Despite unknowns, NNSA plunges ahead on plutonium pits

The National Nuclear Security Administration has delayed by several years the date by which it will comply with a congressional mandate to build 80 pits per year.

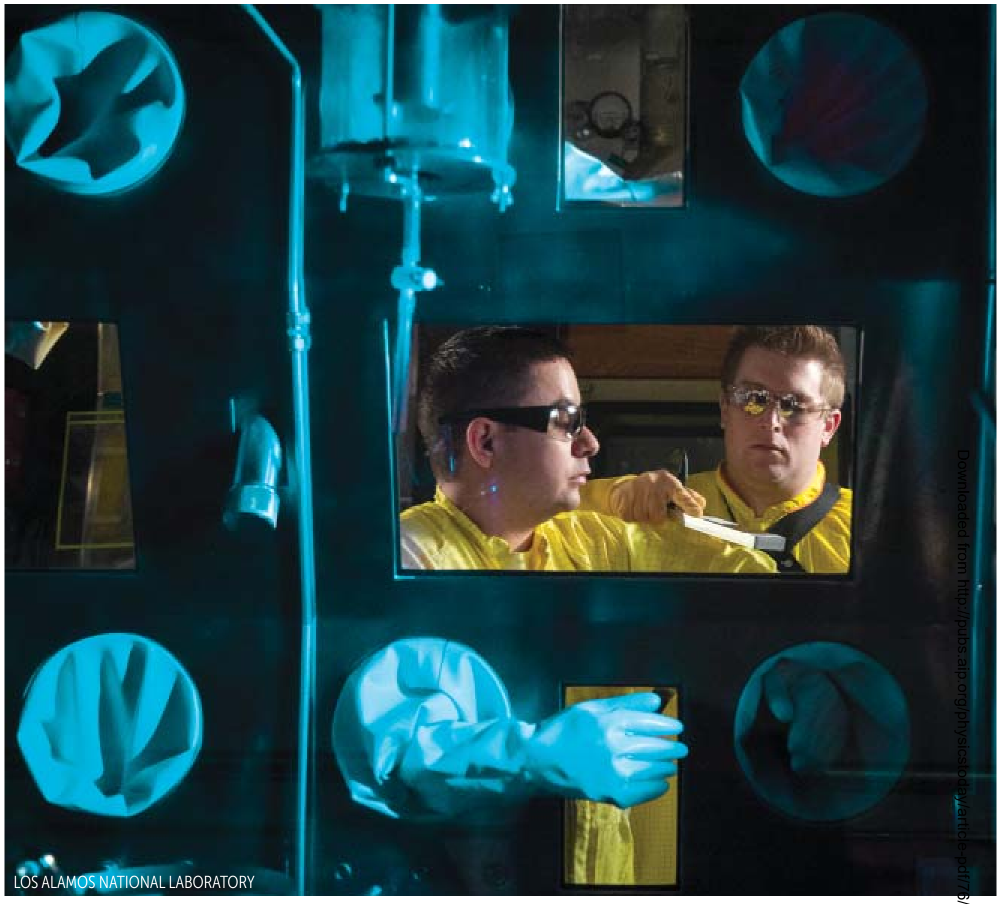
The US has spent billions of dollars over the past 20 years to reestablish pit manufacturing at scale. With prodding from Congress, the Department of Energy's National Nuclear Security Administration (NNSA) will spend billions more over the next decade to build two pit factories.

But the NNSA has scrapped four different plans to establish pit factories over the past two decades, notes a January report from the Government Accountability Office (GAO). And as the agency embarks on the latest one, questions linger: How long will a plutonium pit last? How many new pits are needed and when? How many retired pits could be recycled? How long will it take, and how much will it cost to reconstitute manufacturing capability?

Pits—hollow, grapefruit-sized spheres cast from about 3 kg of plutonium—are designed to implode when compressed by the high explosive surrounding them. The prompt critical mass that results fissions and creates a flood of x rays to trigger the warhead's secondary, fusion–fission stage.

NNSA and Defense Department officials have told lawmakers that they will not be able to meet a 2030 deadline that Congress had established for the NNSA to manufacture at least 80 pits per year. In an interview, Marvin Adams, the deputy administrator for defense programs at the NNSA, said he could not provide a new estimated time frame.

In the January report, the GAO said that the NNSA lacks a comprehensive schedule and an overall cost estimate for the 80-pit-per-year capability that meet GAO standards. On the basis of the NNSA's fiscal year 2023 budget documents, though, the GAO estimates the total price tag to reestablish pit production at the required rate will be at least $18 billion to $24 billion—which could be the NNSA's largest investment to date.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TECHNICIANS PERFORM radiological control assessments after working with plutonium in a glove box at Los Alamos National Laboratory. The availability of new glove boxes is a key constraint on when the NNSA will be able to achieve its goal to produce 80 pits per year.

