NATIONAL SECURITY SCIENCE

Solving a Nuclear Whodunit

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Giving Nuclear Watchdogs Their Bite

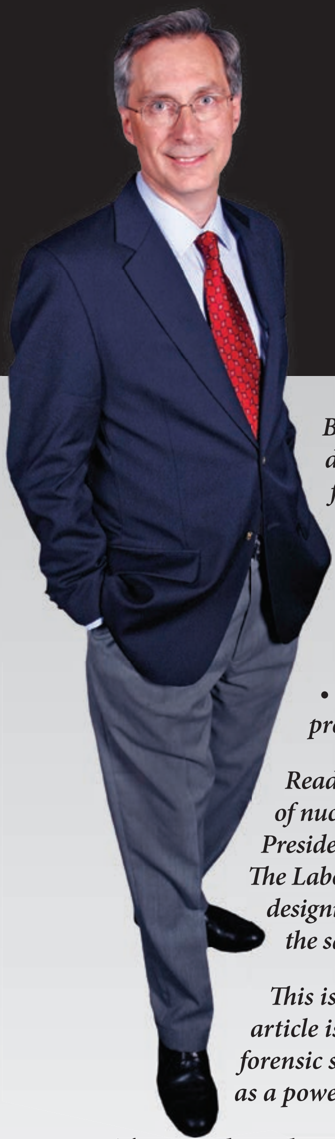
Roasting Plutonium Pits

Why Stockpile Size Matters

Los Alamos NATIONAL LABORATORY EST.1943

About the Cover

Nuclear terrorism must be prevented. Nuclear forensics at Los Alamos provides the nation with the capability to quickly identify and thus deter potential terrorists.



READERS MAY BE SURPRISED

CHARLES McMILLAN, Laboratory Director

Because of our storied history and because we help to safely and securely maintain a reliable nuclear deterrent, Los Alamos is sometimes seen as only a nuclear weapons laboratory. This perception is far from accurate. Los Alamos is a national security science laboratory. The Laboratory provides the government with the science, technology, and engineering needed to help solve many national security problems. Readers may be surprised to learn that Los Alamos is engaged in the following:

- *Researching affordable biofuels to lower U.S. dependence on foreign oil.*
- *Understanding climate change and its national and international ramifications.*
- *Studying the outcomes of natural- and human-caused disasters so the nation can better prepare for events such as hurricanes, floods, and acts of terrorism.*

Readers may also be surprised to learn that the Laboratory is working to prevent the proliferation of nuclear weapons. The spread of nuclear weapons, particularly to terrorists, is—according to President Obama—"the single biggest threat to U.S. security" in "the short term, medium term, and long term." The Laboratory can help prevent nuclear proliferation and deter nuclear terrorists. Its experience in designing and engineering nuclear weapons gives it the capability to help find others intent on doing the same.

This issue presents three articles on the Laboratory's wide-ranging nonproliferation work. The first article is about our nuclear crime laboratory. If an act of nuclear terrorism occurred, our nuclear forensic scientists would help to quickly identify those responsible for the weapon. This capability acts as a powerful deterrent.

The second article reveals that Los Alamos trains the International Atomic Energy Agency (IAEA) inspectors, who raise the alarm if nations with nuclear power, like Iran, covertly try to develop nuclear weapons. The Laboratory also provides the science and technology behind the IAEA inspections. And many of our staff members serve stints as IAEA inspectors—a tough job, sometimes carried out in hostile environments, with enormous truth-seeking responsibility.

Finally, an article highlights the consequences of nuclear stockpile reduction. Eliminating nuclear weapons leaves behind their plutonium pits, which are a proliferation risk. The United States is storing thousands of pits that must be safeguarded and disposed of, consistent with international treaties. The Laboratory is the only U.S. facility equipped to destroy these pits and is already doing so. Readers may find what happens to the plutonium afterward both surprising and ironic.

So while we maintain the nuclear deterrent, we are working just as hard to reduce the worldwide nuclear weapon threat. I know you will enjoy this issue of National Security Science.

Society for Technical Communication

In 2012 *National Security Science* received a **Distinguished Technical Communication** award in national competition, and an **Award of Excellence** in international competition from the Society for Technical Communication.


DEPARTMENT OF JUSTICE
FEDERAL BUREAU OF INVESTIGATION
FIDELITY
BRAVERY
INTEGRITY
THE WHITE HOUSE
WASHINGTON
SHARP

Terrorists run—but they can't hide. LANL's nuclear forensics sleuths untangle the mysteries to solve

A NUCLEAR WHODUNIT

Suppose the unthinkable happens—terrorists explode a nuclear bomb in a major U.S. city. The blast wave, extreme heat, nuclear radiation, and then radioactive fallout from even a simple device would have disastrous effects on the population in and around ground zero, potentially dwarfing the results of the terrorist acts of September 11, 2001. For example, an explosion the size of the Hiroshima blast (approximately 15- to 20-kiloton yield) could kill more than 100,000 people, injure a similar number, and lead to the evacuation of hundreds of square miles of radioactively contaminated land surrounding the blast site.

The economic, political, and social consequences of such an attack would be devastating to the nation and the world.

What is the chance that a terrorist would explode a nuclear weapon? Former president George W. Bush and Congress have recognized this as "a very serious threat." President Obama has warned that nuclear terrorism is "the single biggest threat to U.S. security" in "the short term, medium term, and long term."

Extended Retaliation

What can be done to prevent it? Threatening retaliation against terrorists may have little effect. Many terrorists seek martyrdom by death, and their leaders lack return addresses.

But nuclear weapons are very hard to come by. Terrorists would need plutonium, which is made in nuclear reactors, or enriched uranium, which is made in, for example, huge centrifuge facilities. Both materials take years to produce. In addition, terrorists would need specialized knowledge to design and assemble a weapon, knowledge known only to nuclear scientists—for example, the Pakistani scientist A.Q. Khan, who for decades illegally transferred equipment and technology to rogue nations such as North Korea, Iran, and Libya. In other words, terrorists would need partners in crime: a nuclear state; a subnational military or scientific organization; and very talented, experienced individuals. Unlike the terrorists, these "friends" might indeed be deterred.

President Obama has warned that nuclear terrorism is "the single biggest threat to U.S. security."

Nuclear attribution—identifying the suppliers of nuclear fuel and the design of a device—requires two ingredients: first, technical nuclear forensics (TNF) to analyze the explosion debris and figure out the exact fuel and the exact device design and second, intelligence and law-enforcement information to reduce the potential suspects. The attribution capability, coupled with the threat of extending U.S. retaliation beyond the terrorists to any accomplices, would likely give rogue nations such as Iran or North Korea pause, keeping them from supplying nuclear material to a terrorist organization. It would also be an incentive for Russia, Pakistan, and other nuclear powers to invest in better safeguards to prevent the loss, theft, or diversion of their nuclear materials, weapons, and technical capabilities.

Bottom line: To deter a nuclear crime, the United States needs nuclear sleuths and a nuclear forensics crime lab with the ability to analyze the explosion debris. In the event of an attack, these sleuths would need to be ready, instantly, to get on the case—to unravel the physical evidence pointing back to the perpetrators. Los Alamos National Laboratory is the lab for the job. "It takes a nuclear weapons lab to find a nuclear weapons lab," says Laboratory Director Charles McMillan.

Today, LANL is one of the leading nuclear crime labs for the federal interagency program called National Technical Nuclear Forensics (NTNF). Program members represent the Energy, Defense, Justice, State, and Homeland Security departments, as well as other government agencies.

To deter a nuclear crime, the United States needs nuclear sleuths and a nuclear forensics crime lab to unravel the physical evidence pointing back to the perpetrators.

Los Alamos began developing nuclear forensics in 1945, when Manhattan Project pioneers analyzed debris from the first nuclear explosion (the Trinity Test near Alamogordo, New Mexico). Today nuclear forensics is a mature science, based on the analysis of debris from over a thousand U.S. nuclear tests; extensive research and design in all aspects of nuclear weaponry; modeling of nuclear performance with some of the fastest supercomputers in the world; and use of unique radiological and nuclear facilities such as Technical Area 48, the Chemistry and Metallurgy Research building, and the Plutonium Facility.

Los Alamos now applies all this experience and capability in a new way—its nuclear detectives think the unthinkable to help deter nuclear terrorism.

Nuclear Crime Scene Investigation

A terrorist nuclear explosion anywhere on the surface of the globe would announce itself instantaneously. It would send out an intense flash of light detectable by the global array of satellite-borne instruments, many developed at Los Alamos, that look for violations of nuclear test ban treaties.

The explosion would also produce an enormous blast wave, setting off earth tremors that, in minutes, would reach the treaty-monitoring seismic sensors dotting the globe. Together, these so-called “prompt signals” would be the first definitive evidence that the explosion was nuclear and would give an indication of its magnitude.

George Brooks, TNF program manager at Los Alamos and technical team lead for the field collection operations, describes what would happen next: “Almost immediately after the boom, the U.S. government would try and collect airborne radioactive debris from the mushroom cloud and downwind plume. Within 30 minutes Los Alamos would receive a request for help through the National Command Authority [the President and the Secretary of Defense] and the FBI. We would immediately begin to spin up the NTNF Ground Collections Task Force, composed of LANL staff and other program participants, and develop a collections plan to gather the physical evidence needed for nuclear forensic analysis—samples of the highly radioactive explosion debris.”

Today nuclear forensics is a mature science, based on the analysis of debris from over a thousand U.S. nuclear tests.

Ideally, the collections team, equipped with protective gear against the radiation, could be on the scene in less than 24 hours. Select staff from the Department of Defense would collect the samples. Then on-scene Los Alamos experts would place the radioactive samples inside portable gloveboxes made of Plexiglas and begin to manipulate and analyze them. The scientists would stand outside, and only their forearms and hands, covered by lead-lined gloves, would reach into

Terrorist nuclear attack in New York City. Washington asks Los Alamos nuclear crime lab for help.

these transparent but sealed containers to handle the radioactive samples. The Plexiglas would block the most dangerous radiation, allowing these samples to be safely examined. "After initial analysis at the site, we would reduce the samples to a size suitable for shipment back to our TNF radiochemistry team at Los Alamos, who would then conduct a more exacting analysis," explains Brooks. "Los Alamos plays end to end in nuclear crime forensics. We have people trained to be involved from the onset of collections to the final analysis that determines what the weapon looked like. No other lab has that complete set of capabilities."

Collecting the Evidence

Just as each firearm leaves unique marks on a fired bullet or cartridge case, every nuclear weapon leaves unequivocal nuclear signatures in its explosion debris. But nuclear signatures bear no resemblance to a gun's visible marks. Literally everything in and around a nuclear explosion vaporizes; nothing recognizable of the original bomb is left. All the signs of how the bomb was made and how it worked—all the on-scene evidence that could lead to attribution—are in the vaporized debris that cools and condenses into dust and clumps of glass-like material that rain down as radioactive fallout across the landscape.

Los Alamos plays end to end in nuclear crime forensics, from the onset of collections to the final analysis that determines what the weapon looked like.

Hugh Selby, one of the newer-generation Ph.D. chemist/nuclear sleuths at Los Alamos explains, "At a crime scene, the investigators gather fingerprints, blood samples, hairs, and such and bring them to a crime lab, where technicians check for DNA, identify blood type, and so on. That composite dataset becomes one nugget of information that says, 'It looks like Joe Bob Dillinger shot Sue Ann Ellis with a .38 special.' Analogously, the radiochemistry team gets different samples of explosion debris and through detailed analysis puts together the unique 'nuclear fingerprints' that tell how big the explosion was, the kind of bomb it was, and the materials it was made of." Discovering that information—the nature of the weapon—is the Laboratory's signature capability.

Once the nuclear detectives know all this about the weapon, they have important clues about where the materials could have come from and who could have built the bomb.

Why are Los Alamos nuclear detectives so confident that the debris from a nuclear explosion always contains unequivocal, detailed evidence about the nature of the bomb? They know the effects of "neutron exposure." During the fraction of a second of detonation, the fission and fusion reactions in the fuel produce an exponentially increasing number of neutrons that strike all the materials both inside and outside the bomb, transmuting (changing) some of the materials' nuclei and thereby creating new elements and radioactive isotopes. Those newly made radioactive isotopes are the bomb's post-detonation nuclear fingerprints; the unique nuclei in the debris reveal the nature of the weapon.

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"Exposing materials to neutrons causes nuclear changes the same way that exposing film to light causes chemical changes in the photographic emulsion," explains Selby. "And the more neutrons in the explosion, the more nuclear changes in the material. LANL's job is to analyze that debris for nuclear changes and thereby recreate a picture of the neutron exposure, which leads us to the original bomb materials, bomb design, and explosive performance." This information, the result of LANL's very specialized forensic expertise, can be used to point to or rule out certain suspects.

Aircraft collects airborne debris.

NTNF Ground Collections Task Force collects radioactive debris.

First responders rush to save lives.

"At Los Alamos, we do forensics. We don't say exactly who did it," explains Carol Burns, division leader of LANL's Chemistry Division, "but we say exactly what happened. We provide the scientific and technical information that either supports or refutes a particular case being made by our nation's attribution community."

Inside the Crime Lab

In the aftermath of a nuclear attack, the radiochemical sleuths would have some tough decisions to make about how to get the most out of the debris analysis. The mood would be tense, the time short, and the stakes high. Decision makers in Washington would need answers, and the public would be demanding a response. Neutron exposure would have transmuted the nuclear fuel as well as the other materials in the bomb into an incredibly large suite of newly made radioactive isotopes (radioisotopes), possibly hundreds of them, each with potentially useful information about the nature of the bomb. The most highly radioactive of them would have very short half-lives (hours or days), so the right measurements would need to be done quickly to get the correct diagnostic information before these key isotopes disappeared.

Discovering the nature of the weapon is the Laboratory's signature capability.

What measurements would need to be made and in what order? "Those are very high-pressure decisions," says Selby. "You have only one pass at getting it right, and once you've done the measurement on a sample, that sample is gone."

"Like a DNA sample, radioactive debris from a nuclear explosion is incredibly complicated. It takes a team of world-class chemists working around the clock to separate all the chemical elements in the radioactive debris and parse their isotopic content for nuclear clues," comments Ann Schake, leader of the radiochemistry team for Los Alamos and the person ultimately responsible for generating all the data.

Nuclear Fingerprints

The radiochemical measurements would determine the relative amount of each radioisotope in the samples, and those relative amounts, or ratios, would lead to or be the unique nuclear fingerprints for the bomb's efficiency, total energy release, nuclear fuel, casing, geometry, and more.

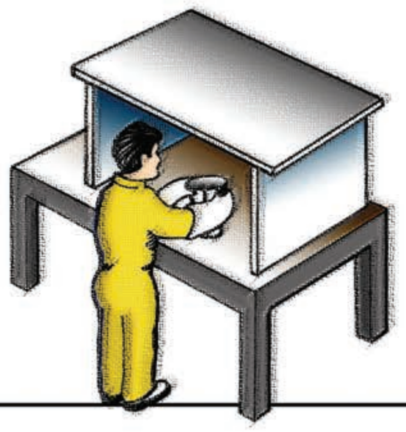
Efficiency, the simplest nuclear fingerprint to find, is the ratio of burned to unburned fuel. That ratio reveals what fraction of the nuclear fuel actually fissioned and released energy—that is, underwent "nuclear burn." In a car engine, close to 100 percent of the gasoline burns, releasing heat and turning the molecules of gasoline into water vapor and carbon dioxide, gases that disappear down the exhaust pipe. In, say, a plutonium fission bomb, only a small percentage of the plutonium-239 (Pu-239, the fuel) undergoes fission, and the waste products of that fission do not disappear but become part of the radioactive fallout. These fission products remain present in the radioactive debris samples taken from the site of a nuclear terrorist attack.

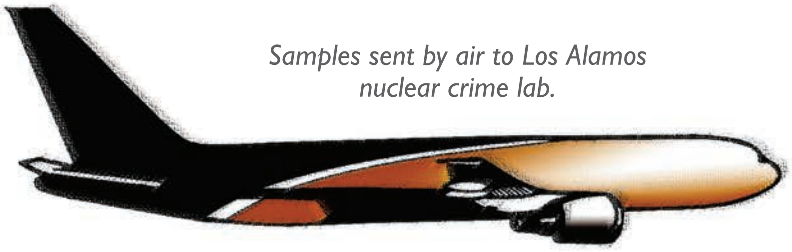
At Los Alamos we don't say exactly who did it, but we say exactly what happened.

