# TRYING TIMES: COST OF REMODELING SSC CAUSES TEXANS TO CIRCLE THEIR WAGONS

The eyes of Texas are firmly fixed on the SSC. The reason, of course, is that the giant Superconducting Super Collider—three times the circumference of the Large Electron–Positron machine at CERN and ten times the size of Fermilab—is to be built some 25 miles directly south of Dallas, under the flat prairie of Ellis County. When completed, within the next eight years, the SSC will collide two countercirculating beams of protons at 20 TeV each. In the event, the machine will be the unrivaled centerpiece of high-energy physics and Ellis County the world capital for particle physicists. Texans believe, in addition, that the SSC will generate economic and cultural benefits to a region that has been all but bypassed during the state's technological expansion in recent years.

So it's not surprising that the state's most powerful forces, including such rich and famous figures as J. Fred Bucy and Morton Myerson, President Bush and three of his Cabinet members and several House and Senate leaders, used their collective muscle to deliver the SSC for the Lone Star State.

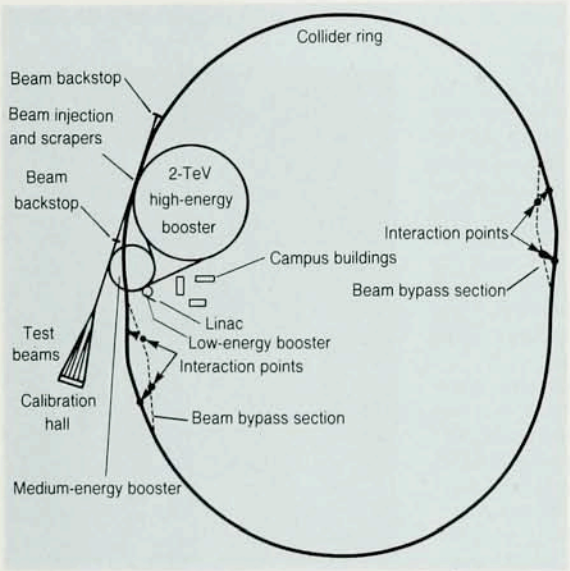
Yet, only weeks after Congress broke down the political and budgetary barriers to the SSC by appropriating $225 million to begin construction in fiscal 1990 (PHYSICS TODAY, October, page 51), Texans began circling their wagons. One attack on the SSC came from the home front on Sunday, 22 October, when *The Houston Post* lamented across its front page: MAGNETS 'INSUFFICIENT' FOR COLLIDER. Worse followed a month later, on Sunday, 19 November, on page 1 of *The Washington Post*: SUPERCOLLIDER COULD FACE CUTBACKS. Both accounts bore the clear message that political movers and shakers should begin thinking the unthinkable: that the SSC might need to be redesigned and that the remodeling job would increase its cost significantly.

*The Houston Post* based its story on a report issued last summer by a team of magnet experts led by Gus Voss of DESY in Hamburg and Thomas Kirk of Fermilab. But the story hardly dealt with the substantive issues uncovered by the panel: the insufficient margins of the dipole magnets for reaching the required operating energy of 20 TeV, the uncertain sextupole field quality at the injection energy of 1 TeV, and the lack of any plan to test a string of magnets, all built to the same design and to the same tolerances. The team noted that it was still early days in dipole design and that additional R&D would be necessary. Work on the dipoles should involve Brookhaven, Fermilab and Lawrence Berkeley as well as the SSC Lab and industrial firms. The report also urged that a magnet test lab be built as soon as possible at the site.

By September, when another group of DOE consultants looked at the situation, all the concerns in the Voss–Kirk report were being pursued. Erratic quenches had been overcome in the latest superconducting dipoles and their reliability had been enhanced by lowering the operating temperature from 4.6 K to 4 K. After some 30 more prototype magnets are completed and tested, SSC leaders are convinced, all the bugs will have been removed and the magnets will be ready for manufacture in quantity. The debugging will proceed at a new magnet test lab, to be built at the SSC site later this year.

