb tested.

Los Alamos has approximately 70 experts, organized into teams, who work full time to provide near real-time analysis and assessment of all foreign nuclear weapons programs and tests.

For example, the Ground-based Nuclear Detonation Detection (GNDD) team, comprising scientists from the Lab's Earth and Environmental Sciences division, look in the atmosphere, oceans, and underground to analyze explosions.

South Korean protesters burned placards of North Korean leader Kim Jong-Un during an anti-North Korea rally on January 7, 2016, in Seoul, South Korea. Kim Jong-Un claimed that North Korea had successfully tested a "hydrogen bomb" the previous day. (Photo: Getty Images)



Seismograms of an Indian earthquake and an Indian nuclear test. Both were recorded at the seismic station at Nilore, Pakistan. These seismic signatures for an earthquake and an explosion are typical and can be clearly distinguished from each other.

The GNDD team develops measurement and analysis systems for nuclear-event monitoring agencies and provides analysis in direct support of the Department of Energy's nuclear treaty verification mission (which includes the Limited Nuclear Test-Ban Treaty, Threshold Test-Ban Treaty, and the current testing moratorium under the Comprehensive Nuclear-Test-Ban Treaty).

"We are very proud of our contributions," says Terry Wallace, the Lab's Principal Associate Director for Global Security and its senior intelligence executive. "We support the nation's intelligence community in its efforts to monitor nuclear programs and verify adherence to nuclear arms control treaties."

Los Alamos has been involved in the assessment of foreign nuclear tests since August 1949, when the Soviets exploded their first nuclear weapon. "Los Alamos's analysis of atmospheric debris was an essential piece of the puzzle leading to the conclusion that the Soviets had copied the Trinity device," Wallace says.

Los Alamos also provided key instrumentation on the Vela Hotel, the very first satellite launched (in 1963) to monitor nuclear testing. The Vela satellite was an essential verification tool of the Limited Nuclear Test-Ban Treaty, which bans nuclear weapons tests in the atmosphere, space, and underwater.

"Los Alamos has been deeply involved since then with monitoring from space," Wallace says. "In fact, the latest detonation-detection satellite carrying Lab-built sensors was launched in February 2016."

In 1957, Los Alamos began studying underground nuclear tests at the Nevada Test Site—which totaled more than 800 by the last test in 1992. Understanding these seismic events ensured test-site safety and required a detailed understanding of geology and the ability to predict subsurface reactions to the explosive shock of a nuclear blast.

"Starting with the Trinity Test, I have looked at the seismographs and other geophysical recordings of *all* nuclear tests except for four or five for which data is not available," Wallace says. "This includes U.S., Soviet, Chinese, British, French, Indian, Pakistani, and North Korean tests, as well as the Vela Incident in the Indian Ocean in 1979, which is without country attribution."

Los Alamos is now the world's leader in underground test diagnostics, nuclear explosion monitoring, and nuclear weapon test treaty verification.

North Korea, of course, often doesn't adhere to treaties, but the country has violated multiple United Nations Security Council resolutions. Determining what the North Koreans are blowing up is a matter of global security—which is why Los Alamos is involved.

In the case of the January 6 test, Los Alamos seismologists began calculating the event location and yield by using data from seismic stations around the globe. Using techniques they've developed to study nuclear (and conventional explosives) tests, Lab scientists analyze data as they receive them to develop a more complete understanding of the nature of the explosion.

"We have developed seismic expertise, and we apply it effectively to understand and monitor nuclear testing," Wallace says. "The Laboratory is one of the remaining places where we see people devoting careers to understanding what other nations are doing in the areas of nuclear testing and technology. The situation in North Korea is illustrative of how the Laboratory is essential to keeping our nation—and the world—safe.

When it hits the fan, the government is counting on us—and we deliver."

~Whitney J. Spivey

Manhattan Project National Historical Park

Pond Cabin, built in 1914, is listed on the New Mexico State Register of Historic Places and is the only surviving log structure at the Laboratory dating to the Homestead period. *(Photo: Los Alamos)*

Plans for America's newest national park include admitting the public onto Laboratory property—without compromising national security or the Lab's mission.

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 1942, the U.S. government purchased the school and launched Project Y (now Los Alamos National Laboratory) of the Manhattan Project in its stead. You know the rest.

But what about the cabin? Pond Cabin, as it's now called, is not only still standing, but the approximately 400-square-foot structure has amassed quite a bit of history under its corrugated metal roof. During the Manhattan Project, Italian physicist and Nobel laureate Emilio Segrè used the cabin for plutonium chemistry research that resulted in the surprising discovery that the Thin Man plutonium gun-type weapon design would never work. As a result, the wartime Laboratory was extensively reorganized to develop an alternative: the incredibly complex Fat Man plutonium implosion-type weapon.

Today, Pond Cabin is one of nine Laboratory properties included in Manhattan Project National Historical Park (MPNHP), which was signed into law on November 10, 2015, and tells the story of America's nuclear weapons science, technology, and industry during World War II. The Los Alamos site is one of three locations for the park—the National Park Service's first multisite, multistate endeavor, which also includes key Manhattan Project facilities in Oak Ridge, Tennessee, and Hanford, Washington.

In Oak Ridge, for example, park-goers can tour the X-10 Graphite Reactor that produced small quantities of plutonium; in Hanford, guests are bussed to the B Reactor, which produced plutonium for the Trinity Test and the Fat Man bomb. In Los Alamos, however, the situation is a bit different because *none* of the designated park buildings are currently accessible to the public (they are located on sites still being used for nuclear weapons research)—and likely won't be for several years.

