

says that based on what former Office of Science director William Brinkman—who resigned last month—told lab directors recently, funding for BES programs is expected to stay even with last year, despite the sequestration. That’s a considerable improvement over the 5% across-the-board cut the lab was expecting. Prodded in part by congressional appropriators, BES has in recent years “aggressively cut research projects that are not so competitive,” Kao says, and that policy has permitted new ideas to be funded even with flat budgets.

Cosmology has become a growth area for SLAC, the growth fueled in part by the presence of the Kavli Institute for Particle Astrophysics and Cosmology on the lab’s campus. “SLAC is positioned extremely well because of the foresight of people like [Fred] Kavli 10 years ago,” says Kao. Researchers from the institute were leaders in SLAC’s construction and assembly of the main instrument for the *Fermi Gamma-Ray Space Telescope*, launched in 2008 (see the article by David Thompson, Seth Digel, and Judith Racusin, *PHYSICS TODAY*, November 2012, page 39).

A SLAC team leads a project to build the digital camera for the Large Synoptic Survey Telescope (LSST), an instru-



Chi-Chang Kao

ment that will scan the entire visible southern sky every week and provide the widest, fastest, and deepest view of the night sky ever observed. “What we see is telescope and satellite projects becoming bigger,” Kao says. “And as they become bigger, DOE labs become more important because universities don’t have the depth of engineering staff or the project management experience to pull together the team of people and deliver the telescope or satellite within time and budget.” He notes the common threads between cosmology and x-ray science: detectors, data acquisition, and analysis. All are historic capabilities of SLAC.

But SLAC isn’t expecting this year’s sequestration to be a one-time event followed by a return to normal budgets. “We are assuming that what we are going to get now will become the new baseline,” Kao says. “We’re hoping things will go up from that new baseline.” Some of his optimism is due to Brinkman’s statement during recent congressional testimony that SLAC’s \$400 million LCLS-II is the highest priority new construction project within the Office of Science. That facility would more than double the capacity and extend the energy range of the LCLS. Kao believes the LCLS-II will draw more investment from BES in the

form of new instruments and more staff to support a greater number of users. “The only thing that is stopping us from starting this now is that it is a new construction project.” Uncertainty over construction approval also hangs over the LSST. “If in 2014 we have a budget, we can start construction,” Kao says hopefully.

Shutting down labs?

Despite the budget pressures and declining number of warheads, Albright insists there is a continued need for the two nuclear weapons design laboratories, LLNL and Los Alamos National Laboratory. “I come from outside the nuclear weapons community, but now I’ve been exposed to it, and I will tell you that the approach that Los Alamos takes is very different to the approach that Livermore takes. In terms of the modeling and simulations we do, the way we reach judgments about the weapons and their state of health is just different. The way we use data, the way we weight the data, is different. We do look at each other’s weapons. It leads to a very healthy interchange.”

Albright also expects that LLNL will increase the R&D work it performs for the Department of Homeland Security as that agency’s science and technology budget rebounds from two years ago, when its budget was cut by nearly half.

David Kramer

China prepares to spend billions on science and technology

With its strong economy, the country wants to play a bigger role on the world science stage.

Sixteen science and technology projects will receive big infrastructure investments in China, the country’s State Council announced on 23 February. The competitively selected upgrades and new facilities focus on such topics as energy, nuclear waste, materials science, ocean surveys, and astroparticle physics (see the table on page 22).

The projects are part of China’s “mid- to long-term perspectives for the development of major national infrastructures in science and technology” stretching out to 2030. Through the end of the current five-year planning period in 2015, the total investment is expected to be about CNY19 billion (about \$3 bil-

lion), more than three times the amount in the previous five-year plan. Individual facilities will get up to CNY2 billion. The construction money comes from the National Development and Reform Commission. Ongoing research is covered by other sources, says Lu Yu, a senior scientist at the Chinese Academy of Sciences’ Institute of Physics, so the new large projects do not threaten funding for laboratory-scale science.

Zhen Cao, the chief scientist for a new cosmic-ray observatory that made the cut, says that with the economy strong, “people are thinking this is the time for China to take responsibility for the development of basic science and technology.” The US and Europe, he

notes, are both home to many large scientific experiments. “China is making major contributions to science too,” he says. “That is why China thinks we should have this concrete plan to build and grow as many big facilities as possible.”

Among the 16 selected projects, some are ready to go forward pending various permits, but others will be put up for bid. That’s the case, for example, for a user facility to study materials under extreme conditions. Proposals for such projects are due soon, and decisions are likely before the end of the year, says Yu.

