In written responses to questions, SLAC director Chi-Chang Kao said, "Ultimately we expect LCLS-II to incorporate the capabilities called for in the BESAC subcommittee report."

The report, Kao wrote, urges SLAC "to go beyond the capabilities that we originally envisioned for LCLS-II, so as to enable a broad range of new experiments—some of which would require high intensity and very short pulse duration—and another class that would require a high rep rate and lower intensity pulses." John Hemminger, BESAC chair, says the LCLS-II could increase its repetition rate with the addition of multiple superconducting undulator magnets.

Although the LCLS already has some capability to assemble a series of images into a movie of chemical reactions, that capability can be enhanced, Kao said.

Lawrence Berkeley National Laboratory had presented BESAC with a plan to upgrade its proposed FEL, called the Next Generation Light Source (NGLS). But a spokesman for LBNL said the lab had withdrawn its proposal and was joining SLAC's upgrade effort.

Hemminger, vice chancellor for research at the University of California, Irvine, says he believes the BES budgets for the coming years have sufficient funding to cover the cost of the recommended upgrade.

The LCLS was the world's first hard x-ray FEL and Japan's Spring8 is the only other FEL that operates in the hard x-ray spectrum. The original LCLS-II was scheduled for completion in 2018. Kung says it is too soon to say when the BESAC-recommended upgrade would be completed. Three other hard x-ray FELs are under construction in Germany, South Korea, and Switzerland. Soft x-ray FELs are already operating in Italy and Germany. In the US, the soft x-ray NGLS was the only other FEL source in the planning stages.

By 2020 Europe will have the most advanced suite of light source tools in the world in terms of capability and capacity, the BESAC report says.

New classes of experiments

What would set the proposed facility apart from other FEL sources is its high pulse-repetition rate and broad photon-energy range. Femtosecond-long x-ray pulses would enable rapid-fire imaging of dynamic processes in chemistry, physics, biology, and materials science. Such experiments, says the BESAC report, include time-resolved physics and chemistry studies of how bonds break and form, how energy flows at the molecular level, and how charge is transferred in nanoscale electronic devices. The x-ray source could perform two new classes of biomolecular experiments, one destructive and the other nondestructive. The first, which the panel calls "diffract-before-destroy," takes advantage of the fact that femtosecond pulses can outrun radiation damage. The second class, pump–probe, uses two or more pulses per sample to study dynamics. It must be nondestructive to allow repeated measurements using subsequent pulses on the same sample. Those types of experiments have already revolutionized spectroscopy in other regions of the electromagnetic spectrum, Hemminger says.

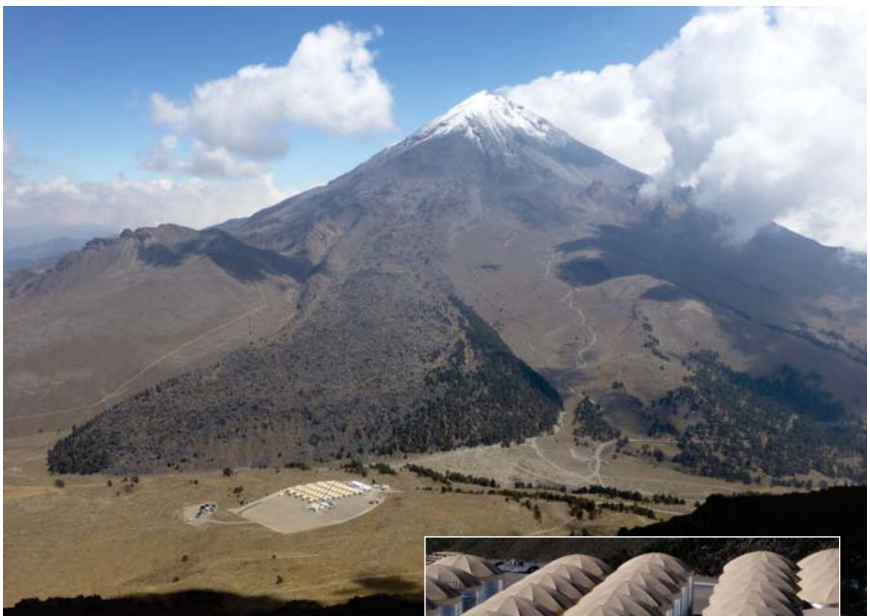
In its report, BESAC also urges a "robust R&D effort in accelerator and detector technology that will maximize the cost-efficiency of the facility and fully utilize its unprecedented source characteristics." It notes that a large class of experiments conducted at a new light source will involve maximum data rates exceeding 10^{10} x rays per pixel per second, and that other experiments will require recording an enormous dynamic range of 10^6 across the detector. X-ray detectors must be capable of capturing that span of data in each image while framing at kilohertz to megahertz rates. Greatly increasing the framing and readout rates of imaging x-ray detectors would allow movies to be made for studies of nonreversible processes.

