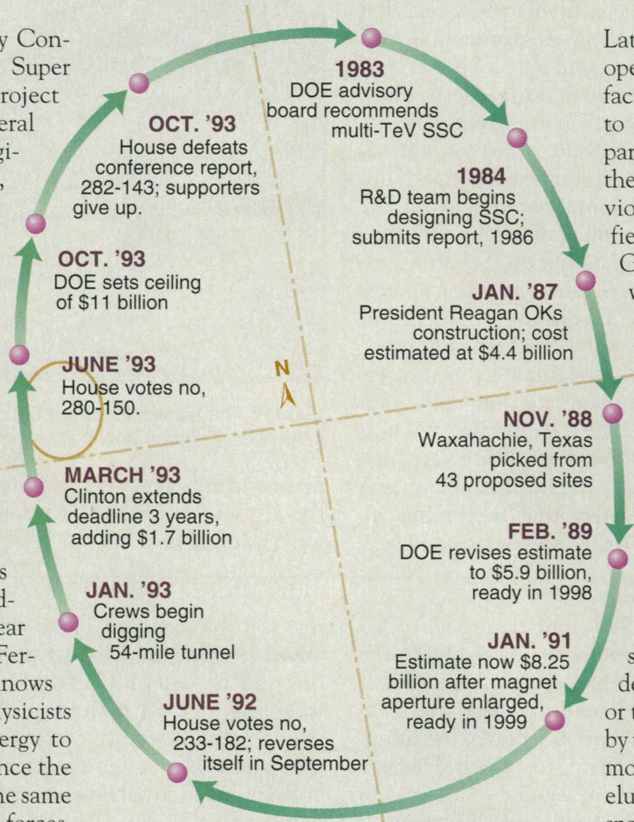
Is There Life After the SSC?

High-energy physicists were counting on the Superconducting Super Collider to jump-start a field that had stalled. The project's surprise defeat has left them with few good alternatives

In last week's bombshell decision by Congress to kill the Superconducting Super Collider (SSC), ground zero was the project site in Waxahachie, Texas, where several hundred physicists, along with engineers and construction workers, watched their jobs evaporate and the value of their houses plummet. But the fallout quickly spread to particle physicists all across the country. For them the impact of the decision to cut off funds for the $11 billion accelerator was less immediate but just as profound: They say the field has lost a big chunk of its future. All other U.S. accelerator projects, they now lament, were peripheral, complementary, or preliminary to the cherished Super Collider.

"We're dead," says Massachusetts Institute of Technology theorist Edward Farhi. "SLAC [the Stanford Linear Accelerator Center] is in old age, Fermilab is well into mid life.... No one knows how we will go on in this field." Physicists had counted on the SSC's high energy to blast them out of a 10-year slump. Since the early 1980s they've been stuck with the same picture of fundamental particles and forces, the so-called Standard Model. Work at existing facilities such as Fermilab and SLAC has concentrated on the fine points of the model—measuring with painstaking precision the masses and decay patterns of the known particles, for example, and hunting for the top quark, the one particle clearly predicted by the model that is still at large.

For answers to questions left open by the Standard Model—and they included such crucial puzzles as why the known particles come in a seemingly random assortment of masses—physicists had looked to the SSC's 54-mile elliptical ring, which would have slammed protons together in collisions 20 times more energetic than any before. Now that Congress has directed that the $640 million that was to have been spent next year on the SSC be spent instead to close the project down (see box on page 646), U.S. physicists will be forced to look for alternatives. A similar but smaller European project called the Large Hadron Collider (LHC) could explore some of the same scientific terrain as the SSC, but for now the project allows only limited roles for U.S. physicists. Meanwhile, a giant linear collider, envisioned as a successor to the SSC, is little more than a concept. A few researchers also think hints of new physics could emerge in low-energy, high-precision experiments, but others call these alternatives long shots. Without the SSC, says physicist Barry Barish of the California Institute of Technology, "The most pressing questions won't be answered. The field won't be as exciting."



Going Full Circle on the SSC

ILLUSTRATION: K. SUTLIFF

Surveying the remains

The real loss, say Barish and others, will be felt 10 years from now. In the meantime, Fermilab's Tevatron, the most powerful existing accelerator, is pursuing the hunt for the top quark, the one renegade particle in the Standard Model. That quest will get a boost in 1998 from a $230 million addition to the accelerator, known as the main injector. The injector's extra power should pin down the missing quark if it eludes the current Tevatron—or help physicists study the particle if it has been found by then.