Pure science

The Large High Altitude Air Shower Observatory (LHAASO), the cosmic-ray observatory that Cao heads, is to be built at 4300 meters in Shangrila,



A high-altitude cosmic-ray observatory planned for the mountains of Shangrila in southwest China is among the winners in that country's science and technology infrastructure competition. (Artist's rendering by G. D. Wang superimposed with photo by Xiao Gang.)

Yunnan Province, in the southwest corner of China. Combining five detector types at high altitude is what makes LHAASO unique, says Cao. For cosmic-ray particles with energies above 10^{15} eV, the existing data are "chaotic," he says. "We have to build many types of detectors to collect information about the air showers." The aim, he says, is "to identify the violent processes that produce the particles. We want to find

the sources of cosmic rays." (See also PHYSICS TODAY, April 2013, page 14.)

One of the LHAASO detectors will be a large pool of water, lined with 3600 phototubes to observe the Cherenkov radiation produced by impinging particles from the air showers caused by cosmic rays. "We will measure the timing and how many particles there are," Cao says. An array of 6000 scintillators over a circle about 1.2 kilometers in

diameter will measure the energy and intensity of incident cosmic rays. The third detector will be an array of bags of pure water with phototubes buried about 3 meters underground to watch for muons. Because the detectors are underground, says Cao, electrons and photons are excluded. In practice, he explains, "you are looking for the [gamma-ray] showers without muons." Finally, the LHAASO will have 24 UV

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telescopes to look for fluorescent light and Cherenkov radiation produced in air showers and 400 burst detectors—scintillators on the surface that are shielded by lead so that they record only the most energetic particles.

Cao hopes construction can begin in two years. “We need to get permission to use the land, and then we face an environmental review,” he says. Once

ground is broken, it will take about four years to build the facility, which is expected to cost about CNY1 billion. Although a mainly Chinese project, scientists from France and Russia are working on aspects of the detectors.

The China Antarctic Observatory also got the nod. Two large telescopes will be added to a site on Dome A in Antarctica where China already has a

small presence. (For more on Antarctic telescopes, see the Quick Study on page 60.) One is a 2.5-meter optical-IR telescope to study dark matter and dark energy and to search for exoplanets; it will be perched on a 14.5-meter-high tower to lift it above the turbulence layer. The other is a 5-meter submillimeter telescope to study star and galaxy formation (see PHYSICS TODAY, January 2011, page 22).

Aside from those two astrophysics projects, most of the megafacilities are a mix of basic and applied science or tend more to applications.

Pushing extremes

Hong Ding, chief scientist at the Chinese Academy of Sciences’ Beijing National Laboratory for Condensed Matter Physics, is working to bring the extreme conditions project to the Beijing suburb of Huairou; word has it that another team may submit a competing proposal. Ding envisions the Synergetic Extreme Condition User Facility (SECUF) boasting some 20 different instruments that can operate at low temperatures (below 1 mK), high pressures (approaching 300 gigabar), high magnetic fields (32 tesla), and

Science and technology infrastructure gets the nod in China’s 12th five-year plan: Mid- to long-term projects ranked by priority

1. Ocean-floor scientific survey network
2. High-energy synchrotron test facility
3. Accelerator-driven subcritical reactor research facility
4. Synergetic Extreme Condition User Facility
5. High-flux heavy ion accelerator
6. High-efficiency, low-carbon gas turbine testing facility
7. Large High Altitude Air Shower Observatory
8. Future network experimental facility
9. Outer-space environment simulating facility
10. Translational medicine research facility
11. China Antarctic Observatory
12. Precision gravity measurement research facility
13. Large-scale low-speed wind tunnel
14. Shanghai Synchrotron Radiation Facility Phase-II Beamline Project
15. Model animal phenotype and heredity research facility
16. Earth system digital simulator

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ultrashort laser pulses (200 attoseconds). “We want to push to extremes to achieve world records, to do world-leading research,” says Ding. He and his colleagues will submit their proposal for SECUF in the coming weeks.

Ding notes that China is not strong in building instrumentation. “We mostly buy commercial products.” But because off-the-shelf products are not available for the proposed extreme conditions, Ding says, “we hope to help China develop and commercialize instrumentation. That is one of our goals.” The suite of instruments would include systems for large-volume high-pressure materials synthesis, time-resolved transmission electron microscopy, high-field scanning tunneling microscopy, refrigeration by nuclear demagnetization, and a laser-wakefield-driven x-ray source.

