A capability restored

Los Alamos builds first certified nuclear trigger in 20 years

by Kevin Roark

Literally taking thousands of hours to make, the use of Plutonium in Pit Manufacturing requires the specialized skills of a glovebox worker to cast, shape, inspect, and assemble the needed components into quality product.

Almost everything about it is secret. It inspires awe, but not from its outward, unremarkable, and yes, secret, appearance.

Imagining what could result from unleashing the power of its elegant, simple, and yet technologically advanced design oftentimes boggles the minds of those even with detailed knowledge of its form and function.

Last month, the Laboratory made good on a promise from the early 1990s: deliver to the nation's nuclear weapons deterrent a new, certified pit—alternatively called a primary or nuclear trigger—for the W88 warhead. Designed by Los Alamos, it is the most highly optimized weapon in the U.S. stockpile for yield-to-weight ratio, meaning it can unleash an unbelievable amount of energy from a very small package.

It was a promise surprisingly hard to keep and all the more scientifically satisfying because of the difficulty, and completed without the benefit of an underground nuclear test, a feat never before accomplished.

The United States lost its capability to manufacture triggers for its stockpile of nuclear weapons when the Rocky Flats production plant in Colorado closed in 1989.

Then, in 1992, the United States conducted its last underground nuclear test and has no plans to resume testing.

Without the ability to test and to make replacement pits, the nation's weapons complex has been assuring the safety and reliability of the U.S. nuclear deterrent through a program called Stockpile Stewardship. One of the basic functions of this program is stockpile surveillance, the systematic inspection and destructive testing of a small number of weapons systems to monitor how they age and determine if there are serious enough problems to weaken confidence in their safety or reliability.

If problems arise, what they are, and how they are successfully dealt with is a secret.

Until now, the United States has been unable to replace those W88 pits lost to the surveillance program.

"Because Los Alamos has the only plutonium pit manufacturing capability in the United States, it fell to us to figure out how to make a Rocky Flats W88 pit and then guarantee it will work if needed without Rocky Flats and without testing," said Glenn Mara, principal associate director for nuclear weapons programs. "As usual, the Laboratory rose to the task, delivering both a high-quality product and a high-quality, highly efficient process."

The Lab cleared a major hurdle in 2003 with the delivery of "Qual 1," the first of 15 "certifiable" W88 pits that marked an end to a manufacturing process development phase and kicked off the engineering qualification and physics assessment, the two roads traveled on the journey to certification.

Exact engineering specifications for the W88 pit and its detailed physics are secrets.

"It was a monumental challenge," said Laboratory Fellow Gary Wall, leader of the certification team and a fixture in the weapons design community. "We are essentially in the business of putting boundaries around what we don't know," said Wall. "We verify that those 15 Qual pits meet engineering requirements like structural and thermal integrity. At the same time we assess the physics—asking how the differences and similarities between the Rocky Flats pit and

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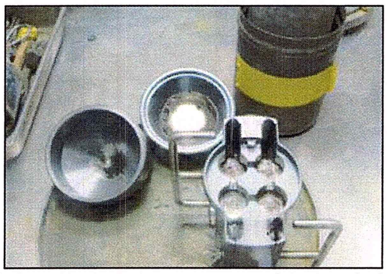

Impure plutonium metal (left photo in glove) is purified creating a 99.95 percent pure plutonium feed source (outer ring) which can then be alloyed (right photo) to produce the required chemical composition to make a pit. Photos courtesy of the Program Management (PM) Division

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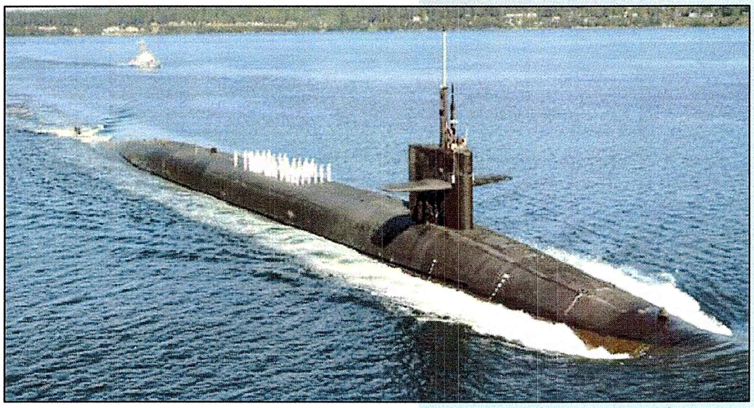

the Los Alamos pit might affect the system's overall performance."

The most glaring difference: Rocky Flats pits are wrought and Los Alamos pits are cast. Because Rocky Flats was a very large facility with essentially one purpose, it could house the large presses and machines used to push, or bend, solid metals into the configurations required for use in a pit. The Laboratory's plutonium facility at Technical Area 55 does not have the characteristics or nearly the size of Rocky Flats and so uses a casting method, where molten plutonium is poured into molds to make the rough shapes required for pits.