Thus, to get the efficiency fingerprint, the radiochemical sleuths would measure the amount of fission products (the burned fuel) and the amount of remaining Pu-239 (the unburned fuel) in the debris samples and calculate the ratio of the two. Manhattan Project pioneers used the identical method to determine the efficiency of the Trinity Test.

The efficiency fingerprint would give a starting point for determining all the other nuclear fingerprints. However, it would take much more detective work to determine the others—such as the fingerprint of the plutonium fuel. The sleuths know that a device's plutonium fuel would not have been 100 percent Pu-239. Depending upon where, when, and how the plutonium was produced, it would have an identifiable set of unique ratios of different plutonium

LANL scientists select debris samples in makeshift lab near ground zero.





Samples sent by air to Los Alamos nuclear crime lab.

isotopes (Pu-239, -238, and -240) and other very heavy elements such as uranium. Thus, the fuel's unique fingerprint would be a strong clue as to its source.

> *The fingerprint of the nuclear fuel would indicate who might have been capable of producing that material.*

"The fuels produced by different reactors, reprocessing facilities, or enrichment facilities are isotopically unique," explains Selby. "So the fingerprint of the nuclear fuel would indicate who might have been capable of producing that material."

Unbaking the Cake

But there is a big hitch. When a bomb explodes, all those isotopes are irradiated with neutrons and transmuted, so the original isotopic ratios become new ones. In other words, the explosion itself would alter the original nuclear fingerprint of the fuel, producing a new, post-detonation fingerprint! How would it be possible to infer the make-up of the original fuel? The scientists at Los Alamos are so well versed in the physics of nuclear explosions that they can reverse engineer the post-detonation products to determine the original isotopic ratios. McMillan calls this "unbaking the cake."

So the crucial first step to identifying the fuel would be to find the post-detonation fingerprint, that is, to measure the isotopic ratios of each of the heavy elements in the explosion debris and get them exactly right, as the guilt or innocence of an entire nation would, in part, depend on it. The radiochemists would separate all the plutonium into one flask, all the uranium into another, and so on. Then they would individually measure each isotope of each element, so the Pu-239 would be differentiated from the Pu-238 and so forth, after which their ratios would be determined.

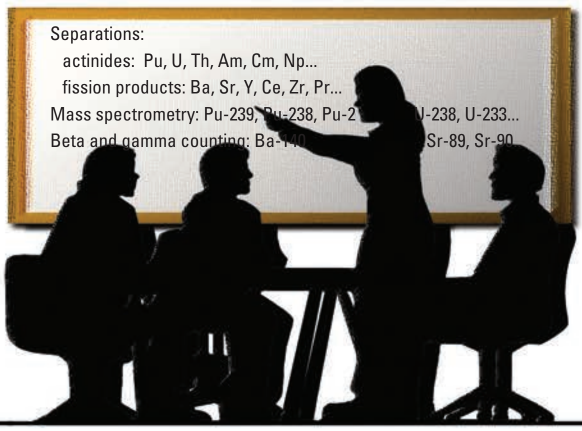
Clearly, the isotopic ratios for each element would come out wrong unless virtually all the atoms of each element in the debris samples were separated from the rest, with no contamination by other elements. Performing such exacting separations is like picking out a few grains of sand from among the trillions spread out over a mile-long beach 100 feet wide and 3 feet deep. This ability to separate all the atoms of each element—and then count them to determine isotopic ratios—is a unique strength of the Los Alamos forensics lab. "We are the nation's premier laboratory for this kind of work," says Selby. "And without this capability, none of the subsequent isotopic measurements would be accurate enough to be of any use as a fingerprint of a bomb."

After uncovering the isotopic ratios in the debris, the radiochemistry detectives would input that information to the Laboratory's radiochemistry computer codes, which would run the neutron exposure reactions backward, reverse engineer the transmutations, and come up with the original isotopic ratios of the fuel.

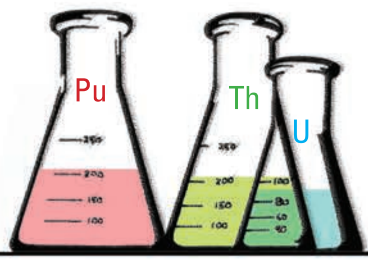
> *Scientists at Los Alamos can reverse engineer the post-detonation products to determine the isotopic ratios of the original fuel.*

Reverse engineering the fuel fingerprint based on the isotopic contents of the debris is possible only because U.S. nuclear scientists have already made precise estimates of how all the various neutron exposures can transmute all the imagined nuclear fuels and combinations of fuels. Los Alamos is the leading center of excellence for the measurements, theory, and evaluation that go into constructing these high-precision estimates.

Radiochemistry forensics team plans sample-analysis strategy.



Chemical elements separated. Radioisotopes of each element isolated and measured precisely.



We'll Know "Whodunit"

The next step would be to send the radiochemistry team's fingerprinting results for the bomb materials' performance and isotopic profiles to the members of the Los Alamos nuclear weapons modeling team. These nuclear sleuths conduct accurate simulations of nuclear detonations and combine the radiochemical results with the prompt signal data. Again using the Laboratory's massive computing power and codes for designing nuclear weapons, they would plug in the combined data and get their answer: the weapon's design.

Stephanie Frankle, Los Alamos project leader for TNF modeling, explains, "Using our wealth of information collected from nuclear weapons tests [collected before the halt of nuclear weapons testing] and our long history of modeling nuclear weapons with powerful computers, we are able to reverse engineer the weapon design using the data and discover what the weapon was and who would be capable of building it."

Finally, the technical evaluations from both the radiochemistry team and the modeling team would be presented to the attributions community, whose members come from the departments of State, Justice, and Homeland Security and from other government agencies. The community's job is to put the technical assessments from the nation's crime labs together with intelligence and law enforcement information gathered from other sources to come up with the "smoking gun"—the conclusive evidence of those responsible. The conclusion would then go to the White House for a determination of the appropriate response.

Selby adds, "Los Alamos has spent its entire 70-year history devoted to solving forensics problems, first for the nuclear test program and now for the stockpile stewardship and technical nuclear forensics programs—determining from explosion debris how a given bomb design performed. We have excellent tools, the best in the world, to investigate a nuclear attack. In fact, we would probably know what happened better than the criminals themselves."

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He continues, "Los Alamos and the entire NTNF community are developing all the tools the United States would need to find out who did it if such an attack occurred, and when the perpetrators were named, we at Los Alamos would tell those villains what they did and how they did it. Terrorists and their accomplices' knowing they can't get away with it—that's the deterrent. That knowledge should make anyone thinking about committing a nuclear crime against the United States, or against its allies, shake in their boots."

A New Manhattan Project

According to Brooks, "The NTNF effort is like a new Manhattan Project; we're gathering the best minds in the country, but this time it's not to build the first nuclear weapon—it's to deter the first nuclear terrorist attack and to make sure that, if the unthinkable happens, the perpetrators will be caught."

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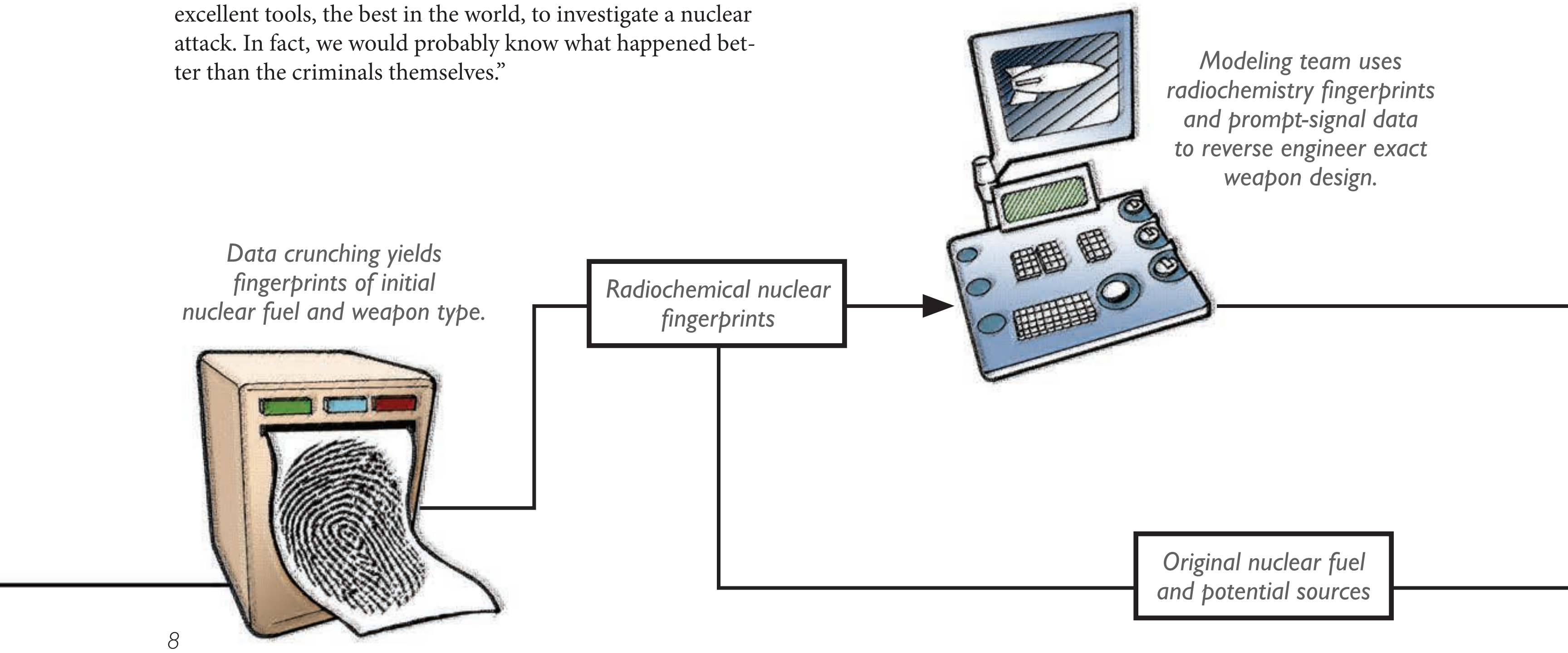


LANL Gets It Right!

In the 50 years of U.S. nuclear testing, testing debris came in the door regularly, and radiochemists and the nuclear weapons modelers quickly donned their forensics hats and went to work. Today the United States does no nuclear testing, so how do today's nuclear detectives stay prepared?

The answer is—exercises, very intense exercises in which teams from national labs compete under severe time constraints. Each team is given data or actual debris based on real or theoretical events, and they have a certain amount of time to come up with answers. "You have to make decisions and do calculations and measurements as quickly and accurately as possible. Failure is definitely an option. People are human and they make mistakes, and everyone has to deal with all that in real time," says Selby.

Despite the complexities, the Los Alamos nuclear crime lab has been very successful in all these exercises, whether local or national. They always have answers for the materials and design of the device—and their answers are invariably right. These exercises demonstrate that the decision makers can rely on a very strong TNF capability should it be needed.

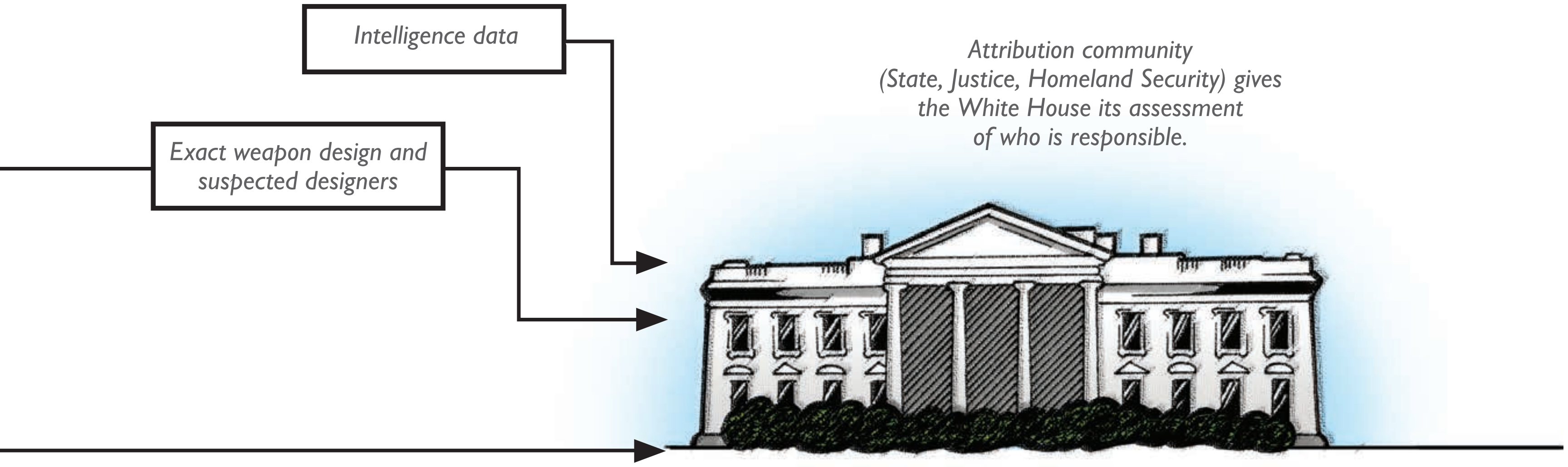
LANL SUCCESSFUL IN DETERRING NUCLEAR CRIME • LANL LEADS INVESTIG

Brooks continues, "Finding out 'whodunit' presents the nation with fantastically difficult problems. Deterring nuclear terrorists and preventing a national catastrophe—the 'single biggest threat to national security'—requires the best and brightest nuclear detectives."

At Los Alamos, the best and brightest are on the case 24/7. Terrorists beware.

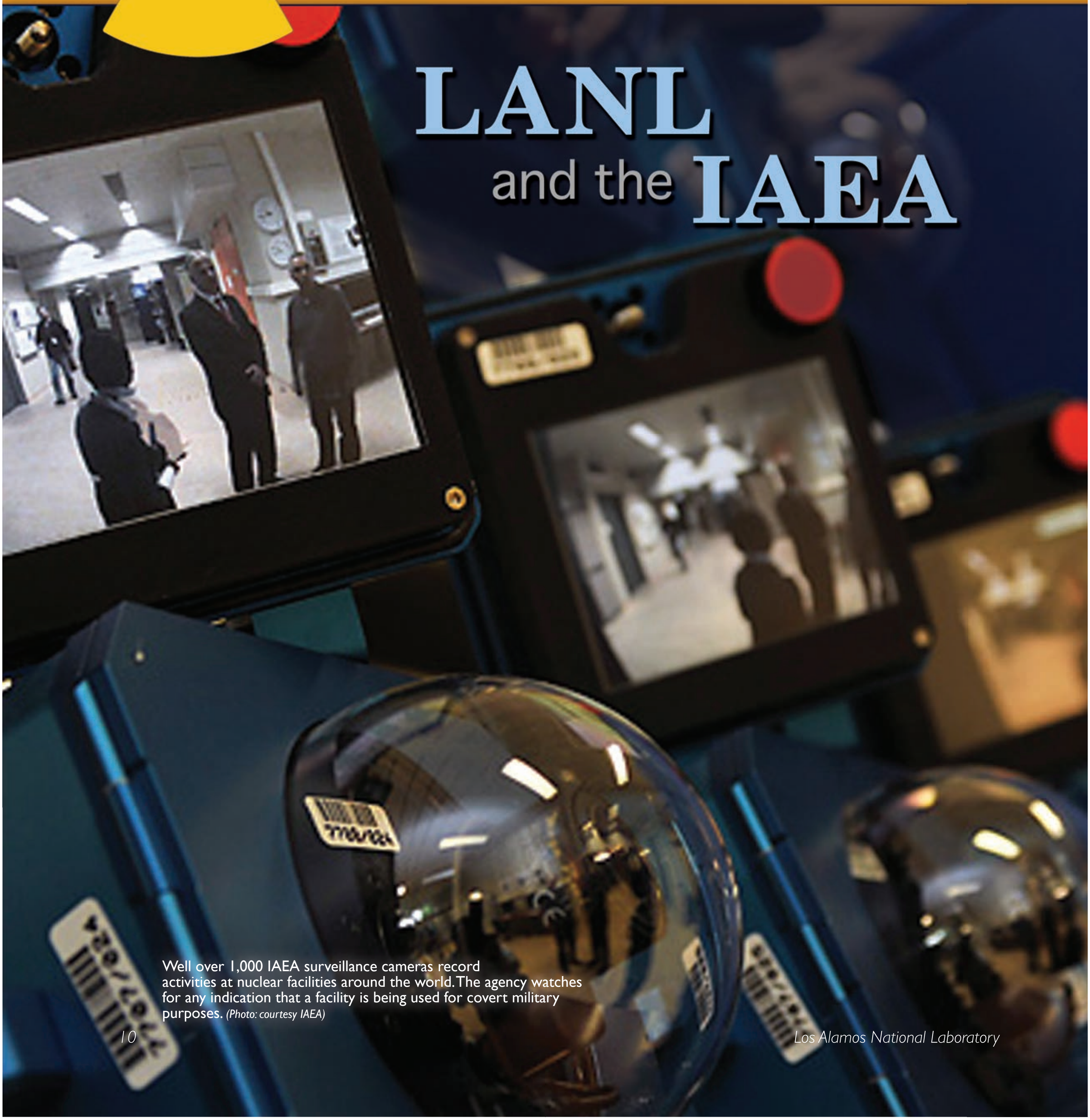
–Necia Grant Cooper

For more information, visit "Tracking the Isotopes"
la-science.lanl.gov/lascience08.shtml
and "CSI Karlsruhe"
arq.lanl.gov/source/orgs/nmt/nmtdo/AQarchive/4thQuarter07/



NUCLEAR WATCHDOGS

LANL and the IAEA



Well over 1,000 IAEA surveillance cameras record activities at nuclear facilities around the world. The agency watches for any indication that a facility is being used for covert military purposes. *(Photo: courtesy IAEA)*

First we got the bomb, and that was good,
'Cause we love peace and motherhood.
Then Russia got the bomb, but that's okay,
Cause the balance of power's maintained that way.

