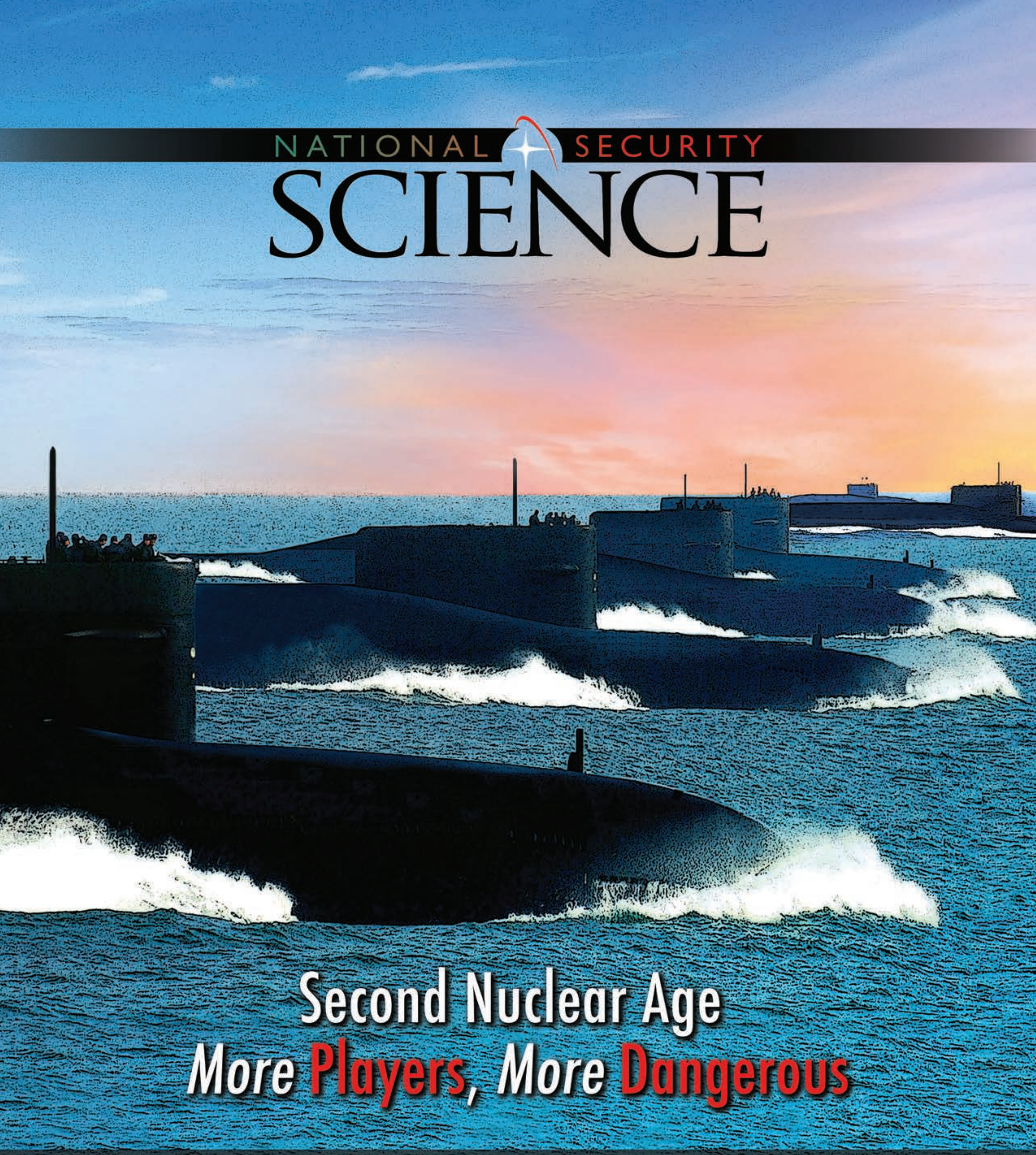
NATIONAL SECURITY
SCIENCE



Second Nuclear Age
More Players, More Dangerous

Also in this Issue

Do Weapons Designers Have Good Judgment?
Laboratory Directors Speak Out
Remembering Harold Agnew

Los Alamos
NATIONAL LABORATORY
EST. 1943

Challenges Facing Stockpile Stewardship in the Second Nuclear Age

CHARLES McMILLAN
Laboratory Director

WELCOME to this issue of National Security Science.

This issue is in celebration of the first Los Alamos Primer lectures, which took place 71 years ago in the spring of 1943. These lectures were held in conjunction with the start-up of "Project Y," which was part of the Manhattan Project. Project Y would eventually become Los Alamos National Laboratory.

The U.S. entry into the Atomic Age had been slow and cautious. But when the United States entered World War II and faced the carnage of the war, fighting and genocide had already claimed millions of lives. Obtaining the bomb before Nazi Germany or Imperial Japan was imperative.

The brightest students (their average age was 24) were recruited from the nation's best colleges and universities. They were joined by other recruits: some of the world's preeminent scientists—for example, Enrico Fermi, Hans Bethe, Edward Teller, and Stanislaw Ulam—many of them refugees from Nazi Germany. The recruits were told very little other than that their work might bring an end to the war. They were given one-way train tickets to the tiny town of Lamy, New Mexico, just south of Santa Fe. There they were met by government agents and spirited away to an undisclosed location in the mountains northwest of Santa Fe.

The youthful recruits, soon to become the world's first nuclear weapons scientists and engineers, knew little about nuclear energy and nothing at all about making an atomic bomb. J. Robert Oppenheimer tasked his Berkeley protégé, Robert Serber, with immediately laying the necessary intellectual groundwork for the arriving scientists.

Serber put the nature of their vital mission bluntly. "The object of the project," he explained to the first several dozen nervous new arrivals, "is to produce a practical military weapon in the form of a bomb in which the energy is released by a fast neutron chain reaction in one or more of the materials known to show nuclear fission."

Using just a blackboard and some brief notes, Serber provided a series of five lectures. He had developed the notes at Berkeley the previous summer while leading a series of secret seminars (which included Oppenheimer, Bethe, and Teller) that explored the potential for building a nuclear weapon. He began the Los Alamos lectures by presenting an essential introductory overview of the relevant nuclear physics. Next, he unveiled the most promising approaches, developed from the secret Berkeley seminars, for building the world's first nuclear bomb.

Following each day's lecture, Serber's original notes were expanded and annotated, based on the questions and discussions traded between audience participants. Formulas, graphs, and simple drawings from the blackboard *were added. The resulting 24-page document was mimeographed and handed out to every newly arriving Project Y scientist.*

The document, titled the Los Alamos Primer, was a slim and parsimonious but powerful map. Although it presented a definitive starting point and destination, and contained several clear landmarks in between, the exact route to building a nuclear weapon was still unclear.

Nevertheless, Project Y's scientists toiled with diligence and determination and managed, by August 1945, to produce two completely different types of practical atomic weapons: Little Boy (a uranium gun-type device) and Fat Man (a plutonium implosion device).

Although the world today is very different from that of 1945, there is still a need to deal with the world's dangers. The United States and its allies remain threatened by traditional nuclear-armed adversaries and new nuclear powers, as well as by states of concern and terrorist organizations seeking nuclear weapons. In this environment, the Laboratory's mission—to do the world-class science needed to meet challenges in national security—has not changed. To succeed, the Laboratory's scientists must above all be free to think critically and examine all possibilities.

As Oppenheimer put it, "There must be no barriers to freedom of inquiry. There is no place for dogma in science. The scientist is free, and must be free to ask any question, to doubt any assertion, to seek for any evidence, to correct any errors. . . .We know that the only way to avoid error is to detect it and that the only way to detect it is to be free to inquire."

As the Soviet Union collapsed, raising concerns about the security of nuclear weapons and materials in the Soviet Weapon Complex, underground testing ended in 1992. This essential tool of U.S. weapons efforts was replaced in 1994 by the Stockpile Stewardship Program. Los Alamos went from designing, engineering, and testing nuclear weapons to stewarding the Laboratory-designed weapons that are aging in the nuclear stockpile, and doing this without full-scale testing. The assessments are reported annually to the president.

The new challenges that stewardship presented the Laboratory were, and still are, daunting. Assessing the health of the stockpile—then, now, and into the future—without additional full-scale testing required building new, revolutionary experimental facilities and investing in new supercomputing, engineering, and manufacturing capabilities. It took less than two-and-a-half years to build the first atomic bombs, but it has taken 20 years of the nation's best scientific efforts to get the Stockpile Stewardship Program as far as it has come today.

How far are we? This new challenge, like the one that began in 1943, is one with a clear objective: a safe, secure, and reliable stockpile. We have made significant strides in stewardship at Los Alamos. Our supercomputers are some of the fastest on the planet. Our Dual-Axis Radiographic Hydrodynamic Test facility is producing world-class radiographs. We have built plutonium pits to support the U.S. Navy, and we are extending the service life of Navy and Air Force weapons.

However significant our successes to date, great scientific challenges remain for stockpile stewardship—assuring that the deterrent remains safe, secure, and reliable without testing requires this capability for the long term.

Because these weapons depend on an in-depth understanding of extremely complicated physics and because the warhead components continue to age, the stockpile continues to present new problems. Although pit aging has begun to be studied, important work remains to be done. As national and international political and economic landscapes shift and as our science and technology improve, there is no foreseeable end in sight to the challenges of stockpile stewardship—nor to the ways of meeting them.

Yet today's austere budget climate threatens our ability to recruit and retain the next generation of scientists and engineers, to optimally use the existing tools of stockpile stewardship; to complete life-extension programs (LEPs) with modern materials and manufacturing that fully meet U.S. military requirements while improving safety and security; and to build the downsized, modernized infrastructure without which we will be unable to carry out our national security mission. In this difficult situation, the path ahead is unclear. But failure is not an option.

The 2nd Los Alamos Primer lectures and discussions, held in July 2013 in honor of the Laboratory's 70th anniversary, explored the changing stewardship landscape, sought new ways to meet its challenges, celebrated our successes, and inspired our current and next generation of scientists. This issue offers our readers an overview of some of those lectures and the challenges we face in stockpile stewardship during the Second Nuclear Age.

Official identification badge photos
from Project Y
frame a color photograph taken of the Trinity test.

> ***"We were lying there, very tense, in the early dawn,***
> ***and there were just a few streaks of gold in the east;***
> ***you could see your neighbor very dimly.***
> ***Suddenly, there was an enormous flash of light,***
> ***the brightest light I have ever seen or that***
> ***I think anyone has ever seen.***
>
> ***It blasted; it pounced; it bored its way right into you. . . .***
>
> ***A new thing had just been born; a new control,***
> ***a new understanding of man,***
> ***which man had acquired over nature."***

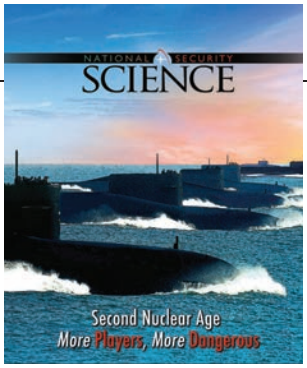
~ I. I. Rabi~
Manhattan Project Scientist

From the Editor

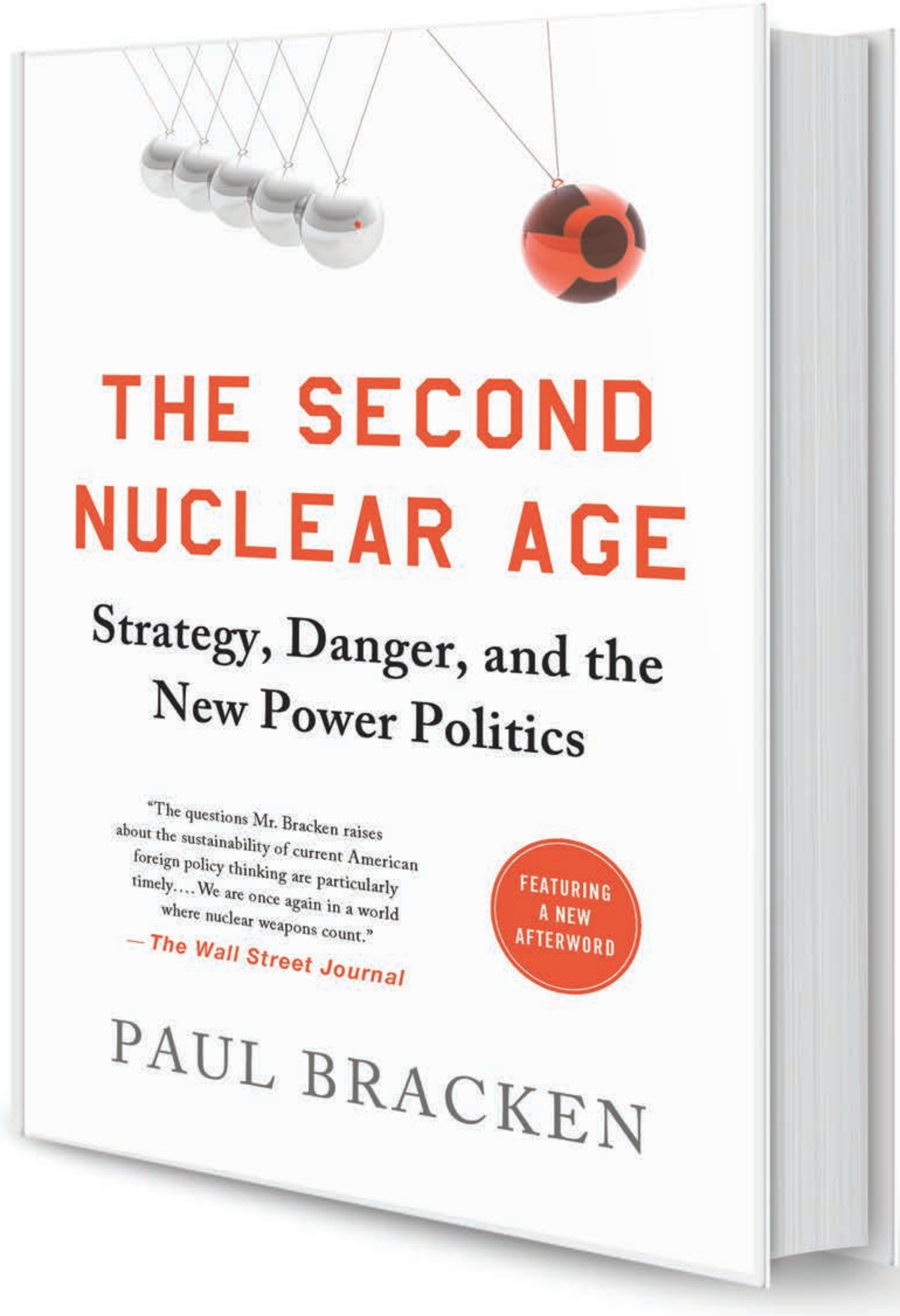
The first Los Alamos Primer lectures took place 71 years ago in the spring of 1943 as part of Project Y of the Manhattan Project. This issue of National Security Science *provides our readers with highlights from the 2nd Los Alamos Primer lectures held in honor of the Laboratory's 70th anniversary. This issue is dedicated to Harold Agnew, the Laboratory's third director.*

About the Cover

The number of nuclear-armed nations is growing. They are also modernizing their nuclear arsenals. For example, many are building modern nuclear submarines armed with advanced ballistic missiles.



It's a multiplayer nuclear world now, making it more dangerous than in the Cold War era.


THE SECOND NUCLEAR AGE

Strategy, Danger, and the New Power Politics

"The questions Mr. Bracken raises about the sustainability of current American foreign policy thinking are particularly timely.... We are once again in a world where nuclear weapons count."
—The Wall Street Journal

FEATURING A NEW AFTERWORD

PAUL BRACKEN

On July 22, 2013, at the 2nd Los Alamos Primer lectures, Paul Bracken, professor at Yale University spoke on the need for the United States to pay renewed attention to nuclear weapons.

Following the end of the Cold War, many world leaders, scholars, and other people of good will were attracted to the idea that the bomb might now disappear and that the world would embrace an international order free of nuclear weapons. While I personally support that idea very much, I would argue that it is not happening and is very unlikely to happen.

Today, social history in regard to nuclear weapons is being written in many other countries. For the physicists and engineers in these countries—India, Pakistan, and others—there is a reward system and a bureaucracy that is building up and thickening around nuclear weapons. In short, many other countries are in a stage of nuclear development the United States was in during the late 1940s and early 1950s. There is excitement as well as fear developing in these new nuclear states. More, their development will have profound implications for international relations. I'd like to consider some of these dynamics here.

This is the Second Nuclear Age: the spread of nuclear weapons for reasons having nothing to do with the Cold War.

First, let me begin with the purpose behind these new nuclear programs by going back to the early U.S. atomic program. A recent book titled *Ike's Bluff* is based on the thesis that President Eisenhower developed and expanded the nuclear complex as a bluff to use in waging the Cold War. I can't imagine any thesis I could possibly disagree with more for one simple reason: it wasn't any bluff. When you build a nuclear force as big as the United States did in the Cold War, what I call the First Nuclear Age, some of the weapons might have gone off. Indeed, the studies done in the 1980s about command and control and crisis stability indicate that the chance of that happening was greater than anyone thought at the time. So the notion that the buildup of weapons was a bluff is, I think, a fundamental misconception about the First Nuclear Age.