"How do we provide visitor access while also maintaining the kind of security and controls that are so important for active sites, as they are right now, for scientific discovery and research?" Department of the Interior Secretary Sally Jewell asked during MPNHP's memorandum of agreement (MOA) signing with the Department of Energy. "How do we maintain security and safety concerns for the public?"

The answer is: Very carefully.

Technical Area-18 (aka the Pajarito Site, home to Pond Cabin and two other MPNHP structures: the Slotin Building and Battleship Bunker) will likely be the first area to open up. "Technical Area-18 is in the process of being closed and is the best bet for nearer-term access because it's no longer a high-security area," explains Ellen McGehee, Laboratory historian and MPNHP project manager. But that doesn't mean history buffs will just be able to enter the Lab willy-nilly; park visitors will likely be bussed to the site from the nearby White Rock Visitors Center and chaperoned during their tour.

"We want to meet requirements for public access without constraining the work required to meet the Laboratory's ongoing national security mission," McGehee says. "The vital mission of the Lab will not be negatively impacted by the public entering the park." McGehee notes that while access issues are being addressed, the Lab has other strategies for engaging and educating the public.

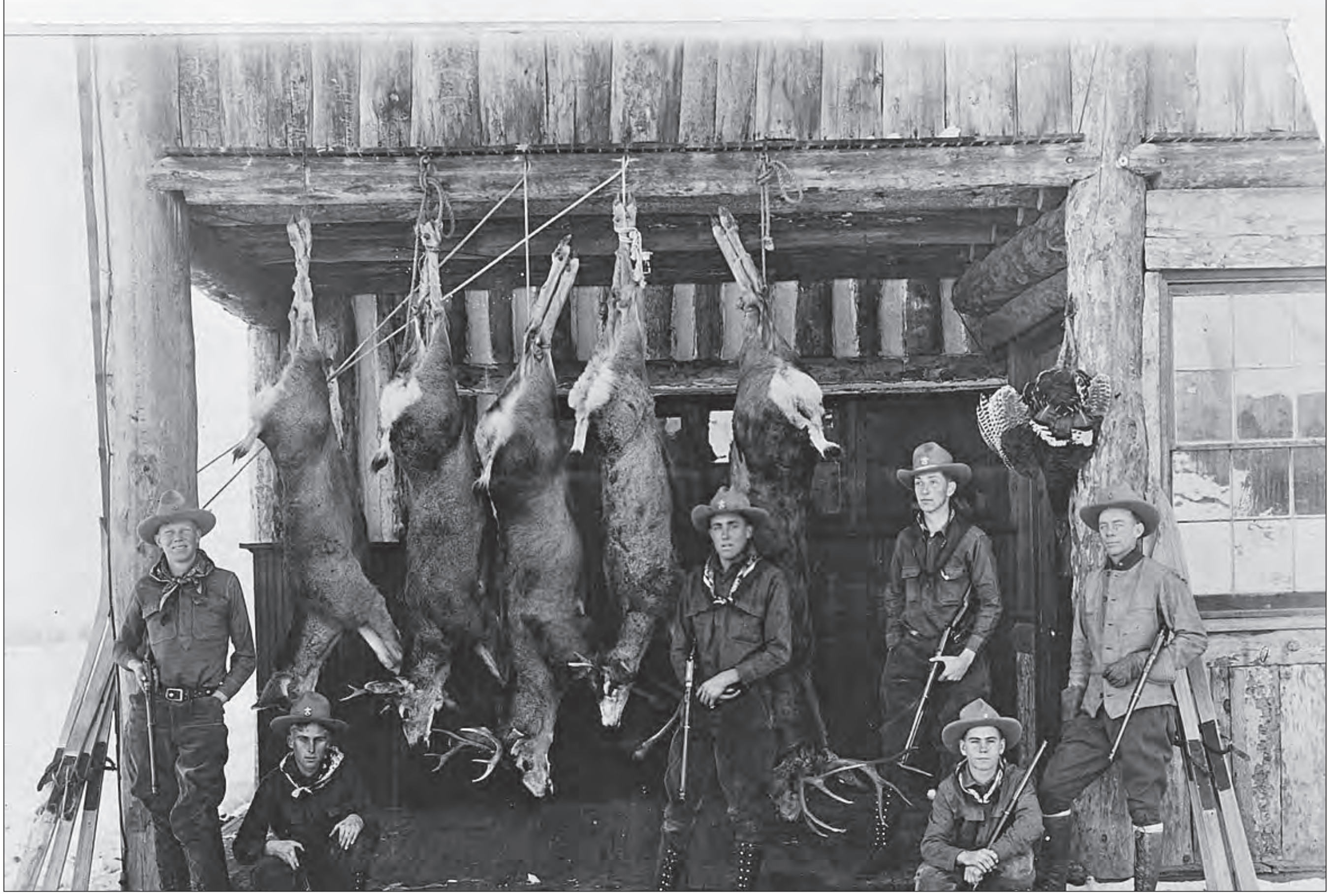
Those strategies include beefing up the Los Alamos Historical Society's walking tour of downtown Los Alamos, which includes several Ranch School-turned-Manhattan Project structures, the Bradbury Science Museum, and Ashley Pond Park.

In spring 2016, visitors will be able to stand in Ashley Pond Park and—via an app developed by the Laboratory—see how the landscape looked in the 1940s when it was the key technical area for Project Y.

A second feature of the app will allow users "to view Los Alamos from anywhere in the world, almost like a computer game," McGehee explains. "You get off the train at Lamy, New Mexico; you meet Los Alamos's 'gatekeeper' Dorothy McKibbin at 109 East Palace Avenue in Santa Fe; you go up 'the Hill' to the Laboratory; as you go through town, sites in the wartime technical areas are unlocked."