Who's next?

When Tom Lehrer, mathematician (once a Los Alamos employee) and sometime singing satirist, wrote those words in the early 1960s, it seemed that one country after another was kicking down the doors to the nuclear weapons club. Lehrer's song—"Who's Next?"—referenced the French and Chinese atomic bombs and, because of the rush to arms, wryly speculated that even Monaco might soon have one.

Some 50 years later, where are we? The United States, the United Kingdom, Russia, France, and China have the bomb. South Africa had it . . . and gave it up. If Israel has it, it won't say so. India and Pakistan have it and *have* said so. North Korea has carried out nuclear tests and has enough plutonium for several bombs. Iraq tried for the bomb, as did Libya, and both Syria and even Myanmar (formerly Burma) have been suspected of trying for it.

Who's next? Iran?

IAEA inspectors use laser scanners to take three-dimensional images of rooms at nuclear facilities. Comparison with earlier images and with building plans ensures that any changes are detected. *(Photo: courtesy IAEA)*

If that never happens, credit will go to the Nuclear Nonproliferation Treaty (NPT) and the International Atomic Energy Agency (IAEA). The NPT, accepted now by 189 countries, has halted the unrestrained spread of nuclear weapons since 1970. In support of that treaty, the IAEA guards against the secret development of nuclear weapons through its safeguards program—inspections of civilian nuclear facilities around the world.

The IAEA's more than 2,000 annual inspections are performed by the agency's Department of Safeguards, which fields an inspection corps of 200 to 300 men and women drawn from the agency's member countries. The results are reported to the United Nations, so the IAEA and its inspectors are often called the United Nations' "nuclear watchdogs."

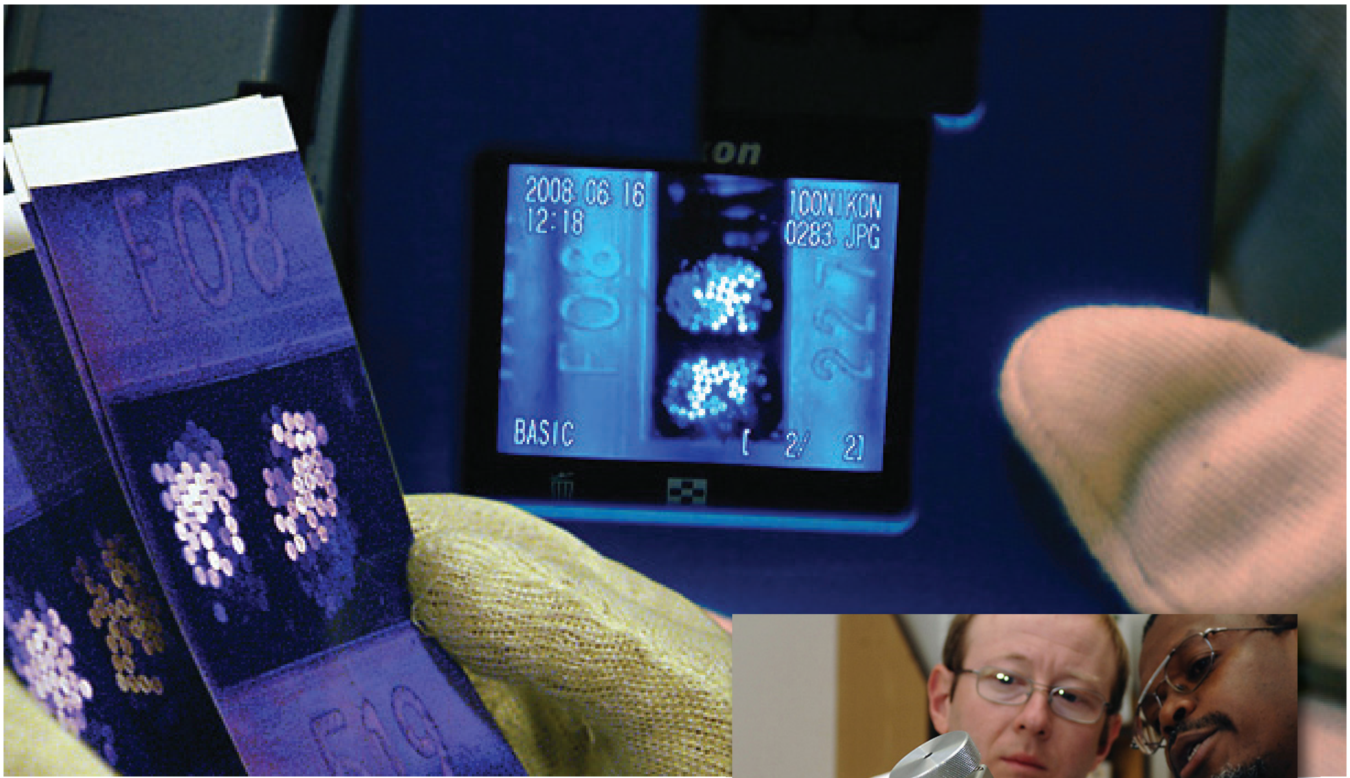
Los Alamos National Laboratory supports that watchdog role. LANL is closely involved with the IAEA. It develops much of the safeguards technology used during inspections and trains the inspectors. And various Laboratory employees regularly take temporary leave from their positions at Los Alamos to fill IAEA jobs, either serving as techical support staff in Austria at the agency's Vienna headquarters or traveling far and often as inspectors in the field.

A "Have–Have Not" Deal

Ironically, the need for IAEA inspections results from a tension at the heart of the agency's and the NPT's well-intentioned goals. Both the IAEA and the NPT promote the beneficial, peaceful uses of nuclear energy and simultaneously seek to inhibit nuclear weapon proliferation. The tension attached to this two-pronged goal centers on uranium and plutonium. Uranium fuels almost all electricity-generating reactors and simultaneously produces plutonium, which can be reprocessed and used as fuel for the nuclear power industry. But both uranium and plutonium are also fuel for nuclear weapons and as such, can be targets for terrorists and nations that *just might* want their own bomb. Consequently, the IAEA's inspections are needed to keep tabs on facilities associated with nuclear power production and on the uranium and plutonium to be found there.

Both uranium and plutonium are fuel for nuclear weapons and as such, can be targets for terrorists and for nations that just might want their own bomb.

The inspections are set in motion by formal safeguards agreements that individual nations negotiate with the agency, partially suspending their national sovereignty to allow IAEA inspectors to cross their borders and enter their nuclear facilities. As remarkable as that is, 178 states (plus Taiwan) have signed such an agreement.



To secure equipment, containers, and vaults, inspectors use seals designed to verify the absence of tampering. Fiber-optic seals (right) can be verified in the field. Each has a unique fingerprint: the pattern formed by the ends of optic fibers inside the seal. The pattern is photographed (above) when the seal is installed and again each time the inspectors visit a facility. Changes in the pattern indicate tampering. *(Photos: courtesy IAEA)*

The vast majority of those states have also signed the NPT and have therefore made themselves participants in a nuclear deal. NPT signatories that had already manufactured and tested nuclear weapons by January 1, 1967—the United States, the United Kingdom, Russia, France, and China (the “haves”)—agree to pursue nuclear disarmament but also to share their nuclear science expertise with the non-nuclear-weapon states (the “have nots”).

For their part, the “have nots” agree never to become “haves,” but instead to use nuclear technology and materials only for civilian purposes. Underdeveloped countries, not ready for nuclear power plants, get help using nuclear technology in such fields as human health and water resource management, the latter involving the use of isotopes to study the movement of water in the environment. Developed nations get direct help establishing and safeguarding their own nuclear power industries. In return, they allow the IAEA inspections.

The Seen and the Unseen

The IAEA inspects facilities associated with all parts of the nuclear fuel cycle, which comprises all the stages uranium goes through as a fuel. Because plutonium is part of that cycle—produced in a reactor’s fuel rods—inspectors visit all the places where uranium and plutonium can be found. That begins with the facilities where uranium is converted from ore concentrate (ground or crushed ore with the waste removed) to uranium hexafluoride, a form that is ready to be enriched (its percentage of the uranium isotope U-235 increased). They also visit the enrichment facilities, fuel fabrication facilities, and, of course, nuclear reactors, where uranium is fissioned to produce heat and electricity, creating plutonium as a byproduct. At the end of the fuel cycle, they visit the facilities where spent reactor fuel rods (now containing both leftover uranium and newly produced plutonium) are stored and the places where the spent fuel, once its radioactivity has declined sufficiently, is reprocessed. In reprocessing, the rods’ uranium and plutonium are separated out so they can be recovered for use in new reactor fuel—mixed-oxide fuel, known as MOX fuel.

Essentially, the inspectors are auditing. Their job is to look at a facility’s records and verify the truth of the statements made there about on-site activities, about the amount of uranium and plutonium in the inventory, and about the percentage of U-235 in the uranium. In short, inspectors check the books

IAEA inspectors use handheld gamma spectrometers to measure the gamma rays from fresh fuel assemblies. The measurements tell them the enrichment level of the uranium in the fuel. *(Photo: courtesy IAEA)*

and compare what they read there with data they collect for themselves from the actual materials. Any mismatch is a warning; a match is verification. And verification for all of a state's nuclear facilities is verification that a state is abiding by its treaty obligations.

Part of an inspection is "low-tech." Inspectors count fuel rods and fuel assemblies. They count and weigh containers of raw material, for example, uranium hexafluoride at a uranium enrichment plant. After uranium hexafluoride is enriched in U-235, it is converted to an oxide for use in making reactor fuel.

To detect signs of tampering, they check surveillance cameras and sensors that the IAEA has stationed at key points in a facility. They do the same for the seals on vaults, containers, and equipment.

They even take such basic steps as banging on containers to learn if they are empty and checking room layouts to see if anything has been changed or moved.

Such eyes-on tasks are vital, but the core of safeguards is measuring what cannot be seen—the radiation that reveals which uranium and plutonium isotopes are present in items such as containers and fuel rods and how much of each isotope is there. Amazingly, the inspectors can often accomplish this on site using a technique called nondestructive assay (NDA). To double check their NDA results, the inspectors often also perform destructive analysis, removing material samples and sending them to the IAEA's Safeguards Analytical Laboratory in Seibersdorf, Austria, where laboratory techniques verify the inspectors' on-site results and measure characteristics that cannot be measured at the facility.

Instead, they only need to place their specialized radiation detectors near an item and measure the unique radiation emanating from each isotope inside. Specifically, they are measuring neutrons and the high-energy photons known as gamma rays. These forms of radiation are continuously emitted by the isotopes of interest, and they are highly penetrating, so they come right through the walls of containers and rods.

The inspectors' gamma-ray detectors measure the rate at which gamma rays of different energies are being emitted by the material inside an item. That information reveals the material's isotopic composition—the ratio of one isotope to others. That ratio can distinguish reactor-grade from weapons-grade material. For example, uranium destined for a civilian power reactor is no more than 4 to 5 percent U-235. If inspectors find a higher percentage of U-235, the planned use for the uranium is suspect. Are facility operators planning to continue enrichment until the uranium reaches the 90-percent level needed for weapons?

Gamma rays can also reveal the isotopic ratios in plutonium that has been separated from spent fuel rods. That information reveals when the separation occurred. If the separation time determined by gamma-ray measurements differs from the declared time written in a facility's records, or if the measurements reveal multiple separation times, there is a problem. The facility operators may have pulled out plutonium earlier than they said they did, or they may have done more separations than they documented. They may be producing additional, undeclared plutonium for diversion to a weapons program.

The core of safeguards is measuring what cannot be seen—the radiation that reveals which uranium and plutonium isotopes are present in items such as containers and fuel rods and how much of each isotope is there.

Detectors measuring neutrons, on the other hand, reveal mass—the amount of a particular material in an item. At a reprocessing plant, that material might be recovered plutonium inside a container. If neutron measurements show that containers hold more plutonium than the facility operator says is there, what is the purpose of that extra amount?

School for Inspectors

The NDA detectors are portable instruments for performing techniques such as gamma-ray spectroscopy and neutron coincidence (or multiplicity) counting. A very large number of these instruments were born or refined—and are constantly being improved—at Los Alamos National Laboratory. NDA is, in fact, a LANL specialty. Says Nancy Jo Nicholas, director of LANL's Nuclear Nonproliferation and Security Programs, "At Los Alamos, we're proud to say we helped invent safeguards technology, and by that we mean nondestructive assay. NDA is a big part of what the IAEA relies on us for."