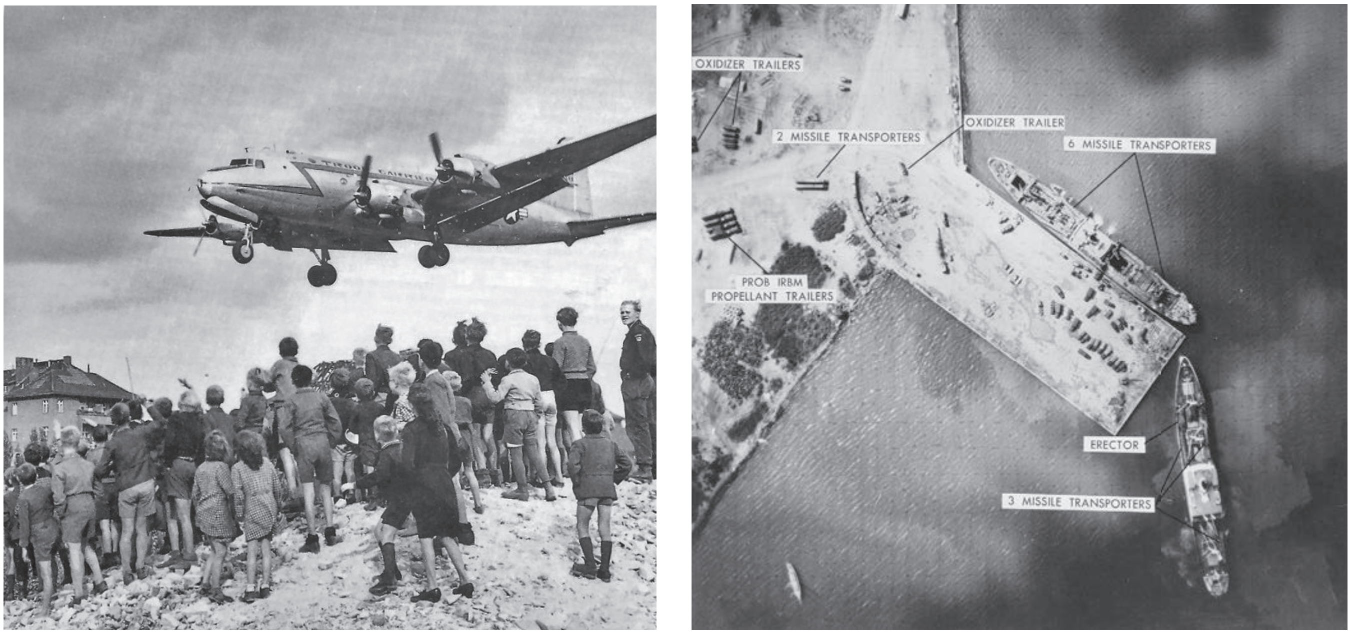
The overwhelmingly most important lesson from the Cold War was this: you don't have to fire a nuclear weapon to use it.

Paul Bracken is a professor of management and political science at Yale University and a leading expert in global competition and the strategic application of technology in business and defense. He serves on several Department of Defense advisory boards. His latest book is The Second Nuclear Age: Strategy and the New Power Politics. *(Photo: Paul Bracken)*

If it wasn't a bluff, then what was it? It was a "Faustian bargain." The bargain was that if the United States built these nuclear systems, we could get away with waging the Cold War on the cheap. The same Faustian bargain is being made today right before our eyes. Pakistan, North Korea, and likely Iran think their best course of action is to base their national security on the bomb. They may think it's a bluff, but it's actually a Faustian bargain.

This is the Second Nuclear Age: the spread of nuclear weapons for reasons having nothing to do with the Cold War. When I look back at the Cold War, it seems to me that it masked very powerful forces of international relations that were moving the world toward this Second Nuclear Age. The framework of the Cold War was applied to the dynamics of that era, but with perspective, it now looks otherwise.

We should look at the two nuclear ages in tandem and consider the lessons of the First Nuclear Age that carry over to the Second. There is a long list of Cold War lessons that I don't think apply—but many that do. For example, "Do not get into a thermonuclear war and kill hundreds of millions of people" still applies. But let me call your attention to some lessons that I think are not so obvious.



Left: Berliners watch a U.S. C-54 transport plane bringing vital supplies into the city during the Soviet Union's 1948–1949 blockade. Right: Aerial reconnaissance photographs like this one, taken in October 1962, proved that the Soviets were staging nuclear missiles in Cuba. *(Photos: Open Source)*

The overwhelmingly most important lesson from the Cold War was this: you don't have to fire a nuclear weapon to use it. The United States used nuclear weapons every single day of the Cold War—yes, for deterrence, but not only for deterrence. The weapons were used in complex ways to signal enemies that the United States was deadly serious about certain issues and that anyone who pressed us on these issues could really get into trouble. Nuclear weapons were used to communicate and bargain with the Soviet Union, making it clear that some Soviet actions would not be allowed, for example, closing down access to Berlin or introducing missiles into Cuba.

Nuclear weapons were used to fight the Cold War on the cheap. We never raised a big army the way the Soviet Union did. The peak size of the U.S. Army during the Cold War was 18 divisions. The Soviets had something like 200, depending on how you count them. We were not going to fight the Cold War that way. Building up a nuclear force cost much less.

Nuclear weapons were used to fight the Cold War on the cheap.

The United States embraced a caution in the Cold War that didn't overload the world with crises and arms races that would have undermined stability. For example, the United States never armed the Soviet Union's two major enemies—Germany and Japan. We never fostered militarism or nationalism in those countries, something that could easily have been done.

Nuclear weapons were also used to create mischief. This is another lesson from the First Nuclear Age for the Second. For example, antiwar movements in Western Europe were founded by honest, sincere people. The Soviet Union often tried to influence those movements, to exploit antinuclear sentiments to split the NATO alliance.

Every president of the Cold War played nuclear head games — putting into the minds of one's enemies illusory models of what might happen if an enemy crossed certain lines.

Another lesson of the First Nuclear Age that I think we should keep in mind is the fact that countries will use their nuclear arsenals to play what I call "nuclear head games": putting into the minds of one's enemies illusory models of what might happen if an enemy crossed certain lines or did certain things. *These head games could have escalated into serious crises.*

Every president of the Cold War played nuclear head games, from Harry Truman to George H. W. Bush. Kennedy did it in the Cuban missile crisis. In another example, Nixon did it in the fall of 1969 when he ordered SAC [the Strategic Air Command] to go on heightened levels of alert, knowing that this would be detected by the Soviet Union. He did this in a way that would not be picked up by the press, and he actually got away with it. SAC was ordered to cancel routine training flights, the so-called "stand-down operations," which looks like you're preparing to do something big and bad, although this was arranged so it would not look like a strike on the Soviet Union.

I've interviewed SAC commanders and deputy commanders about this particular incident. When they got the orders from the White House, they picked up the phone and called back, saying, "If you'd tell us what your objective is with these orders, we could probably help." The response they got—from an unnamed national security affairs advisor with a German accent—was, "If we need your advice, we will ask for it. Shut up and follow orders."

The final Cold War lesson that I think applies to the Second Nuclear Age is this: it pays to think about the unthinkable.

What was going on was an attempt by the White House to communicate to Moscow that the United States might dramatically escalate the bombing of North Vietnam. Moscow should put pressure on Hanoi to give more at the Paris peace talks, which had just started. This nuclear head game didn't work. Hanoi didn't give in at the Paris peace talks; it didn't give in on anything.

Sometimes when presidents use these nuclear head games, they work, but as President Nixon learned, they don't always. But the point isn't that nuclear head games work. It's that every single U.S. administration played these games. During the 1980s I was involved in almost every major academic study that focused on nuclear crisis stability. For example, we'd go to these summer retreats and in each one of these retreats everyone, including people like McGeorge Bundy and Robert McNamara, would agree that the United States should *not* use nuclear weapons in this kind of way. Yet in reality, everybody did it. I am reminded here of the call to abolish nuclear weapons—by individuals who at one time had responsibility for building more of them and for using them to signal U.S. intent.

Let's take another example of a nuclear head game. Look at the history that's emerging about the United States' "advanced technology programs," the code words for the U.S. attempt to convince the Soviets we could go after their submarines in their protected sea bastions. This was not started under President Ronald Reagan; it was started under President Jimmy Carter. He directed the Navy and the Air Force to engage in very provocative operations against the Soviet's submarines.

My overall point here is that if things like this happened in the Cold War, I believe they are likely to happen in the Second Nuclear Age as well.

The final Cold War lesson that I think applies to the Second Nuclear Age is this: it pays to think about the unthinkable. Looking at hypothetical possibilities is the only way I know to figure out the fault lines, the conflict potential of the Second Nuclear Age. There are many ways to do that, and war games are one. I have run many war games, at the

Slim Pickens played Major "King" Kong in the movie Dr. Strangelove *and is shown here riding the thermonuclear bomb that starts an unintended nuclear war with the Soviet Union. Bracken has run many war games and has found that it is generally hard for a nuclear war to get started. But it is not impossible. For example, a war game called Proud Prophet went all the way to an unintended nuclear catastrophe when the players simply followed actual U.S. strategy. In just the initial launch of the game, a half-billion people died.* *(Photo: Open Source)*

Hudson Institute and at the Defense Department, and I generally found that it is hard to get a nuclear war started, just as many academic accounts of the First Nuclear Age have emphasized. But it's not always true. In June 1983 a war game named Proud Prophet went all the way . . . all the way to nuclear catastrophe. In this game a half-billion people died from the initial salvos, and most of Europe, the United States, and Russia were destroyed because the secretary of state [Casper Weinberger], and the chairman of the Joint Chiefs of Staff—both of whom were participants in the game—simply followed the strategy laid out in actual U.S. war plans.

The Second Nuclear Age is a multiplayer game. There's a danger of nuclear war being brought on by regional conflicts.

The lesson Secretary Weinberger learned from Proud Prophet was that we were woefully unprepared to deal with a crisis because we didn't really understand the dynamics. The lesson for the Second Nuclear Age is that you have many more countries possibly involved, not just two, as in the Proud Prophet game. Moreover, many of these countries are new to nuclear weapons. They've never been in a nuclear crisis, and there is a liability that comes with such inexperience.

I'm not particularly concerned about nuclear war with Russia, but I am very concerned about the most distinctive feature of the Second Nuclear Age, that it is a multiplayer game. There's a danger of nuclear war being brought on by regional conflicts. So if you think only in terms of bilateral standoffs—the United States vs. Russia, China vs. India, and so on—you will overlook many of the escalation dynamics. There is a larger, multipolar nuclear system developing right before our eyes. There are the major powers, most of which have the bomb, and there are secondary powers that are increasingly getting the bomb. The monopoly the major powers once had on the bomb has broken down.

Anybody who says North Korea can't use the bomb is not recognizing that it's already actively using the bomb to extort food, oil, and prestige.

Let's look at these major and secondary powers. Who's a major power? I'll be generous; it's the United Nations' Permanent 5—the United States, Russia, Great Britain, France, and China—but also India, which in my view is a major power, and Japan, which is a major power, although without the bomb. So only one of the major powers hasn't got the bomb. There are secondary powers that have the bomb, for example, Pakistan, and North Korea. North Korea is a good example. Anybody who says North Korea can't use the bomb is not recognizing that it's already actively using the bomb to extort food, oil, and prestige from the international system.

President Obama and Russian President Medvedev after signing New START, a treaty designed to prevent a Russian surprise attack on the Minuteman force and the B-52s. But according to Bracken, the treaty completely misses the problems of a Second Nuclear Age because of being hemmed into a bilateral relationship. (Photo: Open Source)

So what might look like bilateral standoffs have to be viewed as involving more than two countries. You can't look at the U.S.-China or the U.S.-Russia relationship absent this broader nuclear system. It misses too much. If we put in a missile defense system to protect Japan and South Korea from North Korea, the Chinese will see that as degrading their nuclear forces. If we put missile defense in to protect Europe against a possible nuclear Iran, it will be seen by Russia as degrading its forces. We can declare that this isn't the purpose of U.S. missile defense. But we know that the United States would not accept such a rhetorical declaration if the situation were reversed, if another country built missile defenses against our nuclear forces.

Interestingly, this very complicated structure of major and secondary powers is the mirror image of the First Nuclear Age. In the Cold War one couldn't get a nuclear war to actually start unless it was authorized in Moscow or Washington. Regional, secondary powers didn't have nuclear weapons, and in cases where they did have nuclear weapons—China in 1964, for example—there was an accepted fiction in the Cold War that said we should pretend we were in a bipolar world even though we were not.

The 1973 Arab-Israeli War was really a nuclear crisis that included the United States and the Soviet Union. Now the situation has flipped. The regional powers couldn't go nuclear in the past, but now they can, and the major powers' control over their regional allies, or opponents, is far less because there's much less bloc [U.S. or Soviet] discipline than during the Cold War.

Let me give you another key difference between the two nuclear ages. What were the ideologies that drove the fundamental competition between the United States and the Soviet Union? It was democracy and liberty on the one hand and totalitarianism on the other, although the Soviet Union might not have seen itself as totalitarian. What is the replacement ideology that drives the world today? I would argue that it's nationalism—the fictitious belief that one country, or people, is superior to another.

Think about it. During no crisis in the Cold War did either superpower instigate million-person marches demanding the blood of the other side. In the Cuban missile crisis, Kennedy could have but did not try to get a million people into Times Square or onto the Washington Mall screaming for the blood of the Soviets. Likewise, the Soviet Union often had staged rallies in Red Square at the Kremlin, but never during a nuclear crisis with the United States. It was too dangerous.

Paul Bracken speaking at the 2nd Los Alamos Primer lecture series, held in celebration of the Laboratory's 70th Anniversary.
(Photo: Los Alamos)

This is not the case today. The demonstrators in Iran are nationalistic. So is Pakistan. You have a very different set of ideological drivers in the Second Nuclear Age than you did in the first.

We had better start thinking about what our design for arms control and strategy looks like in this multipolar nuclear world.

I think the regions, the secondary powers, are where the greatest danger of a nuclear war is. For this reason, I don't understand our fixation on the New Strategic Arms Reduction Treaty (New START), which is designed to prevent a Russian surprise attack on the Minuteman force and the B-52s. Do I support New START? Sure, why not. But it completely misses the problems of a Second Nuclear Age because it's hemmed into a bilateral relationship.

I think that what we're seeing in the United States right now is the beginning of a grudging recognition and acceptance that we are entering a multipolar nuclear world. An example of that is the speech the president gave in Berlin, along with the nuclear weapons fact sheet issued by the White House on the same day. In this fact sheet, the White House talked about ensuring strategic stability with Russia and China. This was significant. I have never before seen China mentioned in a START-like context in an official U.S. document. To me, it signifies U.S. recognition that the world has more than two nuclear weapons states and that we had better start thinking about what our design for arms control and strategy looks like in this multipolar nuclear world.

I believe there's a lot that can be done on arms control. My personal favorite would be the United States declaring no first use of nuclear weapons but *guaranteeing* second use: guaranteed U.S. retaliation against any other country that used nuclear weapons—*any* country, whether friend, enemy, or neutral. I think arms control has to be revitalized far beyond the extremely narrow way it has developed over the last 20 years, which is very much bilateral, or the way it was addressed in the Nuclear Nonproliferation Treaty (NPT). New START solves a problem that isn't going to happen: a Russian surprise attack on U.S. missiles. The NPT is failing to solve a problem that *is* happening. I'm not against either the NPT or New START; I just think they are inadequate to the task. So I'm calling for a rebranding of arms control.

We need Los Alamos thinking in detail about what the nuclear forces of other countries look like, as well as what U.S. forces should look like.

And finally, I'll just say that since the end of the Cold War, the way the United States thinks about nuclear weapons has declined enormously—just the quality and level of discussion, regardless of which side you come out on. Yes, there is a debate. But it doesn't draw in key audiences, like the military, Congress, or other elites. Even in academia, debate about nuclear weapons is now confined to a small group of social scientists, with the science and engineering faculties not involved.

This is where Los Alamos really comes in. I can imagine a wide range of possibilities about who gets the bomb and who doesn't get the bomb. But I don't see the possibility of global nuclear disarmament. As long as that is true, Los Alamos has to continue to serve the country, and I would stress *serve the country*. It may not be what you want to do, but you weren't put here to do what *you* want to do. You were put here to do what the *country* wants you to do. We need people thinking in detail about what the nuclear forces of other countries look like, as well as what U.S. forces should look like. And we need to think about fundamental moral and political issues, with the best technical input you can give us—just as we got from Los Alamos in the Cold War. ✦

(This lecture reflects the opinions of the author.)

Paul Bracken

Q&A

Q: Are there rational players in the Second Nuclear Age?

A: I think yes, but I have concerns that strategic cultures and deep historical forces cause rationality to be defined differently in different countries. I am not of the view, as some people are, that as the bomb spreads, the world becomes more stable. That argument says that if everyone got nuclear weapons, they would behave with extreme caution, and we would have stability. In my opinion, that's a belief only a tenured social science professor could possibly believe.

There are degrees, variants, of rationality, and that is the lesson of modern economics: bounded rationality and its many variants. How that lesson is embodied in the nuclear weapons programs of other countries is something you [LANL] are better at understanding than others are. We need you to help us figure out why the forces of other countries look the way they do, why other nuclear countries do and don't take certain actions.

Q: Do you agree that unless there's control over the spread of nuclear capabilities, everyone is at risk?

A: I would say that, at some point, if we don't get control over the flow of fissile materials, virtually all bets are off. What that control would look like is still to be determined, but whatever it is, it has to be better than the 1928 Kellogg–Briand Pact, which had Germany, France, and Japan as signatories.

I believe that we'll see a great-power arms-control system develop in the 21st century, gradually replacing the NPT regime of the 20th century. Such a control system will involve the United States, Russia, China, India, France, Britain, and perhaps others, such as Japan, if it joins the nuclear club. Major powers will have significantly greater interest in arms control, in my view. This is already developing. For example, every major nuclear power today has either a declared or a de facto no-first-use policy.

Q: Would you comment on the rationality of a no-first-use policy in what you describe as a multipolar world full of national passions? What do you think the end game of announcing such a policy would be? Would it be considered a bluff? Would it be considered real? Would it be a head game?

A: First of all, I think a no-first-use policy is good for the United States today. Guaranteed second use is a lot more controversial and is intended to be so. One of the features of thought leadership in this field, which played out in the First Nuclear Age with people like Henry Kissinger, Tom Schelling, and Herman Kahn, was the intentional overstatement of certain issues to shock bureaucracies into thinking. That's the way I view guaranteed second use.

Let me talk about no first use. I believe that it would get not only the United States but also the bureaucracies in many other countries to think through what they're doing. There is an unfortunate tendency in the United States, transcending both the current and the past administrations, for any assistant secretary of this or that department to give their views on what U.S. nuclear policy is. There's no central story line coming out of the White House. We recognized in the Cold War that such a situation of fragmented policy was dangerous. We've got to get control of this debate. I think no first use would force the U.S. bureaucracy to think through its policies and get other countries to do the same.

A few weeks ago at Yale, I led a seminar on the Second Nuclear Age for visiting members of India's parliament. And what I found was that their parliament is completely in the dark about their country's military and its nuclear programs. It would be very useful to change this situation. In addition, they have thought about arms control only in terms of a reaction to what other people propose. So if the United States had an arms-control proposal—it doesn't matter what it is—the Indians would usually react negatively just because it came from a major power.

