WITH A NEW PREFACE BY THE AUTHOR

THE PHYSICISTS

The History of a Scientific Community in Modern America

DANIEL J. KEVLES

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THE PHYSICISTS

For Bettyann, Beth, and Jonathan,
who have little known this
dancer from this dance

Preface, 1995

The Death of the Superconducting Super Collider in the Life of American Physics

This book accounts for the generation of American physicists who changed the world by forging atomic weapons in the laboratories of World War II, notably at the famed installation on the mesa at Los Alamos, New Mexico. It explores the roots of their revolutionary achievements in the efforts of their predecessors toward building American physics from the Civil War onward, addressing how they overcame the obstacles to the practice of pure science in the American democratic culture to win world standing in their discipline and recognition as assets to American society. It is also occupied with how, after the atomic bombings of Hiroshima and Nagasaki a half century ago, physicists of the Los Alamos generation 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. During World War II, a physicists' war, physicists not only devised the atomic bomb but also crafted numerous other technical miracles, including radar, rockets, and proximity fuses. Throughout the Cold War, they were crucial figures in maintaining American superiority in arms, advising on defense policy in relationship to technical possibilities, training students who joined the weapons laboratories, and carrying out basic research under military contracts. A number of them also fought to slow or halt the arms race, contributing importantly to the movements that led to the Nuclear Test Ban Treaty and the Strategic Arms Limitation Treaties, as well as energizing opposition to President Ronald Reagan's Strategic Defense Initiative. Whichever side they took on issues of arms control and defense, physicists remained honored and empowered because they remained essential in determining the shape and capabilities of American national security.

They were also valued for their role in the development of the high-

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technology postwar economy. Their contributions—made both indirectly, through military spinoffs, and directly, through academic and industrial research—have been essential in myriad fields, including transistors, computers, lasers, and fiber optics, areas that in recent years about one-third of physics Ph.D.s entered a short time after receiving their degrees. State officials, their eyes on the regional economy, established academically connected centers of technological innovation to exploit pertinent areas of physics, among other fields. Politicos at every level extolled research and training in the sciences as requirements of competitiveness in the international marketplace.

Under the circumstances, pure physics prospered handsomely in the United States, receiving abundant support for the pursuit of studies in esoteric areas of knowledge that were mainly conducted either in academia or in federally supported installations such as the Brookhaven National Laboratory, on Long Island. The federal budget for basic physics rose steadily through the late 1960s, turned down, then started rising again in the 1980s. A similar pattern characterized the American production of physics Ph.D.s, although senior members of the field found it disturbing that a steadily increasing fraction of the new recruits—42 percent in 1985–86—came from foreign countries. A good deal of basic research and training was conducted in small groups and concerned the physics of condensed matter, a branch of physics that is related to such practical arenas as semiconductors and superconductivity but that has its own basic conundrums to be explained.

A fresh demonstration of the value of such research was provided when, in 1986, several scientists at the IBM research laboratory in Zurich, Switzerland, reported a dramatic development in superconductivity. Discovered in 1911, superconductivity is the ability of certain materials to conduct electrical current with no resistance when they are cooled to within a few degrees of absolute zero, which is almost 460 degrees below zero on the Fahrenheit scale. The development in the 1960s of new alloys such as niobium-titanium, which permitted the maintenance of large superconducting currents at temperatures as high as 10 degrees above absolute zero, opened the door to the practical exploitation of superconductivity, primarily in the development of superconducting magnets. Such devices could achieve very powerful magnetic fields at high currents with no loss of energy. The scope of such exploitation was limited by several factors, however, including the cost of cooling the alloys to the extremely low temperatures at which they become superconducting. The IBM scientists devised a new compound that achieved superconductivity at a much higher temperature—30 degrees above absolute zero—and in 1987 physicists at several universities in the United States created still other compounds that would superconduct at 90 degrees above absolute zero. The results were scientifically exciting—at the American Physical Society meetings in March 1987, more than a thousand physicists came to hear talks on what was rapidly called high-temperature superconductivity—and the economic implications of the results were declared to be breathtaking by President Reagan himself.