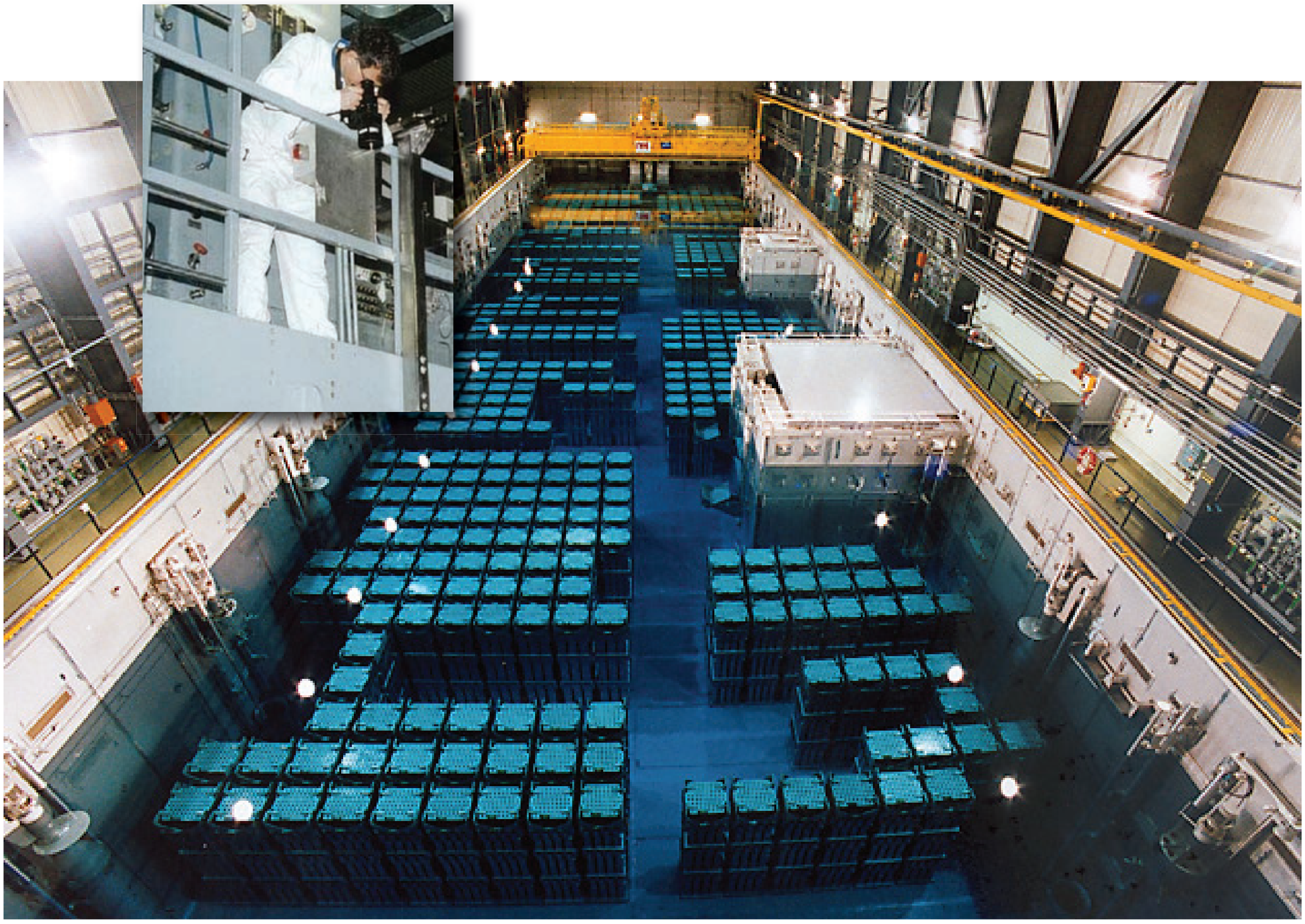
IAEA inspectors initially learn to wield their instruments at IAEA headquarters in the agency's Introductory Course for Agency Safeguards (ICAS). New inspectors complete ICAS and additional training at a light-water reactor, then finish out their first year on real inspections in the company of more-experienced colleagues.

At the end of that year, they are ready to learn even more, and so they come directly to the source: the experts at Los Alamos who teach the Laboratory's NDA Inspector Training course, specially developed for IAEA inspectors.

"We developed the technologies, we're intimately familiar with how they work, and we're constantly working to improve them," says Peter Santi, coordinator of the Laboratory's Program of Technical Support to Agency Safeguards and head of inspector training at LANL "That's why they come here."

A very large number of the IAEA's NDA instruments were born or refined—and are constantly being improved—at Los Alamos.

Los Alamos started teaching the special IAEA course in 1980, and since then, all IAEA inspectors have been trained at



LANL's Brian Boyer (inset) uses an Improved Cherenkov Viewing Device (ICVD) to look at the blue glow (Cherenkov radiation) in the water around spent reactor fuel assemblies (bundles of fuel rods) in a storage pool such as this one at La Hague, France. Spent fuel is kept under water for years until its radiation levels decrease. Cherenkov radiation is caused by charged particles, from the rods, passing through the water. The glow grows dim over time as the radioactive material in the fuel rods decays, but the ICVD is meant to enhance it enough to be seen under normal facility lighting. The absence of glow around one of the rods may mean the rod is a dummy, replacing a real rod that was removed for undeclared uses. *(Large photo: courtesy IAEA; inset: courtesy Brian Boyer, LANL)*

Los Alamos. What LANL teaches takes their initial ICAS training to a higher level.

"The ICAS tells them how to take measurements and how to follow procedures, but by the time they come here, they're experienced enough to be asking questions. They've figured out what they know and what they don't know. And what they don't know is why the techniques work," says Santi. "So that's what we teach them. We teach them the physics behind the measurements and where the techniques work well and where they don't."

The 10-day course, held 2 or 3 times a year, accommodates up to 16 students, who are drilled all day in the "schoolhouse," a laboratory equipped with the same instruments inspectors use in the field. The students work under the direction of the people who developed these instruments. And they take measurements from a more comprehensive group of nuclear material samples than they encounter during ICAS.

Since 1980 every IAEA inspector has been trained at Los Alamos.

The course provides the students with as much one-on-one time with instructors as possible (one instructor for every two students), but the course also requires them to operate all the instruments themselves and make all their own measurements.

The intensity and breadth of classroom experience (7 to 8 hours a day) prepares inspectors to solve problems in the field. Those problems might be as mundane as dealing with malfunctioning equipment or as esoteric as working under conditions that make the measurements harder or less reliable. Measurements can be affected by material composition—whether the material in an item is a pure element or includes traces of other elements such as fluorine, beryllium, or carbon. Even an oddly shaped container of material can cause problems.

For such situations, the students learn when to switch to a different, more robust measurement technique. Or they learn to shift themselves and their equipment to more advantageous positions because measurements can also be affected by background—the nearby presence of other materials producing or blocking radiation, which can be common in a plant's complex environment.

"The final exam," Santi continues, "is much tougher than anything they'll ever encounter on the job. It's a day-long mimicked inspection of a facility, with cans full of items that have no identifier on them. The inspectors have to decide for themselves, 'How do I measure this? How do I determine what's in there?'"

Santi says the students are drained at the end of each day, and "when they're done with the course, they're *done*. They've absorbed as much as we can push into them."

From Los Alamos—Experts and Expertise

Los Alamos people do not just teach safeguards work, they take an active part in it. LANL employees have been taking assignments at the IAEA for decades. Fifteen are there now, on temporary leave from the Laboratory. Most are serving in various positions in the Safeguards Department at IAEA headquarters, and one is a current inspector.

Nicholas actively encourages Laboratory employees to apply for IAEA jobs because she sees those opportunities as a three-way win.

"The IAEA wins because our people have the technical expertise the agency wants," she says. "But it's also a win for our people. The experience expands their knowledge and advances their careers, which in turn benefits the Lab. When they return, they put what they've learned to work on Laboratory projects." Those projects often relate directly to safeguards work.

"The IAEA is where the rubber hits the road for safeguards technology," says Phil Hypes, of LANL's Systems Engineering and Integration group. Hypes was at the IAEA from 2005 to 2007 as a senior training officer for inspectors.

He continues, "We've developed about three-quarters of what the IAEA uses in the field, and we're still working to push the technology forward. Having people who've been out there, who know the inspectors' methods and concerns and the concerns of their technical support people, helps us refine the safeguards techniques and develop new ones. It keeps us doing good work."

LANL does more work on technology for the IAEA than all the other national labs put together.

This good work has national backing at the highest levels. The State Department funds LANL's development of custom safeguards equipment to meet IAEA needs. It also provides the money for the NDA Inspector Training course, and for another IAEA-specific course Los Alamos teaches: Advanced Plutonium Verification Techniques, for a smaller number of inspectors who specialize in plutonium issues.

Nicholas is forceful in her assessment of how important Los Alamos is to the IAEA's work. "LANL does more work on technology for the IAEA than all the other national labs put together. We're definitely the big lab of all the U.S. labs in that sense. Without Los Alamos, the IAEA could not do its job." ✦

–Eileen Patterson

To hear Tom Lehrer's song—"Who's Next?" visit
youtube.com/watch?v=oRLON3ddZIw

For more information visit IAEA's Safeguards Department website:
iaea.org/OurWork/SV/Safeguards/

Sometimes You Start with Tea

Inside an IAEA Inspection

"Inspectors walk a fine line between business and diplomacy," says LANL's Brian Boyer, an IAEA inspector from 1997 to 2002. In some countries, that means being social before beginning an inspection.

Boyer recalls stories of one inspector who bluntly refused proffered hospitality: "I'm not here to drink tea. Let's see the books." His insensitivity bought him less-than-eager cooperation and now serves as an object lesson for new inspectors. Boyer has observed that American scientists coming to Vienna are not usually adept at balancing the work with cultural sensitivity and diplomacy.

"If hosts think you're not behaving well," Boyer continues, "they can make things difficult, taking their time producing records or dragging you out of bed to do a middle-of-the-night inspection, only to make you 'hurry up and wait.'"

Cultural missteps aside, true obstruction is rare. Countries are generally happy to cooperate because IAEA inspections benefit them, proving their honesty and peaceful intent to the world. So most of an inspector's challenges arise from the nature of the job itself.

The challenges begin with months of training, first in the legalities surrounding inspections and then in the work's technical rigors, including learning the operating specifics of various nuclear facilities and practicing the proper use of an inspector's scientific equipment.

One vital element of an inspector's education is mastering the exacting procedures that govern how inspection reports are prepared and how measurement data and material samples are collected, handled, and secured. Reports, data, and samples form the "evidence" that verifies (or not) that a country is meeting treaty obligations, but deviation from procedure can invalidate the evidence, just as it can in a detective's criminal investigation.

If hosts think you're behaving badly, they can make things difficult—slow down the work or drag you out of bed in the middle of the night.

Inspectors collect data through nondestructive assay techniques, but they also collect material samples to be analyzed in an IAEA laboratory. The samples are collected for an inspector by facility personnel, but the inspector must watch in order to speak to the sample's authenticity. Inspectors themselves take "swipe" samples: using sterile gauze pads to wipe surfaces within rooms and on equipment surfaces, then sealing each used pad in a plastic bag for safekeeping.

As basic as the swipe sounds, Boyer describes it as a serious tool. Materials used or produced in a facility always release tiny particles into the air, and these settle on surfaces. So small are such particles—one or two atoms—that no cleaning can ever eliminate all of them. When captured by a swipe and analyzed in a laboratory, they can reveal such vital information as the enrichment level of a facility's uranium or the presence of weapons-grade plutonium.

Inspectors take some of their collected samples away with them but store others on site in a vault for later retrieval. Such vaults are secured with a metal seal made of two parts. The seal is attached with a wire whose ends are tied in a knot inside the seal before the two parts are locked together. It is the inspector who ties that wire

knot, and Boyer admits that this small chore can be a source of tension. The wire must be tied "just so," and considering the bulky gloves inspectors wear and the fatigue generated by long inspections inside hot and humid facilities (in some places, an inspection can last for days), tying those wires can be a simple task that becomes "excruciatingly frustrating."

"To break the seal, you need to cut the wires," he says, "but a badly tied knot can slip loose on its own, invalidating the seal—no one can tell later if the seal was tampered with. That can ruin your whole day because the IAEA could fail to make the year's safeguards goals for a facility, all because you couldn't tie a simple square knot."

Countries are generally happy to cooperate because IAEA inspections benefit them, proving their honesty and peaceful intent to the world.

Inspectors travel an average of three months every year, hauling not just their personal luggage but also the equipment they use to take radiation measurements. Some of this equipment is small enough to be hand carried; some pieces are large enough to need wheeled cases.

They also carry medical papers documenting their fitness for duty and their annual exposure to ionizing radiation. Dosage limits for radiation workers differ from country to country, and inspectors must prove that their annual dosage is below each country's limit. Inspectors without up-to-date medical papers have been denied access to facilities.

During an inspection, protective clothing in the form of coveralls, booties, and gloves are de rigueur, but because these are provided by each facility, a good fit is not part of the style. "Pants can fall down. Shoes flop around like clown shoes or squeeze your toes like a vice," laments Boyer.

And accommodations for changing into these items also differ from country to country. LANL's Deborah Dale, a current IAEA inspector, works exclusively in Japan, where she seldom finds change rooms for women.

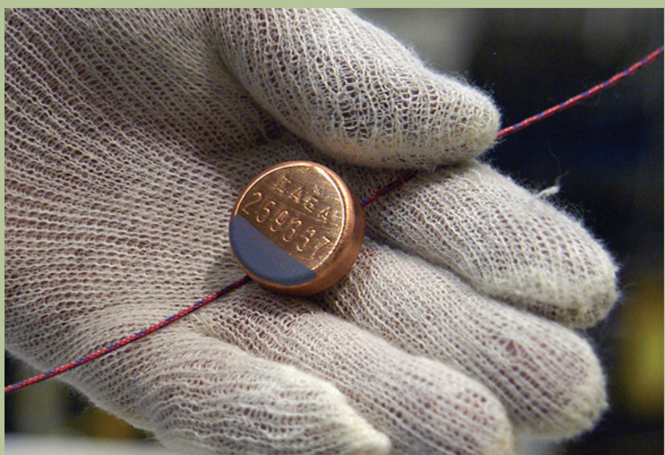
"I have to use the men's," she says, "so to be culturally correct, I wear underclothing so modest that it covers my arms and legs." On top of that, at one reactor, she had to wear three layers of full-body protective clothing, a respirator, and three layers of gloves. "It was summer and very hot in all that gear. Air conditioning was limited because of energy-saving measures after the earthquake [the 2011 earthquake and tsunami]."

One trip all inspectors make is to the United States, for part of their training. For LANL people serving as inspectors, it is a trip home, but to others, it is a special opportunity.

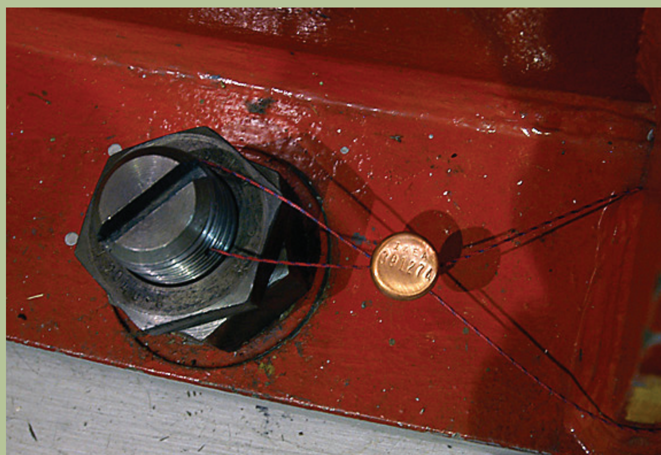
Nicholas tells of one foreign inspector who was being trained some years ago at the Rocky Flats Plant and was able to fill a prescription for insulin that a diabetic relative desperately needed. The relative had gotten the prescription at home, but there was no insulin to fill it.

And if there is any free time when they are at Los Alamos for the NDA Inspector Training course? "They often turn down offers of trips to the usual tourist sites," says Nicholas. "They want to go to Walmart."

–Eileen Patterson



The IAEA uses about 20,000 metallic seals like this one at nuclear facilities. The seals have two parts, which are snapped together when the seal is put in place. Such seals secure equipment, containers, or safes containing material samples. Unique markings inside each seal are photographed before the seal is closed and rechecked when the seal is later collected and returned to IAEA headquarters. Any tampering will have altered the marks. (Photo: courtesy IAEA)



Shown here in use, the seal has been attached with wires whose ends were knotted inside the seal before it was closed. Displacement of those wires or the knot inside is another way to tell if the seal or the item it secures has been disturbed. (Photo: courtesy IAEA)

Meeting Nonproliferation Agreements Requires Destroying Thousands of Surplus Plutonium Pits.

On September 1, 2000, the United States and Russia committed to each "permanently dispose" of "no less than or at least" 34 metric tons of weapons-grade plutonium—enough plutonium to make thousands of weapons.

To help meet this commitment, the Department of Energy (DOE) announced a strategy for the permanent disposition of U.S. surplus weapons-grade plutonium. This strategy included burning the plutonium as fuel in existing domestic commercial nuclear reactors. In essence, this meant finding a way to convert some of the energy stored in the nation's stockpile of surplus plutonium pits into electrical power for homes and businesses.

Nuclear Swords into Nuclear Plowshares

A pit is the spherically shaped nuclear fuel inside a warhead that, when imploded with high explosives, "triggers" (initiates) a thermonuclear explosion. Because pits are made of plutonium they are much heavier than they look. Plutonium is almost two and a half times denser than iron, so a plutonium pit weighs almost two and a half times more than an iron pit of the same shape and size.

Ironically, plutonium can be destroyed in the same way it was created, through modern alchemy.

The ancient search for a process to artificially convert one element into another—alchemy—became successful in the early twentieth century with the discovery that bombarding some elements with subatomic particles could transmute them into different elements. This discovery made it possible, by 1940, to create plutonium by irradiating uranium-238 (U-238) with neutrons. The uranium nuclei capture the neutrons. The additional neutrons transmute U-238 into plutonium-239 (Pu-239).