One of the things that developed out of the seminar was the idea that India should start developing its own arms-control proposals. If India starts generating its own arms-control proposals, forcing Washington, Moscow, and China to react, this would focus attention and, I would argue, raise the level of discussion. Personally, I think we have forgotten far too much about nuclear weapons. So in answer to your question, no first use has a lot more to do with peacetime nuclear diplomacy and arms control than it does with war-fighting doctrines.

Q: Would you talk about the effectiveness of the guaranteed second use if the first use were by a nonstate actor?

A: The structure of the world that I see for the Second Nuclear Age includes major powers with and without the bomb, secondary powers with and without the bomb, and groups—subnational entities, whether militias, terrorists, or lunatics— that are also part of the structure. Thank heavens none of the subnational entities has, or to my knowledge is close to having, the bomb. I think in the case of a nonstate group getting and using a nuclear weapon, you would get worldwide agreement that anybody can go after a nuclear terrorist. The United States, China, Russia, France, and Britain would sign on that immediately.

Another first-use scenario, and it's one I worry about, is a country using tactical nuclear weapons on its own territory. My conversations with Russian planners in recent years have shown me that it is not inconceivable that Russia would use nuclear weapons on its own territories, for example, against Chechnya or other threats.

The current level of debate sort of dismisses such first-use scenarios, or it simply says either that everything is a subset of assured second-strike deterrence or that we should get rid of nuclear weapons altogether. It seems to me that those two big models, which have dominated the American nuclear conversation for the past several years, just don't begin to come to grips with the complexity of what's going on in the world today. It's like looking at mechanics and saying you're going to use only Newton's First Law. We've got to enrich this discussion, or we are going to be surprised at one turn after another.

Q: What are the implications of changes in science and technology?

A: There are a lot of implications, and to help us understand them, we need a national resource such as Los Alamos or Livermore. The intelligence services pick up stuff on certain nuclear weapon designs from other countries. What do they mean for how, say, China or Pakistan thinks about its nuclear force? We need tremendous expertise to help us understand what other countries' nuclear programs and strategies mean and how they interact with each other.

And I want to have someone other than a political scientist tell me about the nuclear strategies of other countries. In the Cuban missile crisis, there was a universal belief in the U.S. political science community that the Soviet Union would never assign launch authority to a field commander. But we now know that they did just that. We know because we have the document, in Russian, that proves it. The consensus view was wrong about the Soviets' command-and-control system.

I would say that *Los Alamos should start considering thought leadership* on nuclear issues. In the 1940s that thought leadership was dominated by the greatest physicists of the 20th century. In the 1950s and 1960s it transitioned away from the physicists and moved to institutions like the Rand Corporation and the Hudson Institute. The leading think tank in the 1930s, the Council on Foreign Relations, was famous for having a global vision. It got us into Lend Lease and working with the allies before Pearl Harbor, but it played little role at the beginning of the Cold War because thought leadership had moved to these other institutions.

I'm not saying that you should be the thought leadership. But I do think Los Alamos needs to construct the intellectual map of where the world is going, where the United States is going in terms of thought leadership, and where Los Alamos fits in.

The days of putting your heads down and saying that you only do technology are over. I would have supported that position for the first 20 years after the Cold War. But those 20 years are over.

You're going to be called upon for advice. If I'm wrong—and Pakistan, China, and North Korea give up their nuclear weapons—then you can go ahead and do all the environmental studies you want. But I don't think I'm wrong. I'm not particularly in favor of a new U.S. nuclear weapon design, but the level of conversation about nuclear weapons in this country is too low for anyone to even know what that design would look like—or why it might be needed.

The debate will start, I feel certain, and you're going to be called upon for your advice. You have to think about it now. If you wait until your advice is needed, it will be too late. ✦

On nuclear issues I think Los Alamos needs to construct the intellectual map of where the world is going, where the United States is going, and where Los Alamos fits in.

How Is the U.S. Preparing for the Second Nuclear Age?

DID YOU KNOW THAT:

In the Second Nuclear Age, eight nations have nuclear weapons. Terrorist organizations seek to acquire nuclear weapons.

Seven of the eight nuclear-armed nations continue to invest heavily in their nuclear capabilities. They are building new, modern nuclear warheads *and* delivery systems to improve their weapons' military characteristics—for example, their range and performance—and to diversify their warhead types. Several nations are believed to also be *increasing* the size of their nuclear arsenals.

What Is the United States Doing?

The U.S. nuclear stockpile deters our adversaries and assures our allies *every day*.

But in contrast to what the other nuclear-armed nations are doing, the United States has not deployed a new warhead type since 1989, or a new launch platform since 1997. Its current nuclear weapons were designed in the 1960s and 70s; the last one was built in 1991. Although other nations have tested their nuclear weapons since 1992, the United States has not.

The United States is dramatically *reducing* the diversity and the number of its weapons. As the size of the stockpile decreases, the need to ensure that the remaining weapons will work increases.

Life-Extension Programs

Instead of building new, modern nuclear weapons, the United States is working to extend the life of its current weapons, which were built decades ago, with a designed life-expectancy of about 10 years. These life-extension programs (LEPs) rely on samples taken annually of the various types of weapons in the stockpile. These sample weapons are "autopsied" to determine the actual condition of the weapon components and evaluate if they still meet design intent. Over time, this process assesses how components are aging and if they will need to be replaced at some point in the future.

In some cases, only a single component will be replaced. In other cases, multiple components have aged to the point where a more general refurbishment, or life extension project, of the weapon is more cost-effective. The end result is a weapon that looks and functions the same as the original weapon, but its service lifetime has been extended for years into the future.

The B61 thermonuclear gravity bomb (meant to be dropped like a conventional bomb from military aircraft) is a case in point.

B61 Gravity Bomb LEP

Los Alamos designed and engineered the B61 in 1963. Production began in earnest by 1967. Most B61s were produced in the 1970s, and production ended by about 1989. The B61 is the oldest type of nuclear weapon in the stockpile. Over the years, the B61 has been modified many times to meet new military requirements. The last model built, the B61-11 (or B61 Mod 11, where 11 refers to the model, or modification, number), was deployed in 1997.

The B61 LEP is underway at Los Alamos and at other nuclear weapons facilities; different facilities are responsible for different aspects of this LEP—Los Alamos is responsible for extending the life of the nuclear warhead inside the bomb. The LEP will increase the B61's safety, security, and reliability and help ensure it remains in the stockpile until 2025.

In addition to extending its life with repaired or replaced components, the LEP will outfit the bomb with a new "tail kit," which will enable the bomb to be precision-guided and extremely accurate. Together, the tune-up and the new tail kit will result in the B61-12.

Put to the Test

This February, scientists from Los Alamos and Sandia National Laboratories put some of their B61 LEP work to the test.

In particular, they examined how their modifications would behave in both routine and extreme environments and in various "accident scenarios." These highly complex bombs (think: more complex than the finest-made mechanical Swiss watch) have it rough. If called into service, these bombs will go from being in storage to being loaded on aircraft and flown at supersonic speeds at ultrahigh altitudes—before being dropped. They must undergo the most-extreme temperature and pressure changes, vibrations, shocks, and other insults, which together push their components—new and old—to their limits. Yet after taking this brutal beating, the B61-12 *has to work flawlessly*.

The tests were successful. After reviewing the results, Don Cook, the National Nuclear Security Administration's deputy administrator for defense programs, described them as "a significant achievement [that] gives us confidence in our ability to move forward with our efforts to increase the safety and security of the bomb." ✦

PASSING GOOD JUDGMENT:

Other nations are racing to improve their nuclear weapons capabilities.

What can the U.S. do to stay competitive?

INTRODUCTION

In the 1990s, with the Cold War over, the United States and the Soviet Union began reducing their nuclear arsenals and, along with other nations, signed the Comprehensive Test Ban Treaty (CTBT), agreeing to stop underground testing of nuclear weapons. The last U.S. nuclear test, "Divider," took place in September 1992. (The United States Senate has not ratified the CTBT.)

In 1994 a new, science-based Stockpile Stewardship Program (SSP) replaced nuclear weapons testing as the way to assess the performance of the existing stockpile. The science part of stockpile stewardship would be the enabler. The U.S. weapons labs would undertake a variety of scientific studies using new specialized experimental facilities, advanced computer simulations of weapons performance, and extensive data analyses of past tests and of new nonnuclear experiments. These activities would allow the existing weapons to be refurbished and assessed without the need for a nuclear test.

The SSP's originator in the Department of Energy, Vic Reis, assistant secretary of energy for defense programs, saw the program as a hedge against an uncertain future. The stockpile was fine at the time, but who knew what the conditions would be in, say, 20 years? Whatever happened, a strong program of weapons-related science would preserve the stockpile. And it would preserve

Bob Webster (left) leads a discussion regarding the challenges faced by the Lab's two generations of nuclear weapons designers in the Second Nuclear Age. The discussion was a main focus of the 2nd Los Alamos Primer lectures, held in honor of the Lab's 70th anniversary. The first-generation weapons designers shown here on the opposite page are (right to left) Gary Wall, John Pedicini, and Jas Mercer-Smith. Continuing right to left, second-generation designers are John Scott, Langdon Bennett, and Brian Lansrud-Lopez. *(Photo: Los Alamos)*

the national weapons labs and their intellectual capabilities and knowledge, enabling them to do whatever was needed for the nation's deterrence, including rebuilding an arsenal should the need arise.

It is now 21 years since the last nuclear test and almost 20 years since the formal inception of the SSP. During those years, the world has changed. Instead of receding from the geopolitical stage, nuclear weapons are again coming forward, front and center, in the Second Nuclear Age. More nations have them, and more covet them as a possible means of increasing their security and their influence on international affairs.

To find out how prepared the labs are to face this newly dangerous world, *National Security Science* (*NSS*) interviewed LANL's most important nuclear stewards: the weapons designers themselves. Their job is to assess the nuclear warheads currently in the stockpile, plan and guide necessary changes in them, and design the steps that will help certify their reliability, safety, and security. They advise the Laboratory director as he prepares his Annual Assessment Letter for the president of the United States regarding the four warhead types (B61, W78, W76, and W88) that Los Alamos is responsible for stewarding. They also brief the director of Lawrence Livermore regarding the weapons that laboratory has designed (B83, W80, W87). The designers must also be able to assess the threat posed by foreign nuclear weapon designs.

The materials presented here were compiled from those interviews and from the Designers Roundtable, which was held as part of the 2nd Los Alamos Primer lectures (July 2013). Part 1 is a discussion with three of LANL's still-active "first-generation" designers, those who participated in nuclear testing. Part 2 focuses on four of the "second-generation" designers, who came to Los Alamos after 1992 and therefore never took part in full-scale nuclear tests.~

~Part 1: First-Generation Designers~

Jas Mercer-Smith, John Pedicini, and Gary Wall

***Also participating**: Associate Director for Weapons Physics Bob Webster*

***NSS*: You're the last of that extremely rare breed: active scientists who have both designed a nuclear weapon and exploded it in a nuclear test at the Nevada Test Site (NTS). What were the days of nuclear testing like?**

Gary Wall: I came to Los Alamos in the 1970s, during the height of the Cold War. Things were very hectic. We were doing experiments and trying to put weapons into the stockpile at a great rate. The Lab was detonating 12 to 16 nuclear tests a year, and each was preceded by 1 to 3 hydrotests. (See sidebar on next page.) The test site was very busy, and the pressure to build the equipment and move quickly from hydrotest to hydrotest or from hydrotest to nuclear test was intense.

Jas Mercer-Smith: NTS was chosen because of its proximity to Los Alamos. I remember taking the "Dash," which was a 2.5-hour nonstop flight from Los Alamos to NTS. You'd get on at 6:30 a.m. and land at Desert Rock in Nevada at 8 a.m. [gaining an hour with the time change], have all day to work, and come back at about 5 p.m. It was a great flight. In the morning you'd be flying over the Grand Canyon at 15,000 feet and the sun's rising. It was really pretty.

It was a heady experience, going out to NTS and making a huge hole in the ground with a test weapon you designed yourself. You may laugh, but designers are very fond of their holes. I remember sitting down with my daughter, bringing up NTS on Google Earth, and picking out my holes for her. My biggest one is about 1,300 feet across [about a quarter mile] and 130 feet deep.

It takes an impressive amount of energy to create a hole that big! Today I think we sometimes forget how powerfully destructive these weapons are because all we look at are computer simulations, the results of calculations. We never see a real test.

Gary Wall *has 42 years of experience in the design and analysis of weapon primaries. Wall was a member of design teams on 25 nuclear tests and the lead designer on another 7.*

Jas Mercer-Smith *came to Los Alamos in 1983. He has contributed to the design of six nuclear tests and was the lead design physicist for another three.*

John Pedicini*, who joined the Lab in 1981, worked on 13 nuclear tests and was lead designer on 3 of them.*

Bob Webster *presently oversees the portion of LANL that includes the Lab's weapons designers. Webster joined the Lab as a technical staff member in 1989. His weapons work was in code development and weapon physics. He has not worked as a weapons designer.*

"Mandrel-Pliers," a nuclear a test conducted in August 1969. The photo shows the surface around ground zero collapsing several minutes after the test, forming a subsidence crater 350 feet wide and 50 feet deep. *(Photo: Los Alamos)*

***NSS*: How did an underground test form a crater on the surface?**

Mercer-Smith: In the test of a nuclear device, a "shot," the device was buried 1,000 to 2,000 feet underground to keep radioactive contamination from escaping. When the shot went off, it vaporized everything around it and formed a tremendous underground cavity. The rock and dirt on the surface naturally fell into the cavity and sealed in the radioactive debris, creating a "subsidence" crater.

John Pedicini: You would dig a deep hole, lower the bomb and the sensors to capture test results down the hole, and then backfill with cement. After the cement had cured, which could take weeks, we started the countdown to detonation. The other weapons designers and the military were watching all this, waiting for crater formation as proof of success. It could be up to two hours after the shot before the surface collapsed and you had a crater.

Wall: Given the kind of diagnostics we fielded, we were able to gather a lot of scientific information from the tests. The tests weren't just for shaking the ground, although being out there when the ground shook was exciting. The shock wave from the detonation moved the ground under your feet, so

Workers prepare for the last U.S. nuclear test, "Divider," a Los Alamos–designed shot that took place on September 23, 1992. Here, the Divider device is shown before being lowered into its test shaft. When the device was in place, the shaft was filled with layers of magnetite, sand, concrete, and epoxy to contain the bomb debris underground. (Photo: Los Alamos)

the power of the shot became a physical sensation in your body. It was exciting, especially when it was a big test, but it was also humbling and stressful.

Most tests were aimed at developing weapons for the stockpile—weapons that had to have very specific military-required characteristics such as size, weight, and explosive yield [energy release]. We had to predict the outcome, and we knew that Washington and our Department of Defense [DoD] customers would scrutinize the test results to see if we had screwed up.

The pressure for success—to predict things right or get a result that was even better than predicted—was so high that we tended to low-ball our predictions. We knew that producing a higher-than-expected yield would have a greater psychological impact than even nailing it exactly. On the other hand, if the yield was lower than predicted, there was tremendous pressure to explain what had gone wrong and to do a better job of designing and predicting next time.

Mercer-Smith: You might think of testing as precise, white-lab-coat work, but that's not how it really was. I have a story. It goes back to 1962–1963, near the end of atmospheric testing in the Pacific and to the way things actually worked. People at the Lab were going through the data from these last shots, and the head of the radiochemistry group says they've got an anomaly in the radiochemistry data; they've got a whole bunch of arsenic, and they can't figure out how the fission process could result in so much arsenic. He says we don't understand this, and it's important to figure out what happened.

Nuclear Weapons and Hydrotests

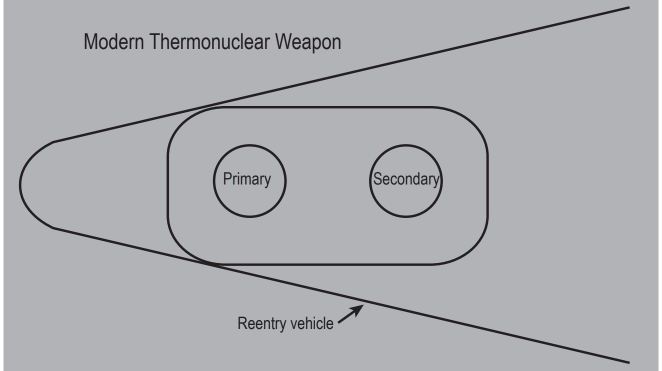
Modern thermonuclear weapons have two stages: the primary and the secondary. The primary, which is a fission bomb, delivers energy to the secondary, which uses both thermonuclear fusion and fission to release hundreds to thousands of times more energy than a fission bomb alone.

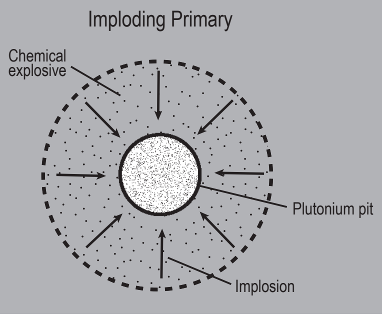
The nuclear core of the primary is a sphere of plutonium or enriched uranium and is known as the pit. Chemical explosives surround the pit and when detonated, send shock waves inward, squeezing (imploding) the pit from a subcritical to a supercritical mass—one that will sustain an uncontrolled nuclear fission chain reaction, ending in a nuclear explosion.

