SLAC Sees Writing on the Wall

Having bet its future on a single, ambitious facility–and lost–the Stanford Linear Accelerator Center now faces the possibility of radical transformation or extinction

PALO ALTO, CALIFORNIA—When he joined the Stanford Linear Accelerator Center (SLAC) in 1977, John Jaros was full of enthusiasm. As a young graduate student from Berkeley, he was bursting with ideas for taking lifetime measurements of the tau lepton—then SLAC's recent and stunningly unexpected addition to the burgeoning particle bestiary. Fifteen years later, however, Jaros is wondering if he'll do groundbreaking physics again in the next decade—or if he'll even have a job several years from now. With SLAC's only operating accelerator lagging well behind its main competitor in physics output, and with a new machine years away, the laboratory could soon be in crisis, Jaros says. "There comes a crucial time, probably around 1995, when this lab doesn't look supportable on the basis of the particle physics we're doing."

SLAC's crisis may, in fact, already be upon it. Having staked his lab's future on starting construction of a major new facility next year, SLAC director Burton Richter saw his hopes dashed last week when an advisory panel recommended delaying construction for 2 years and cutting SLAC's budget in the interim (*Science*, 17 April, p. 305). Unless Congress comes to SLAC's rescue—and new money will be hard to wring out of the budget this year (see page 439)—one of the United States' leading physics centers now faces at best a 7-year hiatus in major experiments, and at worst a complete shutdown of all its accelerators by 1995.

Concern about SLAC's future extends well beyond those whose jobs are threatened. "If we lose SLAC, we lose what has traditionally been our most productive single laboratory," says David Hitlin, a physicist at the California Institute of Technology. The laboratory leads the world in the design and construction of accelerators known as "linear colliders," which are widely expected to dominate the first decade of the next century. Furthermore, as one of only two particle physics laboratories in the United States that work with beams of electrons instead of protons, SLAC represents a significant chunk of the research that has traditionally balanced and complemented proton physics work at labs such as Brookhaven, Fermilab, and, eventually, the Superconducting Super Collider (SSC).

Officially, Richter maintains that he can hold the laboratory together until 1996, when SLAC could begin building a new facility known as a "B factory" that might keep the laboratory viable (*Science*, 22 March 1991, p. 1416). But Richter privately—and bitterly—jokes that he'll soon be checking out retirement communities. It's easy to see why: Not only must he somehow keep a core of engineers, technicians, and particle physicists intact for the 3 years leading up to construction of the B factory, but he also has to fend off stiff competition from other laboratories—notably the Laboratory for Nuclear Studies at Cornell and KEK in Japan—that are anxious to beat SLAC to the punch with B factories of their own.

