US nuclear agency struggles with production and costs

The National Nuclear Security Administration must cope with resurgent geopolitical threats accentuated by Vladimir Putin's nuclear saber-rattling.

Spending on the nuclear weapons complex has exploded in recent years, and budgets are expected to continue on a steep upward path as the US National Nuclear Security Administration (NNSA) works to juggle refurbishments and modifications of aging weapons systems while replacing crumbling infrastructure and building new production plants.

President Joe Biden's budget proposal for the fiscal year that begins October 1 seeks $19.8 billion for the NNSA's nuclear weapons activities—a 4% increase from the current level. That follows an 11.6% rise from FYs 2023–24. The NNSA budget is one element of the $69 billion included in Biden's budget request for nuclear forces and their delivery systems. In all, NNSA funding has more than doubled in real terms since the Soviet Union's collapse and the ending of the nuclear rivalry between the superpowers (see the figure on page 23).

Today, of course, defense planners and lawmakers are addressing a renewed and multipronged nuclear threat: the buildup and modernization of nuclear forces by Russia, the expected push by China for nuclear parity with the US and Russia, and long-range missile testing by North Korea. The Russian threat has been heightened by President Vladimir Putin's repeated threats to use nuclear weapons in the war with Ukraine. Ernest Moniz, US secretary of energy from 2013 to 2017, says Putin's pronouncements have violated pledges made by Russia and all the declared weapons states to never use such weapons against nonnuclear states. The possibility of a nuclear attack now is at least as great as in the Cuban Missile Crisis in 1962, he says.

PLUTONIUM PIT PRODUCTION will be housed in the PF-4 building at Los Alamos National Laboratory. PF-4 also will continue to support a wide range of other plutonium functions, including R&D, fabrication of plutonium-238 heat sources for space exploration, nuclear waste processing, and counterterrorism activities.

The NNSA declined to make an official available for an interview. In a written statement, a spokesperson said that the FY 2025 budget request "reflects significant investments in ongoing modernization and efforts to strengthen our response to a deteriorating global environment. The proposal reflects a demanding, expanded mission. More than anything, it reflects our continued investment into the infrastructure of the Nuclear Security Enterprise that prioritizes sustainability and addresses modern threats."

A nuclear deal

The origins of today's soaring US expenditures on nuclear weapons date to 2010, when then-president Barack Obama approved a 30-year, $1 trillion blueprint for modernizing nuclear weapons and their delivery systems. Moniz says that Obama's go-ahead for the new spending was part of a deal for Senate ratification of the New START Treaty with Russia in February 2011. The treaty limited the numbers of

deployed warheads and delivery systems on both sides. The price tag of the modernization has since grown to as much as $1.5 trillion by some estimates.

Victor Reis, who was assistant secretary for defense programs at the Department of Energy from 1993 to 1999 (prior to formation of the NNSA), says that the weapons complex was funded at around $4 billion annually in the early 1990s. In the immediate aftermath of the Cold War, DOE was not producing weapons, and a halt had been called to underground testing. "The general feeling was there was a peace dividend," Reis says, and the political climate was characterized by a sense of wondering why nuclear weapons were needed at all.

In exchange for not insisting on a resumption of testing, Los Alamos, Sandia, and Lawrence Livermore National Laboratories each received a major new experimental facility and high-performance computing assets that would carry out experiments and modeling to simulate nuclear weapons processes. Known as science-based stockpile stewardship, that program has, by all accounts, succeeded in maintaining stockpile reliability to date. (See the article by Reis, Robert Hanrahan, and Kirk Levedahl, Physics Today, August 2016, page 46.)

Three decades into the post–Cold War period, the NNSA has been working to extend the lifetimes of aging nuclear warheads. The NNSA administrator, Jill Hruby, told a Washington, DC, conference in January that the agency had delivered more than 200 refurbished weapons to the military in 2023. The agency is also designing what will become the first post-1980s all-new nuclear warhead, which will top submarine-launched ballistic missiles. The NNSA has been directed by Congress to make another alteration to the venerable B61 bomb, which entered the stockpile in 1968. And Congress just last year authorized a new nuclear-tipped, sea-launched cruise missile.