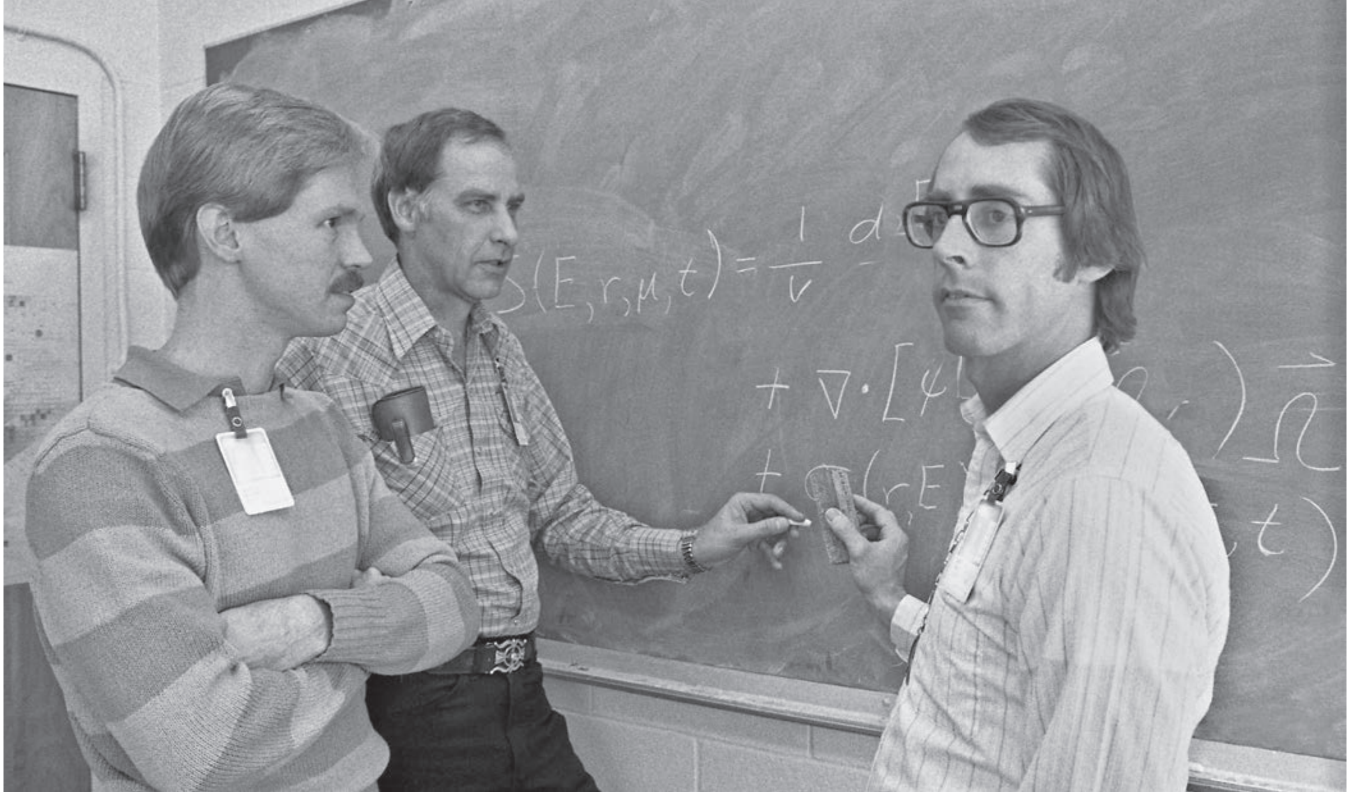
The radiation from this nuclear explosion is transferred to compress and ignite the thermonuclear fuel in the secondary. The entire process, from detonation of the explosives in the primary to the release of fusion and fission energy in the secondary, happens in less than a thousandth of a second.

What Are Hydrotests?

Hydrotests are the most common experiments that scientists do to study the implosion of the primary. To keep the hydrotest nonnuclear, they replace the plutonium in the pit with a surrogate heavy metal such as depleted uranium or lead. The explosively generated high pressures and temperatures cause some of the materials to behave hydraulically (like a fluid), hence the name *hydro*test. During the experiment, scientists collect data on the symmetry and compression of the imploding pit by taking x-ray images.







Gary Wall (right), circa 1984 *(Photo: Los Alamos)*

Then Tom Scolman, who was test director later, when I joined the Lab, starts laughing and says, "I think I may have an explanation. We had a severe rodent problem on the island. And since it was the last shot, we just stuck all the leftover rat poison on the barge with the bomb and blew it up!"

Now that story's not written down anywhere, but that's what happened. I wonder if the arsenic was ever explained in the test data.

***NSS*: Who made all the decisions for a shot?**

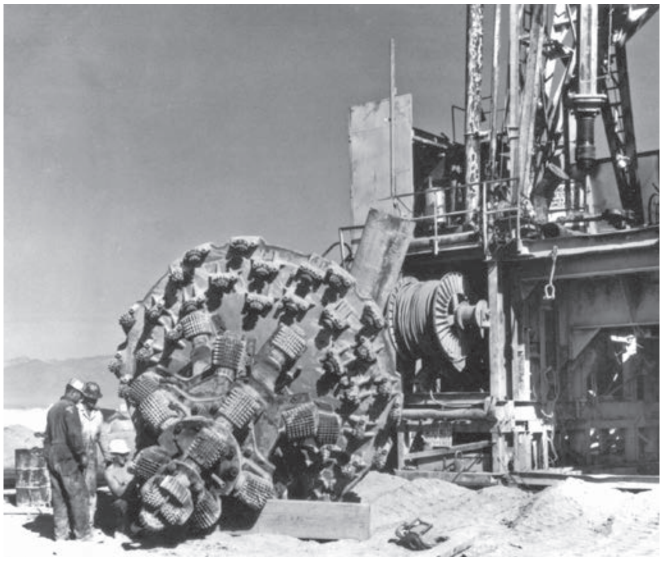
Wall: There was a design team for a shot, made up of three to four designers and a lead designer, who acted as both the team leader and mentor.

Pedicini: Actually, we had relatively few lead designers—people who could design something completely new, who could respond to the military's request for a new weapon that could do a specific mission never before done by an existing weapon. In the old days, to be a lead designer, you had to prove yourself. You had to design the new device and "go public" with it—tell the military and weapons-design communities what the device would do—then go to Nevada, set it off, and see if your judgment was right or wrong. The lead designer was the person who was responsible for the outcome, whether it was a mistake or a success.

***NSS*: How long did it take to become a lead designer?**

Pedicini: It could happen very quickly during the Cold War. In 1980, when I started at Los Alamos, I was 24, and by the time I was 25, I was a weapons design physicist. I fired my first nuclear test, called "Mini Jade," at 26. A year later I designed and tested a "clean-sheet" design, a device that was a completely new concept. The Lab was using New Mexico place names for its shots at the time; mine was "Vermejo" for Vermejo Park. It made a nice crater.

Mercer-Smith: I came to the Lab in 1983. At that time young designers would follow senior people around for the first two years. They wouldn't let us touch anything because we'd just hurt ourselves. And after three or four years, they'd let us do something just to see if we messed up. After five years, if you hadn't messed up, maybe they'd trust you with a shot. I was an apprentice for three years and was on the team for three very successful nuclear tests. At the end of those three years, I had my own shot to design. This was the training process: designers learned by doing. And after a decade you kind of knew how things worked.



Drill bit for drilling a large nuclear test emplacement hole. Drilling time could require as much as 12 weeks of around-the-clock work, depending on the hole's location, depth, and diameter. Large shots required a hole on average 1,000–2,000 feet deep and up to 12 feet in diameter. *(Photo: Los Alamos)*

Wall: I was the lead designer on seven nuclear tests, and like everyone else here, I learned the trade on the job. It wasn't something you could learn in graduate school. A beginning designer would join a design team and work under the mentorship of the lead designer. Relatively quickly, the newcomer would be assigned to work on major hydrotests, and as his judgment developed from hands-on experience, he would be assigned to work on nuclear tests.

Eventually, if warranted, the developing designer got to be the lead in the design of a new weapon, and the test at NTS was the tangible feedback mechanism for developing and demonstrating judgment. Post-shot analyses of the test data allowed you to see which of your predictions were right, which were wrong, and why they were wrong. The test data also helped you evaluate the computer simulations that led to your predictions and learn which parts of the simulations you could trust and which you couldn't. Learning from these tests is what built credibility and judgment.

Gary Wall, today. An avid marathoner, Wall runs along the road up to Pajarito Mountain Ski Area. The Laboratory is seen in the background. (Photo: Los Alamos)

***NSS*: People in the Weapons Program talk about "designer judgment" as if it's something out of the ordinary. Why?**

Pedicini: Weapons design is based on an incomplete science, so designing weapons requires using a great deal of intuition. It's largely an art form. There isn't a set of blueprints or a set of complete equations available for building new weapons. In the absence of a full set of data, designers have to make decisions based on their experience and intuitions—judgments—to create new weapons. Weapon primaries are particularly complex, where the link between one physical process and another is still unknown, so we regularly have to rely on our gut feelings. We're not accountants who have exact numbers and can easily see when column A does not equal column B. We have only partial data on these extremely complex systems.

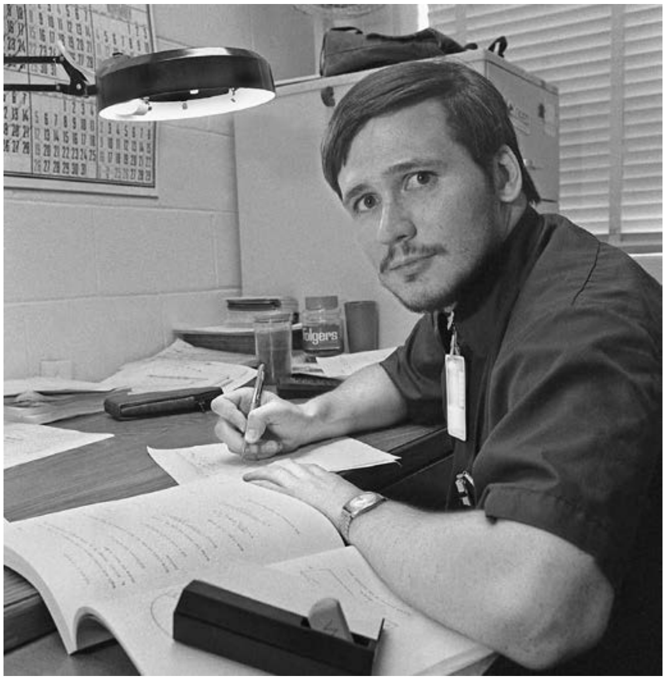
For that reason, it's typically a judgment call as to what would work in a primary design and what wouldn't. For instance, if you wanted to save weight and space and use the least amount of plutonium but still needed to meet the military requirement for a yield of, say, at least 100 kilotons, how much plutonium would you use? And what other warhead components could you change—and by how much—and still get the desired yield?

The test data helped you learn which parts of the simulations you could trust and which you couldn't.

In a system as complex as a nuclear weapon primary, every change could produce the "butterfly effect." In chaos theory a small change in one part of the system, the "flap of a butterfly's wings," could set in motion a series of events with enormous unpredictable consequences. We know this can happen in weapon designs because we've made changes in them, and the consequences in our test results sometimes really surprised us.

The act of designing a weapon primary involves making lots of compromises, and the consequences can't be known with 100 percent accuracy. If you change one thing, it needs to be balanced with some other change to ensure you get the desired result. That second change will need balancing too, and so on. That balancing act is performed in your head, and that's "judgment."

A nuclear test challenged the accuracy of your judgment. Weighing the results of the test against your predictions—what you thought was going to happen—was how you developed better judgment.



John Pedicini, circa 1983 *(Photo: Los Alamos)*

In the absence of testing, that's the kind of judgment we're failing to develop today in our young designers.

Mercer-Smith: Here's an example of how judgment works. We use plastic-bonded high explosives in weapon primaries. The high explosives age along with the rest of the weapon. So will small defects in the aged plastic bonding change the explosives' performance?

Think about what happens with a car. When you get a new car, that new car smell is the plastics outgassing. Well, plastic-bonded high explosives outgas too, and that changes their structure: they'll develop cracks. If you have an old car, you'll notice that the dashboard cracks. Are the cracks in the 20-year-old plastic-bonded high explosives going to change the weapon's performance, safety, or security? In the absence of testing, a designer is going to need good judgment to answer that question.

And when we talk about designer judgment, that judgment is not due to the designer alone. A designer has to be an entrepreneur in the sense of knowing a little bit about everything and when some problem needs an answer from an expert, knowing who in the Laboratory is that expert.

Pedicini: I tell the young designers that any weapons designer worthy of the title has a large Rolodex filled with names of experts in a wide range of fields. Then when there's some really hard design question or a measurement problem or a puzzle about a test result, the designer knows whom to call for the best information available. We work in a national laboratory with a broad array of scientific talent available for consulting. It's imperative that a designer access that talent.

***NSS*: Since no new weapons are being designed or tested, do we still need "designer judgment" today?**

Bob Webster: While we're not designing new weapons, other countries are. We need to anticipate what types of designs might be out there, what threats they pose, and how to do forensics [a nuclear-blast postmortem] on them should they ever be used. It takes a weapons designer with good judgment to do that kind of thinking. We can't afford to be surprised by our adversaries' capabilities.

Also, at some point the United States may decide it needs to modify its weapons to meet new challenges, such as improving safety and security features in the stockpile. The Second Nuclear Age is defined by more players wanting to become—and becoming—nuclear powers (see "The Second Nuclear Age," p. 2). Every nuclear nation is modernizing its nuclear capabilities. Our nation needs designers with good judgment to answer the call whenever it comes.

***NSS*: You're saying that designer judgment will be needed in the future, but what about today? Is it needed in the life-extension programs, the LEPs?**

Pedicini: In most of the LEPs funded so far, we're doing "oil and lube jobs." You take out the warhead, you look for broken parts, you replace those, and you put the warhead back together. We did that on the W87 to bring it back as much as possible to new condition. We did that on the W76, and now we're doing it on the B61.

We also do hydrotests on the designs of the warheads' primaries, and those experiments are crucial for reassuring the military and ourselves that we're delivering a product that meets the specs. But those hydrotests don't really test designer judgment. There are no surprises. The designer does the hydrotest on, say, a refurbished old design and then compares the results with old test data. So the designer has almost nothing new to study or interpret. That doesn't exercise designer judgment.

> *Our nation needs designers with good judgment to answer the call whenever it comes.*

Webster: That may be true right now, but some of the LEPs planned for the future involve bigger changes, such as the ones having to do with increased safety and security. Also, the weapons in our nuclear stockpile were designed to last 10 years but are now 20 to 30 years old, and the materials continue to age and need replacement. As we continue to replace aging materials with new materials that are slightly different than the original ones and remanufacture parts using different processes than were used before, the differences between the refurbished weapons and the original designs will increase. So each time a new LEP is proposed, the weapons designers must judge which changes are necessary and then develop a route to certify—and reassure our military, adversaries, and our allies—that our "life-extended" weapons will still perform, if and when needed, according to their design specifications.

Mercer-Smith: It's up to the weapons designers to assess whether a defect we find during surveillance needs to be addressed and if so, how. That takes judgment. [In surveillance, weapons are drawn out of the stockpile and examined.] Even small defects or changes in a system like a weapon or a rocket can lead to catastrophic results. Judging how an aged weapon with a defect will or won't perform is even more difficult than designing a brand-new weapon, where you work with known quantities and qualities.

Experimental data are essential for developing our ability to judge when, where, and how much the codes are lying.

Webster: Today, we've still got a few designers who developed their judgment in the era of nuclear testing and who can weigh in on these decisions. But LEPs call for extending weapon lifetimes for at least a couple more decades. By then the designers with test experience will be gone, and the people responsible for certifying our weapon systems will be those who have just entered the Lab force today. Will this new generation be up to the task?

Concerns about what our future designers will or won't know are reflected in the Annual Assessment Letter our director sends to the president. The nature of the letter has evolved. Originally, it addressed, "Do you need to do a nuclear test, and is the stockpile safe, secure, and reliable?" More recently, as we respond to questions about the adequacy of the science-based tools and methods being used in stockpile stewardship, we also address the question, "Are we training the next generation of stewards?"

Are we giving the new designers the training and experience needed to qualify them for certifying a stockpile 20 years from now? I'm worried that because we're doing very few experiments, we're becoming much too dependent on computation alone. So when a new question comes up, I might hear the new designers say, "Well, let's just compute it." If that's the only tool they have, I don't think that's good enough.

***NSS*: What's the problem with relying so much on computer simulations?**

Mercer-Smith: It's important to remember that a computer code of a million lines is nothing more than a series of thousands of approximations. If any of those approximations aren't valid, then the probability of error is significant. We use experiments to determine which of the approximations can be expected to be valid.

New designers sometimes expect too much from a computer code. When I joined the Lab, it was pounded into our heads over and over that the *codes always lie* and that the job of a designer is to know when, where, and how much. The key challenge for the future is to train the next generation so they have that kind of judgment.

But today we're forgetting—or ignoring—that the codes can lie, and we don't always have the experimental data we need—the reality check we need—to prove or disprove our conjectures. Experimental data are essential for developing our ability to judge when, where, and how much the codes are lying.

Webster: We're not doing enough experiments to replace the loss of full-scale testing. What we're talking about here is the need for more *integrated* experiments, which are experiments on weapon subsystems. Integrated experiments are the hydrotests we do at DARHT [Dual-Axis Radiographic Hydrodynamic Test facility] and the subcritical experiments we do at the Nevada National Security Site. Subcritical experiments, by definition, use plutonium, but not enough to ever produce a critical mass.

John Pedicini, today (Photo: Los Alamos)

***NSS*: Why are integrated experiments so important?**

Webster: An integrated experiment gives us data about, for example, how an aging primary works. With full-scale nuclear testing forbidden, integrated experiments let us check the subsystems that make up the whole system, and from that we can infer the weapon's overall quality.

Integrated experiments also give us the data needed to validate the predictions of our computer codes and help us improve the codes. Then we can validate or refine the improved codes with further experiments. It's a constant cycle.

Without new experiments, we'll fail in the role of deterrence.

First, the designer runs a simulation that predicts the results of an integrated experiment. The experimental results then either validate the simulation and the prediction or not. The order, prediction first and integrated experiment second, is crucial because human beings can rationalize things faster than we'd like to believe. If the experiments came first, they would color how we read the results of a simulation. We'd always correctly predict the results of an experiment after the fact. Peer review also has its limitations because people can get into groupthink and be fooled by it. The only protection against rationalization and groupthink is doing experiments, new ones where the answer isn't already known.

***NSS*: So without testing, integrated experiments are the key to developing designer judgment.**

Wall: That's right. Compared with the number of predictions we have to make using the codes, we aren't doing enough integrated experiments to back the codes up. There are too few hydrotests, and even fewer subcrits. Right now we're annually doing maybe four or five major hydrotests involving a full-up replica of a weapon primary.

We ought to be doing one hydrotest per month. If the resources were there, we could easily conduct that many experiments and feed those data back into improving both the weapons codes and designer judgment. In the testing era we were doing several hydrotests per month.

