

DOE looks hard at taking over deep underground site

At stake is US leadership in the particle-physics intensity frontier.

After NSF was forced last December to throw in the towel on establishing an underground laboratory in the former Homestake gold mine in South Dakota, the US Department of Energy began analyzing the possibility of making something of the site. If it does, the facility would be smaller and would have a tighter scientific focus than NSF had planned. DOE will decide soon—in time for inclusion in the fiscal year 2013 budget—whether to drop Homestake, go full force, or fund it at an amount that keeps options open.

Since at least 2000, US scientists have been working to have a deep underground lab for experiments that need shielding from cosmic rays and background radioactivity. For DOE, those are the long baseline neutrino experiment (LBNE) and searches for neutrinoless double beta decay and dark matter. The multidisciplinary NSF plan for the Deep Underground Science and Engineering Laboratory (DUSEL) also included programs in nuclear astrophysics, geology, biology, and engineering, and efforts in public outreach and education (see PHYSICS TODAY, February 2011, page 21).

The LBNE aims to look for *CP* violation and to nail down which of three neutrino types is heaviest by studying oscillations among them; Fermilab has made the experiment its top priority. A beam of muon neutrinos from Fermilab would zip some 1300 km to a “far” detector at Homestake. Neutrino oscillations would be studied by comparing the observed neutrinos with the initial beam makeup determined by a “near” detector at Fermilab.

The LBNE collaboration has not yet decided whether to go with the mature water Cherenkov technology, which would require a 200-kiloton detector at Homestake, or with liquid argon, for which the detector would be about one-sixth the size and far more sensitive to particle interactions. But the liquid argon method needs engineering development and prototyping. “We’ll go with whichever gives us more physics for the money, once we know how much we have,” says LBNE project leader Jim Strait.

Cost, benefits, and US leadership

The cheapest option for DOE is to put the LBNE far detector at Homestake but put the double beta decay and dark-matter experiments in Canada’s SNO-

LAB. But that lab is not an option for the LBNE because it’s too close to Fermilab—765 km. Nor does it have a large enough cavern. The total cost for the LBNE, including infrastructure at both Fermilab and Homestake, would be \$1.2 billion–\$1.5 billion; the first additional experiment at Homestake would add about \$100 million in infrastructure, and more would cost \$15 million each. It would not be cost effective to put the dark-matter and double beta decay detectors in Homestake unless the LBNE is installed there. Those are among the conclusions reached by an independent assessment requested by DOE Office of Science director William

against creating and managing a new national lab but encourages the department to maintain Homestake’s viability for science. DOE has requested \$15 million for FY 2012 to keep the Homestake option afloat. Mike Headley, the site’s project director, who works for the South Dakota School of Mines and Technology, says his design team has shrunk to half its earlier size, but the \$15 million would keep the “very knowledgeable” team intact and keep the mine from flooding. “After getting over the initial shock [of NSF pulling out], we certainly want to see the facility move forward,” he says. Some \$70 million from philanthropist T. Denny San-



This cavern 4850 feet deep in South Dakota’s Homestake mine is being prepared to house early experiments, in particular the Majorana demonstrator project, which will search for neutrinoless double beta decay. The cavern is roughly 135 × 50 × 17 feet.

MATT KAPUST/SANFORD UNDERGROUND LABORATORY

Brinkman and released in late June. Carried out over three months, the assessment involved gathering and synthesizing information; no original cost estimates were made.

Despite the extra cost of collocating the three experiments at Homestake, Caltech’s Jay Marx, who cochaired the assessing committee, says, “We pointed out that programs will go on for several decades.” In a 23 June briefing to DOE’s High Energy Physics Advisory Panel, Marx noted the benefits of having a common facility serve as an intellectual center and said that “locating the facility in the US would promote US leadership in these fields for the foreseeable future.”

Adjusting to the switch

The House energy and water development appropriations bill cautions DOE

ford plus about \$50 million from the state of South Dakota have been invested in Homestake, and two physics experiments are getting under way. But an end to federal money would be the death knell for the site.

Headley’s team, together with the experiment collaborations, has begun modifying the lab design. A smaller Homestake facility would be built on a single level, 4850 feet (1480 meters) deep, instead of two or three levels as had originally been envisioned for DUSEL. It would still have a big cavern for the LBNE, but only one additional experimental hall, rather than two; that second hall could house up to three experiments.