*The Houston Post* quoted Russ Huson, director of the Texas Accelerator Center and a member of the Voss–Kirk panel, as saying, "The accelerator only works as well as the poorest magnet." It also quoted Paul Reardon of SAI Corporation defending the SSC Central Design Group. "To be fair," Reardon said, "there never was an attempt to overdesign the project.... Given the cost of the project, everybody was trying to find a design that would work but not jeopardize the project."

The gist of *The Washingon Post* story was that the SSC is likely to be scaled back "because of technical problems that may cause its price tag to jump by up to 30%—or nearly $2 billion." The paper claimed that SSC Director Roy F. Schwitters had asked




**SSC 'footprint'** shown in this drawing includes proposed beam bypass regions with particle collision points and other characteristics of the facility that are being reconsidered in attempts to hold down the machine's total cost. This draft schematic, prepared last October at the SSC Lab, is not drawn to scale.

DOE for the additional sum above the current $5.9 billion estimate to make "extensive design changes" in the CDG's concept. Schwitters wanted to upgrade the injector feeding protons into the main ring from 1 TeV to 2 TeV, which would surely increase the machine's total cost. According to the news story, after being briefed on the changes, Deputy Energy Secretary W. Henson Moore III, a former Republican Congressman from Louisiana, told project managers that "either we're going to build it for the figure of 5.9 [billion dollars] or we're not going to build it at all."

## To be built 'as advertised'

It turns out, according to sources in the Bush Administration, that both Moore and Energy Secretary James D. Watkins told Schwitters in separate meetings that the SSC must be completed "as advertised" for $5.9 billion. Indeed, when Watkins was first informed of the added cost, he went "nonlinear," said these sources, and argued, in effect, that US Treasury vaults were not going to open wide to particle physicists.

Watkins and Moore were forewarned. For months before he was forced to resign last October, Robert O. Hunter Jr, then director of DOE's Office of Energy Research (see page 49), had argued that proposed alterations to the SSC—including a higher injector energy, larger beam aperture, additional magnets and such design changes as beam bypass sections for the detector halls and the addition of a beam calibration hall—would raise the final cost from $2 billion to $4 billion.

Watkins's predecessor at DOE, John S. Herrington, had disregarded a report by the Congressional Budget Office in October 1988 that concluded, after reviewing the SSC design and the history of US high-energy accelerator construction, that the cost of the collider might go up by as much as $1.5 billion. The CBO had used the sum of $4.4 billion as the base cost, which was the estimate made by the Central Design Group in 1986. But the design group had also reported that when detectors and pre-operating costs were added, the total could reach $5.9 billion. DOE refused to admit that the SSC would bear the higher price tab, possibly to make it more acceptable to Congress.

The design group had purposely kept down construction costs by limiting the injector to 1 TeV, the energy of Fermilab's Tevatron, and by scaling up Fermilab's 4-m magnets. Troubles in the prototypes of the SSC's 17-m $\cos\theta$ magnets became apparent two years ago (PHYSICS TODAY, April 1988, page 17) and are now recognized as related to the SSC's magnetic field. The cure, as determined by SSC scientists, calls for changes in the beam lattice that would result in reducing the length of the dipoles from 17.35 m to 15.85 m. The implications of this include increasing the total number of dipoles from 8600 to 8800, which will increase the circumference of the ring from 53 miles to 54 miles, with the cost of magnets and tunneling to rise accordingly.

When all the proposed alterations are taken into account, the total cost goes up to $7.2 billion. In reaching this total the SSC staff added $288 million for the injector upgrade from 1 TeV to 2 TeV, $230 million for bypass tunnels at the detector halls and $300 million for enlarging the aperture from 4 cm to 5 cm and for modifying the dipole magnets to accommodate that difference. The new total also includes more realistic labor costs and profit margins that will need to be paid to get the magnets manufactured in large quantities—matters that were underestimated in earlier calculations. Previous estimates for the SSC also incorporated an inflation rate of less than 2% per year. This rate was unrealistic then and is still considered too low for the period of construction.