Aging concerns

Large-scale pit manufacturing ended in 1989, when the Rocky Flats Plant near Denver, Colorado, was permanently shut down after a Federal Bureau of Investigation raid revealed widespread violations of environmental regulations. The site has been remediated and is now a wildlife refuge. (See the article by David Clark, David Janecky, and Leonard Lane, Physics Today, September 2006, page 34.)

The US has thousands of surplus pits that have accumulated from past generations of weapons. Many could be reused. But some experts are concerned that aging plutonium might change the shape or strength of pits and thus alter their compressibility, causing warheads to not perform as designed.

Plutonium-239, the desired fissile isotope for weapons use, has a half-life of more than 24 000 years. Yet its decay by alpha particles leaves helium trapped within the metal's lattice. If those tiny bubbles were allowed to expand at room temperature and pressure, the volume of helium after 50 years will be equal to that of the plutonium, Adams says. Over the same period, every atom of plutonium will be knocked off its lattice site at least once.

"These radioactive decays are microscopically disruptive events," says Adams, who was a member of the JASON advisory group that in 2019 urged the NNSA in a brief report to establish pit manufacturing capabilities "as expeditiously as possible."

NNSA officials worry that the helium

bubbles might grow into larger voids in the metal, causing swelling. But Frank von Hippel, a retired Princeton University physicist, notes that research has indicated that even as the bubbles increase with age, they remain tiny and trapped within the lattice. (See the article by Victor Reis, Robert Hanrahan, and Kirk Levedahl, Physics Today, August 2016, page 46.)

A more detailed JASON report from 2006 asserted that the pits in most types of stockpiled warheads would last at least 85 to 100 years and that the oldest pits in the stockpile should not require replacement before 2063 (see Physics Today, July 2018, page 22). Several Los Alamos National Laboratory (LANL) directors, including current director Thomas Mason, have said that the classified version of that report was not as sanguine.

A 2012 study by Lawrence Livermore National Laboratory (LLNL) employed accelerated aging techniques in finding that plutonium—but not necessarily pits, which contain other materials—should "age gracefully" for 150 years. The study discounted worries about helium bubbles and phase changes. Plutonium metal has six phases, each with varying densities and crystal structures. Alloying small amounts of metals such as gallium or aluminum stabilizes plutonium in its desired delta phase.

Pits are hermetically clad, typically in stainless steel or beryllium shells. Plutonium will oxidize if the cladding is breached. Corrosion of the cladding can occur in the presence of moisture and chlorides, according to the Defense Nuclear Facilities Safety Board. Galvanic corrosion can occur at joints between dissimilar metals. And differing thermal expansion rates among pit materials can induce stresses that might cause cladding to fail.

Yet cladding can be replaced if corrosion is spotted during stockpile surveillance. Russian scientists told their US counterparts in the past that pits in Russia's stockpile were replaced about every decade because of corrosion at the welds. In some historical cases, a reaction with the high explosive material has caused cladding corrosion.

Varying margins

"You should be quite suspicious of a blanket statement that pits will last for 85 or 100 years," says Adams. "Not all pits are the same. And not all systems have the same amount of margin against degradation." In other words, some pit designs are more forgiving than others to aging.

The NNSA could extend pit lifetimes by increasing the amount of tritium that's injected into the pit during implosion, von Hippel says. Tritium has a half-life of about 12.5 years, and canisters that contain it in warheads are replenished about every 5 years. Loading more tritium into the canisters provides a bigger boost to a pit yield. "That's a great bullet, and we've used it," Adams replies. But it can only go so far. "You do it once and you're done."

The JASON reports from 2006 and 2019 both called for the NNSA to establish a focused research program to improve understanding and mitigate potential risks of pit aging. Steve Fetter, a University of Maryland physicist who studies national security issues, says that a more definitive pit lifetime estimate should be completed before the NNSA proceeds with mass production. Still, Fetter and von Hippel agree LANL should be able to demonstrate a capability to build a small number of pits. "There has been a loss of confidence due to the fact that LANL hasn't been able to produce reliably," notes von Hippel.

To help improve its understanding of aging effects, the NNSA carries out experiments using subcritical amounts of plutonium or surrogate materials at LANL's Dual-Axis Radiographic Hydrodynamic Test facility and the National Ignition Facility at LLNL. Underground subcritical tests are performed at the Nevada National Security Site, and a new subterranean subcritical test device known as Enhanced Capabilities for Subcritical Experiments is under construction there (see Physics Today, February 2020, page 23). The new facility is designed to provide more detailed observations of the later stage of plutonium implosions.

Simple math

At a rate of 80 new pits per year, refurbishing the entire US stockpile of nearly 4000 warheads would take 50 years. Since casting 80 new pits each year likely will not be possible until the mid 2030s, the last of the legacy pits will be more than 90 years old when they are removed from service. "No one has ever seen a 90-year-old pit," Adams says.