Not all the accelerator projects now under way are aimed at refining existing theory. Late in the decade, for example, SLAC may open a window on new physics with its B factory, a $260 million accelerator designed to create B-mesons. Theorists expect these particles to hold a key to a subtle asymmetry in the nature of matter known as charge-parity violation. Finally, physicists listing their field's current hot spots mention DESY, the German physics laboratory in Hamburg, where a new machine, HERA, is smashing electrons against protons in a long-shot effort to reveal smaller structures within electrons and quarks, now seen as fundamental units of matter.

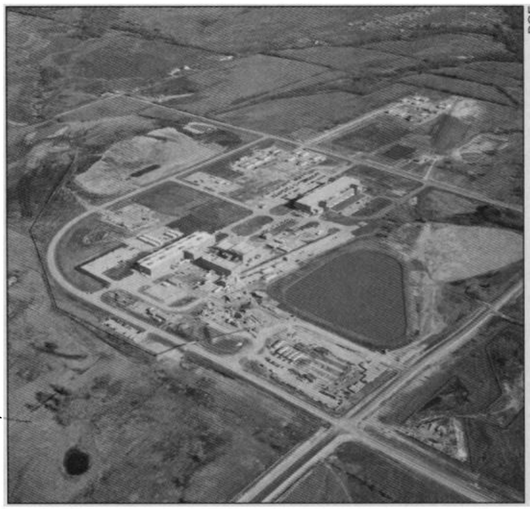
Other physicists, meanwhile, will continue searching for new science in places far from the big accelerator labs, applying finesse instead of brute force. This style characterizes work at Brookhaven National Laboratory, where researchers are running small accelerator experiments, doing precision measurements of such things as the size of the proton or the decay modes of particles such as the muon or the kaon in search of effects not predicted by the Standard Model. Elsewhere, physicists monitor underground detectors of neutrinos, elusive particles that pour in from outer space, in search of another subtle effect that would open new realms of theory—"neutrino oscillations," in which neutrinos transform themselves from one type to another. "There are untapped riches in the boundaries between nuclear physics and particle physics, and between astrophysics and particle physics," acknowledges Caltech's Barish.

Indeed, a few physicists think such small-scale experiments are enough to sustain their field. That's the philosophy of Brookhaven's eternally optimistic Melvin Schwartz. Schwartz, who won a Nobel Prize for gathering experimental evidence of a new neutrino, says he refuses to believe that only the SSC could reveal phenomena novel enough to revolutionize the Standard Model. "When you give people the opportunity to think, they can get the information they're looking for but in a different way," he says. The long-sought path beyond the Standard Model, he thinks, could take the form of some subtle effect, such as a "forbidden" decay of a muon or kaon, that doesn't require lots of energy to elicit—just patient and clever experimentation.

But most physicists don't share Schwartz's confidence. As a source of new physics, says

Yale theorist Mike Zeller, the SSC was a surer bet because existing theories actually predict that something profound will occur in the energy range it would have achieved. "We know the Standard Model is going to fail at high energies," he says. The SSC's high-energy collisions would have recreated conditions that prevailed in the universe's infancy, moments after the Big Bang, when today's diverse particles and forces were "unified" in single entities.

By crossing the line into this simpler era, says Zeller, the SSC could have turned up clues to the "symmetry breaking" that transformed the cooling universe from simple to complex, for example by endowing particles with an array of different masses. The most popular theory predicts that the symmetry breaking will manifest itself in a particle called Higgs, named after British theorist Peter Higgs. "But if there's no Higgs there will be something else that emulates the Higgs," says Zeller. "What takes us by the gut is that with no SSC we can't get there to see it." Theorists were less confident, but just as eager, about other possible glimpses beyond the Standard Model. One theoretical extension known as supersymmetry, for example, predicts a whole slew of new particles that might have been within reach of the SSC.


DOE

Ground zero. The SSC laboratory and construction site, where tunneling had already proceeded for 14 miles.

Now all those hopes have to be pinned on Europe's LHC, a proton-antiproton accelerator that would be built in CERN's existing 27-kilometer tunnel and could be up and running in 2002. The LHC's smaller size leaves it scientifically disadvantaged, limiting it to energies only one-third as high as the SSC would have reached. It will reveal new phenomena only if, as physicists say, nature is kind. One physicist compares hunting for the Higgs particle with the LHC to searching for a watch by combing only one-third of the room. Still, it's better than nothing, says Argonne National Laboratory physicist Tom Kirk, who moved to Waxahachie to work on the SSC: "LHC is the only viable back-stop for attacking the Higgs problem."

Machine dreams

CERN physicists are already building prototypes for the magnets that will accelerate the particles around the ring and are starting work on the two detectors. And although CERN's member countries will not decide for certain whether to proceed with the LHC until 1994, proponents are optimistic. Because it is being built in an existing tunnel, the LHC will cost only about one-tenth as much as the SSC. And CERN's incoming director-general, Christopher Llewellyn Smith, isn't worried that the U.S. Congress's actions will set an example for CERN's members. "I don't think [the SSC's demise] will have much effect" on the decision, he says.

