Weapons labs to build costly new device to better understand plutonium FREE

Scientists say subcritical experiments with plutonium will eliminate the need for nuclear tests, a promise that was first made in 1995.

David Kramer

Physics Today **73** (2), 23–25 (2020);
https://doi.org/10.1063/PT.3.4406

ous scientists." That perception can be stronger in physics than in other fields, she adds, perhaps because it's often considered the toughest major. One way departments can help, the report says, is by creating opportunities "for students to discuss broader societal issues of concern such as gun violence, immigration, hate crimes, and protest movements." (See also PHYSICS TODAY, October 2019, page 24.)

Bertschinger notes that African Americans tend to be socially minded. "Giving back to the community is highly valued." The tendency goes back to the history of supporting each other in the face of systemic discrimination, racism, and hate crimes, he says, and that social context provides important grounding to the African American experience. Faculty may not realize that a physics degree provides a strong background to work in areas that undergraduates are interested in, such as climate change or how technology can enhance or diminish civil rights, Bertschinger says. "But physics training provides rigorous methodology for problem solving. We as physicists could do a better job if we recognized connections beyond our discipline." Along those lines, the report recommends that departments discuss career options for physics bachelors.

Many African American students need support to offset financial burdens and stress.

The TEAM-UP financial challenges are more straightforward than the cultural ones, says Bertschinger. It may not be easy to raise $50 million, but the objective is clear. Shifting attitudes is harder, he says. "Faculty may feel ill-equipped to deal with the issues, or that it's not their responsibility, but I am optimistic because there is so much awareness these days of the inequities in society and on campuses." S. James Gates, a theoretical physicist at Brown University and task force member, agrees: "This report comes at a fortunate time, as academics are already dealing with harassment issues." Partly because of the #MeToo movement, there are more "woke" people walking around, he adds. "I think we can make a difference."

Toni Feder

Weapons labs to build costly new device to better understand plutonium

Scientists say subcritical experiments with plutonium will eliminate the need for nuclear tests, a promise that was first made in 1995.

The pockmarked Nevada National Security Site, where more than 900 nuclear blasts were set off during the Cold War, will be host to a new billion-dollar-plus experimental weapons test facility located more than 300 meters underground. But the observations of how plutonium behaves under the extreme pressures that occur during detonation of a nuclear weapon will be made without those blasts.

The Enhanced Capabilities for Subcritical Experiments (ECSE) facility will capture x-ray images of the dynamics occurring during the implosion of scale models of plutonium pits, which are at the heart of a nuclear weapon's primary stage. When completed in 2025, the ECSE will consist of two major components. The most critical, and by far the most expensive, is Scorpius, a 20 MeV accelerator that will produce x rays from bremsstrahlung radiation generated by decelerating electrons as they hit a heavy metal target. The photons will capture images of the hydrodynamics occurring during the implosions. A second instrument, in an earlier stage of development, will probe the behavior of neutrons as the plutonium samples approach, but never attain, a critical assembly capable of sustaining a chain reaction.

The ECSE will work analogously to how aircraft manufacturers develop new planes, says Los Alamos National Laboratory (LANL) director Thomas Mason: "We can't fly the aircraft, but we can put the model in the wind tunnel." The results will be used to validate the codes that have been developed on high-performance computers to simulate nuclear blasts, "to fly the planes, if you will."

Scientists at LANL and Lawrence Livermore National Laboratory (LLNL) already have several devices for studying implosions. Both labs have aboveground machines that can create x-ray images of imploding targets. LANL's Dual Axis Radiographic Hydrodynamic Test (DARHT) facility is the more advanced of the two, capable of generating four images at 2 MHz of the hydrodynamics of imploding materials. Scorpius will at a minimum have the same imaging capability, but its design may be upgraded to capture eight images at 5 MHz, says David Funk, LANL senior director for the advanced sources and detectors project in Nevada, of which Scorpius is a part.

