The Supercollider, 1 Year Later

The physicists have gotten high marks on their work so far; meanwhile, Washington is pushing international collaboration

Sometime in the next few weeks, Secretary of Energy Donald P. Hodel is expected to approve the official phase one studies of the largest and most expensive scientific instrument in history, a 20-trillion-electron-volt (TeV) particle accelerator known as the superconducting supercollider (SSC). The timing is nicely symbolic: it comes almost exactly 1 year after the American high energy physics community committed itself to the SSC at a dramatic meeting of the Energy Department's High Energy Physics Advisory Panel (*Science*, 9 September 1983, p. 1038).

It also caps a year of exceptionally hard work by the physicists. Starting from nothing—little more than a community-wide consensus that the SSC is a good idea—they have created a set of reference designs that give a reasonably firm estimate of the cost (about $3 billion over 10 years); they have put a management structure in place, including most recently the appointment of a director and deputy director for SSC research and development (Maury Tigner of Cornell University and Stanley Wojcicki of Stanford University, respectively); they have begun to meet with their European and Japanese counterparts to set up a framework of international collaboration, with the blessing of the London Economic Summit; and they have honed the design of the SSC in innumerable working groups on accelerator issues, detectors, and supercollider physics, culminating in July with an intensive series of design studies at Snowmass, Colorado.*

In Washington, meanwhile, their performance has gotten rave reviews. Congress has been generally receptive to the SSC, and the Administration has been downright enthusiastic. Presidential science adviser George A. Keyworth, II, a physicist himself, recently hailed the SSC as "a creative hub for a new generation of scientists . . . an embodiment of our national commitment to excellence."

On the other hand, everyone flinches at the price tag. Initial enthusiasm aside, $3 billion takes a lot of justifying—"years of preparation," as Keyworth warns the physicists, "not just of the technical design but of the public rationale as well."

Inevitably, policy-makers have seized upon the possibility of international collaboration and cost-sharing on the SSC. Unfortunately, it is an issue clouded by international competition: witness the European Laboratory for Particle Physics (CERN), which is offering an alternative to the SSC at one-sixth the price.

The Large Hadron Collider, as it is called, is not a new idea, but in the wake of the American SSC decision last year it suddenly reemerged as CERN's "cost-effective" alternative. CERN director Herwig Schopper recently argued the case at the May meeting of the American Association for the Advancement of Science (*Science*, 15 June, p. 1216). The idea is to take advantage of the 27-kilometer ring tunnel now under construction for CERN's Large Electron-Positron project (LEP), he explained. By adding a ring of current-technology superconducting magnets on top of the LEP magnets, the CERN physicists could have proton-proton collisions at 5 TeV on 5 TeV; by using a new generation of high-field magnets, assuming that they could be developed in time, the physicists could have as much as 9 + 9 TeV. Such a machine would cover a good part of the energy region explored by the United States' $3-billion, 20 + 20 TeV supercollider, Schopper maintained, but it could be built for only $500 million. The United States, of course, would be welcome to participate.

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Given the fiscal constraints in Washington, this sort of thing does sound seductive: why spend $3 billion to go it alone when we could do almost as well by paying half of $500 million? True, the United States would have to give up its "lead" in high energy physics. But presumably the point of the exercise is science, not pork barreling.

On the other hand, one has to consider the bleak realties of finance: the Europeans may well be overextended already. They will be paying for LEP construction until 1989. They are simultaneously building another major accelerator in Germany, the electron-proton collider HERA. And they have to face the possibility that one of CERN's major contributors, the United Kingdom, will soon be pulling out of high energy physics altogether (*Science*, 20 April, p. 266). Any add-on LEP will thus be a long time coming, if ever. Meanwhile, the American program is in a much better position: all the major construction—the Stanford Linear Collider and Fermilab's Tevatron I—should be finished by 1986, freeing up funds just in time for SSC.

More important, there is the matter of the energy scale. Chris Quigg of the Fermi National Accelerator Laboratory, coauthor of a definitive review of the physics to be done at the SSC,† underscored that point recently in a talk at the Snowmass meeting: "Our successes in the last 10 years lead us to think we have a fairly good understanding of the 100 GeV [billion electron volt] region," he said. "So we think we can extrapolate those theories reliably to higher energies—at least well enough to tell us where they fall apart." The result is a general consensus that wonderful things are waiting at 20 + 20 TeV: supersymmetry, perhaps, or technicolor, or Higgs bosons, or evidence for the compositeness of quarks and leptons. Unfortunately, he added, the theorists cannot be nearly so confident about 5 + 5 TeV. The energy is too near the likely threshold for these new phenomena.

Of course, the CERN physicists have done those calculations too; that is why they stress the 9 + 9 TeV hadron collider. But as more than one accelerator designer has pointed out, achieving such energies in the LEP tunnel depends upon the existence of high-field, 10-tesla magnets that no one yet knows how to build. Add the fact that only one of the LEP detectors will be usable in the high-

*The Snowmass Summer Study on the Superconducting Supercollider, 23 June to 13 July, sponsored by the Division of Particles and Fields of the American Physical Society.

†*Supercollider Physics*, E. Eichten, I. Hinchliffe, K. Lane, C. Quigg, FERMILAB-Pub-84/17-T; LBL-16875; DOE/ER/01545-345, February 1984.

luminosity environment of the collider, and it is not at all clear anymore that $500 million is a realistic estimate for the CERN project.

