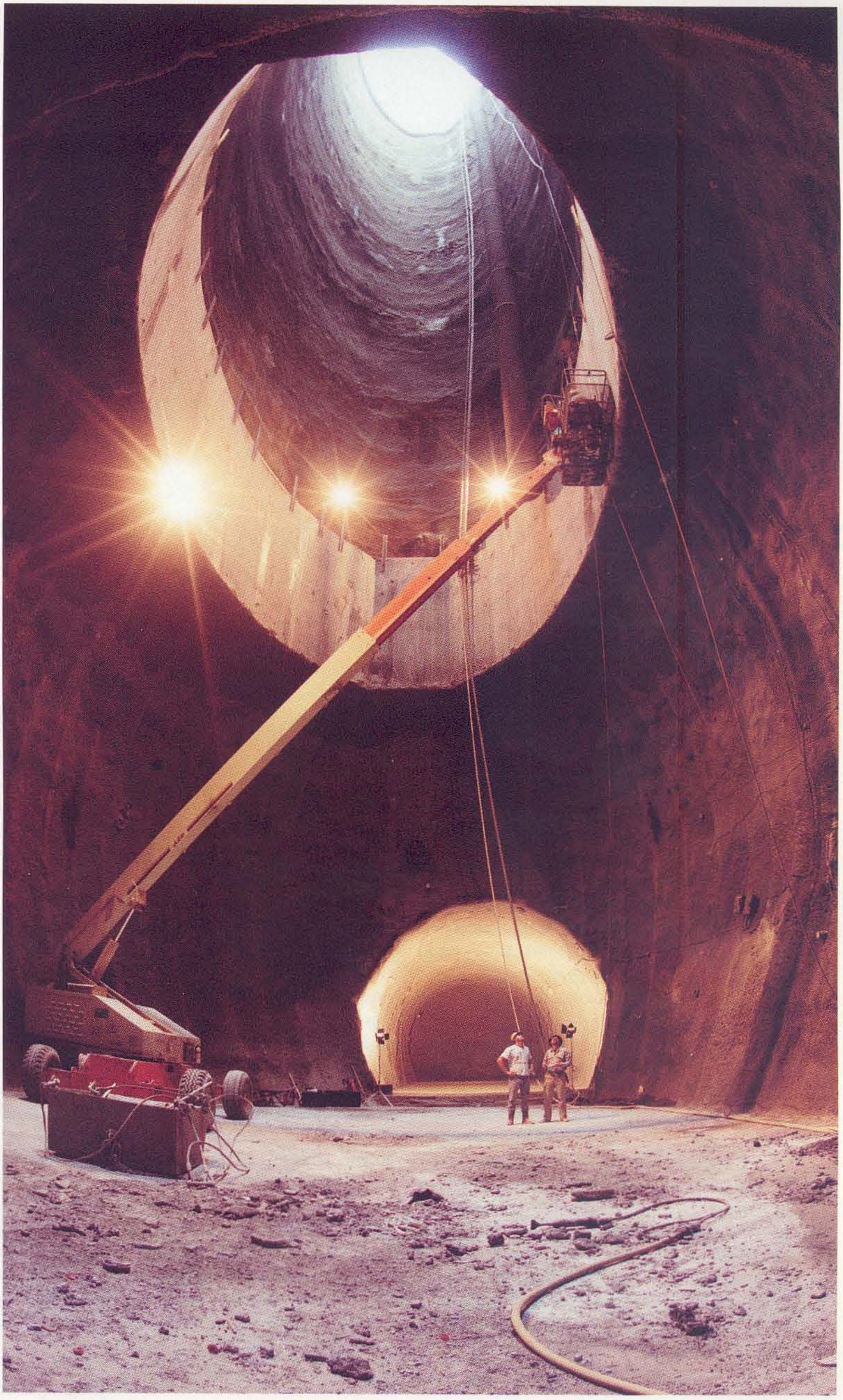


Good-bye to the SSC: On the Life and Death of the Superconducting Super Collider

by Daniel J. Kevles

Particle accelerators have been called the cathedrals of the modern era.

The collider ring's 14-foot-diameter tunnel was blasted about 250 feet deep through Texas rock. This large shaft connects the tunnel to the surface near the injector area and was designed for lowering the long superconducting magnets into the tunnel.

After the atomic bombings of Hiroshima and Nagasaki in 1945, American physicists became a kind of secular establishment, with the power to influence policy and obtain state resources largely on faith and with an enviable degree of freedom from political control. What brought them to power is, to a considerable degree, what kept them there for most of the last half century—the identification of physics with national security. Throughout the Cold War they were crucial figures in maintaining American superiority in arms, advising upon defense policy in relationship to technical possibilities, training students who populated university, industrial, and federal laboratories, including weapons establishments, and contributing to the high-technology postwar economy—both indirectly, through military spin-offs, and directly, through research in myriad fields such as transistors, computers, lasers, and fiber optics.