The most glaring similarity: the amount of highly skilled workmanship that goes into making a pit. Unlike many manufacturing processes that rely heavily on robotic automation, pits are uniquely hand-made.

The certification plan evolved over the years after its start in the late 1990s. Following the Laboratory's transition to a new operating contract in June 2006, the plan was reviewed and revised one last time with clear, aggressive goals and timelines that employed the practice of QMU, or Quantifying Margins and Uncertainties—a system to evaluate confidence that a weapons system will work within carefully considered boundaries or operating characteristics—and generally adopted the certification methodology of another successful stockpile stewardship program, the W76 warhead Life Extension Program.

Through a "bottoms-up" approach, the certification team relied on small-scale plutonium experiments, legacy test data, groundbreaking materials science, extensive statistical analysis, and tried-and-true computer weapons codes to eventually quantify the margins and uncertainties to such a degree that they are now able to say, "yes, the Los Alamos W88 replacement pit will work with the same performance and reliability as a Rocky Flats pit."

"We used our most reliable hydrodynamic computer code—hydrodynamics being the study of how solids flow and mix like liquids under extreme pressures and temperatures—as our baseline," said Wall. "New physics models were added to the code to better distinguish the new pit from the old one. We accomplished that, better understanding where the two systems differed, validating the physics submodels and propagating that data through the models to determine the performance margins of the new pit."

The computer visualization and other data derived from applying the hydrodynamic code to the W88 pit certification; how the pit performs in a virtual detonation, is secret.

As the certification process progressed, the manufacturing systems were refined.

"Building the 15 Qual pits served to center our manufacturing process well inside the margins for error," said Bob Putnam of the Laboratory's Pit Manufacturing Program Office. "Our goal is repeatability, to make the same pit, with the same strict specifications every time, so that the product meets extremely high quality standards."

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The exact size, weight, shape, material quantities, composition, and plutonium chemistry of the pit? All secret.

And at Los Alamos, the science does not stop at manufacturing's doorstep.

"At one point in the process we started to see some unexplained microscopic voids, or bubbles, in the plutonium," said Putnam. "Plutonium is a very weird character with very weird morphology, or structure, and is not an exceptionally well understood material. But because of the Laboratory's broad scientific base, very quickly an interdisciplinary team of actinide chemists, physicists, engineers, and materials scientists went to work and resolved the issue."

Between 2003 and June 2006 the people on the pit manufacturing line at TA-55 honed their skills building Qual pits for the certification process. Shortly after the Laboratory's management and operating contract changed hands, the pit manufacturing program purposely "paused" for three months to fully assess the process and to make small but important adjustments — streamlining by removing excessively complicated, unnecessary, hazardous, or environmentally unfriendly steps — somewhat trivial changes that would paradoxically result in momentous improvements in quality, increased productivity, and better worker safety.

"We've tripled the number of pits we are able to make in a given period of time, while our budget has remained the same," said Putnam. "It's a tangible demonstration of how well everything is working, how well we are meeting, and in some cases, exceeding our customer's expectations."

Supremely confident in the process, the Laboratory began assembly of the first certified pit in early November 2006. By February it was finished and follow-on pits were also in the manufacturing pipeline. After internal quality review the first unit was delivered May 2 to the National Nuclear Security Administration for its quality review. Last month the NNSA accepted the pit, giving it the so-called "Diamond Stamp" of approval, meaning it is accepted for insertion into the U.S. stockpile. The first pit was delivered to the Pantex Plant near Amarillo, Texas, for assembly into a W88 warhead. The Laboratory has committed to the NNSA the ability to continuously deliver 10 identical pits per year and to demonstrate the capacity to deliver 30-50 pits per year by the 2012-14 timeframe.

"There is a growing excitement in the pit manufacturing program," said Putnam. "We're not just seeing the light at the end of the tunnel, we are emerging from the tunnel, and we can see the trees and the mountains—everyone's confidence is growing every day. I've never seen a team work harder, and we're constantly improving.

"It's no secret that this is the best team Los Alamos could have ever put together. It would not have been possible without the great science and technical expertise of the whole Laboratory."

How the W88 works

Modern thermonuclear weapons have two main components, the primary (pit) and the secondary. The primary provides the initial energy that drives the secondary, source of the vast majority of the energy from the weapon. A pit is an assembly of shells of various materials. At its center is a hollow mass of fissile material arranged in a subcritical configuration.

Fissile material in a weapon is usually plutonium or enriched uranium, capable of undergoing a fission reaction when struck by slow neutrons. Subcritical means there isn't sufficient mass—the amount of material in a given space—to sustain an uncontrolled reaction and a nuclear explosion.

High explosives are used to squeeze the subcritical mass into a critical configuration, creating that first fission explosion that in turn squeezes the secondary with enough pressure, heat, and radiation to initiate a fusion reaction, generating tremendous amounts of energy. All of this happens in a very short period of time, just a few millionths of a second.

The W88 is a ballistic missile warhead, typically mounted on submarine launched weapons.