PHILIP BERMINGHAM PHOTOGRAPHY

**Watkins:** No raids on the Treasury.

By mid-January, Schwitters intends to give Watkins a revised SSC cost estimate and a report on various options for the machine. Schwitters will make a strong case that he can deliver a reliable machine that achieves 20 TeV in each beam with a luminosity of $10^{33}$ events per sec per $cm^2$. "There is no reason to back off from that under any SSC scenario," Schwitters tells us. He intends to retain the four detectors, and he will offer DOE the option of building bypass tunnels so that the machine can continue operating by detouring the beam through another line while modifications are made to detectors. To economize on the bypass scheme by not digging the additional tunnel is not the logical thing to do, says Schwitters. If the tunnels are built later, costs will be higher and operations disrupted.

To be sure, some Texans were already worrying about the SSC months before the newspaper reports. Governor William P. Clements Jr, who was deputy defense secretary in the Ford Administration and is a longtime buddy of George Bush and many of the men around the President, had three meetings in the White House on matters involving the SSC during 1989. At his last meeting in October, he complained about the Energy Department's heavy-handed attempts to micromanage the project.

Another Washington visitor was Tom Luce, chairman of the Texas National Research Laboratory Commission, which includes some of the most prominent businessmen in the state. The commission spearheaded efforts that led to voter approval of a $1 billion bond issue for the SSC. Texas lawmakers have also pushed hard for action. Representative Joe Barton, the two-term Republican who represents Ellis County, became the SSC's point man on Capitol Hill. After the newspaper stories appeared on the rising costs of the SSC, Barton proposed that DOE appoint a world-class panel of physicists and engineers to examine the design and cost of the machine. Barton said he didn't want Congress to be surprised to find out the machine could not achieve its advertised energy and luminosity at the proposed price.

Barton believes the panel he advocated is no longer necessary. A half dozen oversight groups have diagnosed the SSC since August. As a result, Schwitters and company now understand the machine's problems and Congress's concerns, says Barton.

Watkins also exudes confidence in the project. During a break in an energy policy hearing at DOE's Washington headquarters, he told us that the SSC was in no jeopardy of being scuttled or postponed. "We're going to make it work," he declared. "The concept is solid, and I expect the options will allow us to produce a machine without rival."

After Schwitters met with Barton before Christmas, they agreed that

DOE should move forward on the "footprint" for building the machine at the site. Approval is necessary before the state begins buying land with some of the $1 billion in general obligation bonds made available last year by voters. Six counties, including Ellis, have agreed to raise vehicle license taxes to pay for roads to the SSC laboratory around the turn-of-the-century town of Waxahachie.

Barton believes that DOE's prudent approach to the SSC was correct. He insists that Hunter had the best interests of the country in mind in being cautious. But sources in the Administration insist Hunter was really trying to micromanage the project. Most criticism centers on how Hunter sought to slow the momentum for the SSC. In January 1989, when Schwitters became SSC director, Hunter organized a separate unit within DOE's high-energy research office to keep tight control on the project.

Hunter, for his part, claimed in an interview that he hadn't been able to get a grip on SSC expenditures or get a schedule of project milestones and deliverables. "Whenever I asked for these," Hunter said, "I would get a runaround: 'We're working on those.' I wasn't getting answers about spending rates or magnet progress."

Schwitters characterizes Hunter's grievances as "nonsense." He argues that he kept Hunter completely informed but wasn't receiving much communication from him in return.

Meanwhile, Clements and Luce complained that the project appeared to be going from bad to worse and that Hunter was causing many of the management and morale problems. On 7 September, Watkins issued DOE's management plan for the SSC, overriding Hunter, by limiting the number of officials in Washington to provide oversight to 30 and authorizing no more than 60 at the site. He restored fiscal supervision to DOE's Chicago Projects Office, which Hunter had removed from the loop.