Even if he's right, however, the LHC will provide only limited opportunities for U.S. physicists. A few Americans have already joined LHC collaborations, but to get a stake in running the lab and more opportunities for scientists, some U.S. physicists want to join the CERN itself, which would require an annual fee of about $200 million. "I'm willing to get down on my hands and knees and grovel," says Fermilab physicist and Nobel laureate Leon Lederman. CERN's Llewellyn Smith is guarded, however: "We have to see how many physicists want to come here," he says.

The only other prospect for reaching energies well above those available today—the Next Linear Collider (NLC)—is far less promising as an SSC substitute. On the very day the Super Collider died, researchers met at SLAC to discuss early plans for this dream machine, which was to be the SSC's companion and successor. To be built as an international collaboration, it would accelerate particles toward one another down a straight path tens of kilometers long and collide them at energies comparable to the SSC. So far, however, the international participants, from Japan, Germany, and the United States, haven't even agreed on a design.

And unlike the SSC, the NLC is poorly suited to flushing out new discoveries, such as the Higgs particle. The SSC would have cast a wide net because it would have collided protons, which are mostly empty space inhabited by three smaller particles, the

The Endgame

For supporters of the Superconducting Super Collider (SSC), the end of the world came just as T.S. Eliot had predicted: not with a bang but a whimper.

The whimper was an arcane parliamentary maneuver in the House of Representatives over a report, written jointly by a conference of two dozen senators and representatives, that was expected to be a final spending bill for energy and water programs for the fiscal year that began on 1 October. Conference committees are supposed to craft a compromise bill from legislation passed separately by the House and Senate, and each house must approve their handiwork before it can be sent to the president. Usually that's a formality, but not this time.

Persistence pays off. Rep. Jim Slattery stalked the SSC for years.

Opponents of the SSC had won a House vote in June to kill the project, but the Senate approved $640 million to continue construction. Earlier this month, the conference committee sided with the Senate's position, giving the project the full $640 million. At that point, even opponents believed that they had lost the battle, at least for this year (*Science*, 8 October, p. 171). After all, that's what happened last year, when the House backed down from an earlier vote to kill the project and accepted continued funding, although at a slightly lower level. But this year, when the conference report came up for a vote in the House, opposition to the SSC had hardened in part because many representatives were outraged that the conference committee had failed to acknowledge their stance.

The decisive vote came on a motion by Representative Jim Slattery (D–KS), a long-time opponent of the SSC, to send the report back to the conference committee with instructions to delete funding to continue with the project. It passed by 282 votes to 143. In effect, the House signaled that it was prepared to hold the entire $22 billion bill hostage if necessary. Two days later, the conference committee bowed to the inevitable and deleted all research and construction funds for the SSC from the bill. Instead, the entire $640 million will now go to terminate the $11 billion project.

–Jeffrey Mervis

quarks. It's the collisions between quarks that produce new particles, and those collisions take place at a range of energies, depending on the way the quarks happen to be rolling around inside the protons. By contrast, the NLC would smash together electrons and positrons, which appear to be indivisible units of matter and would therefore collide at about the same energy each time. The result, says Caltech's Barish, is that "the NLC is a fantastically good place to do quantitative work after initial discoveries isolate something. It's a terrible place to go [beforehand] because you don't know where to look." To live up to its potential, say physicists, the NLC would have to take its cues from the LHC.

In any case, many of the SSC's backers think their project's demise has hurt the prospects for such international collaborations by scaring off potential foreign partners. "We don't have any international credibility," says SLAC's Stanley Wojcicki. After what has just happened with the SSC, he asks, "How can [an international partner] justify getting involved with us?"

Indeed, many physicists say the loss of the SSC, devastating in its own right, marks a still greater watershed in U.S. high-energy physics: the end of a golden age of federal support. Beyond all the particular factors that may have contributed to the project's defeat (see box on page 645), Wojcicki sees an overriding shift: "a very radical change in a partnership between the federal government and the particle physics community that has gone on since World War II and the Manhattan Project."

The several hundred physicists who had settled in Waxahachie are keenly feeling the end of that partnership. The $640 million in termination money will cover 90 days of severance pay and help with relocation, among other things. But after that, many staffers at the SSC laboratory face bleak prospects. Says Kirk, who still has his job at Argonne, "I hope they will realize in Congress that they have disrupted our lives in ways that can't be repaired by a few weeks of severance pay." The same bitter lesson, he says, applies to the field as a whole: "I don't see any future."

