

customs and regulations. “We are trying to get our students to think critically and to challenge their instructors; this is not always easy in a society where respect for teachers is a core value.” Another example is cross-cultural integration of the three communities on campus: Chinese, American, and others. “That requires constant attention and nurturing.”

For institutions that recruit interna-

tionally, language and cultural differences can challenge faculty and students. OIST researchers benefit from the 2009 decision in Japan to accept grant applications in English. At KAUST, the foreigners and many of the Saudis live in an onsite enclave. For some, human rights, political issues, and the country’s links to terrorism can be tough to square with the university’s vibrant research environment. Isolation is a challenge at

many of the new campuses, whether because of a time difference, far-flung location, or other reasons. “If you like living in big cities, Merced doesn’t have as much to offer,” says Gopinathan. But his campus, KAUST, and others got a leg up in hiring during the global recession. And, says Gopinathan, the UC Merced physics department has a high faculty retention record.

Toni Feder

Take your pick: A new warhead or a “new program of record”

Administration officials say a proposed new weapon for the US Navy won’t require nuclear testing.

The Trump administration announced in February that it was initiating a program to develop the first new nuclear warhead since the late 1980s. That action reversed the Obama administration’s policy to neither develop new nuclear weapons nor enhance the military capabilities of existing weapons systems. But the W93, as the warhead is called, won’t be entirely new: Its nuclear explosive package will be borrowed from an existing weapons system.

The W93 was unveiled as a line in the Department of Energy’s fiscal year 2021 budget request for the National Nuclear Security Administration (NNSA). DOE is asking for a stunning increase of 25%, or \$3.1 billion, for the agency’s nuclear weapons programs, to a level of \$15.6 billion. The \$53 million included for the W93 will support conceptual studies of poten-

tial warhead architectures and system requirements, the first stage of a seven-step process that has been followed in the past for new warhead development. Although the W93 isn’t scheduled to enter the nuclear arsenal until 2034, NNSA budget documents show its out-year costs ballooning to \$1.1 billion in FY 2025.

NNSA administrator Lisa Gordon-Hagerty and Charles Richard, the commander of the Defense Department’s Strategic Command, shared few details of the W93 in recent open congressional testimony. At a 27 February hearing before the strategic forces subcommittee of the House Armed Services Committee, Richard repeatedly refused to call the W93 a warhead, referring to it instead as a “new program of record.” He said the W93 will be a payload for a new missile to be carried aboard *Columbia*-class ballistic missile submarines. The new subs are scheduled to begin replacing the US Navy’s fleet of *Ohio*-class SSBNs in 2031. (The navy denotes a class of ships by the name of the first one to enter service.)

The two officials insisted the W93 will use an existing nuclear explosive package and thus won’t need nuclear testing before deployment. Many experts have said that a warhead built with new nuclear components would have to be tested underground before it’s approved for deployment. The US has observed a moratorium on nuclear tests since 1992.

Today, two warhead types top submarine-launched Trident II D5 missiles. The W76, the more numerous of the two, underwent a life extension that was completed last year. It is now designated W76-1. The W88, the higher-yield but less plentiful warhead, underwent a modernization that was delayed a year after a faulty capacitor was discovered. The first refurbished W88 is slated for delivery to the navy later this year. Because the changes made to it will be less extensive than those of a full life extension, the updated warhead will retain its original designation. In the parlance of US nuclear weapons, a warhead’s number denotes approximately the year that the first one



A RENDERING OF A COLUMBIA-CLASS BALLISTIC MISSILE SUBMARINE (SSBN), which will carry ballistic missiles to be armed with the W93 warhead. The boats will replace the existing *Ohio*-class SSBN fleet. The first *Columbia*-class sub is scheduled to begin patrols in 2031.

enters the stockpile. It isn't clear why the W93 will depart from that tradition.

Richard said the W93 would "address an imbalance in a strategic leg" of the so-called nuclear triad of delivery systems: land-based missiles, submarine-launched ballistic missiles (SLBMs), and aircraft. The warhead will "wind up initially being a third [SLBM] warhead." He said the W93 could replace the W76-1, the W88, or both, or it could become a third SLBM system alongside the other two. But a senior defense official told reporters in a briefing last month that the W93 will replace the W88.

"We have an opportunity to address the imbalance between the W76-1s and the W88s," Richard noted, in an apparent reference to the much higher yield of the W88—an estimated 455 kilotons, compared with the W76-1's 90 kilotons. The W93 will not add to the stockpile. According to the NUKEMAP simulator built by Alex Wellerstein of Stevens Institute of Technology in Hoboken, New Jersey, a W88 detonated above a city would vaporize everything within a radius of 0.7 km and collapse most residential buildings within a radius of 5.4 km. The corresponding radii for the smaller W76-1 are 0.5 km and 3.3 km.

New security features

One likely improvement in the new warhead, experts say, is the use of insensitive high explosive (IHE), which is much less likely to detonate in a fire or other accident and disperse plutonium and other nuclear materials. Unlike the majority of US weapons, the submarine warheads contain more volatile conventional high explosive. The decision to eschew the use of IHE was made at the height of the Cold War, when nuclear war planners called for packing eight warheads on each D5. That wouldn't have been possible with the less energetic IHE because of the greater volume of the material required. Today four or five warheads are carried on each missile, which provides room for bulkier designs.

Gordon-Hagerty said the W93 will incorporate modern technologies to improve safety, security, and flexibility to address future threats and will be designed for ease of manufacturing, maintenance, and certification.