The scaled-down option—which for political reasons is not referred to as a national laboratory—has been dubbed the Sanford Underground Research Facility,

or SURF. The estimated infrastructure cost is \$150 million, significantly less than the \$575 million for NSF's grander plan. The annual running costs for SURF are estimated at around \$20 million, less than half the \$50 million–\$70 million for DUSEL.

On 12 July, the National Research Council released a report that will also figure into DOE's decision on Homestake. The NRC evaluated the science proposed for DUSEL, the need for it in the context of similar science programs in other regions of the world, and its broader impact. The science has been reviewed several times over the past decade, and the NRC conclusions held no surprises: The three experiments that DOE is now considering are of "paramount and comparable scientific importance," with each addressing "at least one crucial question upon which the tenets of our understanding of the universe depend." The report also gives high marks to an accelerator-based

study to measure low-energy nuclear cross sections. And it notes that a facility in the US would not only provide access and leadership advantages for the physics community, but could also benefit scientists in other fields.

If DOE does run with Homestake, it would be built incrementally. "DOE is more amenable to phasing things in, which allows us to come up with lower costs in preparing the facility," says Kevin Lesko, who led the NSF-supported efforts for DUSEL and is continuing in that leadership role for SURF. He and others point out that DOE has more experience than NSF in running large projects. But, Lesko says, "We hope that NSF can be reengaged and that more experiments would eventually come to Homestake."

Especially given cuts in federal spending, DOE's decision is "complicated," says Strait. "We don't know whether to expect thumbs up, thumbs down, or thumbs sideways." **Toni Feder**

and counting—and, increasingly, of mobile tablets, such as Apple's iPad. The demand for those devices, which typically cost less than \$1000, has particularly paid off for scientists looking to exploit the once pricey high-tech hardware and software that make them tick. In the early 1990s, says Ozcan, "we could have paid several thousand dollars for a 1-megapixel CMOS sensor. It was a dream for a researcher to have the 5- or 8- or 12-megapixel CMOS sensors that we now have in our cell phones."

Smartphones in space

In addition to a camera, most tablets and smartphones—cell phones that support third-party software applications, or apps—also come with other components used in physics research. By interfacing with an Apple iPhone's three-axis gyroscope, accelerometer, and camera, a new app is expected to give astronauts the ability to measure a spacecraft's position, its altitude, and Earth's curvature, all for roughly \$750—the cost of the phone plus a 99¢ app.

The app, SpaceLab for iOS, will also allow users on Earth to simulate some of those measurements. Last month two iPhones loaded with SpaceLab for iOS were delivered to the International Space Station on NASA's final space-shuttle mission.

After discovering that his Motorola Droid smartphone had a three-axis Hall-effect magnetometer, physicist Randall Peters and colleagues at Mercer University in Georgia secured an NIH grant to test the phone's potential as a seismocardiograph, a wireless monitor of heart health. "Unfortunately the sensitivity of the device is limited by the data range of the available app so it is not yet a viable sensor," says Peters.

Some scientists and equipment manufacturers are exploring apps and Web-based software that can interface with external scientific instruments. Earlier this year, Agilent Technologies released a software platform that allows chromatography users to remotely monitor the status of their equipment and analyze the generated data. "The next step will be to allow the user to receive automated alerts and to remotely control the instrument, not just monitor it," says Agilent program manager Linda Doherty.

The software and technology to remotely operate "sophisticated instruments" already exist, says Supratik Guha, director of physical sciences at IBM Research. For example, IBM physicist Rudolf Tromp, through the internet, can remotely operate his "state-of-the-art low-energy electron microscope

Harnessing consumer mobile devices for science

Researchers are exploring ways to utilize the sensors and software inside cell phones and mobile tablets.

All talk, no science? Your cell phone is smarter than that. Just ask electrical engineer Aydogan Ozcan, inventor of a process for imaging transparent biological specimens with a cell-phone camera's LED and CMOS sensor. In June, Ozcan's UCLA biophotonics research team used its cell-phone microscope in Brazil's Amazon rainforest to capture

images of malaria-infected blood. The researchers are now fine-tuning an attachment that converts cell phones into wide-field fluorescence microscopes for water-quality screenings.

Ozcan is among a growing number of scientists seizing the opportunity created by the global prevalence of cell phones—more than 5.3 billion of them

Photonics researcher Aydogan Ozcan (standing) and his graduate student Onur Mudanyali compare microscopic images taken by a tabletop optical microscope and by a Sony Ericsson smartphone, which was used to capture diffraction shadows of blood cells.

OZCAN RESEARCH GROUP/UCLA