The most prominent and influential physicists were in elementary-particle research, which is occupied with exploring the fundamental structure of matter and energy and uses high-energy accelerators as its primary experimental tool. Constituting about 10 percent of the American physics community in the 1980s, high-energy physicists had won many of the Nobel Prizes awarded to Americans and had been key figures in the nation's strategic defense and science policy-making councils. During the postwar decades, elementary-particle physics prospered handsomely, not least from a reading of history: seemingly impractical research in nuclear physics had led to the decidedly tangible result of the atomic bomb; thus, research in particle physics had to be pursued because it might produce a similarly practical surprise. In the context of the Cold War, particle physics provided an insurance policy that if something important to national security emerged unexpectedly, the United States would have the knowledge ahead of the Soviet Union.

Particle accelerators have been called the cathedrals of the modern era. Those of recent vintage are huge machines, with dimensions measured in miles. Many work by sending charged particles repeatedly around a circular track, adding energy to them at every pass. (The measure of energy is the electron volt, which is what an electron gains by crossing an electric potential difference of one volt.) The United States' flagship accelerator, with a circular track four miles in circumference, is at the Fermi National Laboratory—Fermilab—in Batavia, Illinois. At the end of the seventies, a project was initiated to double the energy of that machine by using superconducting magnets to keep the particle beam on its circular course. (Certain materials, when cooled to close to absolute zero, become superconducting, which is to say that they conduct current with no resistance and, hence, no energy loss.) The doubling would endow the Fermi machine with an energy of one trillion electron volts (Tev), making it a tevatron and one of the most powerful particle accelerators on earth.

In 1983, however, American high-energy physicists called for the construction of the Superconducting Super Collider (SSC)—a

The SSC's acceleration energy would be 60 times greater than the CERN collider's, making it by far the most powerful proton accelerator in the world.

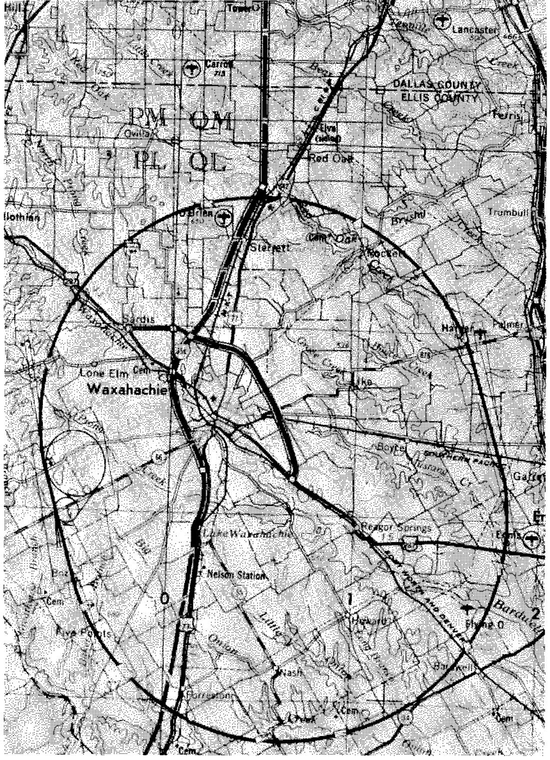
gargantuan machine that would accelerate two beams of protons, each in the opposite direction from the other, through a circular tunnel some 52 miles in circumference to a kinetic energy of 20 trillion electron volts and a collision energy of 40 trillion electron volts. Allowing for inflation, the SSC was estimated to cost roughly $6 billion to construct over 10 years. Although federal funding for all of physics had declined through the seventies, following the Vietnam War, it had been rising dramatically with the Reagan administration's defense buildup, particularly its embrace of the Strategic Defense Initiative, and with the national absorption with economic competitiveness. In that high-technology climate, the SSC was endorsed by the Department of Energy, the agency that funds almost all high-energy physics in the United States, and, in January 1987, by President Ronald Reagan.

Steven Weinberg

High-energy physicists wanted the SSC partly because they saw it as indispensable to further development of the overarching structure of elementary-particle theory that they call the Standard Model. The Standard Model holds that all matter is formed of particles called quarks and leptons, that the existence and behavior of these particles is governed by different types of force fields, and that the interactions of these fields are mediated by the exchange of elementary particles. The Standard Model theoretically unifies three of the fundamental natural forces—the electromagnetic, the weak, and the strong—though the fourth, gravity, has remained beyond its reach. In 1983 experimental evidence was obtained in confirmation of one of the Standard Model's major triumphs: the theoretical analysis that at sufficiently high energies a deep symmetry characterizes both the electromagnetic and the weak forces so that they operate as a single "electroweak" force. By then, too, the Standard Model was being advantageously exploited to understand the behavior of the universe close to the time of its origin in the Big Bang, when enormous energies were concentrated in a very small volume, indicating, for example, that as the universe cooled, the deep symmetry of the electroweak force was broken in a way that generated the electromagnetic and weak forces.

Nevertheless, the Standard Model posed a number of unanswered questions, including some in its electroweak sector. High-energy physicists were particularly interested in probing for evidence of what they call the Higgs force field (named after Peter Higgs, of Edinburgh University, who had most clearly postulated it in 1964), which was believed to play a role in the shattering of electroweak unification and to be necessary to account for why the particles in electromagnetic and weak interactions possess the masses they do; indeed, why they have any mass at all. On theoretical grounds, it was expected that the SSC would reveal the presence of an exchange particle called the Higgs boson, which was predicted to have a mass so large that a machine operating at the SSC's energy would be needed to produce it. The SSC meant a great deal to the theoretical physicist Steven Weinberg, who had independently codevised electroweak theory in 1967 and shared the 1979 Nobel Prize in physics for his contributions to it. In eloquent testimony to Congress and in elegant prose for the public (in a book called *Dreams of a Final Theory*, published in 1992) Weinberg emphasized that physicists were "desperate" for the machine because they were "stuck" as physicists in their progress toward what he called "a final theory" of nature—a complete, comprehensive, and consistent theory that would account for all the known forces, fields, and particles in the universe.