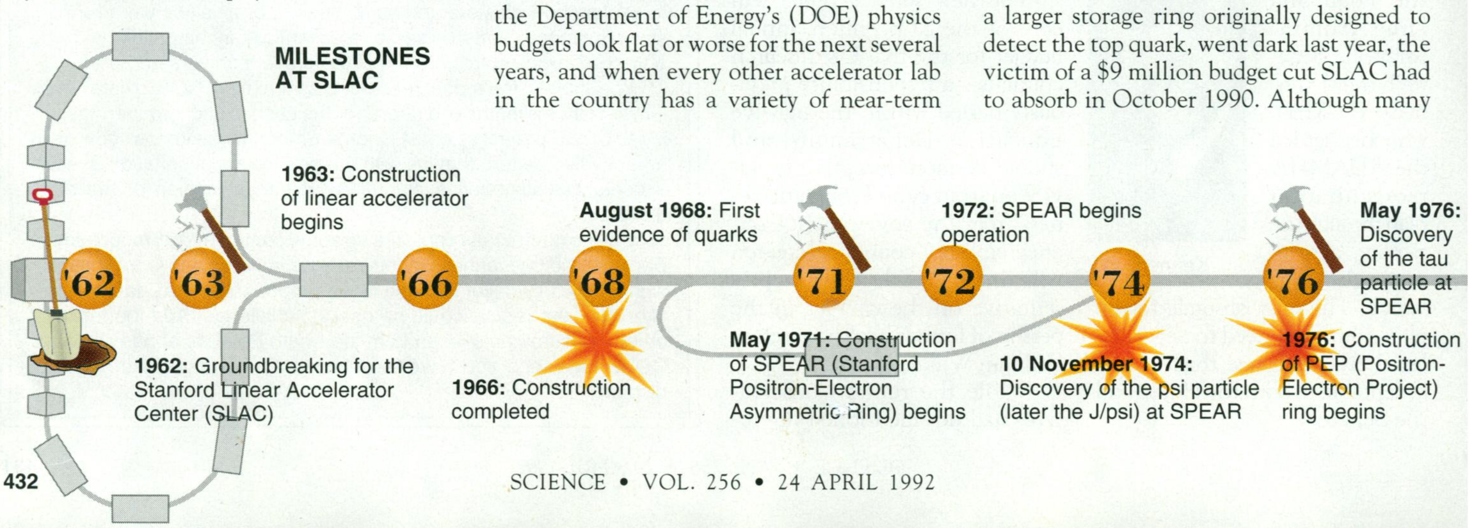
Underlying these challenges is a more serious problem—a widespread perception within the high-energy physics community that there is one lab too many in the U.S. particle physics program. And while SLAC has a compelling long-term vision in its linear collider research, it has had to scramble to produce the B factory proposal to tide it over for the next decade or so. In an era when the Department of Energy's (DOE) physics budgets look flat or worse for the next several years, and when every other accelerator lab in the country has a variety of near-term projects under way, SLAC faces a tough fight to ensure that it is not deemed expendable.

How SLAC stumbled

While SLAC's current problems have a variety of causes, most of them can be traced to a single troublesome machine: the Stanford Linear Collider (SLC). An ambitious undertaking, the SLC was the first machine to attempt colliding two particle beams generated directly by linear accelerators (*Science*, 19 May 1989, p. 771).

The SLC was designed to compete directly with the European Large Electron-Positron (LEP) ring at CERN in obtaining fine measurements of the Z^0 particle, a heavy boson that helps carry the weak nuclear force. Almost immediately upon being turned on in 1988, however, the SLC began to experience a series of mechanical difficulties that still have not been completely worked out. As a result, it has never achieved much about a tenth of its design "luminosity"—a measure of the particle density an accelerator can produce. LEP, which started up about a year later, experienced no such growing pains and quickly outpaced SLAC's machine, producing tens of thousands of Z^0s to the SLC's hundreds (*Science*, 22 March 1991, p. 1417).

Meanwhile, the remainder of SLAC's experimental program has suffered on SLC's behalf. Threatened by budget cuts over the past 2 years that have affected all accelerators in the United States, Richter began sacrificing his operating facilities in an attempt to keep SLC up and running. SPEAR, the storage ring where a SLAC-Massachusetts Institute of Technology team first discovered quarks (see box), was transformed into a synchrotron radiation source in mid-1990; PEP, a larger storage ring originally designed to detect the top quark, went dark last year, the victim of a $9 million budget cut SLAC had to absorb in October 1990. Although many



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SLAC's Greatest Hits

One of the more poignant ironies lurking in the possibility of SLAC's demise is the fact that the laboratory has a long history of prominent discoveries. Among the most noteworthy:

• In 1968, experiments at SLAC's linear accelerator that were designed to measure the diameter of protons ended up providing evidence for hard, pointlike structures within the proton. These structures were quarks, now considered the fundamental building blocks of matter. Richard Taylor of SLAC and Henry Kendall and Jerome Friedman of the Massachusetts Institute of Technology (MIT) shared the 1990 Nobel Prize for this discovery.

• In what later came to be called the "November revolution," experimentalists at SLAC's SPEAR storage ring scored a coup in 1974 when they discovered an unexpected particle—now called the J/psi—concurrently with an MIT team. While the MIT group, led by Sam Ting, technically discovered the particle first at Brookhaven, Ting's caution in announcing his discovery allowed Richter's team to scoop him. (Richter and Ting shared the Nobel Prize in 1976.) The J/psi, whose existence had not been predicted by theory, provided the first experimental evidence for a fourth quark known as "charm."