Users of the app will thus see many of the Laboratory's original buildings that are currently in the park but not yet ready for public admission. The idea is that, even without full access, people will come away with an understanding of the history and legacy of this part of the Manhattan Project.

Technical Area-18 (aka the Pajarito Site—home to Pond Cabin, the Slotin Building, and Battleship Bunker) will likely be the first area accessible to the public. During the Manhattan Project, Italian physicist and Nobel Laureate Emilio Segrè (far left, with his group) used Pond Cabin for plutonium chemistry research. *(Photos: Los Alamos)*



At the MOA signing, Secretary of Energy Ernest Moniz touched on this legacy, recognizing the Manhattan Project as the foundation for federally sponsored scientific research in America. "Our 17 national laboratories that have grown out of the roots of the Manhattan Project are part of this country's science and technology powerhouse," he said. "They drive innovation, they address critical problems, they also provide the backbone for basic science research in this country, serving 30,000 scientists per year with cutting-edge facilities."

Secretary Moniz then mentioned the 2009 Prague Agenda and President Obama's vision for nuclear disarmament. "But doing that requires ongoing first-class science, first-class engineering, as we shrink the stockpile to make sure that what we have supplies a deterrent but also remains safe and secure," he said. "So it's a big job ahead. I think this national park will provide the platform for our citizenry to understand the roots of this and what it means in terms of future responsibilities."

~Whitney J. Spivey

Above: In its 25 years, the Los Alamos Ranch School educated more than 600 boys. In addition to traditional academic subjects, outdoor education was part of the curriculum at the school, and—as seen in this 1922 photo—days-long hunting expeditions were scheduled during deer season.

On December 7, 1942, a letter from Secretary of War Henry Stimson informed students and faculty that the U.S. government was taking over the school "in the interests of the United States in the prosecution of the War…" The last graduates received their degrees the following January "while bulldozers and mechanical diggers were already tearing up the mesa to make room for the Manhattan Project," according to the Los Alamos Historical Society.

Opposite, top row: This spring, visitors will be able to stand in Ashley Pond Park (right) and—via an app developed by the Laboratory—see how the landscape looked in the 1940s when it was the key technical area for the Laboratory during the Manhattan Project (left).

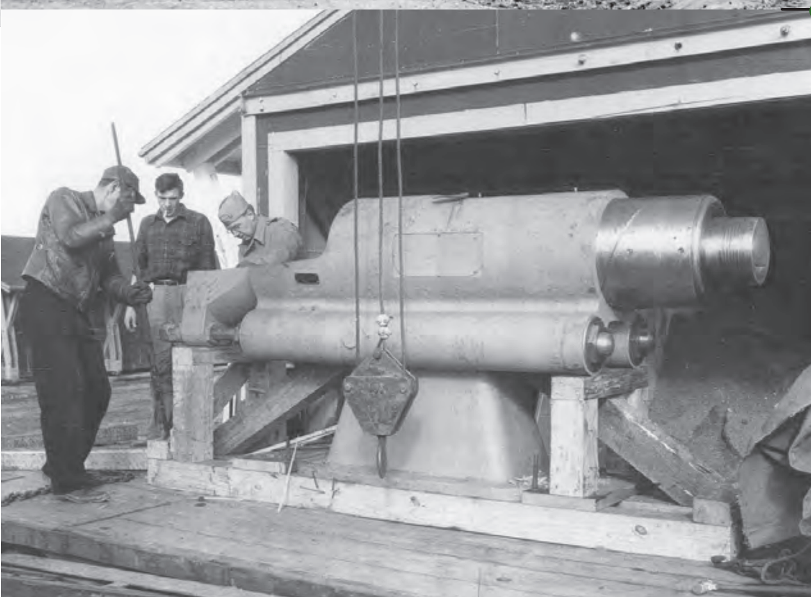
Opposite, middle row: Gun Site was used during the Manhattan Project to conduct tests in support of the gun-type weapon designs known as Thin Man and Little Boy. Components of Little Boy were assembled at Gun Site before being shipped across the Pacific on the USS Indianapolis *for use against Hiroshima.*

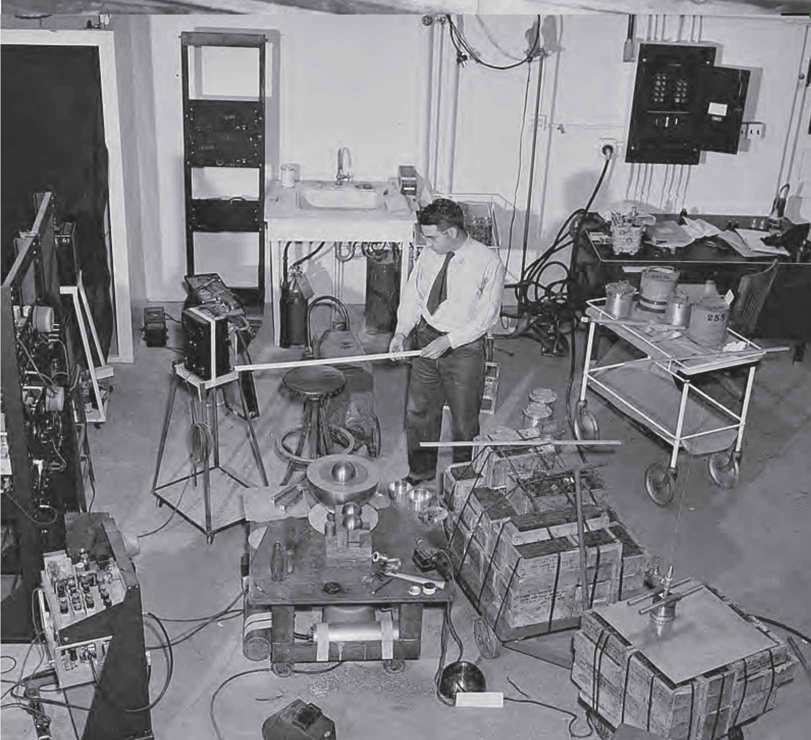
Opposite, bottom row: The Slotin Building at Technical Area-18 is a small, wood-frame building that was built according to World War II temporary construction standards. On May 21, 1946, an accident at this location (re-created for analysis in the image at left) led to the death of scientist Louis Slotin, which is why the structure is called the Slotin Building today.