Zuyu Zhao, who heads the ultralow temperature department at the Massachusetts-based Janis Research, sees increasing interest in low-temperature physics and cryogenic

technologies among scientists in China. A seminar he gave in 2007 at Tsinghua University in Beijing drew few attendees, he says, “and even fewer really understood what I was talking about.” Just four years later, in 2011, Zhao gave another seminar on ultralow-temperature physics in Beijing. That time, he says, “half the audience was in the corridor. The situation has changed completely.” Ding agrees: The driving force behind SECUF, he says, is a growing demand by scientists.

Ding and others’ longer-term dream for Huairou is to collocate an array of facilities there. The Beijing Advanced Science and Innovation Center, or BASIC, would bring together SECUF, the future Beijing synchrotron light source, the Earth simulation computing facility, and perhaps other infrastructures. Huairou is also near the new site of the University of the Chinese Academy of Sciences, which would give BASIC researchers access to students and students access to the center’s facilities.

Toni Feder

Carbon capture may be a ways off, but ARPA-E is working on it

Several technologies are aimed at minimizing the cost of removing CO₂ during coal burning. But their deployment will require subsidies or a price on carbon emissions.

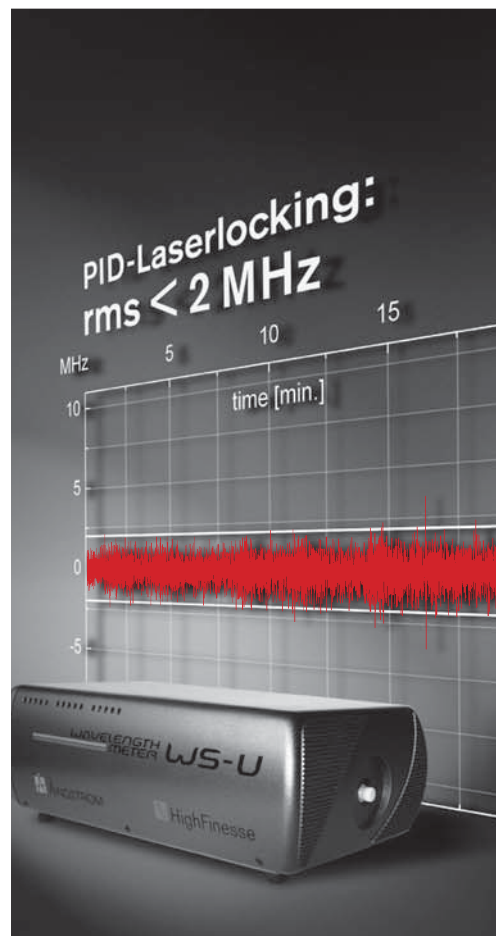
Engineers at aerospace company Alliant Techsystems (ATK) saw an opportunity in a condensation problem they were having while testing components in a supersonic wind tunnel: They realized that carbon dioxide in combustion gases would freeze if it was compressed sufficiently and accelerated to three times the speed of sound. The company is now wrapping up a three-year project funded with a \$2.7 million grant from the Department of Energy’s Advanced Research Projects Agency-Energy. A supersonic inertial CO₂ extraction system from ATK is one of 15 technologies that have been advanced by ARPA-E for their potential to remove CO₂ from the exhaust of coal-fired power plants.

The goal of ARPA-E’s \$40 million, three-year Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT) program is to dramatically reduce the cost of extracting CO₂ from flue gases so it can be sequestered from the atmosphere. All carbon capture technologies consume en-

ergy; the current benchmark technology, an absorber-desorber process that uses a monoethanol amine (MEA) solvent, costs around \$90 per ton of CO₂ captured—which would add as much as 50% to the cost of producing electricity from coal.

In ATK’s system, flue gas is compressed and then accelerated through a special nozzle to supersonic velocities (see figure on page 24). The process produces a rapid decrease in temperature and pressure and a deposition of CO₂. The device proposed by ATK is mechanically simple, contains no moving parts, and is readily scalable. The company projects low capital costs for system construction, and operating costs are estimated to be significantly less than membrane- and absorption-based alternatives.

According to ATK claims, the company’s process would cost \$48 per ton of CO₂. Other grantees claim similar costs. But Karma Sawyer, IMPACCT program manager, cautions that extrapolating cost-per-ton figures from bench-scale demonstrations—the current status of



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