Pit costs soar

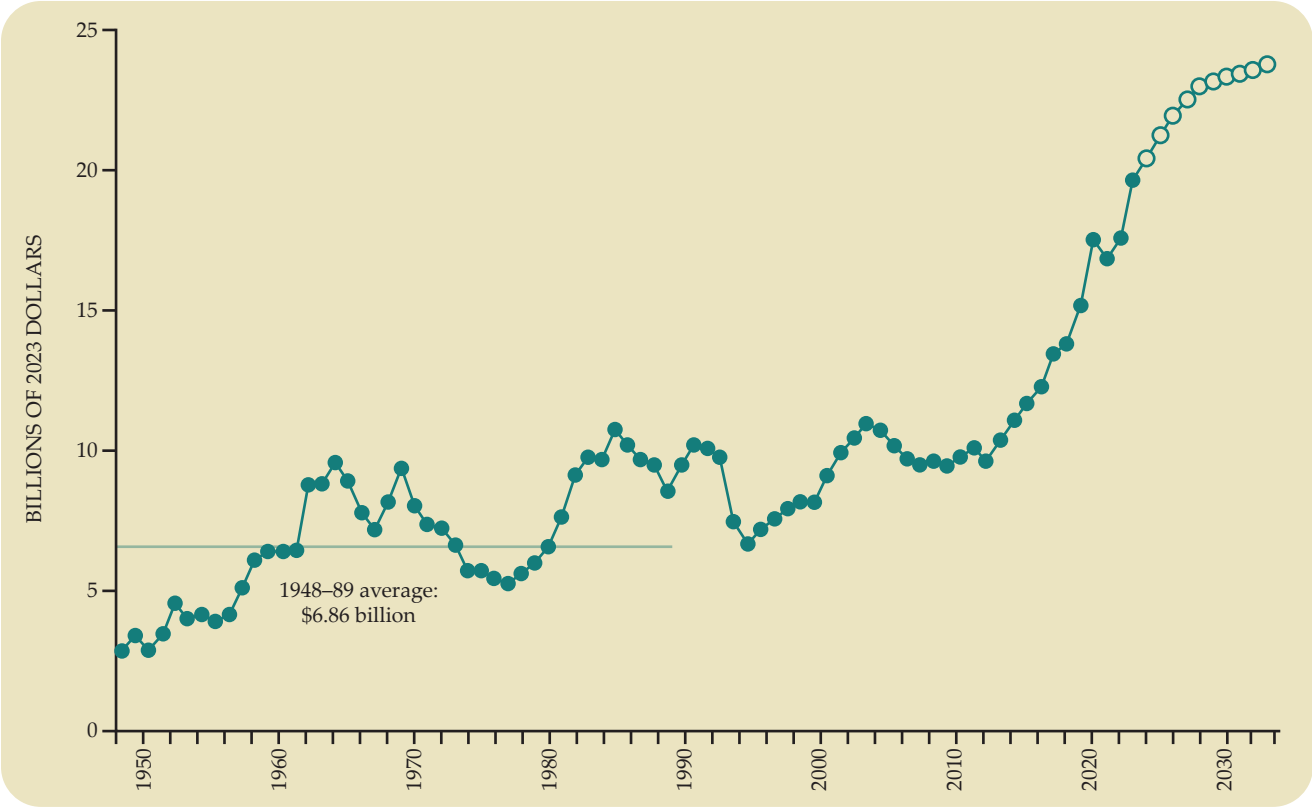
A legislative requirement for new plutonium pits, which are at the heart of all US nuclear weapons, is a large part of the ballooning NNSA weapons budget. Billions are being spent each year to build two pit manufacturing plants, even as a debate continues over whether and when new pits will be necessary. (See Physics Today, April 2023, page 22.) A new review of that question by the JASON advisory committee was ordered by lawmakers last year. An NNSA program of experiments, modeling, and simulations to pin down warhead-pit lifetimes will take 10 years and cost around $1 billion, according to the Government Accountability Office. That's in addition to the cost of the new infrastructure that is needed to help make the assessment, including the Enhanced Capabilities for Subcritical Experiments facility under construction in Nevada.