The upshot is that few, if any, American physicists see the hadron collider as a serious competitor to the SSC—although they are maintaining cordial interest in the project, just in case the SSC somehow falls through. As Quigg gallantly pointed out, a 5 + 5 TeV machine might still be a very useful machine.

The skepticism is echoed in the science adviser's office where, for reasons both fiscal and symbolic, Keyworth is taking the lead on finding international collaborators for the SSC. "We have a strong desire to collaborate," says Keyworth's deputy Ralph DeVries, "but we have to temper that with reality." CERN's hadron collider aside, the Europeans have shown considerable interest in an SSC collaboration, but little ability to act on it. Given the commitment to LEP and HERA, he says, it seems unlikely that Europe could contribute much to the SSC before the early 1990's, by which time the construction would be almost complete. A more realistic possibility is that the Europeans might join later in the game and build one of the major detectors for the SSC.

Japan, however, is another story. The Japanese have extensive experience with superconducting magnets, says DeVries. They have money, and they have a commitment to upgrading their high energy physics capability. "They're the only country we see as a major collaborator," he says.

Keyworth thus led a high-ranking delegation of American physicists to Japan last April to explain the SSC and to invite the Japanese to join in. While no immediate agreement was reached, his hosts seemed to appreciate the message: "The Japanese have complained before that we always invite them in on projects at the last minute, almost like a subcontractor," says DeVries. "We just show them the blueprints and ask if they want to do some little piece of it. But this time, we're inviting them in at ground zero." Japan subsequently sent at least nine physicists to the Snowmass meeting, and DeVries is optimistic that something can be worked out.

The idea of collaboration acquired some additional cachet in May, when the London Economic Summit identified high energy physics as one of several scientific areas having good potential for cooperation (*Science*, 22 June, p. 1317). That agreement led in turn to a seven-nation "Summit Working Group" on high energy physics chaired by Alvin W. Trivelpiece, director of the Department of Energy's office of energy research; its first meeting was in Brussels in July.

"The proposal was for the working group to identify the major facilities needed for high energy research—*anywhere*—and have a report ready by the June 1985 summit in Bonn," says Fermilab director Leon Lederman, who was a delegate.

The chief responsibility for that plan was given to a subgroup under Harry Atkinson of the United Kingdom, says Lederman, although it is already clear that the Bonn summit will have to make do with an interim report. Given the sensitivities, he says, and the fact that CERN's Large Hadron Collider and the Japanese program are not nearly as well developed as the SSC proposal, a full international plan will take 2 to 3 years. Meanwhile, the working group will look at ways to lower the administrative barriers to collaboration—visas, work permits, customs, data communications across borders—and ways to facilitate the exchange of information on technical matters, such as magnets or cryogenics. (In many cases, the flow of technical information is already quite good, notes Lederman.)

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Back at home, meanwhile, the American high energy community has been laying its plans for the management of the SSC—and in the process displaying a regard for consensus and inclusion worthy of the Democratic National Convention. Last April, the Department of Energy gave overall management authority to Universities Research Association (URA), the 54-member consortium of universities that runs Fermilab. To avoid the obvious potential for conflict of interest, URA then vested authority for the supercollider in a separate board of overseers, with members selected through an elaborate review process to ensure that no one region and no one institution dominated over any other. By late spring the 11-member board was in place under chairman Boyce McDaniel of Cornell University. Then, since a part-time board cannot be expected to design an accelerator, McDaniel and company made it their first order of business to search for a full-time director of a Central Design Group.

In parallel with all this, a substantial fraction of the community was hard at work on a reference design study for the SSC, under Cornell's Maury Tigner. The laboratory directors and certain members of the Energy Department's High Energy Physics Advisory Panel had insisted on it: Hodel was looking at estimates ranging from $1 billion to $10 billion, and for credibility's sake they needed something a lot better.

In the end the study actually included three reference designs, reflecting the fact that the choice of superconducting magnets for the main ring will drive the cost of everything else at the SSC. The first design was based on relatively high-field 6.5-tesla magnets. They would be fairly expensive, but they would also give the smallest ring: 90 kilometers in circumference, or just about the size of the Washington, D.C., Beltway. A second design was based on the 5-tesla magnets already demonstrated at Fermilab's Tevatron. They would require a 113-kilometer ring. The third design used a much less expensive 3-tesla magnet and led to a ring 164 kilometers around.

Almost miraculously, after all the factors of design complexity and magnet fabrication were traded off against the tunnel length and other facilities, the estimated cost for each design came out about the same: $3 billion.

Tigner presented the completed reference design study to the Energy Department on 8 May. It covered technical feasibility, the research and development requirements, and the cost of everything from cryogenics to electrical power distribution. The audience was delighted. "Truly outstanding," says William Wallenmyer, head of the department's high energy physics program. "The amount of work and the depth is much better than many things we go forward with construction on."

Thus it was that in June the SSC board of overseers asked Tigner to be director of the Central Design Group. His deputy will be Stanford's Stanley Wojcicki, who headed the subpanel that last year recommended the SSC.

All of this effort so far falls under the heading of the SSC's "Phase 0." Assuming that Hodel gives the go-ahead this summer—and no one seriously doubts that he will—fiscal year 1985 will see the start of "Phase I": the actual research, development, and design work leading up to a specific proposal. "Phase II," the actual construction, should then begin in the late 1980's.

—M. Mitchell Waldrop