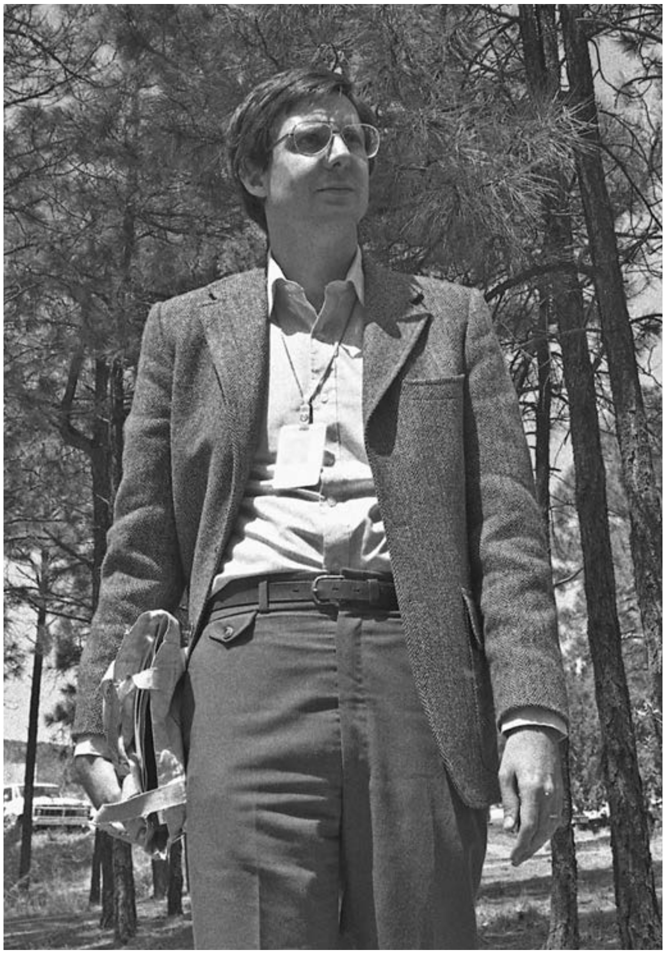
Today, there's so little experimental feedback to validate or contradict their predictive work that the new designers have a hard time maintaining interest. Some want to either become managers or drop out of the program. Sadly, that makes sense, but it's not what the nation's national security needs.

***NSS*: Would doing more experiments help in recruiting new designers?**

Wall: That's one of the benefits of doing more experiments that's often overlooked. Maintaining the stockpile is a long-term effort extending decades into the future. It would definitely be easier to recruit people to be designers if we were doing more experiments. I know this from my own experience and from conversations with the younger designers. You can do computer simulations over and over again, but without having the excitement of anchoring your results in reality, what's the point? Having the data from experiments, having that feedback, creates excitement. Those experiments could be new designs, but they also could be old designs analyzed with new diagnostics that give you more information than you had in the past. That's exciting too.

Gathering data is what keeps scientists excited, and the more experiments they do, the more scientists we can keep excited and interested in becoming designers.

Pedicini: Judgment comes from design experience: designing new weapons and new experiments. But we do very little actual designing now. Most of our integrated experiments don't test new designs, where you can make a mistake and learn from that mistake. Without new experiments, in which we can test ourselves and run the risk of a failed experiment, we'll fail in the role of deterrence. We need to accelerate the pace of trying new things and be willing to make some mistakes.



Jas Mercer-Smith, circa 1984 (Photo: Los Alamos)

Jas Mercer-Smith (left) at the Designers Roundtable (Photo: Los Alamos)

I'm not talking about experiments that just refine old designs. I'm talking about big-picture experiments, integrated experiments on new ideas that are going to reveal if our designers can handle the stress they'll be under in a world that may re-occur in the future. We had a testing moratorium in 1958–1961, and everybody thought, "Hey, the arms race is over!" Then the Russians shot a whole pot full of bombs in one week, and we were off to the races again.

We're in the second moratorium now, but what happened before could happen again. And if it does, the requirements of the stockpile will change. We'll need people who have been hardened a little bit—who have made mistakes and have developed their judgment and kept it sharp. Lack of judgment in designers will be fatal. We'll do things without using the judgment that experience brings, wasting time and resources and risking a catastrophic failure.

Here's an example. The Germans had a first-class navy in World War I, but then the Treaty of Versailles shut down their production for 20 years. When they later built the Bismarck-class battleships, the largest battleships ever built by Germany, they made major mistakes in design judgment. They made the ships very hard to sink but left the rudders unprotected and easy to disable. The British locked up the Bismarck's steering gear with a small torpedo. Also, the ship's main communications were above the armor belt, so an 8-inch shell destroyed them. These were major flaws in design judgment coming from a long span of inactivity in warship design. We run the same risk if we fail to challenge our designers continuously.

Webster: It's the same with students. If students can find their physics problems all worked out in the back of the textbook, they never turn in bad homework assignments. You have to give them problems without already-known answers if you want to know if your students are really thinking.

***NSS*: You mean the next-generation designers need to be challenged with new problems.**

Pedicini: Yes. We should throw design challenges at them and make them do something new. They need to be learning, through as many experiments as necessary, if their design decisions are right or wrong. They need to be taking risks, and by that, I mean they have to risk failure, risk being wrong. You can't just keep doing what's been done before.

The weapons in our stockpile were developed for the world that existed during the Cold War; they're not necessarily the appropriate warheads for whatever comes next. You have to have the appropriate design staff, using good judgment, so that if the world changes, if we go back into another Cold War and we need a different set of weapons, we'll have the people who are capable of designing them.

Of course the new designs they do now won't go into the stockpile. But the judgment they're developing *will* go into the stockpile someday. It's the capital on which we'll build the future.

Preparations for an underground test at NTS. (Photo: Los Alamos)

***NSS*: If experiments are so important, why are so few being done?**

Webster: Cost is a big issue. As experiments become too expensive, we have to shoot them much less often. Then scientists make more diagnostics to cram into each shot because they're worried that they will have only that one shot to get the data they need. This makes the experiments even *more expensive* and even *less frequent*. It's become a vicious cycle.

Pedicini: There's always going to be some cost associated with being competent, honest, and safe about how you do business. But that doesn't account for anything like the cost increases we've had. It seems to me that most of the money for our experimental program is spent on bureaucracy. We're going to have 10 people checking the checkers who are


Bob Webster moderating the Designers Roundtable. *(Photo: Los Alamos)*

checking the checkers who are checking the one guy doing the job. How about train the one guy properly, give him the discretion, treat him like a professional, and get rid of all these layers of bureaucracy?

Money's also being wasted by too much "project management." It's become a profession and a "thing" in and of itself, as opposed to being a means to reaching a goal. We should manage a project so it gets done the best way possible, not just manage for the sake of managing.

Wall: I think our infrastructure has aged to the point that it also affects how much money can be used for experimentation. Since the end of the Cold War, there hasn't been a driver for getting new, more-efficient, more-capable, more-cost-effective machinery to make and assemble parts. There hasn't been any urgency because we're not putting new things into the stockpile. Now that we're doing life-extension programs, we're putting a lot of money into maintaining our aged facilities and outdated manufacturing equipment—infrastructure that hasn't kept up with the times. So by postponing investment to save money yesterday, we made everything in the nuclear weapons complex more expensive today.

Pedicini: The fear of taking risks is another problem. Both in Washington and at the labs there's a growing tendency to foster a totally risk-averse environment. We've become so risk averse because our customers, like the National Nuclear Security Administration [NNSA] and the DoD, expect everything to be a success.

We must allow people to try things that might fail. It's also how you move forward. It's the people who are willing to risk their reputations who drive us into the future. We need to try things that might fail.

I'll give you an example from a recent hydrotest we did on a brand-new design that used high explosives [HE] in a new way. I needed help from an HE physicist, and Dan Hooks offered to help. I asked him right off if he was willing to fail. I said, "This may not work. The entire theory of high explosives and all the codes in the world say it won't work, but they're valid only in a very narrow range, and we'll be stepping outside that range. Are you willing to try something that everyone will tell you won't work? And if it turns out not to work, will you be able to handle the failure?"

He was willing, and the hydrotest was a great breakthrough. It was stunningly good: it actually *exceeded* the implosion quality of anything we've seen before. But we wouldn't have even tried the experiment if Dan hadn't been willing to get dirty. And by "getting dirty," I mean run the risk of failure.

I was a designer on 13 nuclear tests, and I learned more from the one that didn't work so well than I learned from all the others.

Wall: I agree. A successful experiment proves what you already know; it validates your knowledge. In contrast, a failure, a missed prediction or a bad judgment call, lets you know where you need to seek more knowledge, where you need to go in order to expand your understanding.

There was fear of failure during the nuclear testing era too, but it was different. There wasn't *time* to explore riskier approaches that might have resulted in better weapons. The military wanted to put things into the stockpile as quickly as possible during the Cold War. We had a blank check to do that as long as we delivered the product on time.

In my current work, which focuses on understanding the effects of aging, especially plutonium aging, in the stockpile, the risk aversion is about high safety and security costs. The budget is fixed and plutonium science is very expensive—and it keeps going up, largely due to overblown safety and security costs, I think.

> *We're going to have 10 people checking the checkers who are checking the checkers who are checking the 1 guy doing the job.*

Mercer-Smith: The problem is how do we balance, say, the small probability of an accidental release of radiation against the national security requirement that we maintain a nuclear stockpile? There is no incentive for the regulators to approve an experiment because if there were an accident, they'd be held accountable. The only way to absolutely guarantee that you won't have an accident is to *do nothing*. However, it's important to understand that doing nothing also represents a risk—a risk to national security.

We're not saying cut corners and be reckless. We're saying we need to better balance the costs and benefits of doing more experiments: manage the risks better.

Webster: In the National Academy of Sciences' 2013 report ["The Quality of Science and Engineering at the NNSA National Security Laboratories"], they said a very similar thing: "All experimental activities have inherent risk, and successful organizations manage that risk." But the labs have been "focused too much on the safety risks of doing experiments with hazardous materials, rather than considering the risk of not doing them at all." Not doing those experiments, they warned, risks our ability to do stockpile certification down the road, "which could increase the risk to national security."

Wall: It's true that risk aversion about safety is being overdone to the point that it's interfering with getting our work done. The epitome of that is at the Lab's Plutonium Facility, where the safety rules have caused severe limitations on the quantity and speed of the work. And aging plutonium is the material we *most* need to work on in stockpile stewardship.

Mercer-Smith: Beryllium and high explosives also need more research, and doing experiments with these hazardous materials has also become prohibitively expensive because of increasingly stringent safety requirements.

Aging plutonium is the material we most need to work on in stockpile stewardship.

Wall: It's also true that doing so few experiments has led to a downsizing of the complex and a reduction in the number of people who make the parts we need for experiments. Without experiments, there's no driver for attracting those kinds of highly skilled people.

***NSS*: All these barriers—rising costs, fear of failure, increasingly stringent safety requirements, and risk aversion—mean not enough experiments are getting done and people are leaving. What can be done to increase experimentation?**

Webster: We're trying to be more cost effective and break the cycle of doing fewer and fewer experiments that are more and more expensive by adopting a new approach. We're telling people, "We're going to do the shot on this date, and here's the schedule. We've got this budget, and with this budget we can shoot this many times. Make your diagnostics fit because the shot's going to fly on that date whether your diagnostic is there or not." We're trying to get people to think about the costs and use some ingenuity.

Another key factor needed for doing more experiments is garnering not just NNSA and DoD support, but Lab-wide support. Many of the components of Weapons Program experiments aren't specifically about weapon design but rather are concerned with fundamental physics questions. How our physicists respond to help us increase experimentation will be important. And they're doing very well at proposing clever ways of doing diagnostics and coming up with things to measure. Our Operations and Business Directorate is going to have to get engaged too and help us back away from total risk aversion and instead embrace risk management, that is, let us take prudent risks. This will be successful only if the entire enterprise, both NNSA and the Lab, pulls together.

***NSS*: What is the most pressing experimental need now, and are there plans to meet that need?**

Wall: The pressing need now is to learn how aging plutonium affects the stockpile. It's been argued that the plutonium pits in the stockpile will last 100 years, but there's no universal agreement on that. We haven't done enough experiments to know. Manmade plutonium hasn't even existed for 100 years. [Plutonium is made in nuclear reactors, the first of which was Enrico Fermi's "Pile." It went critical in 1942.] In the interest of national security, it behooves us to do more experiments on plutonium to find out whether the claim of 100 years is true or not.

We can steward the stockpile almost indefinitely if we're doing the right homework. But right now, without more work on plutonium, I don't think we're doing the right homework.

Pedicini: But there's something new on the horizon that will allow us to do the needed work on plutonium. The neutron-diagnosed subcritical experiments now being proposed could help us study the properties of aged plutonium during implosion and explore the possibility of reusing older pits. [See Neutron-Diagnosed Subcritical Experiments p. 34]

This new kind of subcrit will also be a real training ground for new designers. They'll be designing experiments, predicting outcomes, and measuring things that have not been measured in 20 years. It will be a real opportunity for trying things that can fail and for honing judgment. If these new subcrits get approved, we'll be seeing the next generation of designers carrying this out.

Preparations for the "Praetorian-Rousanne" nuclear test,1981. The crane (background) is for lowering the nuclear device, along with a rack of diagnostic sensors for monitoring the explosion, into the test shaft. The trailers (foreground), stationed at a safe distance from ground zero, contain instruments to record the sensors' diagnostic data, carried to the trailers by the miles of cables shown here snaking between them and the test. (Photo: Los Alamos)

***NSS*: If you had a chance to tell the Congress, the DoD, and taxpayers about why weapons designers are key to *deterring* a nuclear war, what would you say?**

Wall: What weapons designers do is not so much maintain the stockpile as maintain deterrence. For deterrence to work, stewardship must be working. Stewardship works only if you have good weapons designers in hand.

So far, stewardship has been most successful in the theoretical and computational areas. It has been less successful in the experimental areas. Ultimately, preservation of the stockpile depends on weapons designers and their exercise of good judgment, learned through experimentation.

Pedicini: I'm afraid the Lab is becoming just an old library of ancient nuclear secrets, a monastery for the last few nuclear monks. But the nation has to have weapons designers who possess good judgment so if the world changes and we go back into another Cold War, we'll have the talent ready to go.

That's what we have to focus on: How do we develop that judgment? With experiments, that's how. But under the current constraints, we're not experimenting enough. We have an obligation to the taxpayers of this country to develop new weapons designers with good judgment. But we're not being given the opportunity to meet that obligation.

Mercer-Smith: Sometimes when I'm giving a talk, I end by reading a passage from Mark Twain's *A Connecticut Yankee in King Arthur's Court*. The main character is a very good engineer who goes back in time to the fifth century and totally redoes King Arthur's England. He introduces things like electricity.

At the end of the book, there's a civil war. The engineer and his allies are surrounded by tens of thousands of knights, and he sends them this message: "We know your battle skills. We number 54. Fifty-four what, men? No. Minds. The most capable minds in the world; a force against which mere animal might cannot prevail."

Well, the mass of knights attacks. But knights on horseback do very poorly against the Gatling guns, poison gas, explosives, and electrified fences devised by the 54.

The reason we need new designers is not just to maintain the stockpile but to make sure the nation is never in the position of being like knights on horseback against Gatling guns. ✦

~ NSS Editorial Staff

The Nevada Test Site (now the Nevada National Security Site) was where most U.S. nuclear weapons were tested from 1951 to 1992. Of the more than 1,000 nuclear detonations done in Nevada (some tests had more than one detonation), over 900 were underground. The site covers more than 1,300 square miles.

(Photo: Los Alamos)

~Part 2: Second-Generation Designers~

Langdon Bennett, David Jablonski, Brian Lansrud-Lopez, and John Scott

with Bob Webster

Part 2 is compiled from interviews with the Lab's "second-generation" designers and discussions at the Designers Roundtable, 2nd Los Alamos Primer lectures (July 2013). Their perspectives offer insights into the challenges they face as stewards of the aging U.S. nuclear stockpile in an era when they cannot test it, their resources are limited, and the number of important experiments they need to do is constrained.

***Langdon Bennett** joined Los Alamos in 1996 as a specialist in high-explosives modeling. He currently is the primary lead for the B61 thermonuclear gravity bomb life-extension program (LEP).*

***David Jablonski** joined the Laboratory in 2005 as a physicist. He first came to the Lab in 2002 on an Air Force assignment but then left the Air Force work at the Laboratory on the Stockpile Stewardship Program.*

***Brian Lansrud-Lopez** joined Los Alamos in 2005 as a nuclear engineer. In 2010 he joined the team working on the B61 LEP. His work includes leading hydrodynamic experiments and doing weapons physics research.*

***John Scott** joined Los Alamos in 2000 as a nuclear engineer. In 2006 he became a lead designer for the Reliable Replacement Warhead project. Scott's current work is related to investigating the potential use of recycled plutonium pits in refurbished nuclear weapons.*

***NSS:* What's it like being a second-generation weapons designer?**

John Scott: Sometimes we in the design community have debates about what makes a designer. What makes a designer today is different than what it was before the testing ban. Today, designers make predictions regarding the performance of the aging weapons in the nuclear stockpile, but they can't test their predictions with an underground nuclear test. So some people say we're not really designers.

David Jablonski: There are some people who believe that the only "real" designers are the ones who designed a nuclear weapon that was tested with a full-scale test. By that definition, "real" designers are "the ones who dug big holes" [at the test site in Nevada].

So there are very few "real" designers left in the nuclear weapons complex. Remember, a new U.S. nuclear weapon hasn't been manufactured since about 1991. And since the United States stopped conducting full-scale tests of its weapons in 1992, the first-generation weapon designers, the ones who took part in the testing, are getting scarce—they're retired or getting ready to retire.

In the early 1990s basically everyone in my division at the Lab had nuclear testing experience. Since that time it's been dropping. And that drop has accelerated a lot since I got here. When I came here, in 2002, I'm guessing there were 15 or 20 designers with test experience; today there are maybe 5 or less.

As a result, particularly in the past 15 years, there's been a focus on learning from the first generation while they're still around. Today, we're starting to hire what will become the *third generation* of designers—those who won't have *any* access to designers with underground testing experience. So by and large, they'll be trained by designers who aren't designing [creating new designs] and who don't have any nuclear testing experience.