A solution to meeting U.S. commitments is to convert plutonium used to trigger thermonuclear weapons into fuel suitable for powering civilian nuclear reactors.

By 1945 the process of making plutonium—through neutron irradiation of U-238 inside a nuclear reactor—had been improved and expanded to an industrial level. In the final months of World War II, reactors at Hanford, Washington, met the Manhattan Project's need for enough plutonium to make the first plutonium-fueled atomic bombs. One was tested successfully (the Trinity experiment) and one was subsequently used on Nagasaki, Japan, to help end World War II.

Before 1945, plutonium was so rare as to be virtually non-existent on Earth. Today, the estimated 2,000 metric tons of plutonium in use or in storage around the world were created in reactors. (The majority of the world's plutonium resides inside spent nuclear reactor fuel that is in storage.)

The B61 nuclear gravity bomb (shown here) is assembled and disassembled at the Pantex Plant in Texas. When older versions of these bombs are retired from the nuclear arsenal, they are disassembled and their plutonium pits, which trigger their nuclear explosion, are removed and stored at Pantex. Plutonium pits are being recovered from thousands of retired nuclear weapons. However, Pantex is rapidly reaching its pit storage capacity. *(Photo: courtesy Department of Defense)*

So if plutonium is created in reactors, can it be destroyed in reactors? The answer is yes. A solution to meeting U.S. commitments is to convert plutonium used to trigger thermonuclear weapons into fuel suitable for civilian nuclear power reactors. Irradiating plutonium with neutrons makes it fission (split apart), which releases enormous quantities of energy, and the energy is used to generate electricity. Through the use of reactors, the energy from completely fissioning one kilogram (2.2 pounds) of Pu-239 could produce enough heat to generate approximately 10 million kilowatt-hours of electricity—enough electricity to power almost 1,000 households for a year. When plutonium is burned as fuel, some of the billions of dollars it cost to produce the plutonium is recovered.

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In a reactor, the irradiation with neutrons can be controlled and kept at a critical level. This makes it possible to control the release of energy and use it for peaceful purposes.

Perhaps best of all, the process of fissioning destroys plutonium by transmuting it into different elements.

And that is exactly what the U.S. government has in mind: a strategy for the destruction of surplus weapons-grade plutonium pits by irradiation with neutrons inside already built domestic commercial reactors.

Where do the surplus plutonium pits come from?

Plenty of Pits

In 1967, at the height of the Cold War, the U.S. stockpile of nuclear weapons was at its maximum of 31,255 weapons. (In contrast, the Soviet Union is reported to have reached its maximum stockpile number—approximately 45,000 nuclear weapons—sometime during the mid-1980s.) The U.S. stockpile included intercontinental ballistic missiles as well as a variety of smaller missiles, gravity bombs, artillery shells, land mines, torpedoes, depth charges, and even miniaturized "backpack" bombs light enough to be carried by a single person.

A combination of factors allowed the United States to begin downsizing its nuclear stockpile after 1967. For example, in the early years of the Cold War, the limited accuracy and range of U.S. missiles and bombers meant more weapons were built, deployed, and aimed at targets to increase the probability of their destruction. But continuing improvements made in the accuracy and range of weapons' delivery

Pantex Plant, located 17 miles northeast of Amarillo, Texas. Pantex workers assembled thousands of weapons during the Cold War. The last new nuclear weapon was completed in 1991. Since then, Pantex has safely dismantled thousands of weapons retired from the stockpile and placed their plutonium pits in interim storage until a solution is found for their permanent disposal. Los Alamos is the only place in the nation capable of disassembling these pits and transforming them into a proliferation-resistant powder for use as nuclear reactor fuel. *(Photo: courtesy Pantex)* systems meant it was possible to reduce the overall numbers of weapons without reducing U.S. defensive capabilities.

Thus, improving nuclear weapon technology played a significant role in reducing the numbers of U.S. nuclear weapons.

A series of Cold War–era arms control agreements dramatically reduced the nation's nuclear stockpile even further. These agreements included the United States and Soviet Union's Strategic Arms Limitation Treaties (SALT I in 1972 and SALT II in 1979) and the Intermediate-Range Nuclear Forces Treaty (1987). By 1991, the stockpile was leaner, but it still contained a substantial 19,000 weapons.

Overall, the result of reducing the size of the U.S. stockpile is breathtaking. Today, the stockpile is only about one quarter of what it was in 1991, down to approximately 5,000 weapons—the lowest level since the late 1950s.

But it was the end of the Cold War—and with it the end of the nuclear arms race—that really allowed the U.S. stockpile numbers to shrink. Since the fall of the Soviet Union in 1991 and the end of the Cold War, the reduction of nonstrategic nuclear weapons has been particularly successful. Through the Bush/Gorbachev 1991 Presidential Nuclear Initiative's political commitments, nearly 90 percent of these so-called "tactical" weapons were removed from the stockpile by 2009. Only a few hundred remain. The Strategic Arms Reduction Treaty (START) in 1991 and the Moscow Treaty in 2001 further reduced the stockpile.

In addition, weapons that are retired because of age and changes in military requirements are not replaced with newly built weapons. Today the average age of a nuclear weapon is about 25 years. The United States has not built a new nuclear weapon since 1991.

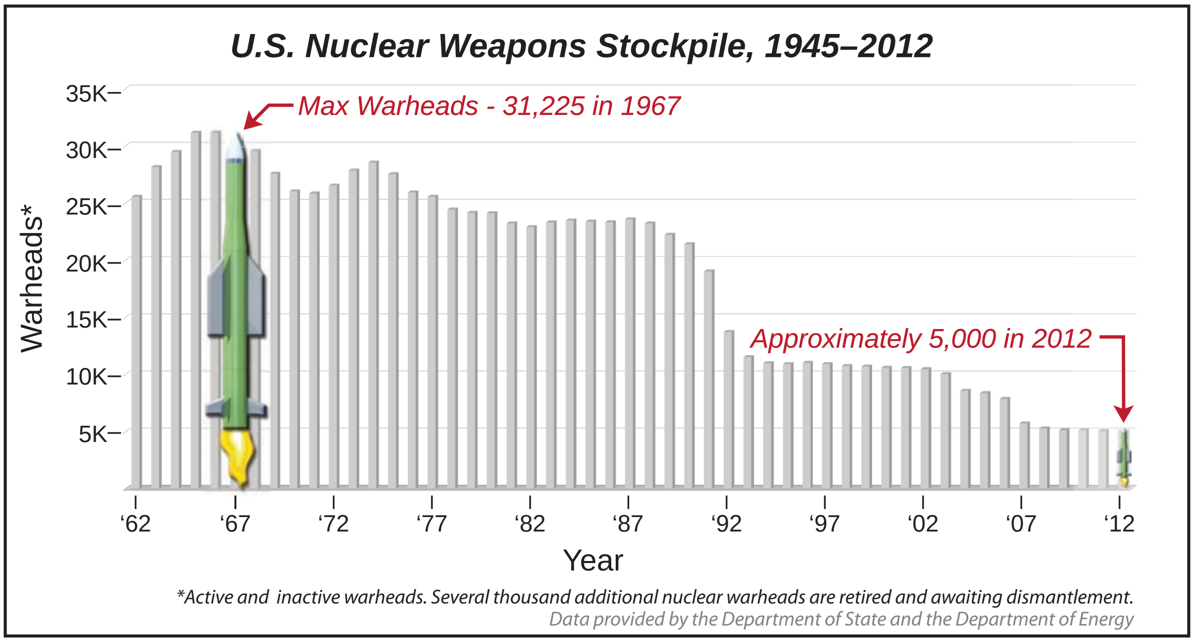
Overall, the result of reducing the size of the U.S. stockpile is breathtaking. Today the stockpile is only about one quarter of what it was in 1991, down to approximately 5,000 weapons—the lowest level since the late 1950s.

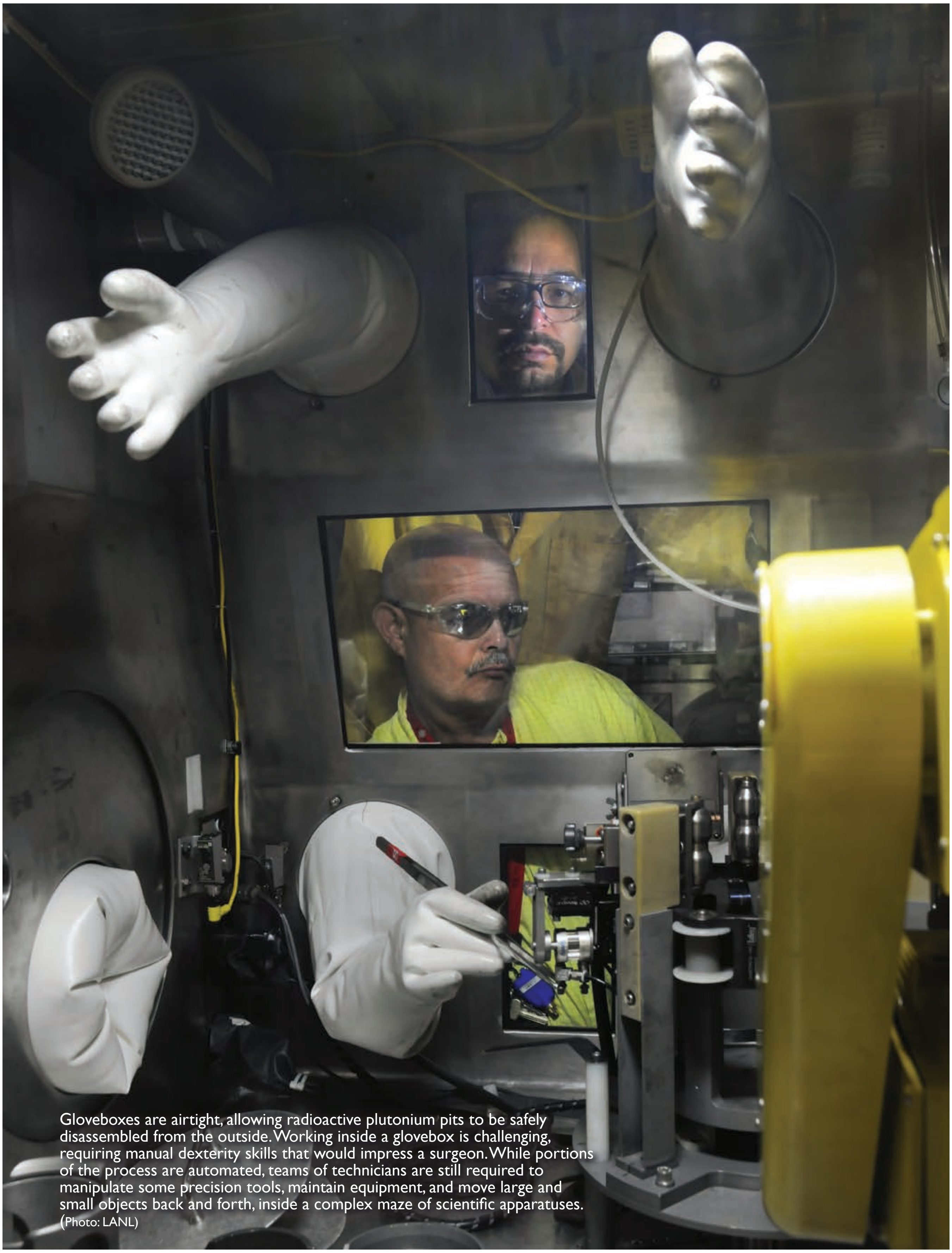
The Pantex Challenge

The Pantex Plant (near Amarillo, Texas) is the DOE facility where all nuclear weapons are assembled. It is also where they are disassembled. The nuclear weapons removed from the stockpile to be dismantled go to Pantex. Although the weapons are disassembled at Pantex, the plutonium pit—one of a weapon's most critical components—remains intact.

Weapons that are retired because of age and changes in military requirements are not replaced with newly built weapons. Today the average age of a nuclear weapon is about 25 years. The United States has not built a new nuclear weapon since 1991.

Pantex is not equipped to handle the special, complex operations required to dispose of these pits or their weapons-grade plutonium. So, safely and securely, it stores the pits. Consequently, the result of years of nuclear weapon dismantlement is a new Cold War legacy: thousands of stored pits awaiting some method of safe, permanent disposal.





Gloveboxes are airtight, allowing radioactive plutonium pits to be safely disassembled from the outside. Working inside a glovebox is challenging, requiring manual dexterity skills that would impress a surgeon. While portions of the process are automated, teams of technicians are still required to manipulate some precision tools, maintain equipment, and move large and small objects back and forth, inside a complex maze of scientific apparatuses. (Photo: LANL)

Meanwhile, the nonproliferation agreements with the Russians regarding permanent disposal of 34 metric tons of surplus weapons-grade plutonium remain unmet.

Pantex is faced with a challenge because it does not have unlimited storage space—it is authorized to store up to 20,000 pits—and the facility is nearing capacity. Yet there are more than 1,000 warheads awaiting disassembly. In addition, the ratified 2011 New START with Russia requires that the number of deployed long-range weapons be cut from some 2,200 down to 1,550. This could mean even more nuclear warheads being dismantled and their pits stored at Pantex. Future arms control treaties may reduce the stockpile numbers even further, making more pits surplus.

Destroying surplus pits and permanently disposing of their plutonium would help meet nonproliferation agreements and make room for additional pits to be stored.

Still more pits could come from the National Nuclear Security Administration's (NNSA's) nuclear weapons Life Extension Programs (LEPs). These programs aim to extend the life of stockpiled weapons, most of which were produced 30 to 40 years ago. National security depends in large part on the nation's nuclear deterrence. Refurbishing these aged weapons is required to assure the nation, its allies, and its adversaries that the weapons remain safe, secure, and reliable. The LEPs will refurbish, reuse, or replace weapon components as necessary. This could include, of course, replacing old plutonium pits with new ones. These old pits could become surplus, too. . .

So destroying surplus pits and permanently disposing of their plutonium would help meet nonproliferation agreements with Russia and make room for additional pits to be stored as more nuclear weapons are retired or refurbished.

Center for All Things Plutonium

But destroying pits and preparing their plutonium for permanent disposal, and doing so safely, is not a simple task—the pits must first be dismantled and their plutonium extracted, then the plutonium has to be converted into a form suitable for burning in a reactor. Plutonium pits have many unique characteristics that make them extremely difficult to handle and dismantle, requiring specialized equipment like airtight and pressurized gloveboxes. Glovebox technicians require highly specialized training. In addition, the extracting and converting of plutonium is a complex set of challenges. The entire process demands a unique set of knowledge, skills, technologies, and facilities for safely doing the work.

Los Alamos National Laboratory is the nation's only "full service" center for understanding and manipulating plutonium. At Los Alamos plutonium science, production, and manufacturing all come together at places like the Chemical and Metallurgy Research facility and the Lab's plutonium processing facilities at Technical Area 55.

The NNSA came to LANL with questions. Could LANL continue destroying pits and converting them to plutonium oxide? Could it do enough of this to help the U. S. meet its agreements with Russia?

Because Los Alamos is the nation's center for all things plutonium, it is the only place in the nation where the people, science, technology, and infrastructure exist for safely destroying surplus plutonium pits and preparing the plutonium to become reactor fuel.

Beginning in 1995, DOE began funding the conceptual and planning work at Los Alamos. The result was ARIES: the Advanced Recovery and Integrated Extraction System.

ARIES

At Los Alamos, ARIES was originally designed as a pilot project, a proof-of-concept that would demonstrate a process for safely and securely disassembling pits and converting their plutonium into plutonium oxide. Plutonium oxide (a compound of plutonium and oxygen in powder form) has properties making it suitable for use as a reactor fuel. In addition, it is more proliferation resistant because the powdered oxide would have to be reprocessed back into plutonium metal to make a pit, requiring a significant and technically sophisticated infrastructure.

LANL is the nation's center for all things plutonium—the only place in the nation to safely destroy plutonium pits and transform them into reactor fuel.

When plutonium oxide is combined with uranium oxide, the resulting mix—mixed-oxide fuel, or MOX—can be used to fuel current U.S. nuclear reactors. MOX fuel has been burned successfully in reactors in Europe, Japan, Russia, and elsewhere.

So the idea was to perfect ARIES at Los Alamos, eventually making it automated, for example, heavily reliant on robotics, to increase cost effectiveness and worker safety.