The aboveground devices have a major drawback: For environmental and safety reasons, they can experiment only on surrogate materials such as tungsten, lead, copper, and gold. Surrogate materials help validate some model properties, but "in the end, plutonium is a unique metal," Funk says. For example, it has seven phases that can be created in a lab without exotic equipment. "At very high pressures and temperatures its behavior may not be very well represented by surrogates."

Since the US halted nuclear tests in 1992, plutonium implosion experiments have been carried out in the U1a tunnel complex at the Nevada National Security Site. The high-explosive-driven experiments are done within containment vessels with quantities designed to remain subcritical.

Funk says the existing pair of 2.2 MeV accelerators located in the U1a complex produce photons with enough energy to

LOS ALAMOS NATIONAL LABORATORY

THE U1A TUNNEL COMPLEX, 330 meters beneath the Nevada National Security Site, will house the Enhanced Capabilities for Subcritical Experiments facility, which will probe the behavior of plutonium under conditions that occur in nuclear detonations.

record only the early stages of implosion. "For quantities of interest—I won't say anything about the scale or size of experiments—it's very difficult to look through a dense metal like plutonium with 2.2 MeV. We need much higher energy photons."

Holding the experiments underground avoids generating a new transuranic waste stream, Funk says. Instead, the waste is simply entombed in the U1a complex. The subterranean environment also is inherently safe and secure, he asserts.

The Department of Energy's National Nuclear Security Administration (NNSA) established in 2014 the need for an ECSE-like capability to ensure proper functioning of the weapons stockpile. The ECSE will also likely be used to evaluate new weapons designs. No new warheads have entered the stockpile since the 1980s, but a replacement warhead for US land-based intercontinental ballistic missiles is now in the design phase.

Fuzzy cost estimates

A preliminary ECSE design, expected by March 2021, will include a cost baseline with a confidence level of at least 80%. Until then, the estimate ranges from \$500 million to \$1.1 billion. Extending the U1a tunnels to accommodate the device will cost another \$111 million to \$175 million, Funk says. Congress included \$145 million for the project in the current fiscal year's appropriations.

Scorpius is named after Scorpius X-1, the first cosmic x-ray source to be discovered, and the brightest. The accelerator will produce x rays sufficient for producing images of the latter, denser phases of implosions. The x rays will also be able to capture images of targets that more closely resemble pits in size and shape compared to current implosion targets. The cameras and other diagnostics at the ECSE will be comparable to those located on DARHT, but with some improvements, he adds.

A second ECSE component, now in the R&D phase, will probe the neutron reactivity of the plutonium as it implodes. In a stand-alone mode, a pulsed-power device known as a dense plasma focus will produce 14 MeV neutrons from a deuterium–tritium plasma. Those neutrons will be directed onto the plutonium target and the decay rate of the reaction measured. Scorpius will serve as the neutron source for combined radiographic–neutronic experiments. That's because neutrons created by the accelerator via photofission will vastly outnumber the neutrons produced by the dense-plasma-focus device. The ECSE's neutronic components are estimated to cost around \$90 million.

The combination of radiographic and neutronic experiments "should preclude the need to do any kind of testing in the future of an underground type," Funk says. That same promise was made by the lab directors a quarter century ago. In that light, what's happened since then to justify the ECSE's costly new capabilities?

Aging concerns

Each year since the cessation of nuclear tests in 1992, the directors of the three US weapons labs—LANL, LLNL, and Sandia—have been required to assure the president that the weapons are safe, reliable, and secure. But lab scientists continue to have concerns over the aging of pits and their interactions with other weapon components. That's despite studies that have concluded that the pits, which date to the 1980s, should function properly for decades to come.

For example, researchers at LLNL applied accelerated aging techniques to the primary fissile material in warheads, plutonium-239, which has a half-life of 24 100 years. The study found that the material, will "age gracefully" for at least 150 years. That research discounted concerns that phase changes or helium bubbles caused by alpha decay in the metal's lattice might change the shape or strength of the pits.