The type case of Big Science was elementary-particle physics, a field in which some 10 percent of American physicists (about 4,000 practitioners) absorbed themselves in the 1980s and whose essential experimental tool was the particle accelerator. The first accelerators were devised in the early 1930s to explore the atomic nucleus; they operated at energies in the range of tens of millions of electron volts, which is characteristic of nuclear reactions. (An electron volt is the energy that an electron gains by crossing a difference in electric potential of one volt.) In the postwar decades, particle accelerators left nuclear physics behind, moving into the high-energy region necessary to probe the elemental structure of matter and forces. The accelerators successively designed for the task were increasingly sizable machines costing hundreds of millions of federal dollars. They ran at billions of electron volts and were exploited by large groups of researchers. High-energy physicists came to represent an influential subfield composed of overlapping groups: physicists who designed and built the accelerators; physicists who did experiments with them; and physicists who theorized about the meaning of the data they produced.

High-energy physicists were among the most prominent members of their profession—key figures in the nation's strategic defense and science policymaking councils and winners of many of the Nobel prizes awarded in physics to Americans. When they spoke, the American government tended to listen, at least about policy for basic physics. One of the leading rationales for the policy that gave abundant funds to particle physics was 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.

In the mid-1960s, high-energy physicists won authorization to build a still more powerful accelerator, to be located at the new Fermi National Accelerator Laboratory in Batavia, Illinois—despite widespread objection to proceeding with "the expensive irrelevance of a 200 billion electron volt accelerator to any real present national problem," as the *New York Times* editorialized, noting the troubles besetting the country as a result of the Vietnam War and the social tensions of the cities.[1] The Batavia accelerator was completed on time, within budget, and with a top energy of 500 instead of just 200 billion electron volts, making it the most powerful accelerator on earth. In the early 1980s, high-energy physicists urged the construction of a new, gargantuan accelerator—the Superconducting Super Collider, commonly called the SSC. It would be far more energetic than the original machine at Fermilab (as the Batavia installation was known) and would encircle an area 160 times as great. Nothing better symbolized the continuing power and influence of high-energy physicists in American society than the

[1] *New York Times*, July 16, 1967, p. 12.

serious consideration that Congress began, in 1985, to give the SSC project, which was then estimated to cost some $4 billion to build and several hundred million dollars a year to operate.

Yet now, just nine years later, the SSC is dead, having been killed in the House of Representatives in October 1993, partly in response to angry opposition from physicists themselves. A high official of the American Physical Society called the Super Collider project "perhaps the most divisive issue ever to confront the physics community."[2] The turn of events sent the nation's high-energy physicists reeling, but bad times have suddenly hit virtually every area of American physics. The sharp change in fortunes no doubt derived in part from the recent recession and the ongoing sluggishness of the economy. But far more important was the singular event of recent years—the end of the Cold War. In the post–Cold War environment, the death of the SSC expressed more than a setback for high-energy physics. It symbolized the end of an era for physics in the United States, especially its high-energy branch, and its relationship to the federal government.

Readers of this book will learn that the fate of physics in recent years was roughly adumbrated a century ago, when hard times overcame the earth sciences in the United States. 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 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 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 occasion for the cutbacks, but the geographical frontier had closed, the country was emphasizing the agenda of its urban industrial order, and the earth-sciences agencies were no longer at the top of it.

A similar coalition formed in the 1960s, holding in one or another of its quarters that physics was too great an absorber of tax dollars, too little attentive to social issues, and too much a creature of the military and the war in Vietnam. It was this coalition that forced the leveling in the growth of federal funds for physics. The turn provoked much more far-reaching effects than the cutbacks of the 1890s, when federal patronage of science had been largely confined to support of work carried out directly by federal agencies. By the mid-1970s, in constant dollars, the federal budget for research and

[2] Steven Weinberg, *Dreams of a Final Theory: The Search for the Fundamental Laws of Nature* (New York, 1992), pp. 54–55.

development was 20 percent lower than it had been in 1967, but the number of physicists was higher. Since the federal government was the primary supporter of basic physics research everywhere it was practiced, the contraction adversely affected virtually the entire enterprise of the physical sciences in the United States, making jobs in academic physics, the center of basic research in many areas of the subject, particularly hard to find. High-energy accelerators were being shut down, research programs terminated.