Yet high-energy enthusiasts also wanted the SSC because they worried that the United States was losing its leadership in elementary-particle physics to Europe, which was supporting the grand multinational accelerator installation called CERN (for *Conseil Européen de Recherche Nucléaire*), on the French-Swiss border. The SSC's acceleration energy would be 60 times greater than the CERN collider's, making it by far the most powerful proton accelerator in the world. It would restore the United States' preeminence in high-energy physics, and, in the view of Leon Lederman, the director of Fermilab, reestablish



The SSC's 52-mile tunnel was designed to ring the Texas town of Waxahachie, just south of the Dallas County line. The location of the accelerators (a linear accelerator and three boosters), which would provide protons to the collider, is drawn as two circles on the west side of the ring, where Highway 66 crosses it.

its "national pride and technological self-confidence."

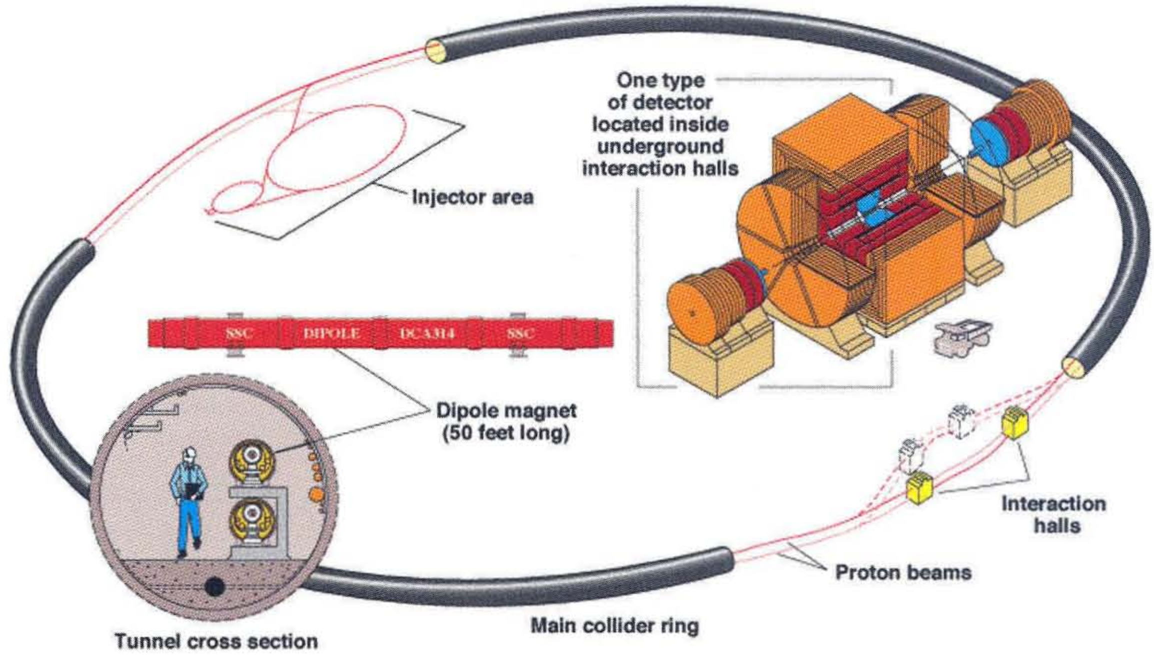
Lederman, one of the principal spokesmen for the SSC, was an accomplished high-energy experimentalist who had made Nobel Prize–winning contributions to the development of the Standard Model during the 1960s (although the prize itself did not come until 1988). He was a fixture at congressional hearings on the collider, an unbridled advocate of its merits who frankly avowed that the primary justification for the collider was intellectual curiosity. Yet neither Lederman nor his fellow enthusiasts minded claiming that the SSC would pay considerable practical dividends to the American political economy. Enlisting the historical record of particle physics in their cause, they pointed to its past spin-offs and extrapolated from them to sketch the SSC's practical promises. Although the knowledge of nature that high-energy accelerators revealed had not been in and of itself practically relevant, the machines themselves had yielded useful dividends—radiation used in the processing of foods and materials and in the treatment of cancer; powerful light beams that etch integrated circuits onto semiconductor chips at much greater densities than could otherwise have been achieved; and computerized methods and sophisticated technologies that screen and analyze superabundant data.

Leon Lederman

Advocates of the SSC declared that protons from one of its low-energy injector accelerators would be diverted to cancer treatment in a facility on the site. They stressed that the SSC would yield advances in superconducting technologies that would contribute to innovations in power generation and transportation in the form, for example, of magnetically levitated trains. Lederman testified before the House Budget Committee that work on superconducting magnets for Fermilab and other accelerators had already "enabled" the deployment of the "powerful medical diagnostic tool called magnetic resonance imaging." Deputy Secretary of Energy W. Henson Moore III, a lawyer and former congressman from Louisiana, went further, indicating to a congressional committee that magnetic resonance imaging had been made possible by the work on superconducting magnets for the SSC itself.