ARIES technology would then be transferred to the Pit Disassembly and Conversion Facility (PDCF) planned for construction at DOE's Savannah River Site, in South Carolina. At that facility, ARIES would be used to dispose of the nation's surplus pits on an industrial scale. The proliferation-resistant plutonium oxide would be mixed with uranium oxide to make MOX fuel at the MOX Fuel Fabrication Facility (MFFF), also at DOE's Savannah River Site.

ARIES has destroyed every surplus pit type and converted the plutonium into MOX-ready plutonium oxide, which was successfully burned in the Catawba nuclear reactor in South Carolina in 2005.

ARIES has been successful. "LANL proved there was a safe way to dispose of the nation's plutonium pits and convert them into material suitable for MOX fuel," says Kane Fisher, an ARIES manager. The program has been able to destroy every pit type in the inactive stockpile and convert the plutonium into MOX-ready plutonium oxide. That plutonium oxide was successfully used in making MOX, which in turn was successfully burned in the Catawba nuclear reactor in South Carolina in 2005.

Then, after more than a dozen years of research and development, "In 2011, ARIES destroyed enough pits to produce more than 240 kilograms of plutonium oxide," says Fisher.

The challenge of how to safely transform plutonium pits into reactor fuel was met. But other challenges loomed.

Overcoming Pitfalls

First and foremost, due in large measure to the nation's current budgetary challenges, construction of the PDCF, estimated to eventually cost several billion dollars, was cancelled in 2011.

The target for fiscal year 2014 is 300 kilograms: doubling the production target of 2012. At 300 kilograms a year, by 2018, Los Alamos will have destroyed two metric tons of plutonium pits.

As a result, the NNSA came to LANL with questions. Could Los Alamos continue destroying pits and converting them to plutonium oxide? Could it do enough of this to help the United States meet its agreements with Russia?

"Our initial scope was to develop the process for destroying pits to meet our international agreements. With the cancellation of the PDCF, the ARIES process at LANL now becomes a key player for this important nonproliferation activity," says Alex Enriquez, also an ARIES manager. "If requested by the NNSA to move from a process development to a production mission, we stand ready to serve. We can do it. Not as fast, of course, nor on the scale of a large, dedicated facility, but our process works."

Hence, another 150 kilograms of plutonium oxide were targeted for production in fiscal year 2012. The ARIES team surpassed that target by producing over 200 kilograms. The target for fiscal year 2014 is 300 kilograms, doubling the production target of 2012. At 300 kilograms a year, Los Alamos will have destroyed two metric tons of plutonium pits by 2018 and shipped the proliferation-resistant plutonium oxide to MFFF.

Like a Chili Roaster

How does Los Alamos destroy a pit?

"Very carefully," says Steven McKee, another ARIES manager. "It's taken years of research and development to come up with the ARIES process, in part because each type of pit presents its own challenges due to its size, shape, weight, and other characteristics. And the entire process has to be done inside a series of connected gloveboxes that keep pits safely isolated from the disassembly technicians."

Inside the furnace is a rotating perforated drum containing the pieces of plutonium. It works like a typical New Mexican green chili roaster.

Gloveboxes are airtight steel containers with windows that allow radioactive materials to be safely manipulated from the outside. Highly skilled technicians insert their forearms and hands, covered by lead-lined gloves, into the glovebox. Working inside a glovebox is challenging, requiring manual dexterity skills that would impress a surgeon. While portions of the process are automated, teams of technicians are still required to manipulate some precision tools, maintain equipment, and move large and small objects back and forth, inside a complex maze of scientific apparatuses.

To oversimplify, the pits are cut in two inside the gloveboxes using an automated, custom-made mill and lathe, along with custom cutting tools. A vacuum system located directly below the cutting area collects all the lathe turnings and cutting chips. This part of the process is important because the Laboratory must account for the total plutonium mass of a pit. The mass is determined before the pit enters ARIES, and the total mass of the pit's separate components, including any turnings and chip waste, is determined again at the end of the process. The two masses have to match exactly. All of the pit's plutonium is thereby accounted for.

Accounting for all of the pit's original mass continues throughout the process, including after it has been converted into plutonium oxide and is ready for shipment to the Savannah River Site.

Following dismantling, the pit's plutonium parts and pieces are made to…well…rust, rapidly oxidize into plutonium oxide by being cooked inside a custom furnace. Plutonium oxidizes spontaneously, but as the temperature increases, the oxidation rate increases exponentially.

"Inside the furnace is a rotating perforated drum containing the pieces of plutonium. It works like a typical New Mexican green chili roaster," says manager Elizabeth Bluhm.

The surplus pits from the nation's Cold War deterrence can now be transformed—from being nuclear weapons triggers into a clean energy source for the nation.

What is a chili roaster? Across New Mexico, beginning in mid-July, at farmers' markets, in grocery store parking lots, at roadside stands, in parks, and at backyard cookouts, the air is regularly filled with the smoky smell of fire-roasting fresh green chilies. The chilies are loaded into a horizontally mounted drum made of heavy wire mesh and the drum then rotated over an intense heat source. This method allows the tumbling chilies to be roasted evenly on all sides, and quickly, too, because it presents the most surface area of the chilies to the greatest amount of heat in the shortest time. The roasting process is thorough and efficient.

There is no proof that ARIES scientists got the idea of oxidizing pit plutonium by watching green chili roasts in the summertime. But the principle is the same.

Clean Energy

After oxidation, the plutonium compound is ground into a powder. The powder is sealed inside a special stainless steel container suitable for long-term storage. To meet the Department of Transportation's demanding safety and security requirements for shipping plutonium oxide, the first container is then sealed inside a second stainless steel container, which is then sealed inside a third stainless steel container.

After a final decontamination check and the completion of an audit confirming the nature of the containers' contents, the plutonium oxide is ready for shipment to MFFF, where it will be blended with uranium oxide.

Because of the years of effort by the ARIES team working at Los Alamos' unique plutonium facilities, the surplus pits from the nation's Cold War deterrence can now be transformed—from being nuclear weapons triggers to serving as a clean energy source for the nation.

–Clay Dillingham

For more information about ARIES visit ***arq.lanl.gov/source/orgs/nmt/nmtdo/AQarchive/1st_2ndQuarter08/***

Plutonium pits are transformed into plutonium oxide powder by roasting them in a way similar to roasting green chili, shown here. *(Photo: LANL)*

PROTECTING PEOPLE & PLUTONIUM

Los Alamos' Security Professionals MEAN BUSINESS

Under the cover of darkness, around 2:30 in the morning on July 28 of this year, three nuclear weapons protestors, wearing backpacks and carrying bolt cutters, evaded armed guards, electronic security systems, and cameras; cut through layers of fences; and then vandalized the nation's Highly Enriched Uranium Materials Facility (HEUMF)**;** the high-security fortress-like structure that stores the nation's stockpile of bomb-grade uranium. HEUMF is at the Oak Ridge National Laboratory's Y-12 National Security Complex in Tennessee**.**

By their own account, it took the protestors close to two hours to navigate through Y-12's defenses. Their journey took them inside a zone where the use of deadly force is authorized, meaning they could be shot on sight. They used flashlights. No one saw them.

Upon reaching HEUMF, the protestors splashed the outside walls with human blood, spray painted religious messages, tied red crime scene tape between concrete pillars, and using a small sledgehammer, succeeded in chipping away at the building's concrete. Eventually confronted by a guard, the protestors—two men (ages 63 and 57) and a nun (age 82), were stopped and arrested.

What if they had been terrorists armed with explosives instead of protestors armed with slogans?

As Secretary of Energy Steven Chu noted in a September 18 speech to the International Atomic Energy Agency, "This unfortunate incident was an important wake up call for our entire complex and an important reminder that none of us can afford anything but the highest level of vigilance."

According to one of the protestors, they initially considered three sites as possible targets: Y-12, Los Alamos National Laboratory, and the Kansas City Plant in Missouri. In fact, in 2010, during a protest at Los Alamos, the nun, Sister Megan Rice, was arrested for criminal trespass.

Could an incident similar to the one at Y-12 happen at Los Alamos National Laboratory?

What if they had been terrorists armed with explosives instead of protestors armed with slogans?

"No," says Michael Lansing, associate director for security and safeguards at Los Alamos. "This year the Lab has had *four* reviews of its security-related policies and procedures and their implementations. Three of these were in the wake of Y-12 to determine if the Lab was similarly vulnerable. What did they find? They each found that we *don't* have the problems with security that were found at Y-12."

Lansing continues, "That said, we don't take anything for granted. We work very hard every day to ensure all our security systems are fully operational. Furthermore, we readily adapt our security program to match any changes in those threats. We also make sure our professionals understand the

fluid nature of the threats we face and train them accordingly. In short, we have the best security professionals in the business. And they *mean* business. No one should try to pull a stunt here like the one pulled at Y-12."

"The security personnel at Los Alamos are not 'rent-a-cops,'" says Jack Killeen, the division leader for physical security. "They're professionals—many are ex-military, like Marines and Special Forces. Because electronic security systems can fail, we rely on our people first and foremost."

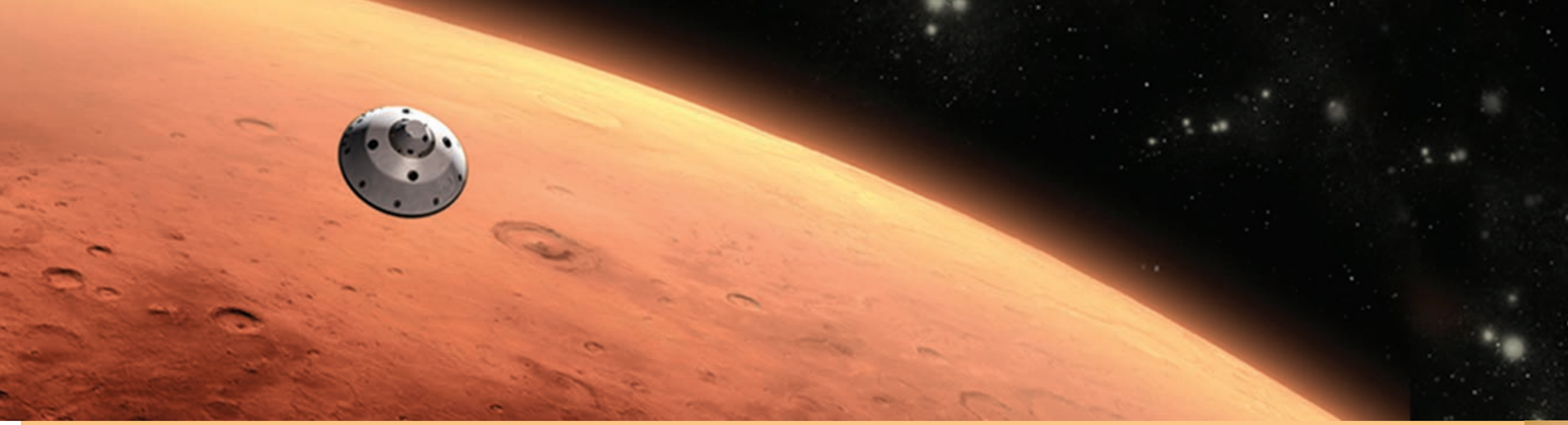
He continues, "When it comes to protecting Lab personnel, the nuclear materials they steward, and their facilities, nobody can do it better."

Because the Laboratory also has facilities and other properties that are accessible to the public, in these more open areas, Los Alamos has not been immune to acts of civil disobedience and protest in the past. But at the secured facilities, the Lab cannot and will not tolerate unauthorized incursions.

"We'll do whatever it takes to protect Lab personnel, the nuclear materials they steward, and their facilities," says Dominic Browning, a lieutenant colonel in the Lab's protective forces. "Even if it means using deadly force. That's not our preferred option, of course. But neither protestors nor terrorists will get close to the plutonium at this laboratory."

Watch Los Alamos' security professionals training at ***youtube.com/watch?v=t5dQy3PXWBIfeature=plcp***.

(Opposite) Patrolling the Lab 24/7 are armored vehicles like this BearCat, armed here with a multibarrel machine gun capable of firing 3,000 rounds per minute. (Above) Entrances to TA-55, LANL's plutonium science and engineering facility, are protected by guards, guns, gates, and working dogs. (Bottom left) Security personnel regularly train using both lethal and nonlethal tactics. (Bottom right) The Lab uses unmanned air vehicles—drones—like the 58-inch-long helicopter shown here, for surveillance. *(Photos: LANL)*



LANL TECHNOLOGY GOES TO MARS

The Mars Space Laboratory, a space probe, landed a rover named Curiosity on Mars on August 6 of this year. Armed with scientific instruments, Curiosity will roam the Red Planet for one Martian year (23 months), investigating the planet's environment. Scientists hope to learn whether Mars has or ever had conditions that could support microbial life.

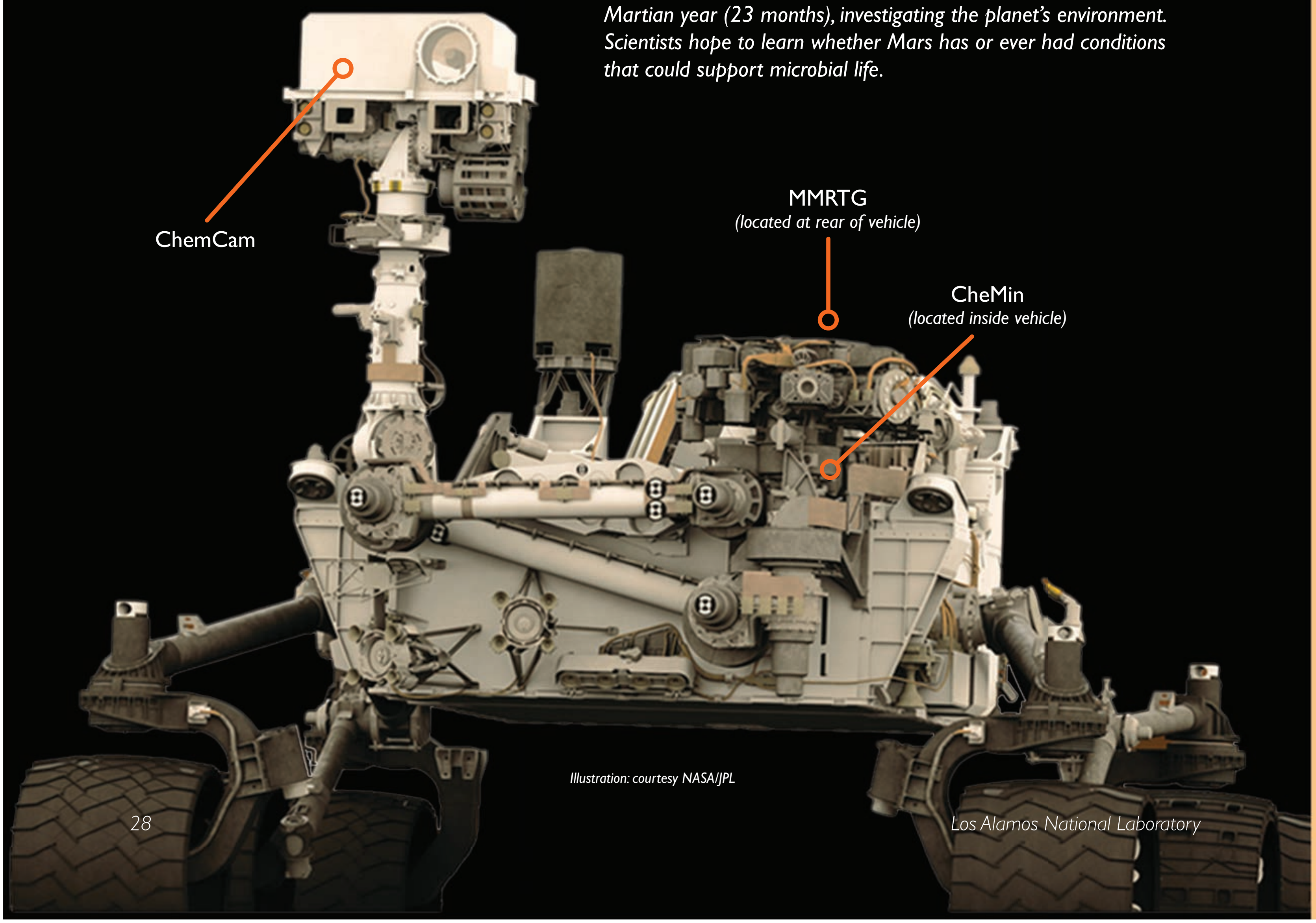


Illustration: courtesy NASA/JPL

The Curiosity rover's power source and two of its scientific instruments are products of Los Alamos National Laboratory and its collaborators.