The trend was well advanced by the time I finished writing this book, in the late 1970s, and it prompted me to conclude that American physicists had undergone a degree of disestablishment. Yet shortly thereafter, the disestablishment appeared to ease. The country was said to have been made militarily vulnerable by the reductions in spending for defense research and development (R&D) and by the weakening of the academic base for technical preparedness. It was declared to be economically vulnerable to vigorous foreign competition, especially from Japan, not only in the world's but even in the nation's own technological markets. Such concerns prompted a boost in federal research expenditures under President Jimmy Carter that continued under President Ronald Reagan, despite the budget slashing that marked the early Reagan years. By 1983, in constant dollars, federal R&D expenditures had reached the level of 1967. The largest share of the increase went to defense, many of whose research programs tended to be directed at a variety of physics-related subjects, including semiconductors, optics, lasers, integrated circuits—subjects that can yield results both of robust economic and of sensitive military utility. A then-recent Ph.D. in quantum electrodynamics, surprised to find herself engaged in defense-connected work at the Texas Research Institute, remarked that "all roads seem to lead to the Pentagon."[3] Support for high-energy physics followed the budgetary rise in the physical sciences, providing the high-energy community with means enough to initiate, in 1977, construction of a powerful new accelerator, called Isabelle, at Brookhaven that would use superconducting magnets to keep the beam on course. Funds also became available to upgrade the main existing machines, including the Stanford Linear Accelerator and the one at Fermilab whose energy would be doubled—to one trillion electron volts (TeV), making it a Tevatron—by similar use of superconducting magnets.

Still, enthusiasts of high-energy physics worried that resources remained inadequate to maintain American leadership in the field. They rightly argued that Europe, which supported the grand multinational accelerator installation CERN (for Conseil Européen de Recherche Nucléaire), on the French-Swiss border, was spending twice as much on high-energy research relative to GNP as was the United States. (Indeed, American investment in research in all the physical sciences was, in proportion to its population and wealth, similarly low.) In 1982, Fermilab had money to operate at only about a quarter of its capacity, while CERN was running at almost a three-quarters level. More-

[3] Bruce Schechter, "Beyond the Ivory Tower," *Physics Today*, 39 (June 1986), 36.

over, European accelerators were beginning to outclass their American counterparts in the significance of the experimental evidence they were producing and the energies they were seeking to reach. Sidney Drell, the deputy director of the Stanford Linear Accelerator, plaintively remarked: "The quality of a society is indicated by the questions it asks. One of these questions is, What is man made of? The answer is matter, and it is the nature of matter that is the domain of high-energy physics. The society that doesn't ask this question is a suffering society."[4]

The drive for more powerful accelerators was symbiotically tied to the development and testing of elementary-particle theory, which in the 1970s had achieved a formal, overarching structure called the Standard Model. The model seeks to account for three of the four known forces in nature: the electromagnetic force, which acts on ordinary charged particles such as electrons and protons; the weak force, which is involved in radioactive decay; and the strong force, which holds together the particles in the atomic nucleus. (The fourth force, gravity, has so far remained beyond the reach of any accepted theoretical 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. Some of these exchange particles tend to be very massive. Since mass is the equivalent of energy, they can represent the compaction of an enormous quantity of energy, an amount rarely found concentrated in single reactions in the contemporary universe. However, they can be—and many had been—produced in the high-energy reactions that occur in accelerators, adding weight to the evidentiary foundation of the Standard Model, which by 1980 included the detection of all the leptons and quarks (except of the "top" quark) whose existence it predicted. In one of its major triumphs, the Standard Model also unifies the electromagnetic and the weak forces, convincingly holding that at high energies a deep symmetry characterizes both of them and they operate as a single "electroweak" force. And it has accomplished plausible though not entirely satisfying unions of the strong force with the electroweak one in a so-called Grand Unified Theory.