In the meantime, lawmakers have kept in place their mandate, first imposed in 2015, for the NNSA to achieve a production capacity of 80 pits per year. The NNSA says it doesn't expect to fully achieve that milestone until well into the next decade.

Although the budgets of all three nuclear weapons laboratories have surged in concert with the NNSA's, Los Alamos National Laboratory (LANL) has seen the largest growth: from $996 million in 1992 to a proposed $4.9 billion in FY 2025 (both in as-spent dollars). The bulk of that increase is devoted to efforts to shoehorn a pit factory into a decades-old multifunctional structure known as PF-4. As that work proceeds, the building will continue to be used for other functions, ranging from the conducting of plutonium R&D to the building of plutonium-238 heat sources for space propulsion. The LANL director, Thomas Mason, says that he's aiming for the lab to attain a capacity of 30 pits by 2028. Not all of those pits, however, will be qualified for nuclear weapons. LANL hired 5000 employees in the last three years alone, Mason told the January gathering, mostly in support of the pit mission. The LANL workforce has expanded from 7400 in 1992 to 11 591 in 2023.

Reis says that the possible impacts of plutonium aging was his major concern while at DOE. He says that Siegfried Hecker, the LANL director at the time, believed that the lab should have the capability to produce at least a single pit as part of its scientific and engineering mission. But he adds that the question of mass production at the lab didn't arise during his tenure. Hecker declined an interview request.

Budget projections for the LANL pit project are difficult to total, since many of the components are scattered among the other costs necessary to upgrade PF-4. For the line item of the pit-production project, the NNSA's FY 2025 budget proposal



NUCLEAR WEAPONS SPENDING by the National Nuclear Security Administration and its predecessor agencies has been on a steep upward path in recent years and has doubled in real terms since the end of the Cold War. The chart shows the annual expenditures, including administrative costs, in constant 2023 dollars. Values for 2024 and future years are estimates. (Adapted from a figure provided by Los Alamos Study Group.)

estimates the cost at $5.4 billion, an increase of $720 million from last year's figure. The documents also acknowledge a one-year stretch-out of completion, until 2032. The antinuclear advocacy and watchdog group Los Alamos Study Group estimates pit production at LANL will cost $30.8 billion through 2039.

Some are concerned that LANL may lose its identity. "Can you maintain the Los Alamos–like character of scientific inquisitiveness at the same time you're dealing with an industrial problem? It's a good question," Reis says. The University of California (UC), which until 2006 was the sole managing contractor at LANL, insisted in 1990 that it had no intention of becoming a production site. UC remains one of a trio of entities that operate the lab today.

Manufacturing the proposed 50 pits per year at the Savannah River Site is likely to be more formidable and expensive. Unlike LANL, the facility has no workforce experienced with pits. The NNSA is working to transform a half-completed plant that had originally been designed to produce mixed-oxide fuel for commercial reactors. In its FY 2025 budget request, the agency warns that the existing official cost estimate of $11 billion could balloon to $18 billion–$25 billion.

Such a wide range of cost estimates is indicative of what the Government Accountability Office last year described as a lack of comprehensive schedule and planning by the NNSA for large new facilities. At the Savannah River Site, "the design challenges may have been foreseen with more-thorough planning," notes Dylan Spaulding, an analyst at the Union of Concerned Scientists. He says that the doubled cost estimates are likely to draw increased scrutiny from lawmakers. In her January speech, Hruby said that the NNSA will continue design, construction start, baseline cost and schedule updates, and long lead procurements simultaneously at Savannah River.