In lieu of testing nuclear weapons, second-generation designers judge the condition of the aging stockpile based on tests of weapon subsystems, computer simulations of both physics phenomena (shown here) and weapon behavior, and knowledge gained from past nuclear tests. (Photo: Los Alamos)

Langdon Bennett at the Designers Roundtable (Photo: Los Alamos)

Brian Lansrud-Lopez: There are those who believe the second generation should be called "weapons analysts." That's because there is an overriding military philosophy about the stockpile: please, don't change it very much. This is what it looks like, and they like the way it looks. It's old, but it was tested and certified. So in that sense, for the Stockpile Stewardship Program, we're analyzing the stockpile.

Instead of a weapons analyst, I prefer being seen as a "weapons physicist." Any particular weapon design is a concrete example of a concept in weapons physics that's brought to life. Our second-generation responsibility is that we understand weapons physics well enough that we know how and why the designs in the stockpile are going to function and well enough that we can look for problems due to aging and seek solutions. We can't analyze a weapon in the stockpile without being weapons physicists.

Jablonski: In the life-extension programs (LEPs) we've done since the end of testing, we've tried to keep the weapons as close to their original designs as possible. But there's clearly a limit to how far we can do that. The suppliers of some weapons' components have, after 30 years without a market, gone out of business. To make those components today, we'd have to start all over. But replicating the *exact* ways certain source materials were made, and how components were made using those materials, may not be possible in some cases. The people are gone. The tools are different. So the things we replace may look the same but really are not *exactly* the same. The goal of course is to make the necessary changes while minimizing change.

***NSS:* The first-generation designers talked about how quickly they got to do experiments and tests. What's been your experience?**

Lansrud-Lopez: In comparison to Wall, Pedicini, and Mercer-Smith's immediate involvement in nuclear tests, we started by learning the simulation tools. We're given a computer and taught how to run the codes. It's a hard job. Today, integrated experiments on weapon subsystems, for example, hydrotests, are largely out of the question in a designer's formative years. It was six years before I was the lead physicist on a hydrotest. I started that experiment in 2010, and it probably won't be done until January 2014.

> *We need to get new designers off their computer screens. We need them to be doing tough experiments instead.*

The hydrotests we do aren't groundbreaking. They're focused on analyzing the stockpile. We're typically looking at things that are already very well understood. Frankly, we're supposed to get the answers the first-generation designers got—because the stockpile better not change very much. These experiments are very mundane.

Langdon Bennett: Today, with the reliance being more on computer codes and less on experimentation, it takes years before we can give the new designer some reality through an experiment. We're moving too slowly in throwing people into the deep end of the pool. We need to get them off their computer screens. We need them to be doing tough experiments instead of just doing another validation experiment on a B61 LEP.

We need to accelerate the learning process. After a year or so, the newcomers need to be conducting basic experiments and comparing their predictions with their experimental results. They need to get to the point, much faster than they do now, where they're ready to do big experiments, with big unknowns and the opportunity to explain something new.

> *Without nuclear testing, how do I know that aging, stockpiled weapons will work on my missiles on my submarines?*
>
> *~U.S. Navy officer*

Today, the new hires must commit two to three years to the Lab's Theoretical Institute for Thermonuclear and Nuclear Studies [the Laboratory's in-house weapons design course]. So it's 5 to 6 years before they're doing even a mundane hydrotest, which just verifies something we know, and 10 years before they're allowed to do an experiment that pushes our frontiers, an experiment not guaranteed to succeed.

***NSS:* What other challenges does a second-generation nuclear weapons designer face if they can't design, build, or test nuclear weapons?**

Bob Webster: It makes it harder for our designers to understand and model foreign weapons designs. The country faces threats from the development of improvised terrorist nuclear devices and from the nuclear weapons designed by other nations. We need to know what's going on in those nuclear weapons programs. There are very likely to be ways of building bombs that are different from anything we've thought of. According to a report published by the National Academy of Sciences in 2013, understanding and evaluating the threats from other countries' novel designs "is of vital importance," and "the need to understand their science and technology in detail is likely more compelling today than it has ever been."

I think if we don't try designing new weapons, at the very least on paper, we won't find out what we don't know. If we don't have some idea of what other nations could be designing, what their weapons are capable of and how we might counter them, we'll be in for a surprise.

Scott: We face a *credibility* challenge with the military. The real question is not just *How do we know we're right?* It's *How do we convince others we're right?*

When we say, "Device A will perform with X kilotons," how do we get the military, our allies, and our adversaries to believe us without a nuclear test? The military says, "Why should we believe you? We test all our stuff. You haven't tested yours."

That's the most difficult question we have to face today with the military, DOE headquarters, JASON [an independent group of scientific advisors to the U.S. government on matters of science and technology], and SAGSAT [Strategic Advisory Group Stockpile Assessment Team, which provides technical expertise to U.S. Strategic Command on nuclear weapons issues]. A high-ranking U.S. Navy officer asked us after the Designers Roundtable, "Without nuclear testing, how do I know that aging, stockpiled weapons will work on my missiles on my submarines?"

How *do* I convince military officers like him? We're really grappling with that right now. We're being asked to do the same job the first-generation designers did—ensure that the U.S. nuclear deterrent works—but without testing. When we rebuild anything in the stockpile, we have to change something. Materials don't exist anymore, or the manufacturing process doesn't exist anymore, and we have to make things differently. Even small changes can have large effects. How can we promise the military things will work as they're supposed to?

So we're asking the military to believe us without the same hard evidence they got before. The DoD goes through a very long process to develop the F-35 Joint Strike Fighter. They have test pilots fly the plane, and they work out the kinks. But what if they built the plane without testing it and trained the future pilots using a simulator of the plane, then told the pilots to get into the cockpit and fly a mission?

That's equivalent to what we're being asked to do. We're rebuilding a weapon but can't test it. We're being trained to be able to design and build a weapon in the future, but we're not allowed to practice those skills, except using a computer simulation. We're expected to be *ready* to do it should the need arise, but we *can't* do it before then. We have an enormous responsibility for national security, but at the same time, it's like our hands are tied.

Brian Lansrud-Lopez (Photo: Los Alamos)

I don't think the DoD gets that. We can't practice in order to show them what we can do, and then they have a hard time believing us when we say we can do it. Without practice, we have a hard time believing *ourselves* some of the time. We're under the political constraint where we can't do nuclear testing, but there are key people who haven't acknowledged the consequences of that constraint. So part of our job is to educate people about the consequences of that constraint, and how it affects us—and them—and how we try to succeed within those limitations. That's what stockpile stewardship is all about.

***NSS:* How can your generation of weapons designers meet this credibility challenge?**

Bennett: Send us some people from the military so they can "watch the sausage being made." They'll have a chance to listen to us debating about whether we've made the right judgment, and why we think so. We need to be transparent and learn to explain things in ways our customers can understand. They need to understand all about our assumptions and approximations. They need to see what goes into making a judgment call, how we debate and how we reach a consensus, so they'll have confidence in our work.

Scott: We'll go a long way toward gaining credibility if we can solve the mysteries surrounding historical test failures, the anomalous results that the older designers couldn't explain.

> *Send us some people from the military so they can "watch the sausage being made."*

Webster: I want to point out that we've always had to convince our customers that we were credible, and they've trusted us in the past. For example, Los Alamos never tested every variation of the weapons it designed for the stockpile. We said that, in our best judgment, these variations would work, and the customers believed us. But they trusted our judgment because of hundreds of previous tests that demonstrated our honesty and integrity and credibility.

John Scott at the Designers Roundtable. *(Photo: Los Alamos)*

Jablonski: We're asking to be able to do as many experiments as possible, both to broaden our understanding and to train us. We need to do experiments—lots of them—but we need to do them on tough stuff—and tough stuff that matters. For example, it would be great to do *one shot a week* at DARHT. It's an absolutely wonderful facility with awesome capability. If we could do one experiment a week, think of all the experience we could get. (See sidebar, opposite page.)

And we need other facilities where we can do the tough experiments, for example, to better understand aging plutonium. Together, these experiments would build confidence in the stockpile *and* build confidence with our customers that they can trust our judgment.

Lansrud-Lopez: We really need a new and important kind of experiment that would help us decide if we could reuse older pits. There are no experiments to measure the neutron-generation characteristics of an imploding aged pit—to confirm if these pits will, indeed, go supercritical. It should be possible to do this with a new type of experiment, one we're calling a neutron-diagnosed subcritical experiment, to do this. (See "What Is a Neutron-Diagnosed Subcritical Experiment," p. 34)

Equally important, we have to be allowed to do experiments that run the risk of *failing*, of not meeting our predictions and therefore challenging our judgment. It's those kinds of experiments that would build our credibility. Using neutron-diagnosed subcrits to study new variations of old designs would do just that.

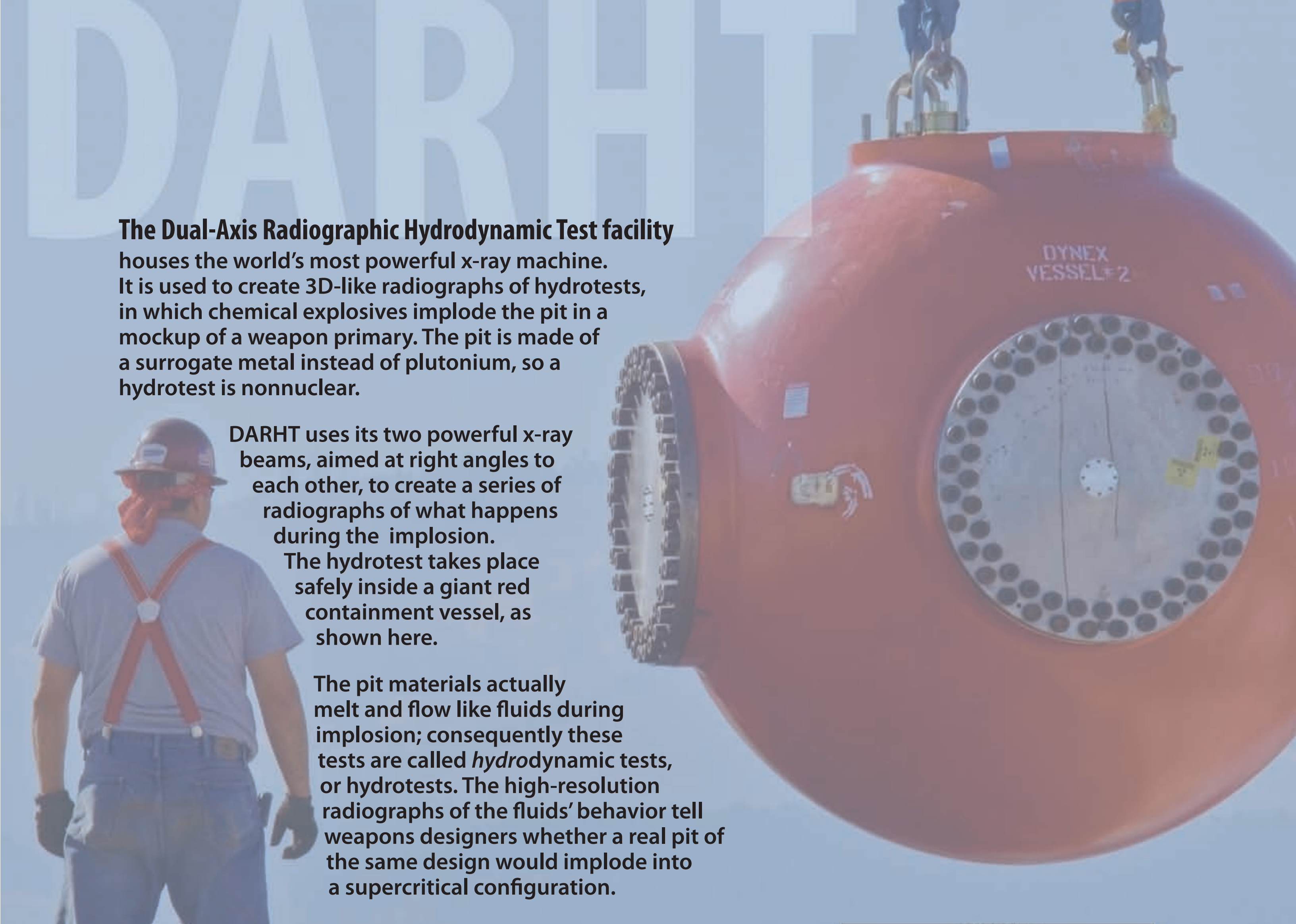
> *We need to fail and then try to understand why we failed—that's how science works.*

Scott: Designers are scientists, so our work relies upon the scientific method. We identify a problem, make a hypothesis, conduct an experiment to test the hypothesis, and then use the experimental results to improve it. So conducting experiments is a crucial part of the scientific process; that's how we advance our scientific understanding. Some experiments yield results that affirm our hypothesis, indicating that our understanding is correct, while others contradict it. But when the experimental results don't match up with our expectations, it's not a failure; it's an opportunity for us to understand something that we clearly didn't understand before the experiment. We need to fail and then try to understand why we failed—that's how science works.

Experimental success is never guaranteed, but we operate today in a business environment where we're asked to guarantee success, where we're allowed no risk of failure. That's not logical. We need to be able to fail and have the scientific integrity to state what we know and what we don't know. That's honest. Honesty builds trust. We need our customers to have trust in us, to trust our judgment.

~continued on page 32

DARHT

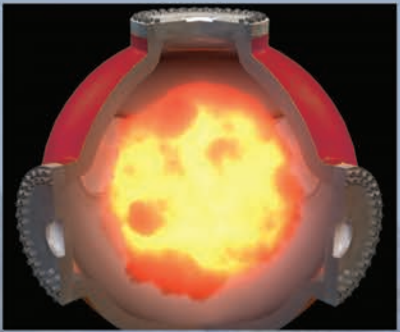


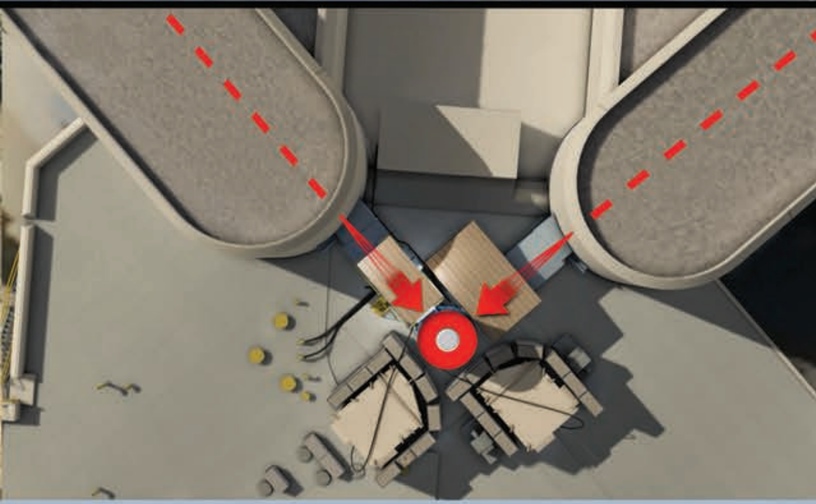
The Dual-Axis Radiographic Hydrodynamic Test facility houses the world's most powerful x-ray machine. It is used to create 3D-like radiographs of hydrotests, in which chemical explosives implode the pit in a mockup of a weapon primary. The pit is made of a surrogate metal instead of plutonium, so a hydrotest is nonnuclear.

DARHT uses its two powerful x-ray beams, aimed at right angles to each other, to create a series of radiographs of what happens during the implosion. The hydrotest takes place safely inside a giant red containment vessel, as shown here.

The pit materials actually melt and flow like fluids during implosion; consequently these tests are called *hydro*dynamic tests, or hydrotests. The high-resolution radiographs of the fluids' behavior tell weapons designers whether a real pit of the same design would implode into a supercritical configuration.

This is important to know because, in a real primary, the implosion must force the pit's plutonium into a supercritical configuration to start uncontrolled fission and a nuclear explosion.





David Jablonski (Photo: Los Alamos)

Jablonski: Yes. Failure is an important part of what we do. Let's say we do an experiment, and we come up with totally different results than we expected. This can be fantastic because it shows us what we don't understand. But today there's a tendency to think of failure as "bad" when it's really an opportunity to fix something that clearly we had wrong. Failure is how we get better at what we do.

> *The stockpile is changing. Deterrence needs people who can do the science and mitigate the problems in the future stockpile.*

Lansrud-Lopez: When you get something wrong, that's a real truth teller. Mother Nature just gave you a wake-up call. Now you've got some serious work to do to figure out why.

***NSS:* What's keeping you from doing more experiments?**

Bennett: Driven in part by our customers, the Laboratory now has a huge problem due to risk aversion. We aren't being given the freedom to do an experiment because of the risk that it might fail. And there's also the risk aversion stemming from excessive safety concerns. Some of these concerns reflect, I think, a lack in common sense. The result is excessive regulation and bureaucracy at the Laboratory. Excessive safety regulations, along with a bloated bureaucracy, drastically increase both the cost of experiments and the time it takes to conduct them.

Jablonski: Bureaucracy definitely gets in the way. It's not ill intentioned, but it blocks us from doing our technical work. Meetings are often valuable, but all of a sudden it's three in the afternoon, and the technical work has to wait another day. There has to be a cost-benefit analysis: bureaucracy balanced with getting the job done.

***NSS:* Do you have confidence in the stockpile?**

Jablonski: Yes, absolutely. We have a suite of more than 1,000 nuclear tests whose data tell us that our devices work just fine. And we have post-test-ban experiments and our computational tools. When we've found issues related to aging, we've been able to address them with our LEPs. These, together with the judgment of lots of other expert scientists and engineers, give me confidence.

Bennett: I have a great deal of confidence in the stockpile as it exists now. But because of aging and replaced components, this stockpile is different than it was a couple of decades ago, and there'll be a different stockpile again tomorrow. How will we have confidence in it then? We need to keep stewarding it and doing surveillance on it. We need to keep doing experiments to see how the weapons age and how we can mitigate the aging process. We can't just swap out old parts with new ones that are made differently and let it go at that. It's not that simple.