A number of particle theorists exploited the Standard Model to understand the behavior of the universe close to the time of its origin in a Big Bang, when enormous energies were concentrated in a very small volume. The Big Bang hypothesis had been bolstered by several arresting classes of observational evidence, particularly detection of a low-energy microwave background radiation that theory predicted should be present throughout the contemporary universe as a residue of its colossal birthing explosion. Using the Standard Model, physicists speculated about cosmological processes back to the first few minutes of the universe, even to its first tiny fractions of a micro-second. High-energy accelerators go some distance toward reproduc-

[4] Bruce Schechter and Gary Taubes, "Battle of the Big Machines," *Discover* (April 1982), p. 68.

ing the energies that were present at those early moments; thus, together with the Standard Model, they provide a window directly onto some of the phenomena of the early universe—strongly suggesting, 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. Grand Unified Theory, by conceptually analyzing phenomena at still higher energies, reaches back theoretically to the behavior of the universe at still earlier moments. It permits physicists to ask not only what the properties of the universe are but why it possesses them. At the beginning of the 1980s, several groups of physicists showed that the Grand Unified Theory could plausibly account for some of those properties. Exploiting the theory, they generated a line of analysis that many physicists found compelling, partly because it solves several conundrums about how the universe came to be the way it is, but also because it provides an entry to the early universe that allows many—if not all—of its features to be calculated rather than posited as arbitrary initial conditions.

The accelerators of the 1970s were inadequate by any measure to test all the facets and assumptions of the Standard Model (and no earthly machine could conceivably reach the enormous energies—a trillion times the designed energy of the Tevatron—necessary to test the Grand Unified Theory). At the opening of the 1980s, electroweak unification theory had been experimentally confirmed indirectly but awaited direct confirmation of one of its essential points—that the electromagnetic force and the weak force are mediated by the photon plus three massive particles from a class called bosons, specifically, the Z-zero, the W-plus, and the W-minus. (The designation "W," a long-standing commonplace in theoretical speculations, stood for weak, whereas the name "Z" had been coined by Steven Weinberg, then at Harvard University, who independently co-devised electroweak theory in 1967, and who would share the Nobel Prize in physics in 1979 for his contributions to it. Weinberg, who in 1983 moved to the University of Texas at Austin, says that he picked "Z" as the name for the W's new sibling partly "because Z is the last letter of the alphabet, and I hoped that this would be the last member of the family."[5]) It was an ambition of high-energy physicists in the United States to beat the Europeans to the punch in observing the particles, using one of the accelerators whose upgrading was then under way. Problems with the development of the necessary superconducting magnets had slowed the enhancement of the accelerator at Fermilab, however, and had put the Isabelle project completely on hold. And then, in January 1983, a team at CERN announced that they had detected the two W particles, and in June, that they had found the Z. In an editorial, the *New York Times* twitted the country's high-energy community: "Europe 3, U.S. Not Even Z-Zero," adding, "The 3–0 loss in the boson race cries out for earnest revenge."[6] What American high-energy physicists were resolved upon was not revenge but a restoration of preeminence—via the Superconducting Super Collider.

[5] Weinberg, *Dreams*, pp. 119–120.
[6] *New York Times*, June 6, 1983, p. 16.