Cost overruns

Around 10% of the $1 trillion spending package approved by Obama in 2010 was dedicated to modernizing long-neglected NNSA nuclear facilities. "The DOE production complex desperately needed to be upgraded," says Moniz. "We were dealing with 50-year-old buildings, and the reality is that rather than having an ongoing maintenance and upgrade program over the decades, we let things go."

For two decades, the NNSA has struggled to replace a 1940s-era building in Oak Ridge, Tennessee, that manufactures uranium weapons components. The new uranium processing facility was first proposed in 2004 at a cost of $1.4 billion. By 2013, estimates had grown to $11 billion. Moniz says that he ordered a redesign that year that would result in vastly downsizing the parts of the plant that required the most stringent security standards. Despite being capped in 2018 at $6.5 billion, the project's cost is now expected to rebound to $10 billion, and its completion extended by seven years to 2032, according to the FY 2025 budget request.

The NNSA blames the impacts of the

COVID-19 pandemic for up to half of that cost overrun. Slippage in the project's completion date was caused by contractor performance and the contractor's failure to notify the NNSA of cost overruns in a timely enough manner to inform the budget process, it said in the FY 2025 budget request.

Spaulding sees another factor responsible for the burgeoning costs for maintaining and modernizing the weapons complex: the "pyramid of contractors" that manage the work. The weapons labs are now operated by partnerships that include contractors such as Battell, Bechtel, Honeywell, and BWX Technologies, he notes.

David Kramer

New center for quantum sensing focuses on medical applications

The techniques promise earlier disease detection that can lead to better outcomes.

Clogged arteries. Osteoporosis. Malnutrition. Brain disease. With quantum sensing, those and other ailments could be detected earlier than is currently possible. The emerging field got a boost in late February: a six-year grant totaling about $22 million from the Novo Nordisk Foundation to form the Copenhagen Center for Biomedical Quantum Sensing.

The new center is a collaboration among three university physics groups—two in Denmark and one in the US. The researchers plan to use squeezed light, entangled atomic spins, and purified stable isotopes to develop and implement detection methods that push sensitivity limits in disease diagnostics.

Medical diagnostics is a relative newcomer to the burgeoning field of quantum sensing, which has applications in communications, imaging, seismology, and other areas. A growing number of research groups, perhaps as many as 50 worldwide, are doing work related to what will be done in the new center, notes Eugene Polzik of the Niels Bohr Institute at the University of Copenhagen and the center's director. "Our strength is in collaboration and in our strong focus on applying novel quantum measurement principles toward goals in biomedical applications. We are also working closely with life scientists and medical doctors."

The center fits into a broader quantum strategy that the Novo Nordisk Foundation adopted a few years ago, says Lene Oddershede, the foundation's senior vice president for natural and technical sciences. It had already been funding quantum computing for a while, with the long-term goal of solving problems in the life sciences, she says. "Now we are supporting quantum sensing with the aim of harvesting nearer-term applications in biology and medicine. I believe quantum technology can have an enormous impact on sustainability and health." (See the interview with Oddershede, who left a position as a tenured physics professor to join the foundation, at http://physicstoday.org/oddershede.)

Quantum technologies

Polzik and his research team use atomic spins as magnetic sensors, expanding on techniques that his and other groups

JACKSON WILLIAMS/NOVO NORDISK FOUNDATION

IN THIS QUANTUM MAGNETIC SENSOR, cesium atoms are in a channel that preserves atomic spin state for many milliseconds—long enough for biomedical magnetic field measurements. The channel's cross section is 300 × 300 microns. The sensor, which records collective spin states, was made at the Niels Bohr Institute in Copenhagen by the group of Eugene Polzik, director of the new Copenhagen Center for Biomedical Quantum Sensing.