For more on Manhattan Project National Historical Park: *nps.gov/mapr*

(Photos: Los Alamos)








Strategic Deterrent Forces

A Foundation for 21st-Century National Security

U.S. Navy Admiral Cecil D. Haney visited Los Alamos in January 2014. The then-newly appointed Commander of U.S. Strategic Command (STRATCOM) toured the Laboratory and was briefed on the Lab's national security mission. "I've been really impressed," he told employees. "It's clear to me that the work we do collectively—work associated with deterrence and assurance—along with the business of space threats, cyber threats, missile defense, and combating weapons of mass destruction…we're teammates in this."

> **As we draw down our nuclear deterrent forces, the remaining systems must be safe, secure, effective, and ready.**

As STRATCOM commander, Admiral Haney works to ensure a safer world through better national security. On January 22, 2016, he delivered the keynote address for the Center for Strategic and International Studies in his native Washington, D.C. His talk, titled "Strategic Deterrent Forces As a Foundation to 21st-Century National Security," is summarized as follows:

A Complex World

The global security environment is complex, dynamic, and volatile—perhaps more so than at any time in our history. Just a glance at headlines today will point to efforts supporting the coalitions in Syria, Iraq, and Afghanistan, as we continue to address a campaign against terrorists including Islamic State (aka ISIL) and other violent extremists. Malicious cyber and counter-space activities are increasing both in number and sophistication. At the same time, we have nation-states such as Russia, China, North Korea, and Iran whose behavior on the international stage warrants our attention.

A number of nation-states are developing, sustaining, and/or modernizing their nuclear forces and supporting capabilities. Meanwhile, we continue to work toward meeting the New Strategic Arms Reduction Treaty (START) limits.

A New Start

The United States has reduced its nuclear weapons stockpile by 85 percent relative to the Cold War peak. Instead of dozens of different delivery systems, we are well on our way to only four [intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs), cruise missiles, and the B61 bomb].

The U.S. Air Force has eliminated all non-operational ICBM silos and is in the process of placing 50 [of our 450] deployed ICBMs into non-deployed status. All ICBMs deploy only a single warhead—they are no longer armed with multiple, independently targetable warheads.

The Air Force is also converting almost half of its nuclear-capable B-52 bombers to conventional-weapons-only bombers. The U.S. Navy is converting [to non-nuclear] four SLBM launch tubes [out of 24] on each of the 14 deployed Ohio-class nuclear ballistic missile submarines, thus removing 56 launch tubes from accountability.

The benefit of the New START is that it engenders stability by maintaining rough equivalency in size and capability. However, in order to maintain strategic stability as we draw down our nuclear deterrent forces, the remaining systems must be safe, secure, effective, and ready.

Clearly, there's a lot going on. The reality is that the strategic environment continues to increase in complexity. Unlike the bipolar world of the Cold War, today's multipolar world includes nation-states and non-state actors that are more akin to multiplayer, concurrent, potentially intersecting games of chess, challenging regional and global security dynamics.

> **I drive a vehicle that is 13 years old—old by auto standards but a real "spring chicken" by our nuclear-deterrent-delivery system standards.**

The Bedrock

I hope you would agree with me that achieving comprehensive deterrence and assurance rests on a whole-of-government approach. Foundational to this approach is America's nuclear deterrent—a synthesis of dedicated sensors, assured command and control, the triad of delivery systems, nuclear weapons, enabling infrastructure, trained

Navy Explosive Ordnance Disposal (EOD) technicians explain the MK II Talon robot to Admiral Haney. To learn more about EOD training at Los Alamos, see "The Hurt-Locker School" on page 3. (Photo: U.S. Navy)

and ready people, and treaties and non-proliferation activities. All remain essential to our national security and continue providing a stabilizing force in the geopolitical fabric of the world.

We've made tremendous progress throughout the nuclear deterrent enterprise—from oversight and investment to personnel and training. Make no mistake: U.S. STRATCOM is a ready force, capable of delivering comprehensive war-fighting solutions for our commander in chief.

Modernizing the Force

Most of our aging delivery systems and their support infrastructure will be extended decades beyond their original expected service life—and must be replaced in the 2025–2030 time frame. Our ICBMs, B-52s, and Ohio-class submarines were designed and fielded in the 1960s, '70s, and '80s.

By comparison, I drive a vehicle that is 13 years old. That's old by auto standards but a real "spring chicken" compared to our nuclear-deterrent-delivery system standards. My car is still reliable but requires more maintenance to keep her that way. Imagine the maintenance logs of our B-52s after 60 years, ICBMs after more than 45 years, and the Ohio-class submarines after 30 years of extended service.

Each leg of the triad provides a hedge against technical problems or changes in the security environment, so the triad must have effective weapons [in addition to effective delivery systems]. For example, the B61 nuclear bomb's life-extension program is needed to continue enhancing the credibility of our security commitments to our allies. The new Long-Range Standoff Missile must preserve existing military capability in the face of evolving threats.