It did not take a physicist to recognize that the SSC, with its $6 billion price tag, would produce an abundance of industrial contracts and, as one congressman put it, "an awful lot of jobs"—some 5,000 to 8,000 of them alone where the SSC would be built. More than half the states in the Union took steps to enter the site-selection competition, which began on April 1, 1987, and which the *New Republic* called an invitation to "quark barrel politics." On November 10, 1988, the day after George Bush was elected to the presidency, Secretary of Energy John S. Herrington announced at a press conference that the winner was Waxahachie, Texas, a town of 18,000 people about 25 miles southwest of Dallas, which had been ranked outstanding on every major criterion by a site-selection committee of the National Academy of Sciences. Texas had also promised the project one billion dollars, a sweetener offered by no other state. Observers could not help but notice, however, that the president-elect called Texas home and that the Texas congressional delegation was a powerhouse. In 1989 Congress voted decisively to fund the construction of the SSC, accepting a total cost for its construction of $5.9 billion.

While physicists, like other American scientists, have embraced political engagement in arenas of technological policy such as arms control, they have tended to resist it on behalf of their science, fearing that it would undercut their social authority, not to mention their self-image, if they behaved like just another interest group in American society. But, among physicists who did not work in elementary particles, the SSC inflamed long-simmering resentments against the power, authority, and budgetary leverage of those who did. Once the collider became a serious public-policy initiative, opposition to it from within the physics community was openly expressed in a variety of forums, especially hearings before the House Committee on Space,



How the world's biggest collider would have worked (not to scale): Protons are collected and accelerated in a string of accelerators in the injection area; proton beams are hurled in opposite directions around the ring at energies of 20 trillion electron volts through two pipes containing superconducting magnets; the beams cross and the protons collide in the underground interaction halls, where huge detectors wait to observe the results.

The budgetary caps made R&D funding into a zero-sum game, which . . . turned the super collider project into what a high official of the American Physics Society called "perhaps the most divisive issue ever to confront the physics community."

Science, and Technology. The dissenters were not, as Senator Dale Bumpers, a leading enemy of the collider, remarked, "people who just fell off the turnip truck." They included former presidents of the American Physics Society and Nobel laureates. Most of them respected and admired particle physics, but, like Nobel Laureate J. Robert Schrieffer, who called himself a "loyal opponent" of the initiative to build the machine, none of them thought it a justifiable use of public resources at its multi-billion-dollar price tag.

The opposition fire intensified after the passage, in 1990, of the Omnibus Budget Reconciliation Act, which imposed caps on defense, nondiscretionary spending such as social security, and discretionary expenditures, including research and development. It limited increases in each area to the rate of inflation while prohibiting the transfer of any savings achieved in one to either of the others. By then, changes in the design of the SSC had been made that would raise its quality and reliability but would also increase its total cost—to $8.249 billion (in 1990 dollars), according to the official estimate of the Department of Energy. The budgetary caps made R&D funding into a zero-sum game, which sent a frisson of apprehension through the American physics community and turned the super collider project into what a high official of the American Physics Society called "perhaps the most divisive issue ever to confront the physics community."

The budgetary claims of the SSC particularly exercised physicists who, like Schrieffer, worked in condensed matter, a branch of physics that deals with matter in the messy aggregate of the solid state and is related to such practical arenas as superconductivity and semiconductors. According to Philip Anderson, also a Nobel Prize winner for his work in condensed-matter physics, high-energy research took a disproportionately large share of the federal basic physics research budget—receiving some 10 times more money per capita than did other fields. Its practitioners also appeared to consider their enterprise intellectually more profound. Although solid-state physics has basic conundrums to be explained, it has been mocked by Murray Gell-Mann, the brilliant particle theorist and Nobel laureate, as "squalid state" physics. Anderson told Congress that the laws of solid-state physics were every bit as fundamental as those of elementary-particle theory and, more important, that fields like condensed matter served society at far lower cost and with far greater payoffs than did elementary-particle research. "Dollar for dollar," Anderson testified in 1989, articulating the conviction of many of his colleagues, "we in condensed-matter physics have spun off a lot more billions than the particle physicists . . . and we can honestly promise to continue to do so."

Condensed-matter physicists were, to say the least, annoyed by the spin-off benefits that had been claimed for high-energy accelerators, especially the alleged decisive contributions to the development of magnetic resonance imaging (MRI) that had been implied by Lederman and explicitly declared by Deputy Secretary Moore. Nicolaas Bloembergen, who had won a Nobel Prize for his research on a precursor to lasers, testified in 1991 that neither superconducting