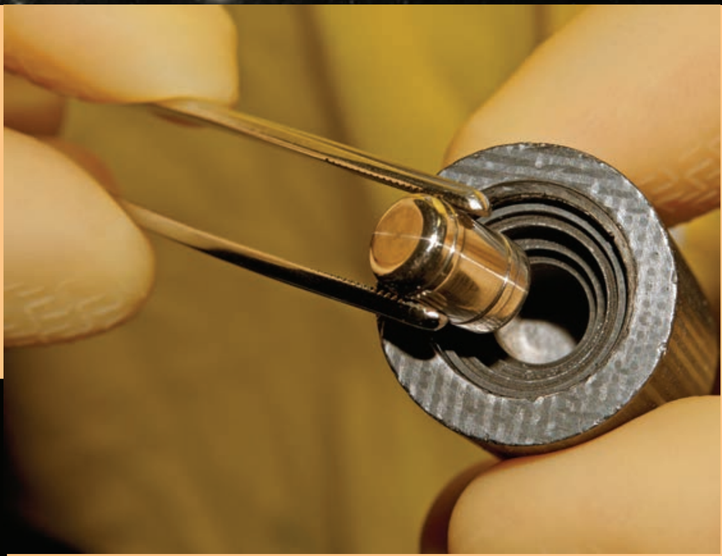


Photo: LANL

MMRTG

Multi-mission Radioisotope Thermoelectric Generator

An MMRTG, a nuclear battery, powers Curiosity and warms its instruments at night. The power source is a plutonium-238 (Pu-238) oxide in the form of 32 pellets like the one at left. The radioactive Pu-238 decays, releasing heat that is converted into electricity.

RTGs are the byproduct of LANL's work with nuclear weapons and its expertise in plutonium science, which NNSA declares has made Los Alamos the "center of plutonium excellence for the nation." NASA has used RTGs for more than 30 years, sending them, for example, on the Cassini mission to Saturn and the New Horizons mission to Pluto.

On October 4 of this year, the Los Alamos team that worked on the MMRTG—David Armstrong, Alejandro Enriquez, John Matonic, Diane Spengler, and Craig Van Pelt—received the Secretary of Energy's Achievement Award for contributions to the Mars Science Laboratory mission. The Achievement Award is one of the Secretary's suite of Honor Awards, called the DOE "Academy Awards."

ChemCam

Chemistry and Camera

The ChemCam instrument, developed with the French Space Institute, uses a laser to vaporize a pinhead-size area of rock or soil. A telescope on Curiosity's mast delivers the spectrum (colors) of light from the resulting flash to a spectrometer inside the rover so scientists can determine the sample's elemental composition. ChemCam can quickly survey portions of the Martian environment, setting the stage for Curiosity's robotic arm to gather physical samples from the most desirable locations displaying the most intriguing features. The laser can also reach otherwise inaccessible targets up to 23 feet away and on high vertical surfaces.

Illustration: courtesy NASA/JPL

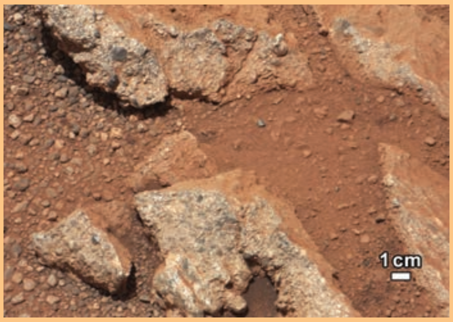


Photo: courtesy NASA/JPL

CheMin

Chemistry and Mineralogy

CheMin uses a combination of x-ray diffraction and x-ray fluorescence to determine the mineral content of soil and powdered rock samples delivered to it by Curiosity's robotic arm. The rover itself powders the rocks with a drill. Because different minerals form under different conditions, they are a record of the planet's environmental history. CheMin's analyses will help scientists study the role of water in the formation of Mars' minerals, for example, by distinguishing between minerals that do or do not contain water in their crystal structure.

For more information about all LANL Mars instruments, see ***lanl.gov/science-innovation/science-features/mars-rover-powered-lanl-technology.php***

For more information on ChemCam, see ***youtube.com/playlist?list=PL2F22B804DDA5ED44***

Why the Nuclear Stockpile Is Still Relevant

~ NSS Interviews Brigadier General Sandra Finan

Air Force Brigadier General Sandra Finan paid LANL a return visit in June of this year. Finan assists the Deputy Administrator for Defense Programs, National Nuclear Security Administration (NNSA), in directing the Stockpile Stewardship Program. This program is responsible for maintaining the safety, security, and reliability of the nation's nuclear deterrent.

Finan also oversees the NNSA's Military Academy Collaboration (MAC) program. The MAC program gives top cadets and midshipmen at the U.S. military academies (West Point, Army; Annapolis, Navy; Colorado Springs, Air Force; Kings Point, Merchant Marine; and New London, Coast Guard) the opportunity to do a summer internship at LANL in the Lab's Service Academy Research Associates (SARA) program. (Internships are also available at other NNSA sites.) This summer's SARA program hosted 17 interns: 1 Army cadet and 16 Navy midshipmen.

During her visit, Finan received updates on the Laboratory's weapons programs, toured key facilities, and met with the interns to get a first-hand understanding of how the program was working.

National Security Science (*NSS*) interviewed Finan. The interview has been condensed and edited.

NSS: What would you like to tell our readers?

Finan: My main message is that the nuclear deterrent is still relevant to national security. While additional reductions to the nuclear stockpile are possible, they must be done thoughtfully and judiciously and be based on current and anticipated threats—because if we keep cutting it, it can get so small that it's not going to be a deterrent.

Also, the nation needs to take action today—to invest in the science and technology that ensure the nuclear deterrent is safe, secure, and effective now and into the future. The work Los Alamos performs is essential to that endeavor.

NSS: Why do you think some folks don't believe the nuclear stockpile is still relevant?

Reductions to the nuclear stockpile are possible, but if we keep cutting it, it's not going to be a deterrent.

Finan: Primarily it's the absence of the threat of the Soviet Union and the rise of terrorist threats. Terrorists probably wouldn't be deterred by the threat of U.S. nuclear weapons. There's a thought that our biggest threats today are really not from a nuclear exchange but from the "suitcase bomb" scenario, or from terrorists getting their hands on nuclear materials to make a dirty bomb.

Of course, while terrorists might not be deterred by the threat of U.S. nuclear weapons, nation states that might aid terrorist organizations can be deterred.

And something that many people don't see is that our nuclear deterrent really is about world nuclear stability. You want your deterrent force to create that stability. Right now, the United States is committed to using its "nuclear umbrella" to protect dozens of allies from attack, allies like Japan and South Korea, which are fearful about North Korea and its nuclear weapons program. The United States' decades-old commitments reduce the incentive for other countries to develop their own nuclear deterrent.

As the United States reduces the number of its nuclear weapons, some of our allies may see the nuclear umbrella shrinking to the point that they no longer feel protected. Even if we say we can still protect them, these allies might not believe it. These allies' perceptions and beliefs are important—it's not what we say that counts, it's what they believe. And our allies are also concerned about the reliability of aging U.S. nuclear weapons.

Without the United States openly testing its weapons so our allies see that they still work reliably and effectively, we need to show strong scientific and technological efforts to keep the weapons operational, as well as keeping adequate funding for those efforts.

Again, perceptions and beliefs are critical. If there's diminishing faith in the reliability and effectiveness of our smaller nuclear arsenal, more nations may feel compelled to create their own deterrent—their own nuclear weapons programs.

NSS: Wouldn't that be an enormous undertaking for most nations?

Finan: Yes. But many U.S. allies have the capability to develop their own nuclear weapons programs, and some could do so very rapidly.

Ironically, by continuing to reduce its stockpile while not investing enough in the science and technology required to demonstrate that the remaining stockpile is good to go, the United States could be increasing the nuclear risk around the world rather than reducing it. The result could be many more nations developing and fielding nuclear weapons.

In addition, allies who become nuclear powers for fear of being unprotected could someday, for any number of reasons, become U.S. competitors. In that scenario, these ex-allies could then become incentivized to build increasing numbers of nuclear weapons to compete with the U.S. stockpile. So again, reducing the size of the U.S. deterrent could result in a world with far more rather than fewer nuclear weapons.

Many U.S. allies have the capability to develop their own nuclear weapons—some very rapidly.

As the United States contemplates reducing its nuclear deterrent, and as it debates funding the Stockpile Stewardship Program, all the risks and possibilities need to be analyzed. What stockpile numbers are the "best" is up for debate, and the debate should be about not just what we need for deterrence but also what we need to help stop the spread of nuclear weapons.

This is why I say the U.S. nuclear deterrent isn't just about preventing an attack, it's much broader: it's about maintaining world nuclear stability.

NSS: Let's turn to the MAC program. What are that program's goals and objectives?

Finan: The number one goal is to create future leaders—and not just for the military because many have new careers, including in politics, after they leave the service. These kinds of leaders need to understand what goes on at the U.S. nuclear science labs. They need to understand all they can about the technology of the nuclear deterrent force, as well as the concepts behind nuclear deterrence. But they also need to know that labs like Los Alamos, in addition to working on nuclear weapons, solve all kinds of problems like those in energy security, prevention of terrorism, climate change. Leaders in public service need to know they can come to the labs to get the answers they need to meet lots of different challenges.

So by involving our cadets and midshipmen—our future leaders—in the MAC program, we give them a very early exposure to all that the labs can do, as well as to the importance of nuclear deterrence.

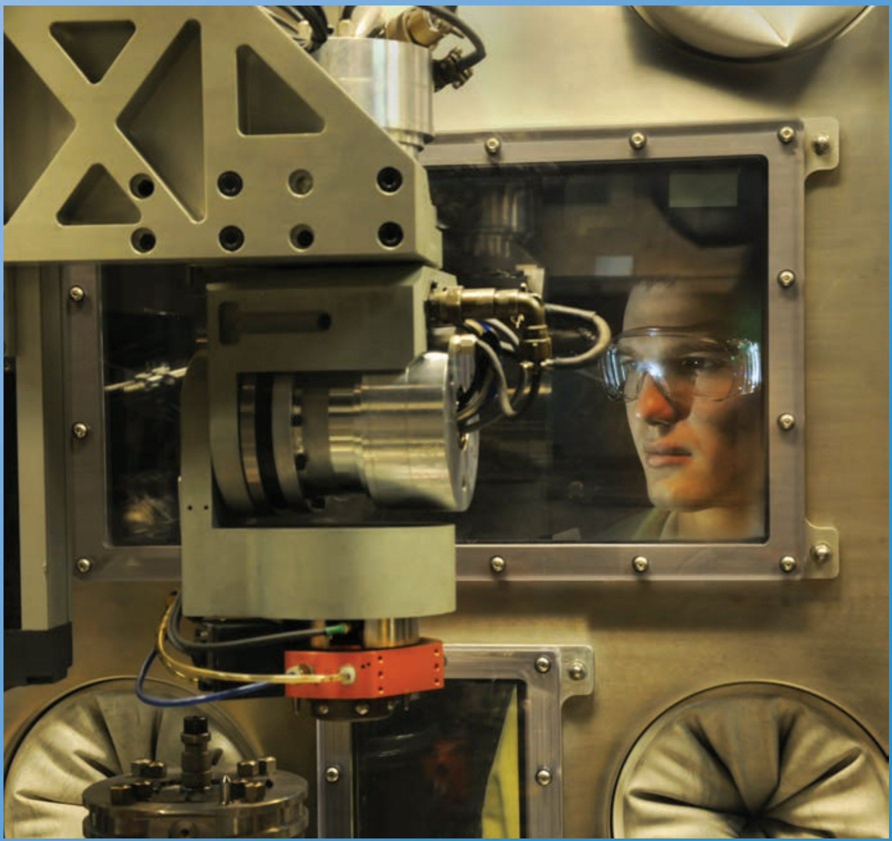
We've got to keep the "leadership pipeline" full with talented people who know where to turn to find answers. They're our future.

NSS: The Lab spends a lot of time looking over student applications for the SARA program and making sure there's a good fit between what they do here and what their interests and academic goals are. This year's interns worked in fields as diverse as computational physics, high-explosives science, and civilian nuclear science.

Finan: It's certainly more than a little bit outside the normal military cadet experience! The SARA cadets get an opportunity to experience and contribute to ongoing scientific and weapons activities at the Lab. It's real work with important consequences. One of them may come up with an idea that changes how we do military operations. And the seed of that idea will have been planted at Los Alamos.

NSS: What would you use as a measure of success for the MAC program here?

Finan: I think that we've accomplished our mission when we build leaders who understand and appreciate the breadth of science, technology, and engineering enterprises at Los Alamos. We want them to be able to speak about the incredible work that's done here to support not only the nuclear deterrent but so many other national security needs as well.



Micah Dose, a midshipman at the U.S. Naval Academy and a SARA intern in the Laboratory's ARIES program, peers inside the glovebox where plutonium pits are disassembled at Los Alamos. ARIES is the only program in the nation that disassembles and destroys surplus plutonium pits. The pits are transformed into plutonium oxide powder suitable for being made into fuel for civilian nuclear reactors. *(Photo: LANL)*

Director Charles McMillan and Colonel Paul W. Tibbets IV, commander of the AFIA exchange "challenge" coins representing their organizations. *(Photo: LANL)*

Honing the Nuclear Sword

The Air Force and LANL Keeping Each Other Sharp

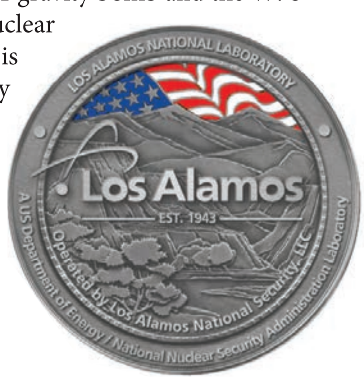
The end of the Cold War, in 1991, brought much relief to a world economically and psychologically exhausted from more than four decades of nuclear tensions and proxy wars between the United States and the Soviet Union.

One unforeseen consequence, however, of being able to somewhat "stand down" became readily apparent in 2006 and again in 2007. As the clear and present danger of the Soviet Union diminished, so too did the Air Force's usually razor-sharp focus on duty and detail regarding one prime mission: to steward, maintain, and operate its portion of the nation's nuclear deterrent.

In 2006, the Air Force mistakenly shipped four nonnuclear nose cone assemblies for intercontinental ballistic missiles (ICBMs), with the cones' associated electrical components, to Taiwan. Then in 2007, a B-52 bomber based at Minot Air Force Base (AFB) in North Dakota was unwittingly flown to Barksdale AFB in Louisiana with six cruise missiles onboard—armed with nuclear warheads. Referred to with black humor as "the unfortunate flight," this event in particular awoke Air Force leadership to the fact that the Air Force had been, well, napping while on guard duty.

The Air Force's response was swift and wide-ranging, and it is ongoing. To prevent a "culture of complacency" from ever developing again, the Air Force continues to seek out new and better ways to improve its vigilance and operations.

For example, in April of this year representatives from the Air Force Inspection Agency (AFIA), based at Kirkland AFB in Albuquerque, New Mexico, visited Los Alamos National Laboratory for the purpose of improving the Air Force's partnership with LANL regarding nuclear weapons. Los Alamos designed and developed the B61 gravity bomb and the W78 warhead used in ICBMs, the nuclear weapons systems the Air Force is charged with safely and securely overseeing—and operating if need be. AFIA, which reports to the Secretary of the Air Force Inspector General, is the primary tool used by the Air Force to inspect and assess what the Air Force calls



the "nuclear surety" of its piece of the nation's "nuclear enterprise."

"The Air Force is transforming its entire nuclear inspection system—our system of nuclear surety—as part of continuing to strengthen the nuclear weapons enterprise," says Colonel Paul W. Tibbets IV, commander of AFIA. "By better understanding what transpires at the beginning of the enterprise—the science and engineering that goes into making nuclear weapons, which is LANL's contribution—the Air Force is better able to do its job, which encompasses the end of that enterprise."