Hans Kristensen, a nuclear weapons expert at the Federation of American Scientists, says a variable, "dial-a-yield" option might be added. The B-61 bomb, some of which are deployed in NATO countries,

offers such a range of yields, as does the W80 warhead for the air-launched cruise missile. Controlling the yield can be accomplished by deactivating the weapon's fusion-fission secondary stage, which produces the most destructive blast, or by varying the amount of tritium-deuterium gas used to boost fission in the primary.

Since 9/11, the NNSA has been upgrading safety and security features as each warhead system undergoes refurbishment, with a goal to prevent a warhead's use if one should get into terrorist hands.

All warheads have been certified to be one-point safe, meaning that a detonation of their high-explosive component at a single point, whether by a bullet or some other method, can't produce a nuclear yield. According to Kristensen, the weapons labs have been striving for two-point safety. Although extremely improbable, in theory a precisely timed detonation at two exact points might result in an implosion that produces a nuclear yield.

Other safety and security features that could be added to a new weapon

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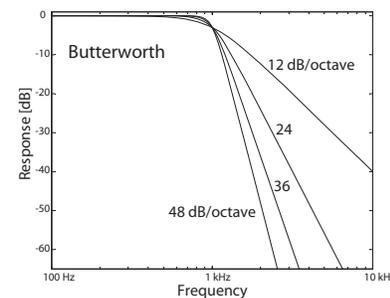
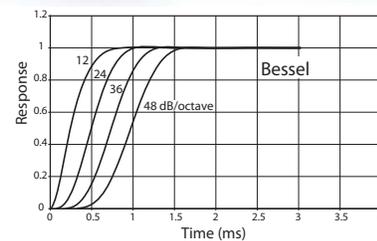


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include improved self-destruct systems, lightning arresters, and optical firing systems. The labs had hoped to introduce optical firing to the B-61 gravity bomb as part of a life extension that is now underway, but officials concluded the technology wasn't ready to meet the production schedule, Kristensen says.

DOE has not yet determined which of the two national weapons design labs, Los Alamos or Lawrence Livermore, will be responsible for developing the W93, Los Alamos director Thomas Mason told reporters in February. In the past, one or the other lab has been given responsibility for birthing a specific weapons system. The other lab reviews the design process.

At the 27 February hearing, Richard warned that US weapons upgrades can't be delayed: "The entire triad is reaching the end of its useful life. Either we replace what we have now or we start to divest almost on a path to disarmament." Russia and China are developing new weapons systems, he said, and although "Russia will tell you exactly what they're doing and why, China does not."

There were some inconsistencies in

Richard's and Gordon-Hagerty's testimonies. The NNSA administrator said the refurbishment of the submarine warheads will extend their lives by 30 years or more. But Richard said the W76-1 and W88 life extensions were "modest" and didn't alter their nuclear components. "If you want to replace those weapons or life-extend them in the 2030s, based on historical timelines, we need to start now," he said.

Richard blamed a lack of new pits for limiting the extent of refurbishments. (The pit is the plutonium core of the primary stage of nuclear warheads.) He told lawmakers that pits to be built at Los Alamos beginning in 2023 will be used to "refurbish the entire stockpile." DOE budget documents, however, show that all 141 pits that the NNSA plans to build through 2030 are earmarked for a replacement warhead series for Minuteman III intercontinental ballistic missiles. Designated W87-1, it will replace the W78 that tops most ICBMs today (see PHYSICS TODAY, February 2020, page 23). The NNSA proposes to establish additional pit production at its Savannah River Site and increase total output at the

two sites to 80 pits per year post 2030.

A very full plate

At a 4 March hearing of the House Appropriations energy and water development subcommittee, Gordon-Hagerty said that the multibillion-dollar increase proposed for NNSA weapons activities in FY 2021 is essential to carrying out life extensions of four warhead types as the agency rebuilds its crumbling infrastructure, 30% of which dates to the Manhattan Project. In addition to the W88, W87-1, B-61, and W93 programs, the agency is in the throes of planning a modification to the W80 air-launched cruise missile. The US Air Force is procuring a replacement cruise missile that it calls the long-range standoff weapon.

During the hearing, chair Marcy Kaptur (D-OH) called the \$15.6 billion request "unrealistic" and questioned the NNSA's capacity to spend it. Last year the NNSA projected a need for \$12.8 billion in FY 2021, Kaptur said, and noted that as of last October, the agency had accumulated \$8 billion in unspent funding from previous years. "This request is simply sprinting toward failure," she said. "We need to give NNSA more breathing room before it falls off the cliff."

Gordon-Hagerty insisted that the NNSA is up to the task. "We're to the point of throwing good money after bad" with regard to the weapons complex infrastructure, she said. "Yes, we are seeking to do things in 10 years that would traditionally take 15."

Gordon-Hagerty didn't respond directly when asked why the NNSA had moved up initiation of the W93 program from its previously planned date of 2023. Until this year the W93 was referred to in planning documents as the next navy warhead.

Stephen Young, a nuclear expert with the Union of Concerned Scientists, believes the military wants to ensure the new warhead program is formally established while President Trump is in office. "A Democratic president would be less inclined to support it," Young says.

Kristensen says the NNSA has too much on its plate. "Everybody not in an official position says they are already overstretched in their ability to manage all of their life extensions. And here comes Trump and throws a bunch of extra systems and work onto the pile."

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