Their eagerness for the SSC was prompted in significant part by the intellectual exigencies of elementary particle physics. A particle accelerator operating beyond a trillion volts would reveal phenomena that must have occurred in the early moments of the universe, when electroweak unity came to be broken; and in any case certain essential theoretical problems connected with the Standard Model could be illuminated only at accelerator energies of at least five to ten trillion electron volts. 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 was considered necessary to explain 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 Super Collider would reveal the presence of a new particle called the Higgs boson. Leon Lederman, the director of Fermilab, attempted to explain the Higgs boson's relationship to the behavior of the particles that come out of electroweak unification by telling a Senate hearing to think of a group of extraterrestrials watching a soccer game who are somehow incapable of seeing the ball: "They see a lot of people running around seemingly at random in a chaotic disorganized activity, but if someone postulates the existence of a soccer ball, then the whole thing becomes clear and simple and elegant."[7] Theory predicted that the Higgs soccer ball is a particle with a mass equivalent to an energy of up to a trillion electron volts, which is about a thousand times the mass of the proton.

Lederman was one of the principal spokesmen for the SSC—in congressional hearings an unbridled advocate of its merits, which he advanced with colloquial and often comic directness. An accomplished high-energy experimentalist, he 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. For some time, along with other physicists, he had been dreaming of building a huge, multinationally sponsored accelerator powerful enough to reveal the Higgs particle, but at a meeting of high-energy physicists in Snowmass, Colorado, in mid-1982, he had advanced the idea of the United States's recapturing leadership in the field by building a super, predominantly American, machine.[8] In July 1983, the High Energy Physics Advisory Panel to the Department of Energy, the agency that funds almost all high-energy machines in the United States, issued a formal recommendation for the SSC, stressing its essential importance to further progress in elementary-particle physics.

The proposed machine, a circular accelerator, would operate at perhaps

[7] U.S. Congress, Senate, *Joint Hearing before the Committee on Energy and Natural Resources and the Subcommittee on Energy and Water Development, Importance and Status of the Superconducting Super Collider*, 102nd Cong., 2nd Sess., June 30, 1992, p. 25.

[8] Adrienne Kolb and Lillian Hoddeson, "The Mirage of the 'World Accelerator for World Peace' and the Origins of the SSC, 1953–1983," *HSPS: Historical Studies in the Physical and Biological Sciences*, 24 (Part 1; 1993), 117–120.

ten trillion electron volts, an energy a million times greater than that of the accelerators in the 1930s and high enough to reveal phenomena in the Higgs region. It seemed technically feasible: the superconducting magnets for Isabelle and for the Fermilab enhancement had by now been successfully developed; they could be scaled up and would serve to keep the SSC particle beam on its curving track. The machine was estimated to be costly, but the project seemed so important to the high-energy community that many—though not all—of its policymaking members were willing to scrap Isabelle to get it. (Even though its magnet problems had been solved, Isabelle would not be powerful enough to explore the energy region where Higgs phenomena would manifest themselves. Nick Samios, the director of Brookhaven, nevertheless called the scrapping of Isabelle "one of the dumbest decisions ever made in high energy physics."[9]) In November 1983, the Department of Energy halted work on Isabelle and obtained authority to redirect its funds to research on the SSC.

Extensive technical studies of the proposed machine followed, and by 1986 the SSC had taken detailed conceptual shape. It would accelerate two beams of protons, each in the opposite direction from the other, through a circular tunnel some fifty-two miles in circumference to an energy of twenty trillion electron volts. Because they would be rotating contrary to each other, the two proton beams could be made to collide with an energy of forty trillion electron volts. (Such an energy was needed to explore phenomena in the Higgs range—that is, of several trillion electron volts—because a great deal of the acceleration energy is shared among the constituents of the proton, which do not participate in the interactions of interest, leaving only a fraction of that energy available for the particles that do.) The SSC's acceleration energy would be sixty times greater than the CERN collider's and twenty times greater than that of Fermilab's upgraded machine. Allowing for inflation, it would cost roughly $6 billion to construct over ten years. It would be by far the most powerful proton accelerator in the world, could be ready by the 1990s, and would restore the United States's preeminence in high-energy physics.