Tibbets continues, "Dealing with nuclear weapons is a unique and special duty that must be performed with exceptional care. Our airmen never take for granted the knowledge and skills required to properly maintain and employ these weapons or understand what makes them tick. Having a strong sense of pride in our history and military capabilities instills excellence in our work. With the knowledge gained through our partnerships, like with LANL, we can advance our tactics, techniques, and procedures in the spirit of being stronger, better, and more effective."

"There are a wide variety of technical experts assigned to AFIA," he adds. "Sharing information and learning from each other is in everyone's best interest. Perspectives gained through collaboration expand each person's toolkit, and learning is multiplied when aircrews, ICBM launch officers, technicians, and inspectors share knowledge with their friends and colleagues in the course of doing business."

In addition to rebuilding the entire nuclear inspection system and conducting nuclear inspections, AFIA is responsible for training all Air Force nuclear surety inspectors and conducting its periodic audits. The LANL visit gave the AFIA team the opportunity to learn about new science and technology that will be of value in conducting nuclear surety inspections and training inspectors.

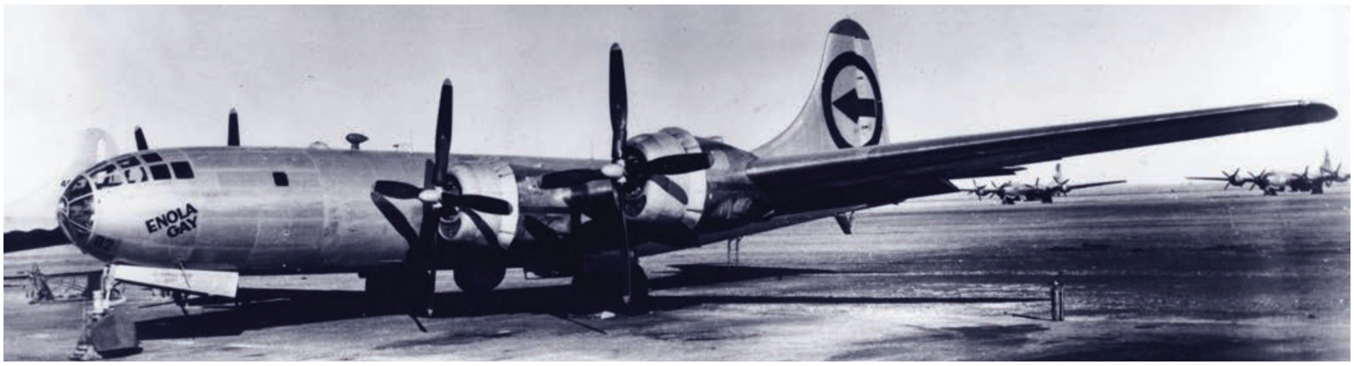
LANL's role in the nuclear weapons Stockpile Stewardship Program (SSP) is to advance the science and technology needed to keep weapons systems operating reliably into the future. It is important for the Air Force to understand how projects and activities managed by LANL may affect what its operators do and how surety inspections may need to flex to better support the SSP. It is a give-and-take relationship with information that flows both ways.

"We have the opportunity to tell scientists and engineers at LANL what we'd like to see changed on weapons systems to make it easier for airmen out in the field who have to maintain and operate them. We want the LANL folks to think about things like the ergonomics that pertain to the movement, operation, and maintenance of LANL's weapons systems," says Tibbets.

The Air Force needs the Laboratory to help it stay sharp. But it's a two-edged sword. As iron sharpens iron, so we sharpen each other. The Lab needs us to help it retain its edge, too.

For example, Los Alamos staff regularly use computers when designing and engineering weapons systems. While some of the weapon's characteristics make perfect sense on a computer, from a physics design or engineering perspective, the weapon's deployment can raise real-world, unanticipated difficulties. "Our inspectors watch the technicians while they work on these weapons systems. What the AFIA team brings to the Laboratory is eye opening. We help the designers and engineers see the challenges a 19- or 20-year-old airman may face when operating or maintaining the actual weapon inside a cramped missile silo or in the bomb bay of a nuclear-capable bomber, when it's 20 degrees below or 115 degrees above zero."

"When it comes to stewarding our nuclear weapons, the Air Force needs the Laboratory to help it stay sharp. But it's a two-edged sword," Tibbets says. "As iron sharpens iron, so LANL and AFIA can sharpen each other. The Lab needs us to help it retain its edge too."



Colonel Paul W. Tibbets IV is the grandson of Colonel Paul W. Tibbets Jr., who piloted the *Enola Gay* and dropped the first atomic bomb, Little Boy, on Hiroshima, Japan, in 1945. *(Photo: LANL)*

LANL's Military Academy Interns Visit Minot AFB

An Air Force sergeant inspects a Minuteman III inside a silo. LANL designed and developed the W78 nuclear warhead used in the Minuteman III missiles, which are deployed at Minot and other ICBM bases overseen by the Air Force. *(Photo: U. S. Air Force)*

Los Alamos thanks the men and women of the U.S. Air Force's 91st Missile Wing and the 5th Bomb Wing, stationed at Minot Air Force Base (AFB), in North Dakota, for hosting a visit by LANL's military academy interns.

In June of this year, seven midshipmen from the U.S. Naval Academy, who were interning at LANL during the summer as part of the National Nuclear Security Administration's Military Academy Collaboration (MAC) program, traveled to Minot with their LANL sponsors. At Minot the midshipmen were given the opportunity to witness, firsthand, how the Air Force maintains and operates two critical component of the nation's nuclear deterrent—the intercontinental ballistic missiles (ICBMs) and strategic bombers that deliver nuclear weapons.

LANL designed and developed the W78 nuclear warhead, which is used in the Minuteman III ICBM. LANL also designed and developed the B61 nuclear gravity bomb, which can be dropped by a variety of strategic aircraft, including the B-52 Stratofortress.

The midshipmen witnessed day-to-day operations in support of ICBM activities, including training and maintenance activities, and the security response capabilities that ensure safe and secure operations. The midshipmen also participated in one of the daily predeparture briefings, which bring together command staff with the security and maintenance personnel scheduled to stand alert in the missile fields. These briefings are a critical tool used by the Air Force to ensure that the highest level of rigor and discipline is applied to all aspects of ICBM operations.

In addition, the midshipmen witnessed how Minot's personnel would man and deploy the ICBMs in the event of a presidential decision to launch the missiles. "We wanted the Navy's midshipmen to understand the professionalism and precision with which the Air Force executes its part of the nation's nuclear deterrence," says Jon Ventura, LANL's MAC program advisor. "Both branches of the military have tremendous responsibilities for the deterrent. This gives the Navy's future leaders the opportunity to better appreciate the role of the Air Force in their national security partnership."

A B-52H Stratofortress lands, using a parachute to rapidly decelerate, after taking part in an annual "rapid launch exercise" at Minot Air Force Base. The exercise trains Air Force units to rapidly respond to a military attack against the United States. *(Photo: U.S. Air Force)*

The invitees to the international 2012 Strategic Weapons in the 21st Century Conference were given the opportunity to confer with the leaders of the U.S. nuclear weapons complex. Shown left to right are co-hosts Parney Albright (Director, LLNL) and Charles McMillan (Director, LANL), along with General Robert Kehler (Commander, USSTRATCOM) and Don Cook (Deputy Administrator, NNSA Defense Programs). *(Photo: LANL)*

LANL Co-Hosts Strategic Weapons Conference

The international security environment continues to evolve in the face of the the world's complexity and fluidity. In that dynamic atmosphere, concerns regarding nuclear energy, nuclear proliferation, terrorism, and nuclear weapons policy continue to pose serious challenges, which senior government officials and academicians from the United States and other countries discuss, debate, and deliberate at the annual Strategic Weapons in the 21st Century Conference (SW21).

Participants in each year's conference engage in an ongoing, in-depth dialogue on topics related to the role of strategic weapons in national and international security, with special attention to the interface between technology and policy. Specifically, the SW21 enables the exchange of national and international perspectives on the deterrence policies and postures of the United States and other states in a complex, changing, and fiscally challenged world.

The sixth annual SW21 was held on January 26 of this year in Washington, D.C. This year's conference included representatives from Congress; the departments of State, Energy, and Defense; U.S. nuclear weapons laboratories; the United Kingdom's Atomic Weapons Establishment; NATO; and the United Nations Security Council's five permanent members, the so-called P5—the United States, Russia, China, the United Kingdom, and France.

The conference focused on three particular areas: assuring U.S. allies of the continuation of extended deterrence (protection of allies under the United States' "nuclear umbrella"), enhancing security and stability through the P5, and implementing the 2010 U.S. Nuclear Posture Review (NPR) in a fiscally constrained environment.

First, as rearticulated within the 2010 NPR, the United States remains committed to its extended nuclear deterrence and is working to assure its allies of this commitment. However, some participants raised concerns about the ability of the United States to meet such obligations while also reducing stockpile numbers, especially within declining budgets. In this context, it was emphasized that the United States is meeting the challenge of those obligations and that the U.S. nuclear stockpile remains safe, secure, and effective. Additionally, discussions addressed the way in which the role and posture of U.S. nuclear (and other) capabilities differ around the globe, reflecting different regional security challenges, with concomitant challenges to the United States' provision of extended deterrence and assurance.

Second, participants considered the need to increase cooperation among members of the P5. The P5 states have different self-interests and security policy perspectives, and those differences pose challenges to increased cooperation. As a result, dialogue among these states is widely recognized as critical to future international stability. Persuading P5 members to allow transparency with regard to nuclear issues is seen as especially challenging. For example, there is considerable U.S. interest in promoting transparency on the part of Russia and China about their nuclear weapons and production facilities. Such transparency is necessary for strategic stability dialogues. Yet the Russians and Chinese hesitate to seriously engage in these arenas.

Current nuclear budget shortfalls facing the United States might undercut NPR implementation.

Third, the SW21 addressed the challenges facing the U.S. government: needing to reach a national, bipartisan consensus on nuclear weapons and deterrence policy; determining if out-year budgets will allow that policy's objectives to be met; and performing the technical work essential for implementing the NPR.

Together, the NPR, the annual updates specified in Section 1251 of the National Defense Authorization Act for fiscal year 2010, and the New START treaty provide the basis of current U.S. nuclear policy. Discussions during the SW21 highlighted the extreme fragility of that policy. There was limited consensus among SW21 attendees about what the fundamental requirements are for sustaining the deterrent and modernizing its supporting infrastructure and about what activities should be pursued to reduce nuclear dangers.

Participants pointed out that the U.S. nuclear stockpile and its critical infrastructure have deteriorated since the end of the Cold War. There was considerable support, therefore, for the NPR's call for maintaining a sound Stockpile Stewardship Program, extending the lifespan of U.S. nuclear weapons, and modernizing the supporting infrastructure. Meeting these objectives would help to ensure that future defense requirements can be met. In addition, this approach would provide an opportunity for enhancing the safety of weapons systems by, for example, using modern insensitive high explosives in warheads. Insensitive high explosives can withstand insults like fire and shock and so are less likely to explode because of an accident, such as a plane crash.

The NPR initially led to increased Department of Energy budgets for policy implementation. However, it was noted that current nuclear budget shortfalls facing the United States might undercut NPR implementation. There were also major concerns that the budget shortfalls would force essential National Nuclear Security Administration mission programs to compete for available funds. For example, some participants suggested there might be a shift of resources away from science, technology, and engineering and to the Life Extension Program (LEP) for the nuclear stockpile's aging weapons.

Some participants noted that although the Defense Strategic Guidance (released by the Department of Defense just before this conference) recognizes the importance of sustaining a safe, secure, and effective nuclear deterrent, the budget sequestration called for by the Budget Control Act (2011), which might occur in 2013, would force the Administration to return its NPR to the drawing board.

It was widely recognized that the United States faces an exceedingly difficult path on all these issues, especially in fully realizing the objectives in the NPR. However, many participants attempted to strike a positive note and argued that there is no choice but to move forward. Several participants suggested that a strategy-driven approach offers the best prospect of reconciling requirements with available funding.

The Los Alamos and Lawrence Livermore national laboratories initiated and have annually co-hosted the SW21 conferences since the first in 2007. In the middle of the last decade, issues such as future nuclear weapons requirements, nonproliferation, and the complicated nuclear stockpile LEP efforts were at the heart of the debate on nuclear weapons policy. There were divergent views on the purpose, character, and costs of transforming the U.S. nuclear stockpile and its infrastructure, as well as on certain nonnuclear programs.

There was also no general agreement on how these issues are, or should be, affected by U.S. obligations under the Nonproliferation Treaty and various arms control treaties (for example, the New START) or how the issues affect extended deterrence and assurance obligations to U.S. allies, as well as broader U.S. nonproliferation goals.

Annual SW21 conferences were established to provide an international forum for a reasoned debate on these issues; to further the development of a strategic view of nuclear weapons, as well as realistic cost-benefit analysis for the U.S. nuclear weapons program that looks at the broader defense and security context; and to help forge a sustainable U.S. bipartisan consensus on nuclear weapon policy.

The next SW21 conference, by invitation only, is scheduled for January 31, 2013, in Washington, D.C., and will focus on strategic stability and deterrence. ✦

–Bryan Fearey

STRATEGIC WEAPONS IN THE 21st CENTURY
LOS ALAMOS AND LAWRENCE LIVERMORE NATIONAL LABORATORIES
2012

REFLECTIONS ~ HISTORY REPEATS ITSELF

Pride and joy: Grandfather and grandson Tibbets together flying the only flyable B-29, *Fifi*, left in the world. The younger Tibbets was an Air Force captain when the photo was taken near Midland, Texas, in 1998. *(Photo: courtesy Colonel Paul W. Tibbets IV.)*

The course of history changed on August 6, 1945, when Colonel Paul W. Tibbets Jr. piloted the first nuclear bomber, *Enola Gay*, and delivered the first nuclear weapon in combat. A week after the attack, the Japanese government surrendered unconditionally, thus ending the most catastrophic war in history.

Leading up to that history-changing event, Colonel Tibbets visited Los Alamos, the birthplace of the first nuclear weapon, to learn more about "the device" he was charged with safely, securely, and accurately delivering.

Sixty-seven years later, his grandson, Colonel Paul W. Tibbets IV, USAF, visited LANL. Colonel Tibbets, himself a nuclear bomber pilot who flew B-1s during the Cold War and flies B-2s today, has combat mission experience in wars as far apart as the Balkans and Afghanistan. His visit to LANL in April of this year was his first, but most likely not his last; Tibbets is also commander of the Air Force Inspection Agency, based at Kirtland Air Force Base in Albuquerque, New Mexico.

Tibbets shared one of his grandfather's wartime stories during this visit. It was in 1945 when the colonel was stationed at Wendover Army Air Field, in Utah. There he trained flight crews and oversaw the modification of their B-29 Superfortress bombers assigned to deliver the device. These modified B-29s were called "Silverplates" because that was the code name of the modification project. The nuclear mission and the special modifications to the planes remained top secret.

One morning, a general who commanded another unit stationed at Wendover went to the secure area where the colonel's mysterious Silverplates were parked and insisted on inspecting them. The young guard, maybe 19 or 20 years old, entrusted with protecting the entry point to the planes, denied the general's demand and stated, "General, if you take one more step, I will have to shoot you." The general did not test the young guard's resolve.

Upon returning to his headquarters, the frustrated general demanded Colonel Tibbets report immediately. The colonel duly met with the general who relayed the story of being threatened by the young guard. At the end of the exchange, the general asked, "What I really want to know is, was the soldier under your command really going to shoot me?" Colonel Tibbets replied, "Absolutely."

"My grandfather pointed out, proudly, that he 'had the upmost confidence in his people to do the right thing at all times—without hesitation,'" said Tibbets. "I like to repeat this story because I believe we have the best recruits in the Air Force, just like my grandfather had back then. And we count on them and trust them to do everything we give them to do—without hesitation—whether guarding our nuclear weapons or flying our airplanes or staying on alert 24/7 with our missiles. It's an enormous amount of responsibility, and we don't think twice about it because they're just that well trained and dedicated to their mission."

He paused and added, "My grandfather also used to say, 'We hope we never have to use nuclear weapons in anger again. But if you think about it, we use these weapons every day—as a credible deterrent. We, as a nation, should never forget that.'"

–Alan Carr

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