The SSC— An Engineering Challenge

by Mahlon T. Wilson

The accelerator known as the SSC (Superconducting Super Collider) is a bold idea that will enable a giant step forward in high-energy physics. Within a circular ring fifty to one hundred miles around, two proton beams will collide and liberate enough energy to create new particles up to fifty times heavier than the weak bosons. These energies are necessary to go beyond the plateau of understanding summarized by the standard model. Specific issues to be addressed include the mechanism for breaking the symmetry between electromagnetic and weak interactions, the possibility that quarks and leptons are composite particles, and the existence of quark-lepton families heavier than those now known. In addition, exploration of this higher energy region is quite likely to uncover entirely new phenomena.

To bring some order to the multitude of suggestions put forth for what should be attempted with this machine and how it should be built, the high-energy physics community has held a series of workshops both here and abroad. The workshops resulted in a decision to study in detail the technical feasibility and estimated cost of achieving one particular set of beam parameters. Over 150 representatives from a number of national laboratories and universities and a few commercial firms contributed to this Reference Designs Study, which was headquartered at Lawrence Berkeley National Laboratory and directed by Maury Tigner of Cornell University. This heroic effort occupied the first four months of this year and produced many thousands of pages of text and cost estimates. From these has been extracted a summary document of about two thousand pages, which will serve as a point of reference for continued discussion and development of a proposal to the Department of Energy for funding.

The objective addressed in the Reference Designs Study was provision of two 20-TeV proton beams capable of being collided head-on at up to six locations. The maximum luminosity of each beam was set at 10^{33} per square centimeter per second. Three design concepts for the magnetic field were considered, all incorporating superconducting magnets of niobium-titanium cooled by liquid helium to 4.5 kelvins. The accompanying table lists some features of the three designs worthy of the adjective "super." Much care was taken to include in the reference designs components whose performance and cost were based on those of existing equipment. When this was not possible, advocates of a proposed component were required to break the component down into items of known cost and to defend their estimate of total cost. A disagreement of even a few dollars in the estimated cost of any one item can be significant, since thousands of each of hundreds of items are needed for the accelerator. The similarity of the estimated total costs for the three reference designs reflects a similarity between the greater costs associated with higher magnetic fields (more superconducting material) and those associated with physically larger accelerators (more cryogenic equipment, more excavation, more piping and cables, and so on).

The Reference Designs Study brought to light several engineering challenges that can be characterized as interesting, to say the least. A good first question is how to lay out an 18- to 33-mile-diameter circle with the required dimensional accuracy. The sheer size of the facilities being considered—the circumferences of which range from the highway distance between Los Alamos and Cochiti Pueblo to that between Los Alamos and Albuquerque—create unusual problems in communications.

The long magnets present challenges in fabrication, transportation, field testing, and alignment. For example, the 3-tesla magnets, which are about one and one-half football fields long but only a bit over one foot in diameter, will behave like wet noodles if improperly lifted. And although such long magnets can be bent sufficiently to conform to the topography of specially tailored roads, they must be supported during transport at intervals of about every ten feet. All the magnet versions raise other issues. The numerous plumbing and wiring connections must be of the highest quality. Several inches

Features of the three SSC designs considered in the Reference Designs Study. The 6.5-tesla design involves a conductor-dominated field with both beam tubes in a common cold-iron yoke that contributes slightly to shaping the field. In this design the dipole magnet, beam tubes, and yoke are supported within a single cryostat. The 5-tesla design involves a conductor-dominated dipole field with a heavy-walled iron cryostat to attenuate the fringe field. This single-bore design requires two separate rings of dipole magnets. The 3-tesla design is similar to the 6.5 tesla design except that the field is shaped predominantly by the cold-iron yoke rather than by the conductor.

Dipole Field (T)	Dipole Magnet Length (ft)	Accelerator Diameter (mi)	Total Estimated Cost ($)
6.5	57	18	2.72 billion
5	46	23	3.05 billion
3	460	33	2.70 billion

of thermal contraction of the components within the cryostats must be accommodated. Heat leaks from power and instrumentation leads must be minimized, as must those from the magnet supports. (What is needed are supports with the strength of an ox yoke but the substance of a spider web.) Alignment will require some means for knowing the exact location of the magnets within their cryostats. And if a leak should develop in any of the piping within a magnet's cryostat, there needs to be a method for locating the "sick" magnet and determing where within it the problem exists.

Questions of safety, also, must be addressed. For example, the refrigerator locations every 2 to 5 miles around the ring are logical sites for personnel access, but is this often enough? What happens if a helium line should rupture? After all, a person can run only a few feet breathing helium. Will it be necessary to exclude personnel from the tunnel when the system is cold, or can this problem be solved with, say, supplied-air suits or vehicles?

Achieving head-on collisions of the beams presents further challenges. Each beam must be focused down to 10 microns and, more taxing, be positioned to within an accuracy of about 1 micron. It takes a reasonably good microscope even to see something that small! Will a truck rumbling by shake the beams out of a collision course? What will be the effect of earth tides or earthquakes? Does the ground heave due to annual changes in temperature or water-table level? How stable is the ground in the first place? That is, does part of the accelerator move relative to the remainder? Will it be desirable, or necessary, to have a robot system constantly moving around the ring tweaking the positions of the magnets? What would the robot, or any surveyor, use as a reference for alignment?

These are but a few of the many issues that have been raised about construction and operation of the SSC. Resolving them will require considerable technology and ingenuity.

In April of this year, the Department of Energy assigned authority over the SSC effort to Universities Research Association (URA), the consortium of fifty-four universities that runs Fermilab. URA, in turn, assigned management responsibilities to a separate board of overseers under Boyce McDaniel of Cornell University. This board selected Maury Tigner as director and Stanley Wojcicki of Stanford University as deputy director for SSC research and development. A headquarters is being established at Lawrence Berkeley National Laboratory, and a team will be drawn together to define what the SSC must do and how best that can be done. Secretary of Energy Donald Hodel has approved the release of funds to support the first year of research and development. Since the $20 million provided was about half the amount felt necessary for progress at the desired rate, shortcuts must be taken in reaching a decision on magnet type so that site selection can begin soon.

Los Alamos has been involved in the efforts on the SSC since the beginning. We have participated in numerous workshops, collated siting information and published a Site Atlas, and contributed to the portions of the Reference Designs Study on beam dynamics and the injector. We may be called upon to provide the injector linac, kicker magnets, accelerating cavities, and numerous other accelerator components. Our research on magnetic refrigeration has the potential of halving the operating cost of the cryogenic system for the SSC. Although the results of this research may be too late to be incorporated in the initial design, magnetic refrigerator replacements for conventional units would quickly repay the investment. ■