Time is Running Out

We are fast approaching the point where we will put at risk our safe, secure, effective, and ready nuclear deterrent, potentially jeopardizing strategic stability. We must not let

An Air Force B-52 Stratofortress bomber aircraft. The youngest B-52 is 54 years old. *(Photo: U.S. Air Force)*

our deterrence capabilities be determined by a failure to sustain and modernize our forces. This is critical in a global security environment where it is clear that, for the foreseeable future, other nations are placing high priority on developing, sustaining, and modernizing their nuclear deterrent forces.

Delaying the development and fielding of any of these programs would unacceptably increase risk to our nation's strategic deterrent capabilities. Equally, if not more important, delaying would directly affect our credibility and ability to deter and assure.

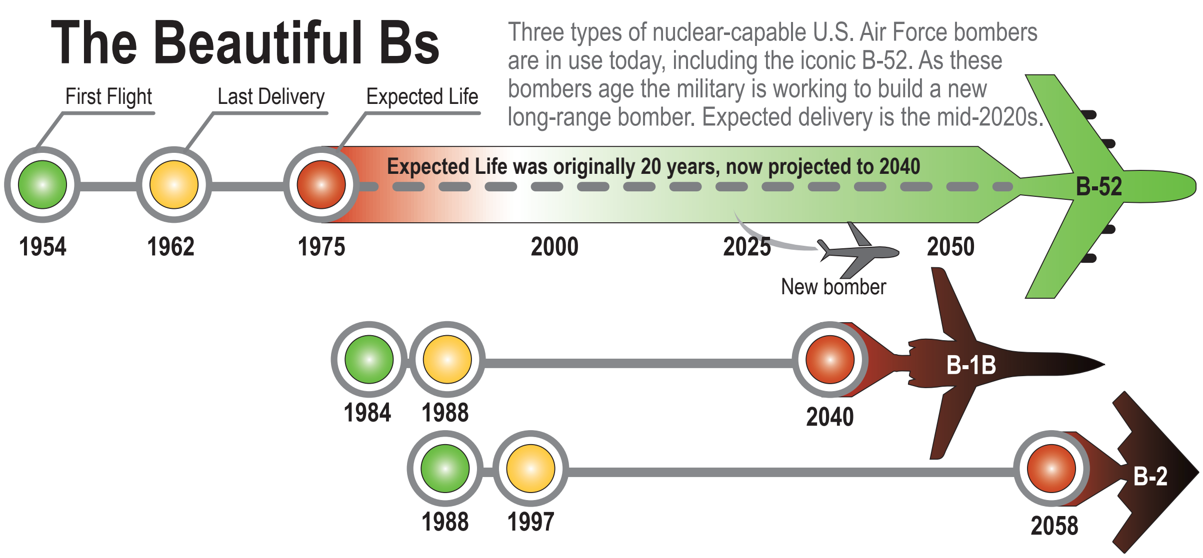
We are out of time. Sustainment is a must. Recapitalization is a requirement.

Although many talk about sustaining and modernizing our nuclear enterprise in terms of cost (which is important in this fiscal environment), it is imperative that we expand the conversation to seriously consider the value derived from investment over the long-term.

> **We must modernize the force—including our people—to ensure this force remains capable of delivering strategic stability and foundational deterrence well into the future.**

Our budget has a deterrent value of its own and reflects our nation's commitment to our deterrent strategy. If we are to meet future challenges, we must have a synchronized campaign of investments supporting the full range of military operations that secure our national security objectives across the globe.

Our choice is not between keeping the current forces or replacing them. Rather, the choice is between replacing those forces or risking not having them at all. Without



timely investment, we risk degrading the deterring and the stabilizing effect of a strong and credible nuclear deterrent force. Similar to how the United States analyzes the budgets of other countries, our adversaries pay close attention to how we back up our words with resources. To that end, budget stability is integral to our strategic stability.

> **Our choice is not between keeping the current forces or replacing them. Rather, the choice is between replacing those forces or risking not having them at all.**

In much the same way we sustain and modernize our platforms and weapons, we must also sustain and modernize our workforce. We must invest in the future of the professionals, both civilian and military, who operate, maintain, secure, engineer, and support our nuclear enterprise.

We need individuals who are willing to develop and stretch their intellect well beyond one-dimensional problems. We need "chess players" who can operate in a multi-dimensional environment with multiple activities taking place simultaneously, on a board where they may not fully understand the rules by which our adversaries are playing.

Can We Afford Not to Modernize?