The price might have been high, but to the devotees of particle physics it unquestionably merited payment. To many of them, particle physics was a transcendent pursuit made holy by its quest for a theory of physical nature at its deepest level and for how that theory might illuminate the origins and development of the universe. Some of them likened the great particle accelerators to modern-day cathedrals. Indeed, their devotion to the newly fashioned mixture of particle physics and cosmology resonated with popular educated culture of the period, in which particle-physics theories of the early universe were prompting an avalanche of quasi-religious treatises. (In *Roger's Version*, the novelist John Updike expressed the gist of the outpourings in the

[9] The report is reprinted in U.S. Congress, House, *Hearings before the Committee on Science, Space, and Technology: Superconducting Super Collider*, 100th Cong., 1st Sess., April 7, 8, 9, 1987, pp. 59–132 (hereafter, House, *SST Hearings*, 1987); Weinberg, *Dreams*, p. 265.

remarks of an upstart computer hacker to the divinity teacher Roger Lambert: "Dr. Lambert, aren't you excited by what I've been trying to describe? God is *breaking through.* They've been scraping away at physical reality all these centuries, and now the layer of the little left we don't understand is so fine God's face is staring right out at us."[10]) Lederman would dip into the cultural trend by referring to the Higgs boson as "the God Particle" in a book that he published in 1993 under that title. The book, which illuminatingly recounted the history of atomic and particle physics, especially the experimental side of the high-energy epoch, amounted to a historical brief for the SSC, including a rendering of what Lederman semimockingly called "The Very New Testament": "And the Lord came down to see the accelerator, which the children of men builded. And the Lord said, Behold the people are unconfounding my confounding. And the Lord sighed and said, Go to, let us go down, and there give them the God Particle so that they may see how beautiful is the universe I have made."[11]

Steven Weinberg declined to indulge in such notions. In a book on the very early universe, he had written that "the more the universe seems comprehensible, the more it also seems pointless"—by which he meant in part that the more the fundamental principles of the universe were revealed, the less they seemed to have to do with us. When given an opportunity in a congressional hearing to comment on whether the SSC might reveal the face of God, he maintained a prudent silence.[12] What Weinberg preferred to emphasize was that physicists were "desperate" for the SSC 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 accounted for all the known forces, fields, and particles in the universe.[13] In eloquent testimony before Congress and elegant prose for the public—in a book called *Dreams of a Final Theory,* published in 1992—he explained the intellectual content of the Standard Model, including the questions concerning it that needed to be explored at the energy level of the Higgs field and that the SSC would address. The SSC was a sure bet, Weinberg stressed, not because it would reveal the deity or enhance American prestige, but because even if it did not find the Higgs boson it would expose the existence of new forces and phenomena that would bring the achievement of a final theory closer.

For the most part, conventional religious implications had no bearing on the particle-physics community's eagerness for further knowledge. They located themselves in the traditional drive to understand nature that had originated with the ancients and that—in the view of both Lederman and Weinberg—the United States might break faith with only at its peril. In 1985, in an article on the SSC, Lederman and Sheldon Glashow, a co-winner of

[10] John Updike, *Roger's Version* (New York, 1986), p. 20.

[11] Leon Lederman, with Dick Teresi, *The God Particle: If the Universe Is the Answer, What Is the Question?* (New York, 1993), p. 24.

[12] Steven Weinberg, *The First Three Minutes* (updated edition; New York, 1988), p. 154; Weinberg, *Dreams,* pp. 253–254, 243–244.

[13] Weinberg, testimony, House, *SST Hearings,* 1987, pp. 243–244.

the Nobel Prize with Weinberg for his role in the development of electroweak theory, averred that "high-energy physics must go in this direction or terminate the 3000-year-old quest for a comprehension of the architecture of the subnuclear world," adding, "If we forgo the opportunity that [the] SSC offers for the 1990s, the loss will not only be to our science but also to the broader issue of national pride and technological self-confidence. When we were children, America did most things best. So it should again."[14]