Sherwood Boehlert

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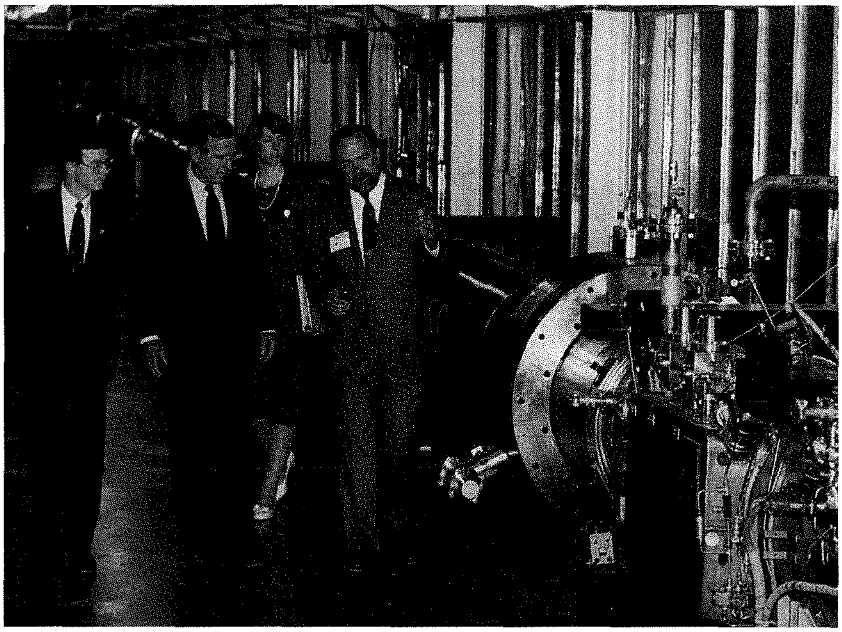
magnets, the superconducting magnet industry, nor magnetic resonance imaging had come primarily from the development of accelerators, adding in a follow-up letter to an official at Fermilab that was entered into evidence in a congressional hearing in the spring of 1992, that "MRI would be alive and well today even if Fermilab had never existed." To Anderson, "the saddest sight of all is to see officials of the department responsible for our energy supply deliberately misleading Congress and the public with these false claims, and to see my particle-physics colleagues, many of whom I admire and respect, sitting by and acquiescing in such claims."

In the spring of 1992, amid the deepening economic recession, the attacks against the SSC were drawing blood on Capitol Hill. The Reagan and Bush administrations had assured Congress that fully one third of the collider's total construction costs would come from nonfederal sources, which now meant, at the elevated price of the machine, $2.7 billion. A billion dollars would come from Texas, leaving $1.7 billion to be provided by foreign countries; much of that was expected to come from Japan. Yet by 1992 nothing had been pledged from abroad except $50 million of in-kind contributions by India. On the night of June 17, 1992, the House voted to terminate the SSC by the hefty margin of 232 to 181, stunning its advocates everywhere into a frantic effort to reverse the decision in the Senate. The effort was successful, but early in 1993 Washington insiders were saying that, with a new Congress and a new administration in office, the prospects of the SSC's surviving another year were problematic. Voters had sent 113 new members to the House, refreshing more than a quarter of that body, with the message to cut spending. President Bill Clinton reiterated a campaign endorsement of the SSC, but his first budget called for stretching out the project by an additional three years—a ploy that would reduce its annual cost but raise the total to almost $11 billion, according to a report from the General Accounting Office, in May 1993, which declared the SSC behind schedule and already over budget.

In the House, now as in 1992, the SSC faced unremitting opposition from its chief critic, Sherwood Boehlert, a moderate Republican of independent mind and pungent tongue from the Oneida district in upstate New York. The year before, he had derided the SSC as a medley of endlessly increasing costs, threats to other sciences, and unwarranted predictions of spin-offs for competitiveness, declaring, "Contrary to all the hype, the SSC will not cure cancer, will not provide a solution to the problem of male-pattern baldness, and will not guarantee a World Series victory for the Chicago Cubs." On June 24, 1993, Boehlert and Jim Slattery, a middle-of-the-road Democrat from Topeka, Kansas, introduced an appropriations amendment to slay the SSC once and for all, with Boehlert summarily averring, "In short, the costs are immediate, real, uncontrolled, and escalating; the benefits are distant, theoretical, and limited. You don't have to be an atomic scientist to figure how that calculation works out. We can't afford the SSC right now."

The defense of the SSC was led by Waxahachie's congressman, Joe Barton, a smart, arch-conservative Republican, who in 1992 had spearheaded an unsuccessful fight for a balanced-budget amendment to the Constitution. (This prompted Congressman Lawrence J. Smith, an outspoken liberal Democrat from Florida and an enemy of the SSC, to gibe that Barton, the budget balancer, was "obviously a contortionist, being on two opposite sides of fiscal policy at the same time.") Barton's case was strengthened by allies from California, hard hit by defense cutbacks, and nearby districts in Texas, who pointed out that the SSC had already provided hundreds of millions of dollars for defense conversion, creating thousands of jobs and awarding some 20,000 contracts to businesses in most states of the Union, more than 10 percent of them to firms owned by women or members of minority groups. Congresswomen Carrie P. Meek, from Miami, Florida, and Eddie Bernice Johnson, from the Dallas area—both black and both newly elected to the House—praised the



Roy Schwitters (right), director of the SSC Laboratory, escorts President George Bush on a tour of the SSC in 1992. Here they view the test facility for the strings of superconducting magnets designed to accelerate the beam of protons through the collider tunnel.