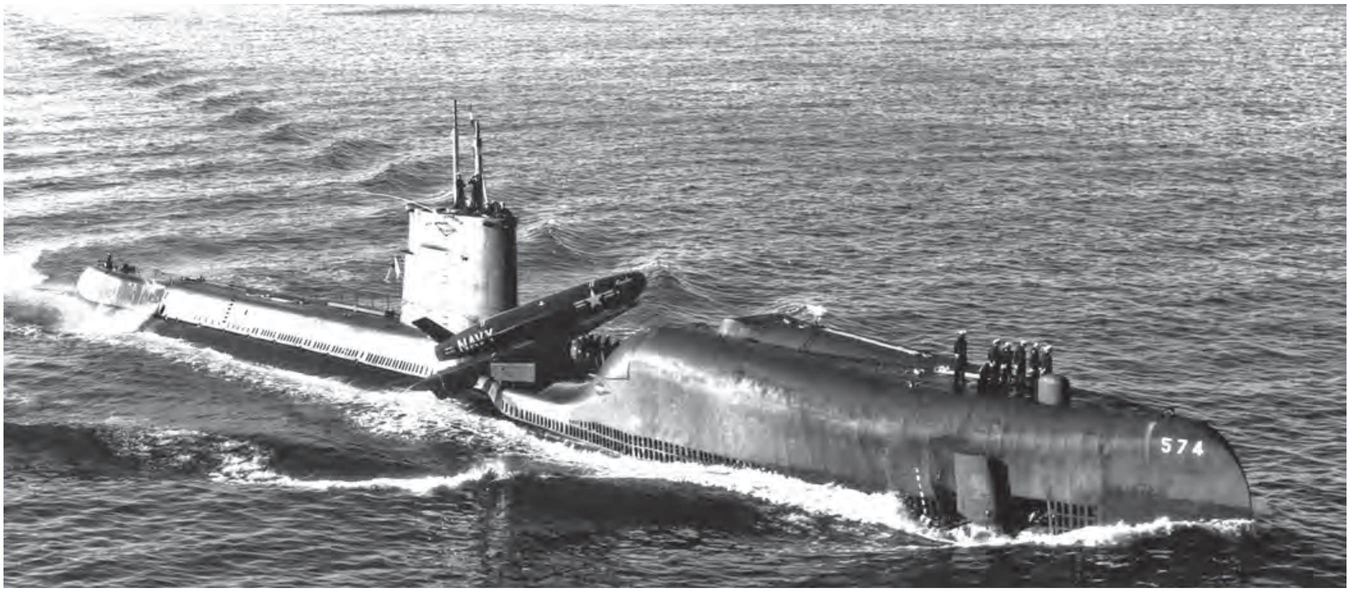
There is no doubt that for 70 years, thanks in part to our credible nuclear forces, the United States has deterred great-power war against nuclear-capable adversaries. But we can't continue to rely on that. We must modernize the force—including our people—to ensure this force remains capable of delivering strategic stability and foundational deterrence well into the future.

There are many who voice concern regarding affordability of the recapitalization programs, but my answer is simple: In this era of explicit and emerging security threats to our nation and its allies, how can we afford *not* to?

~Admiral Cecil D. Haney,
Commander, U.S. Strategic Command

The current phase of the B61 life-extension program (LEP) is expected to be completed during summer 2016. Once completed, the B61 LEP will provide continuing assurance of the safety, reliability, and effectiveness of a unique and critical component of the nation's nuclear deterrent that is the bedrock of U.S. national security. (Photo: Sandia National Laboratories)

View the complete version of Admiral Haney's talk:
csis.org/multimedia/video-strategic-deterrent-forces-foundation-national-security



A Regulus nuclear-armed cruise missile sits aboard the USS Grayback *submarine. The Regulus, designed by Los Alamos, was the first nuclear weapon to enter the Navy's stockpile.* (Photo: Open Source)

Los Alamos and the U.S. Navy: Partners Since World War II

On December 7, 1941, Imperial Japanese forces launched a surprise attack against the U.S. Pacific Fleet at Pearl Harbor. This attack, which claimed the lives of 2,400 Americans, marked America's entry into World War II and, ironically, represented the beginning of the end of Imperial Japan, which would suffer defeat after defeat at the hands of the U.S. Navy in the years to come. The final blow to Imperial Japan came in the form of two atomic bombs in 1945. Surprisingly, the Navy also played an important role in the development of these weapons and has continued to be a key partner with the institution responsible for designing, constructing, and delivering them: Los Alamos National Laboratory.

The Navy's first major contribution to Los Alamos was by providing the Laboratory with one of its best experts in ordnance: Captain William Sterling Parsons. Known as "Deak" (short for Deacon, a nickname he acquired during his days as a midshipman at the Naval Academy that played off his last name), Parsons became the head of the Laboratory's Ordnance Division in June 1943. Little more than a year after arriving in Los Alamos, Parsons was promoted to associate director. (To put that promotion in perspective, his only peer as associate director was the legendary Italian Nobel Laureate Enrico Fermi.)

The Ordnance Division was tasked with engineering and building the final combat-versions of the experimental atomic weapons. For example, under Parsons's guidance, the Navy built the special-purpose gun barrel that became the heart of Little Boy's "gun-type" weapon design that was used to destroy Hiroshima.

Deak Parsons moved to Fort Sumner, New Mexico, at the age of 8 where he learned to speak fluent Spanish. He attended the United States Naval Academy in Annapolis, Maryland, from 1918–1922 and eventually returned to New Mexico in 1943 to work at Los Alamos. (Photo: Open Source)

In addition to serving as a division leader and as an associate director, Parsons co-led Project Alberta with future Nobel Laureate Norman Ramsey. The Alberta team was responsible for overseeing the safe delivery of nuclear bomb components from Los Alamos to Tinian Island. (After its capture in August 1944, the Navy built Tinian into one of the largest airfields of the war—essentially a 39-square-mile island airfield from which to bomb Japan.) Little Boy's key components, including the uranium projectile to be fired in the bomb's Navy-built gun, were delivered to Tinian aboard the cruiser USS *Indianapolis*. (The *Indianapolis* was sunk by a Japanese submarine shortly after delivering its nuclear cargo. Only 317 of the ship's crew of 1,196 survived—the greatest loss of life in a single incident in the history of the Navy.)

Once the components were delivered, the Alberta team constructed the bombs, maintained them, and loaded them aboard B-29 bombers. Parsons, concerned about the possibility of a crash during takeoff, decided to personally arm Little Boy after it was in flight and then witnessed the culmination of the Manhattan Project when the bomb successfully detonated over Hiroshima. (A naval officer also armed Fat Man, the bomb deployed against Nagasaki.) For his wartime efforts, Parsons was promoted to commodore and awarded the Silver Star and Navy Distinguished Service Medal.

The war would soon come to a close, as would Parsons's time at Los Alamos, but the partnership between the Navy and the Laboratory was only beginning.

