would total almost exactly the $4.4 billion (in 1987 dollars, before taking inflation into account) that DOE wants to spend for the SSC.

'Camel's nose.' The SSC's cost in fiscal 1988 would be just $35 million—all of this coming from reprogramming DOE's high-energy physics budget, with the major losers being Fermilab and SLAC. Not surprisingly, Congressmen in California and Illinois objected to that plan. Members of the budget and appropriations committees in both bodies of Congress are wary of making a commitment to the SSC now because of the massive outlays ahead—rising to between $600 million and $700 million each year until 1996, if it proceeds on schedule. As Buddy MacKay, Democrat of Florida, and Ritter stated in their "Dear Colleague" letters last May and June, the 1988 commitment to begin the SSC "is the proverbial camel's nose in the tent."

Thus, on 17 June the House agreed to the 1988 Energy and Water Development Appropriation Bill that excluded the DOE request for $10 million to begin construction of long-lead-time items for the SSC. It approved $25 million for continued R&D on the collider. The House Appropriations Committee report expresses concern that DOE has not come forth with a plan for paying for the machine in a period when deficit reduction is a singular goal on Capitol Hill. The report calls on DOE to "continue to explore cost participation in this project by foreign countries. The committee believes that progress in identifying foreign financial participation will be very beneficial in firming up the overall fiscal picture for this project."

DOE officials and some physicists acting at the behest of the department have discussed participation with government and scientific leaders in Japan, Canada and the European Community, but no formal agreements have been reached. Canada has shown interest in a cross-border tunnel located principally in the state of New York. The rules of the competition require the SSC to be built entirely within the continental US, however.

European rival. Officials from 17 states appeared before the House Science, Space and Technology Committee last April to argue for full funding of the SSC. The committee also heard Herwig Schopper, director-general of the European Organization for Nuclear Research, describe the Large Hadron Collider that CERN physicists want to construct in the 17-mile circular tunnel that is now being completed for the 110-GeV Large Electron Positron collider. A special committee under Carlo Rubbia reported in June that the proposed LHC could produce particle collisions at five times the rate of the SSC for less than 20% the cost. In its current design, the LHC would have about 16 TeV compared with the SSC's 40 TeV. Under questioning, Schopper admitted that in the community's current financial straits, neither Europe's leading ministers nor its parliamentarians were keen on spending additional sums for scientific research.

It has not been overlooked by some on Capitol Hill that DOE created a timetable that allows the Administration to choose the winning site in January 1989 as one of its last official acts. And some are already saying it's unlikely that Reagan can bear to pass over his beloved California for such a plum. Few in Washington would be shocked if the final decision is based on political considerations, says New York's Lundine. "Believe me," he says, "there are science politics every bit as intriguing as welfare politics or military politics that we know so well in Washington."

—Irwin Goodwin

Will high-T_c superconductivity affect the SSC's design?

Because superconducting magnets are so central to the design and engineering of the SSC, the progress and promise of a new group of superconducting materials known as layered perovskites have excited some physicists to claim the giant machine could be built cheaper and smaller. Relatively soon, perhaps in a few years, these physicists say, high-temperature superconducting materials are likely to make possible, among an astonishing array of applications, particle accelerators whose magnets would no longer need to be cooled by costly liquid helium to 4.2 K above absolute zero but would operate at or near room temperature. Indeed, they seem confident that those materials will generate magnetic fields much higher than now known, with virtually no loss of current.

But predictions are no guarantee such things will come about, let alone in a few more years. Still, the assertions, coming from several prominent physicists, trouble and tantalize many members of Congress just when they are deciding whether to approve the fiscal 1988 budget to begin work on construction items for the SSC. Politicians abhor uncertainties. What they read and hear about the superconductivity phenomenon leaves them agog, puzzled by speculations that the new materials should enable physicists to redesign the accelerator so that it will require a lot fewer than 10 000 magnets, a tunnel much smaller than 53 miles in circumference and a total price tag well under the advertised $4.4 billion (in 1987 dollars).

Speculations. This belief was apparent in several "Dear Colleague" circulars issued in May and June in the House of Representatives. In these, four members of the Science, Space and Technology Committee identify such respected solid-state physicists as Philip Anderson and James A. Krumhansl as opposing construction of the SSC now. A quotation from Anderson, taken from an article in *The New York Times* (14 April 1987), has him saying: "It is important to wait awhile on the SSC. [I had thought that superconducting] technology was not going to move fast enough to make a difference to the Supercollider, and I've changed my mind. Things are moving faster than I ever thought."

The House letter contains a portion of the testimony presented by John M. Rowell of Bell Communications Research at the April hearing of the House Science, Space and Technology Committee. On that occasion, he observed that much more should be known about the current-carrying capability of new superconductors by the end of this year and that he would be "very surprised" if a lot more isn't also known by early next year about fabricating the materials into magnets and wires for the SSC. In an earlier version of the "Dear Colleague" statement, Krumhansl's letter of 19 February to Energy Secretary John S. Herrington is quoted: "The implications [of high-T_c superconductivity] are vast! These materials are inexpensive, they can be easily made, and can be refrigerated by a variety of widely available cheap methods. They unquestionably have the potential to save billions of dollars in construction and operation of particle accelerators like the SSC. Because they are easily fabricated, I have little hesitation in predicting that they will be brought to technological usability in three to five years, if materials research is supported adequately. By contrast with particle physics, I can assure you that this discovery is so important that it will find its way into almost every area of materials, energy, electronic and military technologies. A scientific development such as these new materials comes once in decades."