• A mere 2 years later, another team at SPEAR led by SLAC experimentalist Martin Perl turned the theoretical world on its head yet again with the discovery of the tau lepton—an unexpected third addition to the family of pointlike particles, which at that time consisted of electrons and muons. The tau lepton and its associate neutrino implied the existence of at least two more quarks, the top and the bottom. Researchers at Fermilab discovered the bottom quark in 1978; the top quark, now believed to be the heaviest quark in existence, remains undiscovered.

–D.P.H.

researchers at SLAC acknowledge that Richter had little choice in closing down the two machines, the aftermath still rankles. "There was some necessary hard-headedness in that decision, but to shut off everything we've gained in favor of a single program seems to me a terrible mistake," says Jaros.

Ironically, things have begun looking up for the SLC in just the past 4 months. The collider has produced 10,000 Z^0s since February, and work toward polarizing its electron beam took a major step forward with the installation of new equipment 2 weeks ago. "We've learned a great deal about the machine physics of linear colliders from the SLC," says Martin Breidenbach, a co-leader of the SLC's detector collaboration. But the improvements have come far too late for the SLC's scientific mission, which LEP has already dominated. Except for taking measurements of polarized Z^0s—experiments LEP won't be able to duplicate until the end of the decade—"we don't have a lot to offer the world of physics," experimentalist Morris Swartz says ruefully.

Don't B cruel

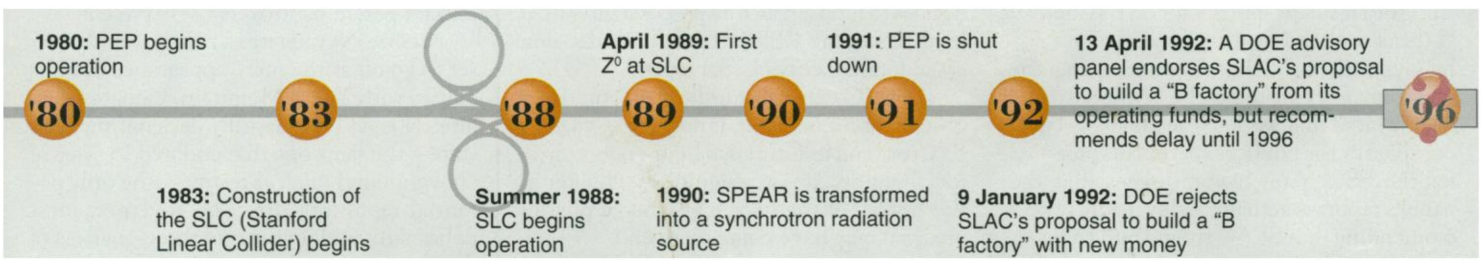
Given enough time and money, SLAC's accelerator physicists are confident that they could capitalize on their experience with the SLC to build what they call the Next Linear Collider, a $1 billion-plus machine Richter envisions as a "truly international project" that might not even be built in the United States. Richter's dream machine isn't feasible until early next century, however, and if SLAC's existing accelerators are shut down in the meantime, linear collider R&D probably won't be enough to sustain the laboratory as a vibrant high-energy physics center. "Labs that don't keep big physics projects tend to decay," says Swartz, noting that the Argonne and Lawrence Berkeley national laboratories, which both once ran state-of-the-art accelerators, now harbor little more than "user groups" whose members carry out their work at other major accelerator labs. "The infrastructure will decline, and we'll have morale problems," adds Dave Burke, who directs a beam focusing program for the Next Linear Collider. Leadership of linear collider research might move out of the United States to a lab such as DESY in Germany, Burke warns.