Scott: Without testing, our confidence is based on our assessments of the weapons. To make assessments, we rely on the interplay between computer simulations and experiments. We designers say, "The codes always lie." To make the codes more accurate, we conduct experiments and adjust the codes accordingly. This interaction between experiments and computer simulations is what gives us the confidence to say that, as of today, the aging weapons will work as designed.

Lansrud-Lopez: If we want to know positively how our nuclear stockpile will work, we obviously should be doing nuclear tests. We recognize that we can't do full-scale tests, so we are trying to do the best we can with what we've got. Today, our deterrence rests upon *science* and the *people* who do it.

Webster: We get a lot of pushback from our customers when we talk about the "value of doing science." They tend to want just those experiments that are directly about the stockpile, that keep the stockpile looking just like it did 20 to 30 years ago.

Bureaucracy definitely gets in the way. There has to be a cost-benefit analysis: bureaucracy balanced with getting the job done.

But the stockpile *is* changing due to aging and our replacement of aged components with new ones made in new ways, with new materials. Deterrence needs people who can do the science that can predict and mitigate the problems in the *future* stockpile—it needs designers with judgment who, without testing the weapons, can predict how the weapons will perform down the road.

We're going to have to educate our customers about what it takes to train new designers: more experiments, more science.

As Vic Reis, the architect of stockpile stewardship, said during the 2nd Primer lectures, "The issue is this: the key to deterrence is not just the weapons, it's the scientists and the science. This is very hard for the DoD to understand. If we don't have full-scale testing and if the DoD relies on its LEPs, then deterrence ultimately rests on *the science and the people with judgment*."

Yuri Trutnev, the Russian who co-developed the Soviet's 50-megaton weapon—the most powerful nuclear weapon ever detonated—said to Vic one night over a drink, "The reason we did all those nuclear tests was not to test the weapons, but to *test the designers*. We could then tell how good they were."

Vic said, "The Russians get this, but not the DoD or the NNSA. We need to educate our customers about how people and science integrate into our deterrence posture. They're not something separate."

He paused, pointed at the audience, and said, "*They're where the rubber meets the road*." ✦

~Dominic Martinez

John Scott (left) and David Jablonski in front of the Strategic Computing Center, the home of Los Alamos' supercomputers. (Photo: Los Alamos)

Highly trained technicians at the Nevada National Security Site maintain a high-intensity x-ray machine at the U1a experimental facility, built at the bottom of a shaft almost 1,000-feet deep. If approved, neutron-diagnosed subcritical experiments would be conducted at U1a. (Photo: National Nuclear Security Administration)

What Is a Neutron-Diagnosed Subcritical Experiment (NDSE)?

It would be a special kind of hydrotest. An NDSE would test the quality of a real nuclear trigger—the plutonium pit—by testing how well it implodes *and* predicting its ability to go supercritical. Previous subcritical experiments have provided scientific data for understanding the physical properties of plutonium, but NDSEs could also tell us about the pit's ability to generate enough neutrons to go supercritical and about how effectively it does it. For a weapon to detonate, a supercritical state is where the real action is, so the Lab needs to understand how a pit goes supercritical.

How Would an NDSE Work?

Other subcritical experiments use a scaled-down plutonium pit. These pits are used because it is physically impossible for them to generate enough neutrons to go critical (and thus not supercritical). This advantage is also a disadvantage: without enough neutrons being generated, neutron generation—the key to a nuclear detonation—cannot be tested.

An NDSE, however, could use a *real* pit, identical to the ones used in a weapon, except this pit would be modified: it would generate more neutrons than in a typical subcritical experiment but still *not enough to go critical*. (There are several ways that a pit can be modified to prevent it from going critical.)

During the implosion neutrons from an external source would be sent into the pit. There would be just enough of these external neutrons to make the pit "think" it is still a normal pit and start to behave like one. In contrast to a critical system that grows the number of neutrons exponentially, a pit in an NDSE would generate more of its own neutrons in proportion to the number of external neutrons sent in. Because the number of neutrons sent in would be controlled, the number of neutrons the pit would generate in response would also be controlled. An NDSE is an exquisitely precise experiment.

The pit's ability to generate neutrons at the subcritical level would be measured and the result extrapolated to infer how the pit, if not modified, would perform. That is, the measurement could reveal whether or not an unmodified pit would generate enough neutrons to go supercritical. Because the pit's ability to generate enough neutrons to go supercritical is a function of the pit's design and manufacture and of the quality of its plutonium, an NDSE would, by determining the pit's neutron production, also provide critical information about a pit's characteristics.

Why Are NDSEs So Important?

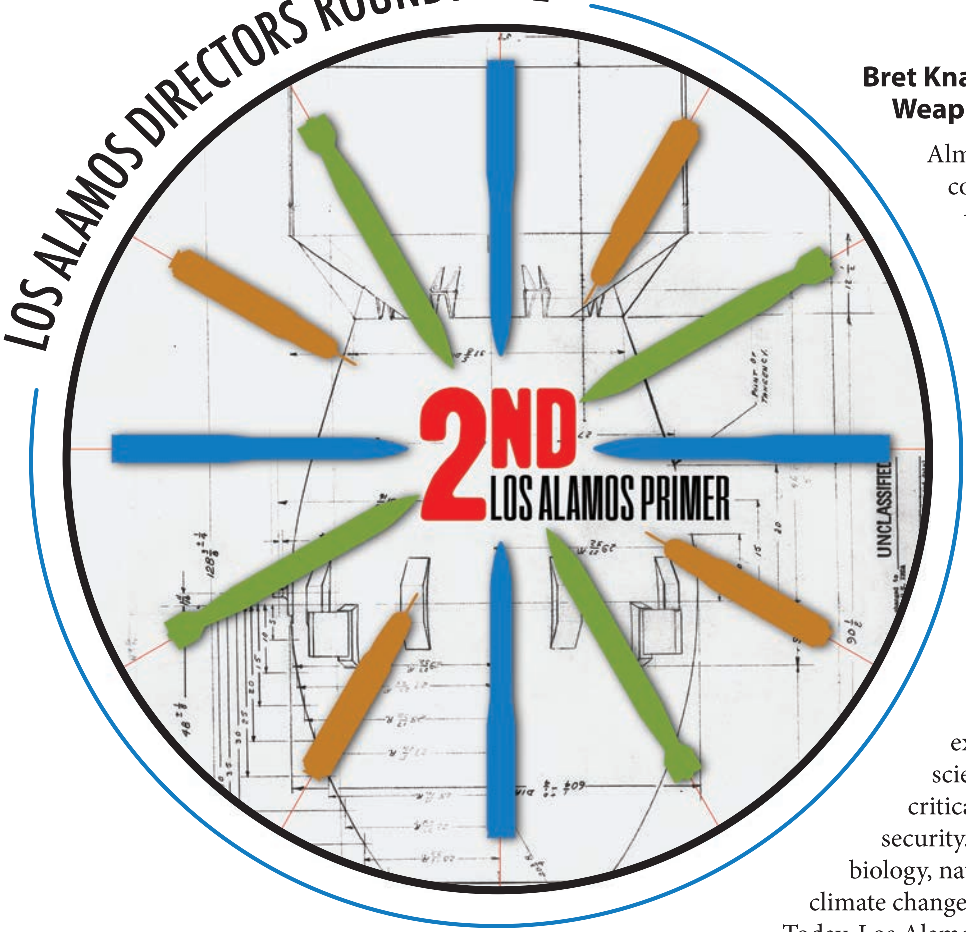
NDSEs could help weapon designers answer, about plutonium pits, key questions they cannot currently answer without testing. For example, will an implosion using aged plutonium pits or using newer pits designed and manufactured using new processes be good enough to trigger a nuclear explosion that meets military requirements?

Today second-generation designers are already asked these questions by their customers, including the military. The designers run supercomputer simulations that help provide a basis for their answers. But how do the designers, or their customers, know the simulations are correct? An NDSE could corroborate their simulations.

In addition, designing an NDSE, and designing supercomputer simulations that successfully match the experiment's outcomes, could train second-generation weapons designers in how to reuse plutonium pits in the life-extension programs for current stockpile weapons. NDSEs could test their judgment and credibility when making predictions about pit performance.

In short, NDSEs could offer second-generation designers a way to answer, without testing, key questions regarding the implosion performance of plutonium pits. Equally important, these experiments would provide the designers the opportunity to design and execute the kind of experiments that would demonstrate their judgment and predictive skills, and so build their credibility with their customers and peers. ✦

LOS ALAMOS DIRECTORS ROUNDTABLE



Laboratory Directors **Pete Nanos, Bob Kuckuck, Michael Anastasio, and Charles McMillan have all signed Annual Assessment Letters regarding the health of the nuclear stockpile weapons that were designed by Los Alamos. This roundtable, moderated by Bret Knapp, principal associate director of the Weapons Program at the time of the 2nd Los Alamos Primer, explored the directors' views, opinions, and concerns regarding the aging stockpile; the challenges created by the moratorium on underground testing; and the challenges confronting the Laboratory in its efforts to maintain its scientific and engineering capabilities for addressing issues in national security.**

(Note: Directors Sig Hecker and John Browne, who also signed Annual Assessment Letters, were unable to attend. Bret Knapp is now acting director of Lawrence Livermore National Laboratory.)

Bret Knapp, Principal Associate Director for Weapons Programs

Almost 70 years ago [July 16, 1945] Los Alamos conducted the world's first nuclear weapons test and started the Nuclear Age, putting us on a path of no return and helping us end WWII. Since that time, Los Alamos has become known as the world's center for nuclear weapons. Los Alamos designed the bulk of the stockpile, and we continue to keep the certification responsibility for those weapons.

Out of the Weapons Program have grown lots of different areas of LANL technical expertise and science that are critical to national security. Those areas include biology, national intelligence, global warming and climate change, seismology, and computational science. Today, Los Alamos is known for the quality of its science in general.

Each of the directors speaking today was a director during the era of stockpile stewardship. Each went through his own periods of turmoil and stress at the Lab and found ways to lead the Lab through traumatic change—political and technical. I want to personally thank each of them.

Director Pete Nanos (2003–2005)

Every American has to worry about this institution and the importance of the science done here. People are the most important part of that, and Los Alamos and Johns Hopkins [Nanos is currently at JH] are competing for the same talent: postdocs in the hard sciences in their late 20s who are in the top 10 to 20 percent in their field. It's important for Los Alamos to win that competition, but right now Johns Hopkins is winning. What the Lab has to do is show young talent a future with work that is relevant and exciting. It has to provide the opportunity for new people to do high-risk, high-payoff work with recognition and rewards. The best and the brightest want to be at the forefront, taking on the toughest problems.

The Director's Roundtable included (left to right) Pete Nanos, Bob Kuckuck, Mike Anastasio, and Charles McMillan. Bret Knapp is standing at the lectern. (Photo: Los Alamos)

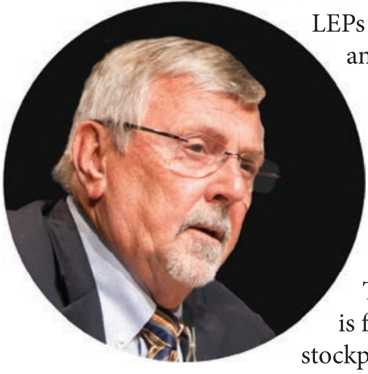
There has to be a future beyond stockpile stewardship, and the young designers have told us the kinds of things they want to do. The RRW (Reliable Replacement Warhead) was a very exciting and important project, but that was stopped about seven years ago. Today, it's research to understand weapon failures that occurred during testing, solving other legacy questions from that era, and doing more experiments now—experiments where designers can strut their stuff, make more predictions, and have a chance to win or fail. There must be a competitive element. Designers need tough grades to know they're good.

When the designers with nuclear test experience don't answer the phone anymore, we'll need to have confidence in the new generation in the same way we had confidence in the old generation, with its test-born judgment.

Working to understand proliferant weapon designs is another way to attract new people and develop their judgment. What worries me is that our thinking about proliferation may be "path dependent." Proliferators don't have to follow the same path we did. They have computing power that we didn't have when we started. They have materials we didn't have. They don't have to design weapons the way we did. Weapons science is going to internationalize, and we have to stay in the mix and know what's going on. We must make sure we don't ignore paths because they're different from what we did.

Doing science and simulation without experiments is what I call theology, and we don't need faith-based weapons. Experiments validate intuition and tell us who knows this game and who doesn't. Scientists will not come to Los Alamos without experiments.

The competition between Los Alamos and Livermore is a good thing. Without competition between the two labs, I don't know how we can have confidence in the stockpile. And we also need new science and new experimentation to undergird that confidence.



Director Bob Kuckuck (2005–2006)

The Stockpile Stewardship Program (SSP) has been incredibly successful. We've encountered serious materials and manufacturing process problems and "code blues" in the LEPs [life-extension programs for aging weapons], and we've been able to resolve those. But stockpile stewardship has an end. I doubt our grandchildren will be doing it in the 22nd century. Stockpile stewardship has been stockpile research. We've advanced our understanding of nuclear weapons beyond simple sustainability.

The way we implement stockpile stewardship is focused on a set of materials that are in the stockpile. Because materials and manufacturing have changed, there's going to be a time when we can't fix things [that were manufactured decades ago]. The 3+2 strategy [reducing the different types of warheads from seven to five] might extend that time by giving us more things to think about, but eventually we'll be there [at the end of the SSP]. But I believe that when that time comes, it will not be an end [to the Lab's national security science mission]. It will open new doors; it will be the onset of bigger and more challenging things to do.

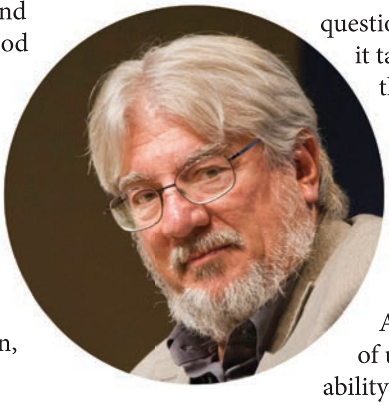
My concern with stockpile stewardship is its narrow approach: it's all about LEPs and weapons in the stockpile. I think sustaining the stockpile may not be sustaining deterrence. The world's evolving fast and so are threats; we need to think about the deterrence of tomorrow. What will future deterrence look like? What science will we need to underpin that deterrence? Who will do that science?

A few thoughts I want to share with you:

We will still need a vital national defense 70 years from now. Human behavior convinces me of that.

Defending freedom has attracted the best and the brightest over the past 70 years. And good science attracts them. Defending freedom with good science attracts absolutely!

The University of California model of laboratory oversight was extraordinarily successful, producing first-rate science. Under that model, the labs thrived in capability, mission, and size. Freedom to speak out and to follow where the science leads is part of that model. In my generation, it was something we took for granted.



This model followed the lead of E. O. Lawrence, with interdisciplinary teams and the flexibility and responsiveness to enable people to move around among teams and projects. Loose organizational structure, minimal hierarchical constraints, and minimal formality allowed ideas to be confidently presented and challenged.

A meritocracy, with merit-based rewards and merit-based assignment of responsibilities and authorities, scientific leaders who are scientifically credible—these have been very important and have made Los Alamos the model it is. But much of that model is under attack or at least under stress.

Communication needs to be better. There is an impedance mismatch in communication between the labs and the people we work for: the public, Congress, our federal overseers, the military, and so on. We're communicating on different wavelengths, so the signals aren't getting through. The history of the labs has been fraught with tension: the public has a fear of all things nuclear and even a concern about the morality of the work.

Our federal overseers have the perception that we're often not efficient, safe, or secure. They often see us as arrogant and narcissistic—believing we're always right. That perception has manifested itself in many ways—environmental laws, Tiger Teams [outside experts assigned to come onsite and vigorously investigate and solve systemic problems], excessive regulation, and micromanagement. Both sides have valid points and faults, but it's the labs that suffer.

It's imperative that we develop better ways to communicate our scientific capabilities in answer to the other side of the argument and do it with integrity and respect.

Director Mike Anastasio (2006–2011)

Where are we? Where are we going? Stockpile stewardship will survive in the sense that we will continue to advance our scientific understanding of the stockpile without nuclear testing—BUT:

Its character will change as the context of the central question changes. That question is, What does it take to have the confidence to underwrite the stockpile, to sign that letter [the Annual Assessment Letter] that assures the nation that the weapons will work? What does it take for the new designers, who have a different set of experiences than we had in the past, to provide the assurance our weapons-lab directors need to sign that letter?

Advancing the scientific and engineering depth of understanding of the stockpile underwrites our ability to make judgments, have confidence, and give assurances about the stockpile, but what it takes to get that done is something the next generation has to figure out. For example, how would designers of weapon secondaries use a hydrotest? How would designers of weapon primaries use NIF [National Ignition Facility at Livermore]? What's going on in climate change modeling or in global security and/or in nuclear power that would help? Where are the opportunities to do things that will expand new designers' skill sets and allow them to develop judgment, given that they don't know what questions will be asked in the future? The new generation will have to figure that out.

How do we keep our focus on science and engineering in an environment of declining budgets, indecision in Congress, and an emphasis on a 40-year program of LEPs for the current stockpile?

I helped develop the 3+2 strategy, but who in their right mind thinks we're going to take weapon concepts from the 1970s and extend them for another 40 years? My answer is, that's crazy. But that's what we're embarking on.

The thing that makes me have a little hope is that we'll probably not fully execute the LEP program. Something will happen to break us out of it. Nevertheless, while we have the LEP program, we need to do a very good job on it to maintain our credibility.

The coming of the "second nuclear era" [see "The Second Nuclear Age," p. 2) will also change stockpile stewardship. If a country feels its principles, its sovereignty, and its fundamental way of life are at risk, it will do what it takes to survive. That's what the Cold War was about.

We won that struggle with communism and the Soviet Union, so now we're relaxing and reducing our stockpile. But that's not the way the rest of the world is thinking, and you see that in Iran, North Korea, and Pakistan, countries with smaller economies than ours. The Pakistanis say to us, "We have to have nuclear weapons to protect our sovereignty. You're helping to build up India's conventional weapons as a bulwark against China, and we can't keep pace with that." That will be the way of the real world, with each country facing its own survival issues.

What does our nuclear force need to look like in a world like that? I would argue that it's not the Cold War kind of stockpile. It's something different. The weapons we'll need in the future won't be the ones from 1970 designs. The Lab needs to think about that right now—because nobody else will. There isn't the political climate for talking about new kinds of nuclear weapons, but that doesn't mean the Lab shouldn't be thinking about them.