In the text of his statement to the committee last April, Rowell agreed with Krumhansl that "good, reliable research magnets" using new ceramic oxides might be ready in three to five years.

Few materials researchers accept such roseate prophecies. "The scientific discovery [of the new materials] is the easy part," says John Hulm, the research director at Westinghouse Electric Corp, where work in the early 1960s on an earlier generation of superconductors roused similar talk of an imminent technological revolution. "Application and fabrication are much harder."

Design. The Congressional letter writers, led by Buddy MacKay, a Florida Democrat whose deliberative approach to issues is respected by other members, and Don Ritter, a Pennsylvania Republican who holds the only DSc (in materials science from MIT) in both houses, argue that development of new superconductors could cause physicists to rethink the machine's design to include more powerful magnets with stronger fields. This, they contend, would result in possibly tenfold reductions in the number of magnets and length of the ring. With a more compact machine, the House members speculate, the land area for it might be only 1% that of the currently planned site. This would certainly lower the cost of the SSC, so the MacKay–Ritter letters claim, and the money saved could go into other scientific research without affecting the progress of particle physics. But for all this to happen, they conclude, the SSC "would have to wait."

How long? That depends on how quickly the status of technology advances. The critical current densities of the new materials are at least two orders of magnitude less than those in NbTi wires used in today's large magnets. It took nearly 20 years from the discovery of superconductivity in NbTi to develop stable magnets using this material. The SSC magnets being developed at Brookhaven National Lab operate with about 6700 amperes in cables made of fine filaments embedded in copper. The new superconductors achieve about 1000 times less current per unit of cross section than the SSC wire.

Critical current density is usually not an intrinsic property of high-temperature superconductors but depends on the metallurgical processes used in making the material. However, some experts think it may not be possible to raise the current density in wires made of the new materials because of their

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highly anisotropic crystal structure. Designing around the problem may not be easy—or even possible.

"While it is dangerous to predict how long it will take to make practical uses of the new materials," Rowell told the committee last April, "it is safe to say that it will be much faster than for NbTi and Nb_3Sn, in that all the engineering knowledge that was accumulated for those materials can now be applied to the new ones, except for the complication of ceramics." Rowell observes that superconducting magnets for bubble chambers were introduced

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in 1968 from materials first proposed for magnets in 1960.

For an even longer period, physicists and engineers have sought to develop pulsed superconducting magnets out of Nb_3Sn, an intermetallic compound with inbuilt stress problems and fabrication difficulties. Work with Nb_3Sn comes to grief primarily because the brittleness of the material makes the production of wire and yokes most difficult. The new class of high-temperature ceramic superconductors presents far greater problems.

Forces. The powerful tensile and shear forces in dipole magnets such as those now being developed at Brookhaven for the SSC are likely to break the brittle new ceramic oxide materials. In fact, materials researchers and accelerator experts agree that the ceramic oxides used in superconducting experiments so far would literally explode when subjected to such stresses. Another potential risk may arise when quenching causes the temperature in magnets of this sort to rise suddenly, increasing the chance of melting the wire filaments. "We're not at a point where we can address the question of whether the new materials are more prone to melting than the ones we now use," says Alvin Tollestrup of Fermilab.

It is still far from clear how durable and reliable the new materials would be. What's more, it is not at all certain how the materials work. No single theory fully explains their behavior, though they appear to be explicable in terms of the traditional BCS theory (named for John Bardeen, Leon Cooper and J. Robert Schrieffer, who won a Nobel Prize for it in 1972).

Even assuming the new superconductors could be developed for accelerator magnets in the next two to three years, an entirely new R&D program would have to be initiated to devise new magnets and design a new SSC. If the SSC were to be put off until high-T_c superconducting technology comes of age, the machine would not be built for many years.

At present the operating cost of a completed SSC facility is estimated to total about $270 million per year (in 1987 dollars). Cryogenics are reckoned to run at less than 5% of the full operating cost—or some $13 million per year. The Department of Energy and the Office of Management and Budget figure that if a reliable high-T_c superconducting material can be found, it may take as much as $300 million to conduct R&D for materials fabrication and accelerator design over five or six years.

Evaluations. DOE has already considered using more powerful magnets to reduce the size of the SSC. The final design is not based on using the strongest possible magnets but rather on optimizing the magnetic field at the lowest cost. Higher-field magnets would require stronger structures to withstand the electromagnetic forces, and that would cost plenty. Even if the new ceramic superconductors could be made as cheaply as those currently in use or under development, the DOE analysis would still hold, according to an OMB evaluation.