Before Parsons came to Los Alamos, he worked at the Naval Proving Ground at Dahlgren, Virginia, with a young Naval Reserve commander named Norris Bradbury. Parsons ordered Bradbury, a Berkeley-trained Stanford professor, to join him in New Mexico in 1944. Bradbury was assigned to work on the complex implosion-type design (that became the Fat Man bomb), wrote the procedure for conducting its test—the Trinity Test, and played the lead role in assembling the device for the Trinity Test.

After the war, though he had hoped to return to Stanford, Bradbury reluctantly agreed to serve for six months as Oppenheimer's successor as Laboratory director; he ultimately served for 25 years. Bradbury turned out to be the ideal leader to guide the Laboratory through the uncertainty of the postwar years.

At the end of the war, the Laboratory faced an uncertain future: it had a product (nuclear weapons), but it lacked a customer. Fortunately, the Navy arrived on the scene in the closing months of 1945. Atomic weapons had revolutionized warfare, and naval leaders hoped to determine whether their ships could survive a nuclear blast. The Navy collected a test fleet comprised of dozens of captured and surplus World War II ships of various types, and Los Alamos prepared nuclear weapons to use against them. The operation was code-named Crossroads and conducted at the Marshallese atoll of Bikini. These important weapons-effects tests confirmed naval vessels were vulnerable to atomic attack.

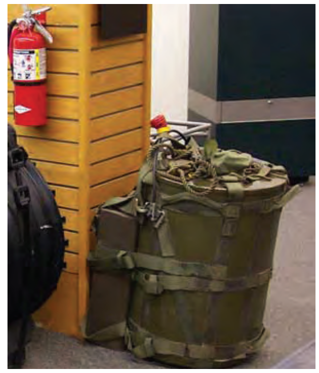
On July 24, 1946, the Crossroads test (using a device identical to Fat Man) was detonated 90 feet below the surface of Bikini Lagoon. The test was conducted for the Navy by Los Alamos to assess how well naval vessels could withstand a nuclear blast. The 21-kiloton yield caused several warships to sink. The battleship USS Nevada *remained afloat but suffered significant damage.* (Photo: Los Alamos)

According to Bradbury, the Navy kept the Laboratory in business. "What held the place together was the Navy's program to determine the effects of nuclear bombs against naval vessels," he said. Today, the Bradbury Science Museum in Los Alamos is named in his honor.

In the decades that followed, Los Alamos designed a wide variety of nuclear weapons for the Navy. The first nuclear weapon to enter the Navy's stockpile was the Regulus, a large cruise missile that could be fired from the deck of a submarine. Other innovative weapons systems used by the Navy soon followed, including the Special Atomic Demolition Munition (SADM). The SADM was a low-yield tactical nuclear weapon that could be delivered by a scuba diver. Los Alamos also developed atomic depth bombs, torpedoes, rockets, and even a 16-inch-diameter nuclear projectile that could be fired from a battleship.

During the 1960s and 1970s, Lawrence Livermore National Laboratory designed the warheads that armed the Navy's Polaris and Poseidon submarine-launched ballistic missiles (SLBMs). The year 1979 marked the transition from Livermore-designed warheads to Los Alamos-designed warheads when the Navy armed its new Trident I SLBM. Today, these Los Alamos-designed warheads continue to arm the Navy's current SLBM—the Trident II.

Given the close and ongoing nature of the Navy-Los Alamos partnership, it should come as no surprise that a naval vessel once bore the name USS *Los Alamos*. The *Los Alamos*, a floating dry dock used to service nuclear submarines, enjoyed a long and useful career from 1961–1994. Today, there is growing interest in resurrecting the name USS *Los Alamos*. On December 15, 2015, the Los Alamos County Council voted unanimously to approve a resolution requesting that a future U.S. Navy submarine receive the name *Los Alamos*.



The Special Atomic Demolition Munition (SADM) was a portable nuclear weapon in the U.S. stockpile during the 1960s. Although SADMs were never used in combat, the Navy tested a version that could be used to attack targets accessible by sea. *(Photo: Los Alamos)*

This gesture serves as a tribute to those in the community who have served in the Navy, those who helped develop the nation's sea-based nuclear deterrent, and as an enduring symbol of a nearly 75-year partnership that has served the nation's best interests.