Some but not all pits are interchangeable, Adams notes. The NNSA wants to use the first of the newly made pits in two new warhead types being designed to use insensitive high explosives (IHEs). Compared with conventional high explosives (CHEs), IHEs are less likely to detonate in an accident that will spew plutonium and possibly injure or kill those in the vicinity. All warheads are engineered so that an accidental nuclear explosion won't occur in any case.

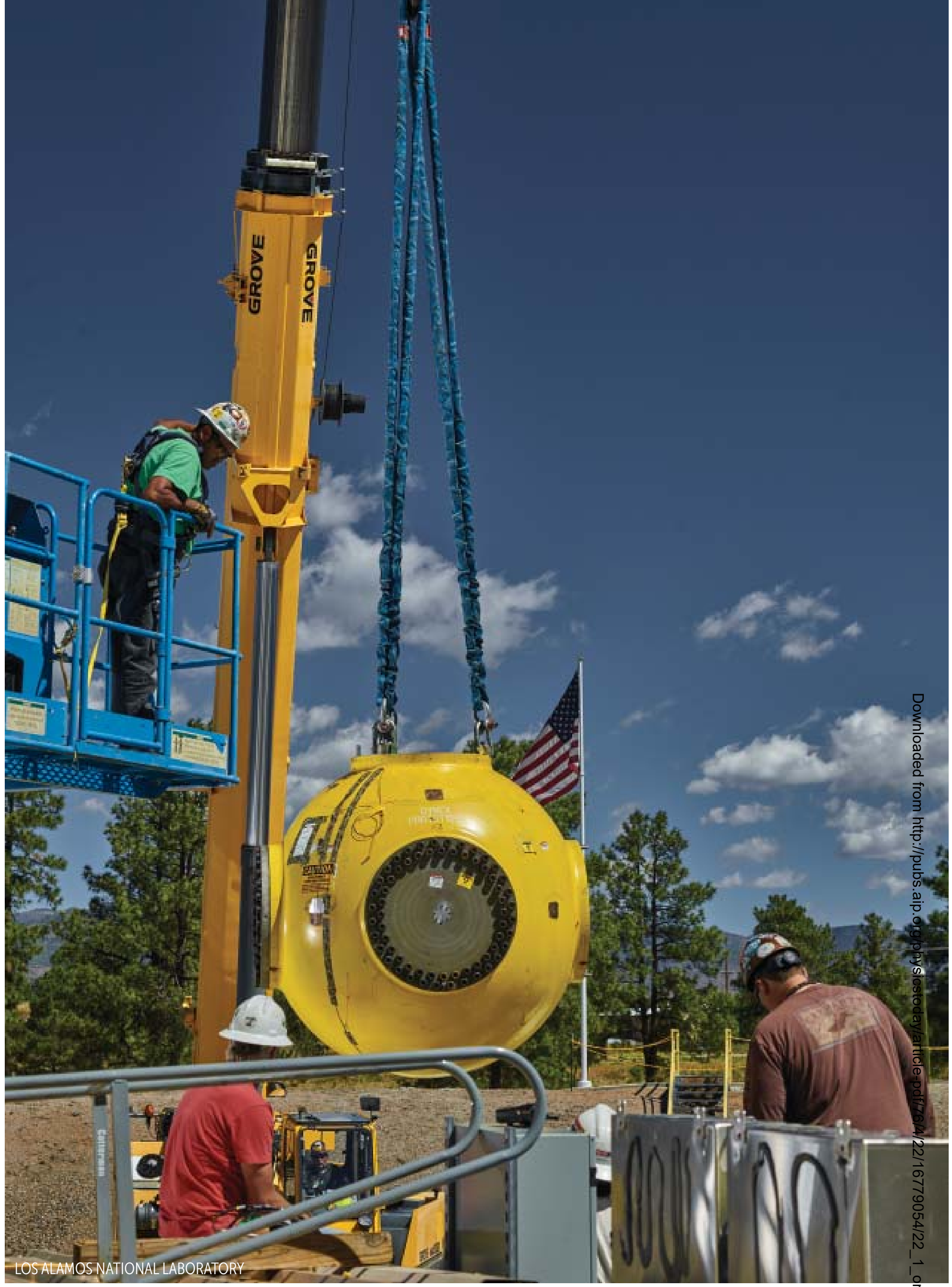
Because IHE has lower energetics and burns slower, pits that are paired with IHE require a different design from those coupled with CHE. Adams says there are no mothballed IHE pits that are suitable for the new warheads. Some of the new warheads will have to have recycled pits made for CHE, because not enough newly built pits will be ready when warhead assembly begins in the 2030s. "That puts constraints on you, and it's not optimal," he says.