Another examination of the subject, performed by Gene Loh (University of Utah), Uriel Nauenberg (University of Colorado) and Peter Carruthers (University of Arizona) for the Western States SSC Working Group, decided that "any realistic assessment of the time needed to develop the new high-temperature superconductors to the stage where they are economically and industrially competitive for large magnet application is long, probably 15 to 25 years.... Therefore it would be judicious to proceed to construct the SSC with conventional superconducting technology and begin the technological development of new higher-field magnets for a future SSC higher-energy upgrade about 15 years from now."

—Irwin Goodwin

Academies select panel to judge ideal SSC site

At the request of the Department of Energy, the National Academies of Sciences and Engineering have organized a 20-member committee to evaluate the site proposals submitted by the states for the Superconducting Super Collider. The list of members, announced by the academies on 18 June, boasts 10 physicists, among them the committee chairman, Edward A. Frieman, director of the Scripps Institution of Oceanography. Frieman was deputy director of Princeton's Plasma Physics Laboratory from 1952 to 1979, when he became DOE's director of energy research, the same position from which his successor, Alvin W. Trivelpiece, stimulated government support for the gargantuan particle accelerator.

The committee's job is to evaluate the proposals that get a passing grade from a DOE technical task force under Wilmot (Bill) Hess, associate director for high-energy and nuclear physics. Hess's team will do a first reading of the proposals, determining if the sites meet the minimum eligibility criteria set by the agency. This test of whether a site has any chance at all in the competition will be decided entirely on the information the states submit about the topography and geology of the proposed site, the plan for making the land available free to the government, the environmental and socioeconomic features of the area, and the availability of electrical power, water, housing, schools, transportation and cultural amenities.

It is within the academies committee that the more rigorous elimination will take place. The committee is expected to select some five or six of the best sites in a procedure similar to the one used by an earlier Academy of Sciences panel for the 200-GeV accelerator in 1966. In that competition, which was fiercely fought out in Congress and the Bureau of the Budget, the academy found six sites to be virtually equal. The winner was Batavia, Illinois, near Chicago, where Fermilab was built.

According to Glenn Seaborg and Gerald Tape, who were on the Atomic Energy Commission at the time, the agency made the final decision—though not without the approval of President Lyndon B. Johnson, his White House aides have told historians. Johnson's interest in the selection procedure went back to 1963, when he killed attempts of the now defunct Midwest Universities Research Associates to build another high-energy accelerator in Wisconsin, arguing that ones already operated at Berkeley and Brookhaven. But he succumbed a few years later, it seems, to the pleas of Illinois Senators Paul Douglas, who had invariably supported the President on foreign and domestic policies, and Everett M. Dirksen, Republican minority leader, who needed to be wooed on critical issues.

Similar political pressures may be expected in the SSC site selection. The academies committee, however, is above that battle. Unlike its earlier counterpart, the new committee is unlikely to visit any site for fear of tipping off physicists and politicians that a location is possibly among the finalists and running the risk of fending off entreaties. What's more, since the committee plans to spend only three months examining the proposals, it is unlikely to have time for site visits.

Besides Frieman, the members are:

Robert McCormick Adams, secretary of the Smithsonian Institution
William J. Baumol, professor of economics, Princeton University
John E. Cantlon, environmental biologist and vice president, Michigan State University
Lloyd Cluff, geosciences manager, Pacific Gas and Electric Co
Ernest D. Courant, senior physicist, Brookhaven National Laboratory
Don Deere, consultant engineer for geology and rock mechanics
Thomas E. Everhart, physicist, chancellor of the University of Illinois at Urbana–Champaign and president-elect of Caltech
Marvin L. Goldberger, physicist and director, Institute for Advanced Study, Princeton
William R. Gould, chairman emeritus, Southern California Edison Co
Lieutenant General Elvin Heiberg III, chief of Army engineers
Edward G. Jefferson, retired chairman and chief executive officer, E. I. du Pont de Nemours & Co
Herman Leonard, professor of economics, Kennedy School of Government, Harvard University
Paul J. Reardon, physicist, vice president and director of experimental projects, Science Application International Corp
Nicholas P. Samios, director, Brookhaven National Laboratory
Roy F. Schwitters, chairman, department of physics, Harvard University
Charles H. Townes, professor of physics, University of California at Berkeley
Victoria Tschinkel, former secretary for the environment in the state of Florida and member of DOE's Energy Research Advisory Board for six years
Steven Weinberg, professor of physics, University of Texas at Austin
Stanley Wojcicki, professor of physics, Stanford University

DOE's timetable calls for the committee to submit its short list to the agency by next December. "To ensure the integrity of the DOE's competitive selection process and to prevent the details of proposals still under consideration from being made public," says Trivelpiece's signed preface to the *Invitation for Site Proposals for the SSC*, issued last April, "the DOE does not intend to authorize the release of the NAS–NAE report until after the DOE has identified the preferred site." The timetable puts that decision in July 1988. It should be easy to determine the preferred site shortly thereafter, when tests and surveys are conducted to meet the requirements of the National Environmental Policy Act and related laws. In the event, the choice should be known before the Reagan Administration departs in January 1989—unless, of course, the DOE plan is disrupted by act of Congress.

—Irwin Goodwin