–Faye Flam

RESEARCH MANAGEMENT

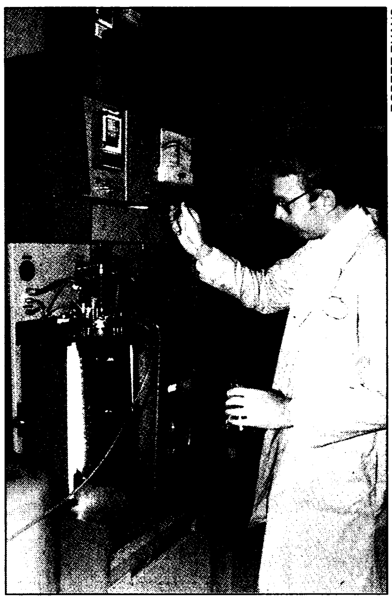
New Rules Squeeze EPA Scientists

Microbiologist David Lewis of the Environmental Protection Agency's (EPA) research laboratory in Athens, Georgia, has won seven performance awards for the quality of his research on microbial ecology. Nowadays, however, Lewis feels it's a major achievement if he's able to do any research at all.

What's changed? EPA scientists like Lewis are spending less time on their own research and more on monitoring researchers who work for EPA under contract. The reason: Last year, EPA adopted new requirements—which include filling out more paperwork and seeking multiple approvals for research projects—to make sure contractors aren't ripping off the government. After a year trying to work with the new rules, EPA researchers are complaining the rules not only have crippled EPA's ability to conduct research, but also fly in the face of Vice President Al Gore's campaign to reinvent government by removing bureaucratic barriers to increased efficiency. The changes "run 180 degrees counter to Gore's plan," says Bob Swank, research director of the Athens lab. "Productivity, morale, and esprit de corps have never been so low," adds Swank, who has worked at EPA since its inception in 1970.

The paper avalanche was triggered by an internal investigation alleging serious problems in EPA's $1.2 billion a year program that funds outside research and consulting. Investigators cited such abuses as a Superfund cleanup company that spent contract money on alcoholic beverages and tickets to sporting events, as well as the practice of allowing contract researchers to operate "sensitive" EPA management databases as though they were government employees (*Science*, 7 August 1992, p. 740). In response, EPA now requires agency scientists to record every interaction with contractors and to follow every regulation scrupulously. Although the new procedures may stop some of the most egregious practices, the cost to EPA's science has been enormous.

The bottom line, according to Swank and others, is that EPA is "doing less science for more money." For example, the length of time between when an EPA scientist proposes an idea for a contract research project and when it's funded has grown from 16 to 26 months. That delay, he says, forces scientists "to be clairvoyant about what they'll need 2 years from now."



ROBERT RYANS

Seeing red. EPA scientist David Lewis is fuming over additional red tape.

Although it's hard to quantify the damping effect on science, EPA researchers have a personal measure of what the changes have meant—a sharp increase in the time spent managing contracts. That includes writing elaborate work assignments that require approval from several EPA and contract officials, and performing such tasks as ordering lab materials, something contractors are no longer allowed to do. Lewis estimates he now spends 90% of his time on contract management, compared with 10% before the reforms went into effect.

Lewis' may be an extreme case, but other EPA researchers say the time spent on contract work has at least tripled, from about 10% to 30% or more. "I have had to postpone setting up experiments to get contract work done," complains James O' Callaghan, a neurotoxicologist at EPA's health effects research lab in Research Triangle Park. "It's a total mess," adds Linda Birnbaum, a toxicologist and top official at the health effects lab.

The added red tape has forced Lewis to forswear daily interactions with two contract scientists who work in his lab because such interaction could be seen as a form of "personal services" provided by contractors, an administrative no-no. The result, Lewis claims, is a scientific "nightmare." "It is evident...the quality of research and level of productivity of my project has suffered rather severely," Lewis wrote recently to the director of the Athens lab, Rosemarie Russo.

Top EPA officials say the agency is sympathetic to the complaints from scientists but is powerless to change the situation. Gary Foley, EPA's acting research chief, says EPA would prefer to do more research in-house, but a shrinking staff—1800 compared with 2250 in 1971—makes that impossible. At the same time, he says, the EPA research office's spending on contract research has grown by one-third since 1980.

EPA would like to reverse this trend by converting contract scientists into EPA employees, thus reducing the number of contracts EPA scientists must oversee. Although that would run counter to President Clinton's promise to reduce the federal work force, EPA officials have asked the White House Office of Management and Budget to make an exception for the agency. "If we can't fix the problem," says Foley, "the only alternative is to do less research." That's a concession few at EPA want to make.

–Richard Stone