Enter the B factory—a relatively cheap, although technically forbidding, machine that would allow physicists to study the decays of B mesons for a phenomenon known as "CP violation." Current models of the early universe hold that matter and antimatter were created in equal amounts, but nothing in the Standard Model of particle physics explains why matter dominates the universe today. CP violation—an unexplained difference in the decay rates of particles and their antimatter counterparts—might offer an explanation. Indeed, experimentalists and theorists alike regularly cite CP violation as one of the two most intriguing questions in particle physics today—the other being the origin of mass, a question researchers hope to answer at the SSC.

In early 1991, SLAC proposed building what its physicists call a "high luminosity, asymmetric B factory"—a facility that would produce large numbers of B mesons by colliding electron and positron beams of different energies. As originally proposed, SLAC would begin building the factory in late 1993 and complete it by 1997, at a cost of $151 million in 1991 dollars. From SLAC's perspective, the B factory would kill two birds with one stone: It would put the laboratory atop a "gold mine" of groundbreaking physics, and would also give experimentalists something to do after the SLC finally runs out of steam and before the Next Linear Collider could get started.

But while DOE's High Energy Physics Advisory Panel (HEPAP) has repeatedly endorsed the idea of a B factory, it has consistently ranked it below the SSC and an upgrade to Fermilab's Tevatron. A further blow fell when DOE and National Science Foundation (NSF) officials co-authored a 9 January letter to Richter and Karl Berkelman of Cornell, who had submitted a competing B factory proposal to NSF, stating that there would be no new money for a B factory until at least 1997—a move that seemed to end hopes both for SLAC and Cornell.

Richter, however, quickly bounced back with an audacious plan to build the B factory out of SLAC's operating budget. By scaling



back the operation of SLAC's linear accelerator from 9 months to 6 months, the lab would free up $35 million to $45 million each year—enough money to start the B factory in 1994 and complete it in 1998.

Shifting the budgetary SLAC

But Richter's seemingly thrifty plan appears to have backfired badly. On 13 April, a HEPAP subpanel accepted his idea to scale back SLAC's experimental program, but effectively decided to apply the roughly $20 million saved each year to programs at other facilities—in particular, the Tevatron upgrade and research support for the SSC staff. SLAC could still build a B factory, the panel's report stated—but in 1996, not in 1993. In addition, the panel recommended closing the SLC at the end of 1993 and shutting down SLAC's accelerators altogether if DOE's high-energy physics budget doesn't keep pace with inflation.

Panel members justify their decisions as striking a necessary balance in the overall U.S. high-energy physics program, given the budgetary constraints they were handed. Delaying the start of the B factory by 2 years was a "very difficult thing to do," says panel chairman Michael Witherell, a University of California at Santa Barbara physicist. "The most efficient thing is to do it right away while people are there and ready to go.... But we had a constant budget to get into, and in making hard decisions over balancing near-term, mid-term, and long-term goals [for the program], we found we couldn't do it."

Richter, however, argues that Witherell's panel "did not fully understand the complexities of running a national laboratory." Without a B factory, he says, SLAC will be "a different kind of laboratory"—one that supports work in synchrotron radiation and high-powered microwave energy systems, but little in the way of high-energy physics. And delaying the B factory until 1996 could create serious problems for the laboratory. "It's very difficult to cut a lab back and then come back up to gear 2 years later," says Michael Riordan, a special assistant to Richter. "The best engineers and technicians among those who get laid off will find jobs elsewhere." By one estimate, between 15% and 20% of SLAC's personnel could be laid off in a $20 million budget cut.

Surprisingly, not everyone is gloomy—especially not Jonathan Dorfan, the lead author of SLAC's B factory proposal and something of a resident spin doctor on the subject. "I think the report is very good news for us," he says. First, he claims, by emphasizing the importance of CP physics the Witherell panel has elevated that work to the same level now occupied by the physics experiments proposed for the SSC. And Dorfan argues that the panel's report is actually a clever way of recommending that SLAC should build a B factory in 1994. When the panel noted that additional funding of $40 million would allow construction to begin in 1994, he says, "I think they put in a little tease to argue for doing it on a realistic time scale."