SSC, with Meek declaring, "It gives us a chance, the minorities in this country . . . to get into jobs that are developed by technology and science."

The House nevertheless voted once again, on June 24, to end the SSC, by a strongly bipartisan vote of 280 to 150, which was so lopsided as to make the project's friends wonder whether this time it could prevail in the Senate. The SSC's most important friend in the upper chamber was J. Bennett Johnston, of Louisiana, a Senate insider who chaired the Energy and Natural Resources Committee and also the Energy and Water Development Appropriations Subcommittee, both of which had jurisdiction over the collider project. Originally an opponent of the SSC, Johnston had turned into a formidable ally after General Dynamics committed itself to producing superconducting magnets for the accelerator at a large factory in Hammond, Louisiana. An outspoken opponent of the Strategic Defense Initiative, he counted the collider as important to the post-Cold War, high-technology economy. He had also developed a genuine intellectual enthusiasm for the quest after the Higgs boson, providing the Senate with several rare moments of attempted instruction in theoretical physics, including the observation that particle physics, with its cosmological extensions, touched "the hand of God."

Johnston worked his magic again, guiding the Senate on the morning of September 30 to reject an attempt to kill the SSC by a bipartisan majority of 57 to 42. The SSC cleared a House-Senate conference with its full appropriation embedded in a multi-billion-dollar energy and water appropriations bill, but it was decisively and irrevocably turned back in the House, on October 19, by the overwhelming vote of 282 to 143. "The SSC has been lynched, and we have to bury the body," Johnston snapped.

Johnston, like a number of analysts, blamed the execution on the House freshmen, typically describing them as "the product of an angry electorate that wants to cut projects and cut perks." True enough, the 113 House freshmen voted against the collider by almost three to one and, in the charged economizing atmosphere, it did not help matters that not a single yen had been pledged for the SSC. Yet the incumbent House voted against the SSC by a margin of 200 to 111, almost two to one. And from the beginning the House, as well as the Senate, had been of divided mind on the issue of foreign cost sharing—on the one hand wanting the money but, on the other, not wanting to relinquish any of the project's jobs or control of its technological spin-offs to the nation's economic competitors. Besides, the Congress of the United States is selective in its economizing, tending to be tolerant of expenditures for high national purposes, especially if they are reinforced by important local political and economic interests. Far more important than the freshman effect or the foreign deficiency in shaping the fate of the SSC was the fact that the SSC failed to qualify on national or local grounds.

Missing at the national level was what had made physics, including its high-energy branch, so important since World War II—real or imagined service to national security. Several times both the House and the Senate debates made the point advanced at summary length in a report that the General Accounting Office prepared for Senator John Warner, a conservative Democrat from Virginia, who presented it to the Congress on May 18, 1993. The point was that the SSC had no direct bearing on national security, though its indirect benefits, such as more powerful superconducting magnets and conversion awards to defense contractors, could assist the military indirectly. Indirect defense benefits no longer sufficed. The SSC was disadvantaged by the general outlook, which went almost without saying but which was made explicit by Senator Dave Durenberger, a Minnesota Republican: "If we were engaged in a scientific competition with a global superpower like the former Soviet Union, and if this project would lead to an enhancement of our national security, then I would be willing to continue funding the project. But . . . we face no such threat."

Dissociated from national security, the SSC was subject to the play of domestic politics, presidential as well as congressional. Clinton was far less active in its support than Bush. The clout of the Texas congressional delegation had been weakened. To be sure, SSC expenditures reached almost everywhere: by 1991, more than $100 million in grants and contracts for SSC research had gone to scientists and engineers at 90 universities and institutes in roughly 30 states. But the vast majority of procurement contracts (the big money) had gone to only five states—Massachusetts, New York, Illinois, California, and, of course, Texas, which took the lion's share. Besides, as Slattery pointed out to the House, most states would pay far more for the project than they would receive from it. Boehlert summarized, with only slight exaggeration, the political dynamic of the SSC: "My colleagues will notice that the proponents of the SSC are from Texas, Texas, Texas, Texas, and Louisiana, and maybe someone from California. But my colleagues will also notice that the opponents are . . . from all across the country."

Respectful of the science or not, the opponents of the SSC considered the project simply too expensive, yet its opponents were not all simply economizers as such. The congressional debates revealed that while many wanted to kill the collider solely for the sake of cutting the budget, many other enemies of the SSC insisted that expenditures for it were unwarranted when appropriations for social programs such as Medicare, nutrition, vaccination, education, and inner-city redevelopment were being cut. Analysis of the 1993 House SSC vote in light of the voting record of incumbents on other issues shows that its opponents comprised a coalition of conservatives and, in greater proportion, liberals. Its defenders included a higher proportion of conservatives, a tendency echoed by the vote in the Senate that year, where the collider won only a bare majority of Democrats but prevailed among Republicans by more than 2 to 1. In 1993, Congressman Ralph M. Hall, of Texas, wondered wistfully whether the SSC might not "bring us back one more time to the financial position that we had in the early 1950s and the geopolitical strength that we had." The SSC tended to receive support from the minority of House members who, following a more specific but similarly wishful preference, voted for the Strategic Defense Initiative. In the end, the collider resolved into a creature of Cold War conservatism at a time when the majority of Congress—both liberals and conservatives—was undergoing a fundamental change to a post-Cold War political order.