### Competing to build the SSC

Moreover, when members of Congress expressed worry that DOE would abuse its power to choose subcontractors, lawmakers clamped fetters on the department with specific language in a report by the Senate Committee on Energy and Water Development. Watkins made it clear in his memorandum that he would not tolerate the department's interference with the choice of subcontractors by SSC and Universities Research Associates, the organization of 72 US and Canadian universities that directs both the SSC and Fermilab.

Somewhat ironically, it was neither DOE nor URA that made public the names of the three teams of industrial firms that will compete for the $1 billion contract to manage engineering and construction for the SSC tunnel. On 6 December the news was released by Barton's office, because, says the Congressman, "the winners and losers were all calling me and so I thought the information should be made public." The finalists, from among 14 contenders for the contract, are Fluor–Daniel, the construction arm of Fluor Corporation and ICF Kaiser Engineers; Parson, Brinckerhoff, Quade and Douglas, MK Ferguson and CRSS of Houston; and a joint venture of Daniel, Mann, Johnson and Mendenhall of Los Angeles and Bechtel National Inc.

It is likely that the engineering and construction contract will be awarded this year, though there is little money in the SSC budget to begin work. Much will depend, obviously, on the fiscal 1991 budget, which President Bush will deliver to Congress on 22 January. Members of Congress from Texas say the DOE budget will contain $393 million for the SSC. But at the White House Office of Management and Budget they speak about $310 million—scarcely enough to get on with producing the remodeled machine at its higher new price.

—IRWIN GOODWIN

# SSC DESIGN REVISIONS CALL FOR THINNER BEAMS AND FATTER MAGNETS

The Central Design Group for the Superconducting Super Collider produced its conceptual design for the proposed $20\times20$ TeV proton–proton collider in 1986. Since then, a specific site for the SSC has been selected in Ellis County, Texas; experimental models of the 6.6-tesla bending magnets required for the collider ring have been extensively tested; and powerful new computer codes have now made it possible to simulate the trajectories of individual protons over millions of circumnavigations of the 54-mile storage ring.

Armed with this new knowledge of how the protons stored in the ring will behave during the crucial beam-injection phase and how the unprecedentedly long and powerful superconducting bending magnets perform at operating temperature and currents, the SSC Laboratory in Dallas, which has taken over the responsibilities of the CDG, has produced a supplemental design for the accelerator. The principal changes in the revised SSC design are a doubling of the injection energy, more focusing magnets in the ring and a 25% increase in the width of the vacuum beam pipe.

The 1986 conceptual design called for the countercirculating protons to be injected into the final ring at an energy of 1 TeV after preacceleration in a sequence of linacs and booster rings. Filling the ring with its full complement of protons will take a half hour, after which the rf cavities spaced around the ring begin accelerating the protons up to their final energy of 20 TeV. During the filling phase the protons will have to survive $10^7$ trips around the ring without being lost in collisions with the walls of the vacuum beam pipe.

### Beam-pipe aperture

In the original design, the aperture diameter of the vacuum beam pipe that threads its way through the thousands of bending and focusing magnets is specified as 4 cm. Was that wide enough? The larger the aperture, the smaller is the likelihood of wayward beam protons striking the wall. But bigger apertures are also more expensive. They move the magnet coils farther away from the beam axis, making it necessary to build magnets with more superconducting cable. The unprecedently narrow 4-cm original design was described by the Central Design Group's director, Maury Tigner, as one of the "aggressive" specifications chosen for reasons of economy. (See PHYSICS TODAY, April 1988, page 17.)

It's not just a matter of the beam scraping the walls. Ideally the bending magnets would have perfect dipole fields. But real bending magnets are inevitably plagued with higher-multipole field components, whose adverse effects on beam quality become worse as the protons find themselves farther from the magnet axis. The beams must also be kept narrow so that the experimenters will have adequate collision rates where the beams intersect. The question is, how good can and