LANL's designers should explore new ideas, then develop new designs and test them because the country will need them in the future, and when it does, there won't be a lot of time to think about it. Don't wait. Find a way to do it.

The technical barriers to nuclear proliferation have been coming down for years, and in the next 70 years, it will be easy to proliferate. I urge you to think about how countries will proliferate 10 or 20 years from now. They probably won't do it the way we did it in 1943, so how will we know what they're doing? What should we look for? How do we work with the intelligence community to make sure they're looking for the right things? And if we can figure out what other countries will do, why don't we do it? Why continue to make pits the way we do? Why does Y-12 [in Oak Ridge] do what it does, the way it does? Is additive manufacturing [making 3D objects from digital models] in our future? If it is, how would we certify something made that way?

On such nuclear matters, we need to be out front, so the country needs you working on new ideas. Don't wait. The country can't have us wait.

Whatever you do, do more experiments. There's nothing more important in science than data.

The one thing the Laboratory has to have is integrity, and integrity is about people and their judgment. How does anybody have confidence in what the Lab says? It's about the Lab's people, and it's about the Lab's integrity. The Lab needs to nurture and sustain its integrity because without that, the Lab is nothing. Without that, the Lab will go away.

Director Charlie McMillan (2011–present)

How is the Laboratory going to maintain its scientific edge into the future? I see our science flowing from the mission, and the Laboratory's mission space [doing national security science] is very broad, broader than the stockpile and deterrence. We are a national security science laboratory.

We've talked a lot today about deterrence, but what about assurance? We have to convince not just the Navy but also Japan and South Korea that the stockpile is safe, secure, and effective.

The central point about our people is creativity. I've seen that rise to the fore time and time again in projects like Gemini [experiments recently conducted at the Nevada National Security Site]. Creativity is important because we will not solve the problems of the future by looking in the back of the textbook. We will execute the program of record, but I believe we'll be surprised.

Things will happen that we don't expect, so we need creative people who can address the unexpected problems that are sure to come. And they have to be working in an environment where people see things others don't see and where they ask unfettered questions.

Our budgets won't look good until the economy is good. But today is the time to get ready, to do the research for projects we'll need to do when larger investments become possible again. When that time comes, we'll need ideas that are well thought out and mature. ✦

(Photo: Los Alamos)

Directors Q&A

Q: What gives a Lab director the confidence to sign those annual letters assuring confidence in the reliability, safety, and performance of the stockpile when the people in charge of assessing the stockpile don't have testing experience?

Anastasio: That's the issue. How does the country have confidence? It's a risk-management issue, and it depends on the people. I was a designer with test experience. But still, as a director, you look to the people you trust in the organization and ask them. On the other side, who are the people who take ownership and take on responsibility? As director, you have to make a judgment even though you don't know all the answers. There are so many dimensions to it, but in the end, it's about trusting the people.

Q: This is a national security science lab with multiple national security challenges to help solve. Global security is a major challenge, but we don't have a vision for that beyond taking the capabilities from the Lab's Weapons Program and applying them elsewhere. How might we start to get to a vision for global security?

Nanos: The Lab's disadvantage is a lack of contact with the customer. We don't have contact with the warfighters. The world is flat technologically. Everybody's going to fight with the same software. Science is ubiquitous. Our edge could come from employing technology and integrating the technology into operations in an almost seamless way, but to do that, the Lab needs to see what the problems are—get out in the field and talk to the warfighters—and apply the Lab's creativity in a profound way.

Anastasio: The second nuclear era is with us today. How will it play out? We have an advantage in this new nuclear world because we can anticipate how it will evolve. That's a niche we can be in and should be in, now. The Pakistanis say their technical people can build something that has an 80 percent chance of working, without doing a nuclear test. That may not be good enough for the U.S. Navy, but it may be for the Pakistanis. What might other countries do, and how will they go about it? How do we look for it? How do we help the intelligence community know what to look for?

McMillan: Los Alamos needs to be involved in everything nuclear. We have a long history of doing it well, and we're the logical place for it.

Q: What is the calculus that would have to go through your minds to make the recommendation to return to testing?

Anastasio: The decision to return to testing is a political decision. It does not depend on what I say in my letter.

McMillan: Were we to return to testing, it would be because there was a change in the global security situation. Suppose we had a technical problem in the stockpile and couldn't solve it. We could field a nuclear test, and we might solve the problem, or we could retire the system.

Nanos: Returning to testing is a presidential decision. The Annual Assessment Letter is specific to the systems in the stockpile. You might report the news that a particular system has a flaw, and then people higher up make the decision.

Anastasio: I'm concerned that we stopped doing weapons design and development. It's a bigger risk than to stop nuclear testing. There are a lot of other things we do to have confidence in what we put in the stockpile. When we stopped doing weapons design and development—that's a different kind of risk, a bigger risk than not testing. That's not doing anything at all.

That's like we're in the car business and we stop making cars, which means you don't do it at all and you lose the skills. How do you keep people's skills so that when we have to do something again—or something different to meet a different need than we had in the Cold War—we're prepared to do that?

That's what was discussed in the Designers Roundtable, and it's key. How do we make sure the weapons designers keep their skills? ✦

> *I'm concerned that we stopped doing weapons design and development.*
> *It's a bigger risk than to stop nuclear testing.*
> *~ Mike Anastasio ~*

Harold Agnew, the Laboratory's third director, rides his bike by the Laboratory's Study Center, which was completed during his tenure as director. (Photo: Los Alamos)

Remembering HAROLD AGNEW

Over the past decade, I've fielded some interesting questions as a Laboratory historian. Among the now-trite queries, such as those pertaining to alien autopsies and Area 51, one simple question stands out as my favorite: "Was I at the Trinity test?" That question was asked of me by Harold M. Agnew, the Laboratory's third director. Though initially puzzled, I confirmed that he indeed was not there. This prompted Harold to say: "Fine, I didn't think so. Luis [Alvarez, a wartime Los Alamos scientist and future Nobel laureate] said in his memoir I was, so I just wanted to make sure I wasn't." Classic Harold.

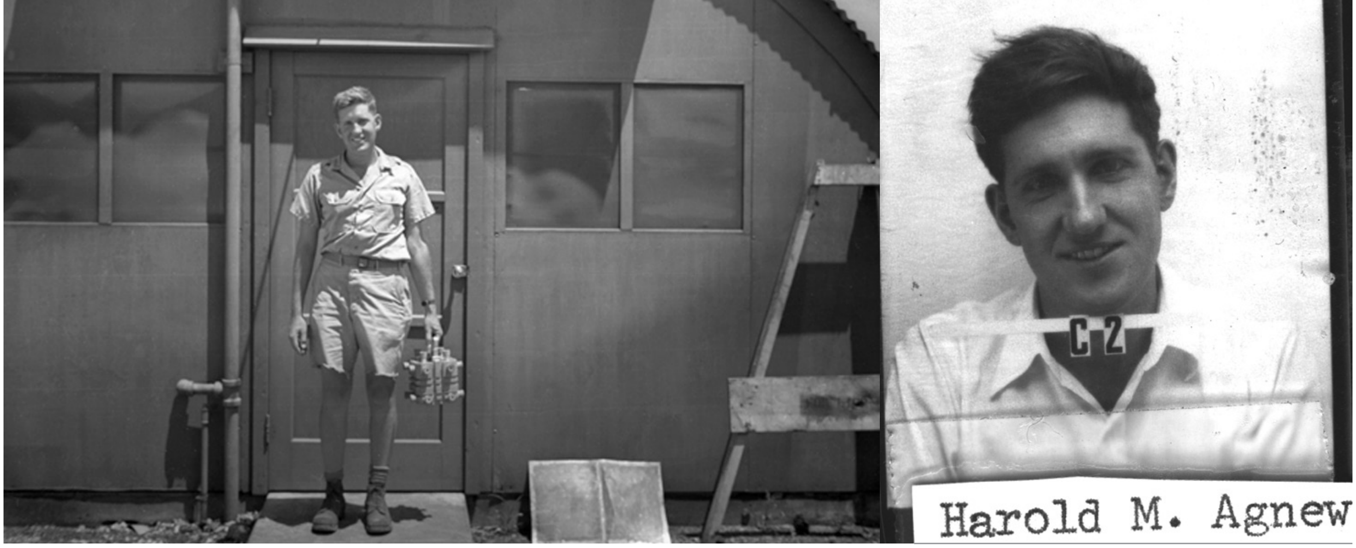
Harold Agnew grew up in Denver during the Great Depression. His father was a hard-working roofing contractor who always managed to put food on the table, although on one occasion Harold's family had to turn off the lights and pretend they weren't home when the rent collector came. Many considered Harold a cheapskate, but his thrifty ways were adopted early in his life out of necessity.

When he was a child, Harold's interest in science was sparked by a chemistry set he received as a gift. A few days before he died, Harold told me he still had that chemistry set in his possession. It helped launch a career in science that first took him to the University of Denver, where he studied chemistry and started dating his future wife, a lovely student named Beverly, who worked in the dean's office.

Only months after the Japanese attack on Pearl Harbor, Harold and Beverly, who were still dating, both decided to join the Army Air Corps. However, because of his training as a chemist, Harold was instead recruited to work for the Manhattan Project under Nobel laureate Enrico Fermi at the University of Chicago. As a member of Fermi's team, Harold helped build the world's first nuclear reactor and on December 2, 1942, witnessed it produce the world's first sustained chain reaction.

Now married, the Agnews followed Fermi to Los Alamos in the spring of 1943. Beverly served as a secretary for the Lab's first director, J. Robert Oppenheimer. Harold, among other things, helped design and build diagnostic instruments to measure the atomic blasts.

When the Trinity test was conducted on July 16, 1945, Harold was already on Tinian Island preparing for the atomic strikes against Japan. As a member of the scientific observation team, he filmed the attack on Hiroshima—for posterity, on his own initiative. As the bright light from the flash enveloped the plane's cabin, Harold thought, "It worked! It really worked!" Many years later, when asked if he had any regrets about the atomic bombings, Harold replied, "From Pearl Harbor, to Bataan, to Nanking; all the atrocities that took place, all the grief that we suffered. I just felt they bloody-well deserved it." Although Harold and Beverly did not join the military, many



(Left) Harold holds a case containing the plutonium for the Fat Man bomb (dropped on Nagasaki) on Tinian Island in the closing days of World War II. The Agnews were two of the earliest residents of wartime Los Alamos, then known as Project Y. (Right) Harold's Project Y identification photo. *(Photos: Los Alamos)*

of their friends did. Harold would often remind us that several of them never made it home.

After the war, Harold returned to the University of Chicago to complete his Ph.D. in physics. When he came back to Los Alamos, he started working in the Weapons Program in the uncertain months following the detonation of Joe-1, the first Soviet nuclear test. As a weapons physicist, Harold truly was a pioneer. He played a major role in the development of deliverable thermonuclear weapons for the United States in the mid-1950s and during that time, had another brush with history. In 1952 Harold witnessed the world's first thermonuclear test. Code-named Ivy-Mike, the blast produced a yield of over 10 megatons, an explosion hundreds of times more powerful than the atomic bombs that had helped end World War II. The test left a lasting impression. Years later Harold said, "I've advocated that every five years, all world leaders should strip down and have to witness a multi-megaton shot. It would really put the fear of Allah, or God, or Mohammed, or Buddha, or somebody, in their veins. It's really quite a terrifying experience. . . ."

In the years that followed, Harold had a hand in developing a vast majority of the nation's stockpiled weapons. During a trip to Europe with NATO, he came up with an idea that would revolutionize weapons safety. When he saw that the only safety feature American nuclear weapons had was a guard with a rifle, he conceived the idea of the permissive action link (PAL). PALs, which ensure that weapons cannot be detonated without proper authorization, are now a standard feature on all U.S. nuclear weapons.

In 1970, when Harold became director, times were changing. The public was growing more fearful of nuclear technology, the Lab was facing budget problems, and the federal bureaucracy was rapidly expanding. In fact, Harold once said, "The ever increasing bureaucracy, composed of managers who require more and more detail, justification, and guaranteed schedules, will, in the not too distant future, completely eradicate our nation's world position in research and technology."

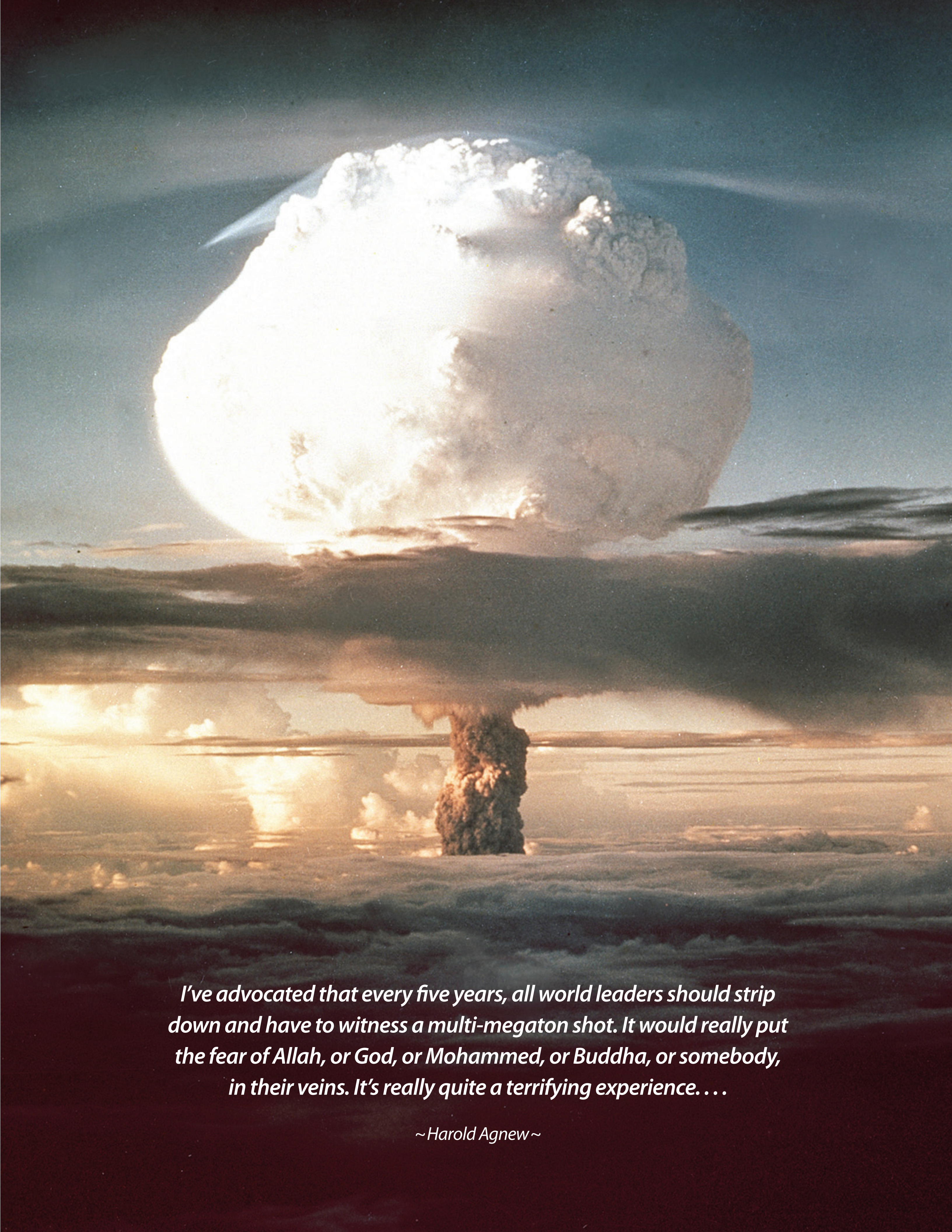
Nonetheless, Harold grew the Laboratory from 4,000 to 8,000 employees in the 1970s. His legacy as director is not merely a laundry list of scientific achievements but is a new idea for what a national laboratory can be. Technical diversification started under his predecessor, Norris Bradbury, but every program had some tie back to nuclear weapons. Under Harold the truly multidisciplinary Laboratory of today was born. His legacy as director is given new life each time a Los Alamos scientist helps cure a disease, develops an energy-efficient technology, or makes a discovery on Mars.

Harold left the Laboratory in 1979 to become president of General Atomics in San Diego but returned to Los Alamos regularly. Throughout the 1980s he served as a science councilor to the Reagan administration and remained a vocal advocate for nuclear power.

Today's U.S. nuclear deterrent is largely Harold's legacy but so is our modern multidisciplinary Laboratory. He helped shape our world through advising many presidents on nuclear policy and never abandoned his bold yet personally modest demeanor. Harold was a phenomenal scientist, a dedicated patriot, and a good friend to so many of us. He passed away in September 2013 at the age of 92. We'll miss you, Harold.

~ Alan Carr

After retiring from Los Alamos, Harold served as a scientific advisor to Ronald Reagan throughout Reagan's years in the White House. *(Photo: Los Alamos)*



I've advocated that every five years, all world leaders should strip down and have to witness a multi-megaton shot. It would really put the fear of Allah, or God, or Mohammed, or Buddha, or somebody, in their veins. It's really quite a terrifying experience. . . .

~ Harold Agnew ~

National Security Science
Mail Stop A107
Los Alamos National Laboratory
Los Alamos, NM 87545
Email: NSSPub@lanl.gov
Tel: 505-667-7814
www.lanl.gov/science/NSS

Los Alamos staff members enjoy a picnic on a sunny day in 1961 in front of the Lab's first administration building, built in 1951.

Fifty-three years later, students in the Laboratory's summer intern program— replete with their modern personal electronic devices— walk in front of the Laboratory's current administration building, the National Security Science Building.

February 2014 • LALP-14-003

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

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Los Alamos National Security, LLC, for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-ACC52-06NA25396. A U.S. Department of Energy Laboratory.

Managing Editor • Clay Dillingham
Writers/Editors • Eileen Patterson, Lisa Inkret, and Dominic Martinez (student intern)
Science Writer/Editor • Necia Grant Cooper
Designer/Illustrator • Kelly Parker
Art Director • Donald Montoya
Photographer • Ethan Frogget
Editorial Advisor • Jonathan Ventura
Technical Advisor • Sieg Shalles
Laboratory Historian • Alan Carr
Printing Coordinator • David Van Etten