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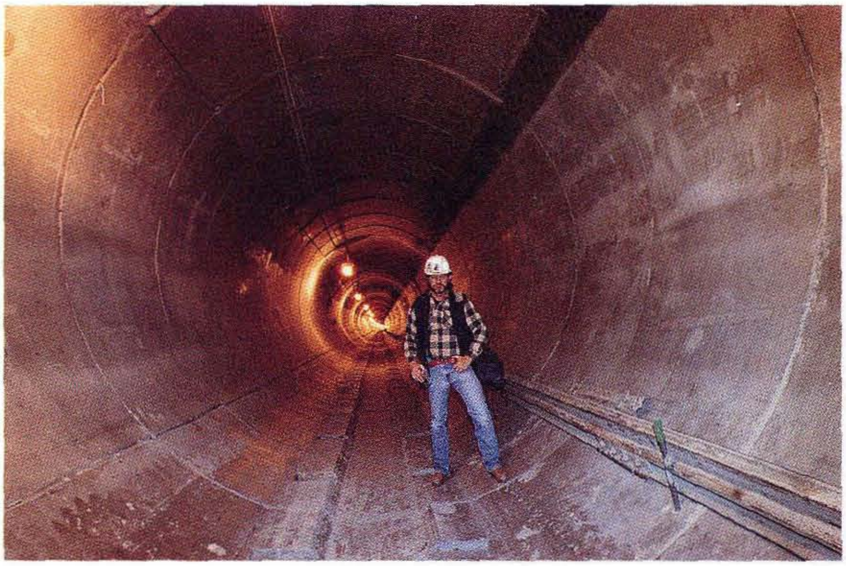
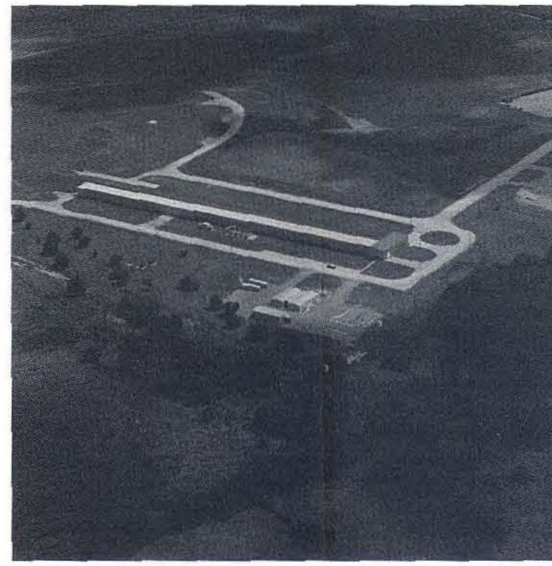
As far as many pro-SSC physicists saw it, the collider's fate defined one of the chief features of the new order: that, as Roy Schwitters, the head of the project, remonstrated, "curiosity-driven science is somehow frivolous, and a luxury we can no longer afford." Leaders of American physics variously declared the collider's death to mean that high-energy physics had no future in the United States, that the country was relinquishing its role as a scientific leader, and that the half-century-old partnership between science and the federal government was ending. At the level of grand interpretation, Murray Gell-Mann called the cancellation "a conspicuous setback for human civilization." At the level where scientists worried about jobs and opportunities, the killing of the collider was proclaimed in a letter to *Physics Today* to have sent a clear message: "Physics and physicists are not valued in this country! Enter this profession at your peril!"

The death of the SSC exacerbated a broad contraction of opportunities in physics that had begun with the defense cutbacks and economic downturn around 1990.

The death of the SSC exacerbated a broad contraction of opportunities in physics that had begun with the defense cutbacks and economic downturn around 1990. By every measure, the supply of physicists exceeded demand in most fields and in every sector—government, industry, and academia—and predictions were that prospects would worsen as new physics PhDs continued to pour out of the graduate schools and emigré Russian physicists sought work in the United States. Young physicists applied by the hundreds for single faculty positions, even at liberal arts colleges with limited research programs. Those who did land jobs reported that competition for funds was so intense that they





When construction halted, about 15 miles of tunnel had been dug (photographer John Bird stands in a section of the empty collider tunnel above), and the facility for housing the linear accelerator (above, right) was almost complete. The Linac was finished after the vote and will remain to provide protons for cancer treatment. The facility was built by a disadvantaged small-business contractor from Fort Worth.

spent more time trying to raise money, often without success, than doing research. Some theorists left physics to deploy their analytical skills on Wall Street. Asked about the job market in 1994, one young physicist, quoted in *Science,* called it about average: "worse than last year, but better than next year."