But SLAC physicists who take the report at face value are much less sanguine. "I believe it was unintelligent to say we'll clip SLAC's budget by $20 million in 1994 and 1995 and then build a B factory in 1996," says one. "That isn't how it works. You can't be throwing away people and have an atmosphere of panic and worry preceding a major project like that." Swartz, for one, says he's seen no sign of a drop in morale. But in reacting to the possibility of seeing SLAC's high-energy physics program end in 1995, one of his colleagues implicitly suggests that morale already might have bottomed out. "Those are frightening words...but I think frankly the community is right to be upset with the level of particle physics output of SLAC," this physicist says. "I don't disagree with [the panel's] judgment even though it's a frightening one."

The interregnum...and beyond

If no B factory appears on the horizon soon, SLAC's experimentalists will be left with nothing more than the tail end of the SLC program and a handful of much smaller experiments. Some of these experiments are attracting interest: A team led by Charles Prescott, for instance, is preparing to take spin measurements that could help explain how the spin of protons and neutrons is distributed among their constituent quarks and gluons. Similarly, Swartz and Jaros are putting together a proposal for a molecular beam experiment that could definitively answer whether or not the elusive and controversial 17 keV neutrino really exists. No one, however, is pretending that these efforts are anything more than sideshows to the main attraction of a large accelerator facility.

Meanwhile, SLAC's competitors for the B factory are moving forward with their plans. Cornell's Berkelman says he soon hopes to upgrade his accelerator to near B factory luminosity—a step that may allow it to begin preliminary work on the physics of CP violation by 1996, he says. David Berley, an NSF program director for particle physics, says the upgrades necessary to create a Cornell B factory have "strong support" within NSF, and that a funding decision could be just 2 years away. Moreover, if Japan's Ministry of Education decides to fund a B factory proposal submitted by that nation's KEK laboratory, its decision could forestall either U.S. proposal.

If SLAC can still hurdle the formidable obstacles now before it, it may yet salvage its B factory and its future as a high-energy physics laboratory. If not, a significant chapter in the history of the U.S. high-energy physics program may have come to an end.

–**David P. Hamilton**

NUCLEAR WASTE

Another Panel Rejects Nevada Disaster Theory

Barren, remote, and of limited intellectual appeal, Yucca Mountain in far southern Nevada is fast becoming the world's most intensely studied piece of real estate. In a project expected to cost $4 billion over the next decade, the U.S. Department of Energy (DOE) is working to determine whether this heap of volcanic rock between Death Valley and the Nevada Test Site would be a suitable place to inter the most radioactive waste from the nation's nuclear power plants. But even before it is deemed fit to receive hot waste, the mountain has generated more than its share of heat. Last week a 17-member panel of experts assembled by the National Research Council (NRC) made the latest effort to quench it.

In a 240-page report, the 17-member panel unanimously dismissed a 1987 claim by a dissident DOE staffer that, within the next 10,000 years, an earthquake could suddenly drive ground water upward hundreds of meters, flooding the repository and releasing its store of deadly wastes. The concern had slowed the project by making it hard to obtain state permits for field work, prompting state politicians to demand that the site be abandoned, and causing scientists on and off the project to spend thousands of hours investigating its plausibility. As the third review body to find the flooding scenario scientifically groundless, the panel couldn't help asking why the controversy has been so persistent. It suggests in its report that an independent chief scientist—something the project has lacked—could have headed off the controversy. But other scientists familiar with the politics and personalities of the debate aren't so sure.

"I don't see that the scientific community could have acted too much differently," says William Dudley of the U.S. Geological Survey (USGS) in Denver, who headed up an earlier study of the Yucca Mountain flooding issue by federal scientists. No matter what researchers did, say Dudley and others, a protracted public debate was probably inevitable. From the beginning, they point out, two essential ingredients for potent controversy were present.

For one, Nevada was a political tinderbox set to go off at the mere appearance of difficulties with Yucca Mountain. Congress had already riled Nevadans by designating their state—the same one that endured 15 years of above-ground nuclear testing—the only potential repository site. The governor, most politicians, and upwards of three-quarters of the populace have been vehemently opposed.