The recycled pits, 40 or more years old when they are installed in the new weapons, must then endure for several more decades. "We've got more science work for the labs to do to be able to say that in 2035 or so that a pit of that age will last for another 30 years," Adams says.

A two-site solution

When the stockpile peaked at more than 30 000 warheads in the late 1960s, Rocky Flats cranked out between 1000 and 2000 pits each year. Since production was halted there in 1989, LANL has built 31 pits that were qualified for the stockpile, the last one in 2012. Qualification to enter the arsenal requires sign-off by the weapons design laboratory (LANL or LLNL) and certification of pit components that are made elsewhere and assembled at LANL. The lab has fabricated 35 noncertified demonstration pits in recent years.

To address the lack of physical space at LANL, the NNSA in 2018 devised a two-site strategy: The sprawling Savannah River Site (SRS) in South Carolina was designated to fabricate 50 pits out of the 80-pit requirement per year. That plan requires repurposing a partially completed 46 000 m^2 facility that was intended to turn surplus weapons plutonium into mixed oxide (MOX) fuel for commercial reactors. (See "Los Alamos to share plutonium pit production with Savannah River facility," Physics Today online, 18 May 2018.) Much of the MOX building's interior will be reconfigured and existing equipment torn out, a two-year process.



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A BLAST CONTAINMENT chamber is lowered into place at the Dual-Axis Radiographic Hydrodynamic Test facility at Los Alamos National Laboratory. Explosive tests on mock pits made from surrogate metals are used to help determine how plutonium will compress as the pit of a nuclear weapon implodes.

Congress appropriated $1.3 billion this year for the SRS project. The NNSA expects to achieve the 50-pit goal in the mid 2030s.

Assigning a pit-production role to the SRS placated South Carolina's congressional delegation, notably Senator Lindsey Graham (R), who fought vigorously against scrapping the MOX project. But Senators Martin Heinrich and Tom Udall (both D-NM) helped ensure that LANL wasn't left out, says Greg Mello, executive director of the Los Alamos Study Group, a watchdog organization.

Unlike LANL, the SRS has plenty of room to expand output beyond its initial annual target rate. Jill Hruby, NNSA administrator, told attendees of a Washington, DC, conference in February that the NNSA already foresees years in which it will need more than 80 pits.

Dual sites will provide resilience when one plant is shut down for maintenance or when breakdowns occur, says Adams. But the strategy requires duplicating the fabrication processes and equipment that are in development at LANL. It also necessitates hiring and training an SRS workforce from scratch. A 2019 study by the Institute for Defense Analyses warned that success for the two-site plan was "far from certain," pointing out that no successful major NNSA project costing more than $700 million had been completed in less than 16 years.

Environmental organizations opposing SRS pit production won a victory of sorts in February when a federal judge ruled that their lawsuit seeking to compel the NNSA to prepare a programmatic environmental impact statement of the pit plan could proceed. Such studies require extensive public input from impacted regions and often take years to complete.

Mello says his group didn't join the plaintiffs because their objective is limited to preventing pit operations at the SRS. "[The plaintiffs] have calculated that pit production solely at LANL is the lesser of two evils."

30 pits at Los Alamos

Over the past two decades, the NNSA spent more than $5 billion to modernize and sustain LANL plutonium operations, according to the GAO. The spending addressed widespread safety and operational deficiencies at its plutonium facility.

In February, the NNSA approved a $1.8 billion package of equipment needed to meet the 30-pit annual requirement at LANL in 2030. Three additional acquisitions are planned, for which the NNSA says it does not have firm cost estimates. Congress appropriated $1.5 billion for plutonium modernization activities at LANL this fiscal year, an increase of more than $500 million from last year.

The first stockpile-certified pit at LANL is scheduled to be built in 2024, a year later than planned because of a design change made late last year to simplify its manufacture. "What you need is mature enough production processes so that a large fraction of the pits you build will pass all their specifications," Adams says. "For that to happen, you have to have a design for the pit that is manufacturable enough."

Mello says LANL's limited capacity makes its role over time of little value. "It's a lot of money to pour into Los Alamos for a very limited product even under optimistic conditions." The 2019 report by the Institute for Defense Analyses advised that two-shift operations at the plutonium facility—which will be required to make 30 pits per year—is high-risk.

Currently, work at LANL focuses on decontaminating and removing old glove boxes and equipment. The new components will be installed at night, in the same rooms where other mission work occurs in the daytime. "It's a complicated choreography," says Adams.

Procuring new glove boxes is a major bottleneck, Adams says. They are often custom-made, room sized, and designed to fit around production equipment and require attachment to gas supplies and conveyor belts.

There are only a small number of US glove-box manufacturers. The NNSA has invoked authorities that give priority to national security needs. Congress has appropriated funding in the current fiscal year to allow the agency to place advance orders, and Adams says he hopes that will encourage manufacturers to increase their capacity.

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