The physicist Walter E. Massey, director of the National Science Foundation at the opening of the 1990s, observed a "growing perception that the research community considers itself exempt from the pressures of competition and accountability and 'entitled' to public funding." The impression of entitlement left by high-energy physicists—their tendency to measure the quality of society by how generously it supported their enterprise—irritated many people and infuriated some. Rustum Roy, a distinguished materials scientist at Pennsylvania State University who considered high-energy physicists "spoiled brats" for wanting a multi-billion-dollar accelerator when the country was running up $200-billion annual deficits, was gleeful at the death of the SSC and told a *New York Times* reporter that "this comeuppance for high-energy physics was long overdue." During the 1970s, observers had warned that exponential growth in physics, measured by PhD production or any other indicator, could not continue indefinitely; the warnings had been forgotten amid the defense-driven resumption of expansion in the 1980s. Now, to resolve the emerging crisis, Lederman proposed a restoration of the golden age of autonomy and opulence that had characterized science in the United States in the quarter century after World War II, urging a doubling of the funding for all of academic science, which meant enlarging its annual budget by 10 billion federal dollars. Frank Press, who had been President Jimmy Carter's Science Adviser and was president of the National Academy of Sciences, reminded Lederman and his allies that "no nation can write a blank check for science" and that, if the number of scientists had doubled in 20 years, there was no reason why taxpayers should come to the rescue, or why science should take precedence over other meritorious demands on the federal treasury.

The vote against the SSC was not a vote against science or for an end to the longstanding partnership of science and government; rather, it signified the kind of change in federal scientific research that occurred a century ago, when hard times came to the earth sciences. During the years following the Civil War, federal support of research in the earth sciences had expanded enormously, supplying unprecedented patronage to disciplines relevant to one of the major national missions of the era: the exploration, settlement, and economic development of the Far West. Yet the degree of expansion in federal science generated suspicion among a number of fiscal conservatives that the government was spending too much money for seemingly impractical work, and among populist-oriented congressmen who did not see why funds should be spent for research on the slimy things of the earth when human beings were earning too little to keep their farms. During the depression of the 1890s, the conservatives and reformers formed a

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coalition that sharply reduced the government's support of impractical science and forced the federal scientific agencies onto bare-bones budgets. The depression was the immediate occasion for the cutbacks, but there were other reasons also: the geographical frontier had closed, the country was emphasizing the agenda of its urban industrial order, and the earth-science agencies were no longer at the top of it.

The economic downturn of the early 1990s was, similarly, the occasion for a fundamental shift in the longstanding orientation of federal policy for the physical sciences, a redirection of the science-government partnership's aims in line with the felt needs of post-Cold War circumstances. Emphasis would go to what policy makers were calling "strategic" or "targeted" areas of research—fields likely to produce results for practical purposes, such as strengthening the nation's economic competitiveness or its ability to deal with global environmental change. Emphasis would also be given to science education, and to efforts to diversify the social composition of the scientific professions so that they would better mirror the increasingly multicultural makeup of American society. (American physics remained predominantly white and male, with women accounting for only 10 percent of its yearly crop of doctorates, and blacks and Hispanics less than 2 percent.)

Yet the vote against the SSC was not a vote against all curiosity-driven research either. Virtually no significant policy maker at either end of Pennsylvania Avenue urged that all undirected, untargeted basic research be denied federal largesse. The Congress maintained appropriations at a substantial level for many areas of basic physics, awarding even high-energy research dispensation for several new initiatives in the same year that it killed the SSC. Physics continues to be recognized as a mighty source of innovation and, as such, essential to sustain in a high-technology society.

But not at any price. Observers in and out of government agreed that in the new era the big-science effort required to pursue the questions that the SSC would have addressed had to be genuinely international. During the hearings on the collider, the further internationalization of high-energy physics had been called for by critics like Anderson and Schrieffer, who remarked, "Not to build the SSC is conceivable. Not to pursue particle physics is totally unacceptable to those who are concerned with and depend upon the health of science." In 1994, high-energy policy makers were giving serious consideration to the United States' joining CERN, if CERN would accept a formal American contingent, and to participating in the development of a new accelerator, called the Large Hadron Collider, likely to be built there. The machine would smash protons and antiprotons together at only 40 percent of the SSC's energy but was thought to have a chance, albeit a small one, at finding the Higgs boson. When Sherwood Boehlert was told about the prospect at a congressional hearing, he responded favorably, calling the idea "a thoughtful specific blueprint for how to pursue this most basic of basic sciences."

Whether the federal government would commit substantial funds to CERN would be a matter for political decision—political in the best sense, that is, that politics is the means by which the state resolves conflicting claims for the allocation of resources. So, similarly, would politics determine the country's mix of investment in targeted and untargeted research. The scarcity of resources for research provoked competing interests in physics to resort to the political process in the SSC controversy, and it will likely prompt them to make a habit of the practice. With the end of the Cold War, American physics has been disestablished; its claims to a share of the public purse are no longer taken largely on faith or fulfilled with little obligation to accountability. Physics in the United States has been irreversibly incorporated into the conventional political process, become a creature of political democracy, its fortunes, like those of other interest groups, contingent on the outcome of the fray. □

Dan Kevles adapted this article from a new preface to his 1978 book, The Physicists: The History of a Scientific Community in Modern America, *which has been rereleased this month by Harvard University Press. Kevles has been a member of the Caltech faculty since 1964, after receiving his AB and PhD degrees from Princeton. Appointed professor of history in 1978, he was named the J. O. and Juliette Koepfli Professor of the Humanities in 1986. He is also the author of* In the Name of Eugenics: Genetics and the Uses of Human Heredity *(1985) and coeditor of* The Code of Codes: Scientific and Social Issues in the Human Genome Project *(1992). Kevles is head of Caltech's program in Science, Ethics, and Public Policy.*