A 2007 report by JASON, the secretive group of scientists who advise federal agencies, also found little age-related reason for concern—at least in the unclassified summary. Nonetheless, Congress last year ordered JASON to take another look. The group's November report provided no estimates for pit lifetimes. It recommended that the labs continue with plutonium aging research. Mason says the ECSE will be an important component of the "focused program to understand aging" that the study called for.

Mason says the 2007 JASON review included a number of important caveats that often get lost in the slogan "we don't have to worry about plutonium aging." The report, he says, "has a much more nuanced view of that," although those details are classified.

Apart from assessing aging concerns, Funk says the ECSE will help evaluate whether weapons will be affected by new manufacturing methods and the addition of new safety and security devices.

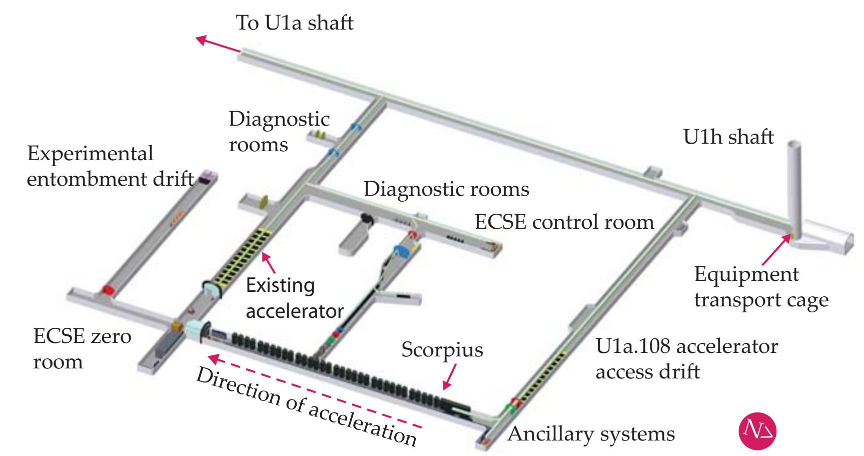
Mason points out that the NNSA plans to ramp up production to 80 new pits per year by 2030 in response to a directive in the 2018 *Nuclear Posture Review*. Those pits will be cast instead of wrought, as was the case for manufacturing all but a handful of pits in the current stockpile. The wrought pits were proven to work in full-scale nuclear tests. In the absence of testing, the ECSE will help certify the performance of the new pits to be manufactured at LANL and DOE's Savannah River Site, Mason says.

Critics argue that the ECSE is unnecessary. In fact, LANL manufactured more than two dozen cast pits over a decade ago that were certified for submarine-launched ballistic missiles. "All of this is about the future stockpile and future heavy modifications, if not outright new designs," says Jay Coghlan of the watchdog group Nuclear Watch New Mexico.

Budget documents for the current fiscal year indicate that all 141 pits scheduled to be fabricated from FY 2023 through FY 2030 will be used for a new warhead rather than as direct replacements for aging weapons. Designated W87-1, the new warhead is to replace the W78 that tops most of the US Air Force's Minuteman III intercontinental ballistic missiles. The W87-1 will be the first new warhead design to be certified without the need for underground testing.

Coghlan and others worry that facilities such as the ECSE are being created to support increasingly major modifications to existing weapons systems. The changes are creating "code drift," he says, by moving the remodeled weapons further away from the simulations that were validated by nuclear testing. That will degrade rather than improve their reliability, he argues.

David Kramer PT



A SCHEMATIC OF THE U1A TUNNELS shows the locations of the proposed Scorpius electron accelerator and one of the two existing accelerators. Scorpius will produce x rays to image the hydrodynamics of plutonium as it implodes. The smaller accelerator will generate high-energy neutrons to probe time-dependent neutron reactivity during implosions. Both types of experiments occur inside containment vessels located in the zero room at the lower left. Spent vessels are entombed in the vertical tunnel at the far left. (Courtesy of Los Alamos National Laboratory.)