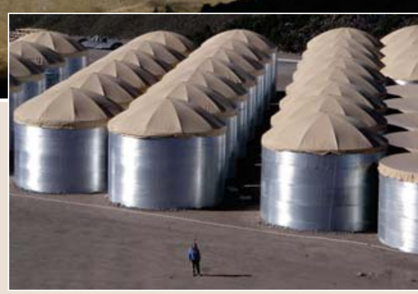
David Kramer

Gamma-ray survey observatory starts up

Nestled at 4100 m on the slopes of Sierra Negra, an extinct volcano 200 km east of Mexico City, the High-Altitude Water Cherenkov Gamma-Ray Observatory (HAWC) began waiting for prey on 21 August. Mexico is providing the site and about a quarter of the \$13.8 million for construction, with the US agencies NSF and the Department of Energy splitting roughly two-to-one the rest of the binational project's cost.

HAWC is capable of finding "the highest-energy photons ever detected by man, and higher than what can be produced by man," says Brenda Dingus of Los Alamos National Laboratory. "The gamma rays we detect are produced where particle densities are high, so it's one of the best ways to look for





At the High-Altitude Water Cherenkov Gamma-Ray Observatory (above) in Mexico, about four light-tight detector tanks (right) will be added each week until 300 are in operation by late 2014.

high-energy particle sources." Sensitive to gamma rays in the 100-GeV to 100-TeV range, HAWC detects the Cherenkov radiation emitted when showers of charged particles that the gamma rays create in the atmosphere fly through its water tanks at speeds faster than light.

The observatory's main focus is to search for variable sources such as gamma-ray bursts and active galactic nuclei, plus higher-energy steady sources like supernova remnants, neutron stars, and subhalos of dark matter around the galaxy. In addition, says Dingus, at the highest energies, "gravity has to fail. Photons may be slowed down or sped up by quantum gravity. HAWC can look for variations in the arrival time to measure fractional velocity differences [in cosmic gamma rays] as a function of energy."

HAWC runs day and night and can see about one-fifth of the sky; as Earth turns, the observatory passively surveys about two-thirds of the total sky. The wide field of view, allowing a general search for gamma-ray sources, "is our advantage," says Alberto Carramiñana of Mexico's National Institute of Astrophysics, Optics, and Electronics in Puebla. The *Fermi Gamma-Ray Space Telescope* has a larger field of view than HAWC, but observes at lower energies.

As of mid-September, HAWC had installed 130 of a planned 300 detectors—cylindrical tanks 7.3 m tall and 5 m in diameter, each outfitted with four photomultipliers and containing 180 000 liters of purified water. They form a close-packed array that will eventually be 150 m on a side. The observatory will be completed by the end of 2014, says Carramiñana. "But you can do good science with 100 tanks."

Compared to its predecessor, the Milagro Gamma-Ray Observatory, which ran in New Mexico from 2000 to 2008, HAWC is at a higher altitude, has a larger total volume, and, with separate tanks rather than a single pool, has better angular resolution. Three-quarters of HAWC's photomultiplier tubes, plus electronics and other parts, are salvaged from Milagro. Because of the large amount of data HAWC will collect—500 megabytes per second—its data acquisition system uses electronics that were developed for the Large Hadron Collider at CERN. The Sierra Negra site in Mexico won out over potential sites in Tibet, Bolivia, and Argentina; one reason was the infrastructure available thanks to another US–Mexico collaboration, the nearby Large Millimeter Telescope.

Toni Feder