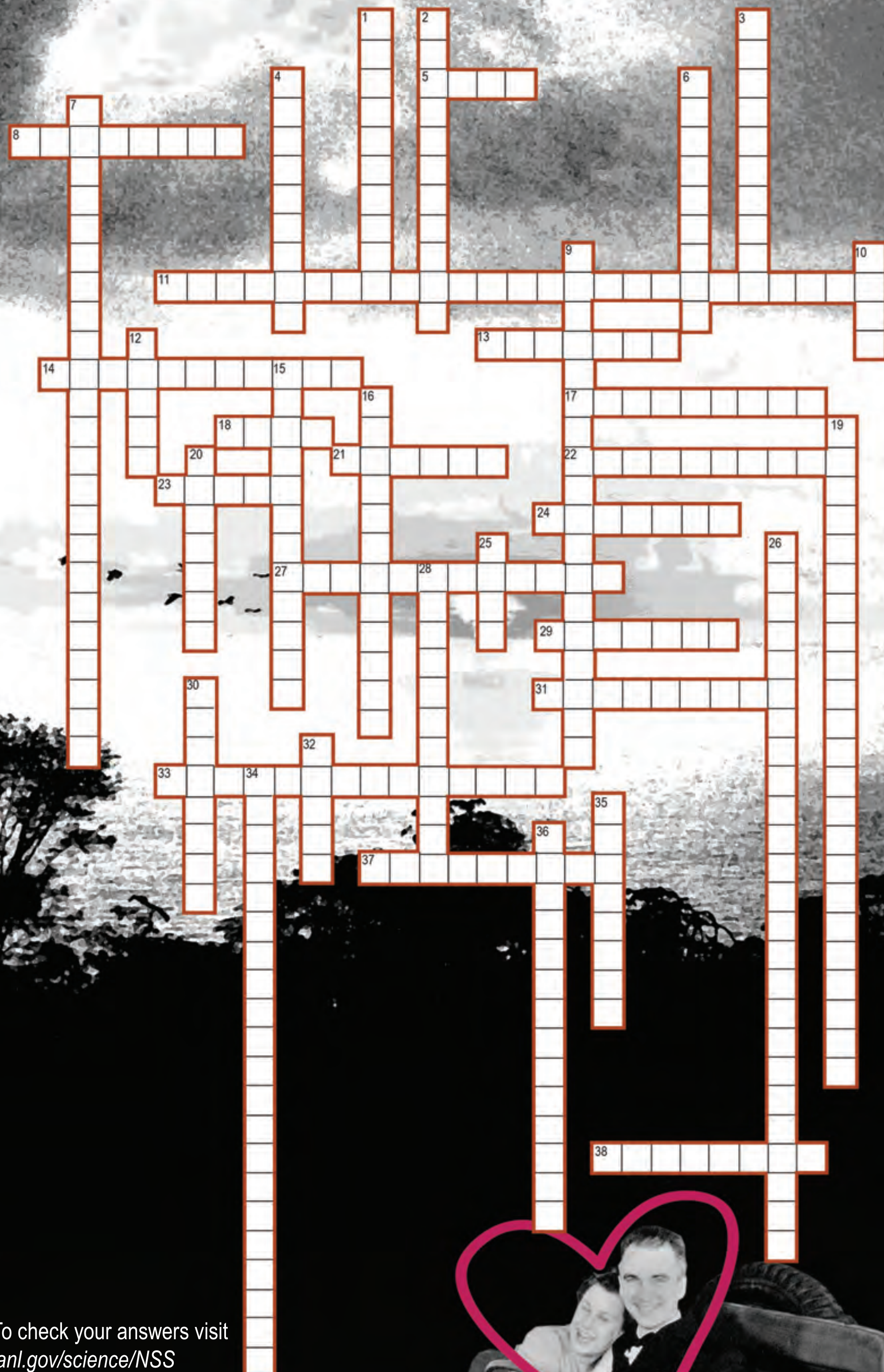
The Navy-Los Alamos partnership was forged during the dark days of history's most deadly conflict. Today, the partnership continues. For example, every year, midshipmen from the U.S. Naval Academy vie for summer internships at the Laboratory (through the National Nuclear Security Administration's Service Academies Research Associates program). For up to six weeks, interns receive hands-on scientific and engineering experience working to solve real challenges in U.S. national security. The program perpetuates the Lab's partnership with the Navy and fosters military decision-makers who will better understand and appreciate the science and technology capabilities of the Laboratory.

The Laboratory continues to ensure the safety and reliability of every naval nuclear weapon, while the Navy reminds adversaries that acts of aggression against the United States or her allies will be met, just as they were in 1941, in a swift and decisive manner.

~Alan Carr

The USS Los Alamos *services a U.S. nuclear submarine in Holy Lock, Scotland.* *(Photo: Los Alamos)*

NATIONAL SECURITY SCIENCE
Crossword Challenge



Across

5. Laboratory historian
8. Oppenheimer's successor
11. IED
13. *NSS* Editorial Advisor
14. Spray explosives with a liquid
17. Collision location of refueling tanker and B-52 carrying nuclear weapons
18. Los Alamos team that characterizes underground explosions
21. New segregated fuel oxidizer system used in propellants
22. Means of transport for SADM
23. Spanish tourism minister who swam off the coast of Spain to assuage fears of radioactivity in the water
24. Principal Associate Director, Weapons Program
27. Pond Cabin was originally HQ for this dude ranch
29. First naval nuclear weapon to enter the stockpile
31. Designer of every nuclear weapon deployed by the Navy
33. Where U.S. tested nuclear weapons until 1992
37. 237,000 cubic feet of contaminated ice and debris were removed after a bomber carrying nuclear weapons crash-landed here
38. Hanford plutonium producer and part of MPNHP

Down

1. Operation conducted at the Marshallese atoll of Bikini
2. Millionths of a second
3. Naturally occurring seismic event (usually)
4. A loud noise and the sudden going away of things from the place where they have been
6. Number of U.S. national laboratories
7. The Lab does _____ (3 words) for the nation.
9. February 2014 DHS threat
10. Captain William Sterling Parsons aka
12. Italian physicist who used Pond Cabin for plutonium chemistry research
15. USS on which Little Boy components were transported
16. Floating dry dock used to service nuclear submarines
19. TATB for short
20. Succeeded the 100-Ton Test as the world's largest man-made blast
25. Get left of the
26. The Naval School's military training on explosives
28. Hard to accidentally detonate
30. The HM in HME
32. U.S. Naval Admiral and head of U.S. Strategic Command
34. Also called 3D printing
35. Type of bomb more powerful than atomic
36. Recognized by EOD techs in homemade bomb labs

To check your answers visit *lanl.gov/science/NSS*

Naval Commander Norris Bradbury and his wife, Lois, circa 1945. (Photo: Los Alamos)

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Spanish Tourism Minister Manuel Fraga (left) and U.S. Ambassador Angier Biddle Duke (right) emerge from a swim off the southern coast of Spain to assuage fears of radioactivity following a hydrogen bomb accident. (See "Learning from (Near) Disaster," page 16.) (Photo: Gianni Ferrari/Getty Images.)

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