Such arguments received a friendly reception in congressional hearings on the progress of the SSC planning program, where the question of whether God was to be found in the particles cropped up only occasionally, but where more than one congressman reminded scientific witnesses that the SSC might be an unaffordable luxury. At a House hearing in 1985, Congressman Joe L. Barton of Texas asked the physicist Alvin W. Trivelpiece whether, high-energy physics being an international enterprise, the United States should build the SSC by itself. Trivelpiece, the director of the Office of Energy Research in the Department of Energy and an enthusiast of the SSC, was working hard on its behalf. He had to say, nevertheless, that "a project of this sort is almost certainly going to be an international activity one way or another," continuing, "The idea or the luxury that this would be done entirely within the United States exclusively by U.S. scientists with exclusive U.S. support is unrealistic."[15] To the congressmen, the costs of the project had to be closely counted, as always, but especially now that the passage of the Gramm-Rudman-Hollings Act had committed both Capitol Hill and the White House to deficit reduction.

President Reagan's science adviser, the physicist George Keyworth, was on record that if the SSC were built elsewhere it would be "a serious blow to U.S. scientific leadership."[16] Trivelpiece persuaded Secretary of Energy John S. Herrington, a California attorney who had come to his post in January 1985 freely admitting that he knew nothing about energy issues, nuclear or otherwise, to support the SSC. Herrington, who was close to Reagan, lobbied hard for the project, but he faced opposition from hard-nosed officials who saw no need for it and worried about its impact on the budget. In a showdown at the White House, President Reagan, having heard the arguments on both sides, issued his decision in the form of an anecdote about the Oakland Raiders star quarterback Kenny Stabler. Taking a card from his pocket, Reagan read a poem by Jack London that began: "I would rather be ashes than dust / I would rather that my spark / Should burn out in a brilliant blaze / Than it should be stifled in dry rot"—and ended: "I shall

[14] Sheldon L. Glashow and Leon M. Lederman, "The SSC: A Machine for the Nineties," *Physics Today*, 38 (March 1985), 37, 34.

[15] U.S. Congress, House, *Hearing before the Subcommittee on Energy Development and Applications of the Committee on Science and Technology: Status and Plans of the United States and CERN High Energy Physics Programs and the Superconducting Super Collider [SSC]*, 99th Cong., 1st Sess., Oct. 29, 1985, p. 20.

[16] Gary Taubes, "The Atom," Collision over the Super Collider," *Discover*, July 1985, p. 62.

use my time." According to Reagan, Stabler, when once asked about the poem, said that it meant "Throw deep," which Herrington took to mean that he should go for the SSC.[17]

The arguments being made for the SSC in and out of the White House, including in newspapers, magazines, and congressional hearings, indicated that there was more than one intended receiver—not only the intellectual adventurers of high-energy physics but also their prospective allies in the American political economy. Enthusiasts of the SSC held that it would pay considerable practical dividends. The outcomes of cutting-edge scientific endeavors being largely unpredictable, they could not be very specific about the future; they thus enlisted the historical record of particle physics, pointing to its past spinoffs and extrapolating from them to sketch the SSC's practical promises. Once accelerators had moved beyond the relatively low energies of nuclear interactions to the higher energies of elementary-particle research, the knowledge of nature that they revealed was, in and of itself, no longer practically relevant. Elementary-particle research had produced many highly trained physicists, however, a number of whom migrated from the field and successfully deployed their skills in other branches of science and technology. And since the first inventions of particle accelerators, a series of useful dividends had come from the development and operation of the machines themselves.

For example, accelerators running in the range of tens of millions of electron volts supply radiations used in the processing of foods and materials and in the treatment of cancer. (At a House hearing in April 1987, Lederman declared that "one person in eight in this room will at one point in their life be treated in a hospital by an accelerator, generally in a beneficial manner."[18]) Accelerators at the level of hundreds of millions to several billion electron volts provide sources of powerful light beams that can etch integrated circuits onto semiconductor chips at much greater densities than could otherwise be achieved. And most contemporary high-energy accelerators rely on computerized methods and sophisticated technologies to screen and analyze the superabundance of data they generate that have been exploited in many other fields. The drive to develop machines operating at or near a trillion volts—the push for Isabelle and then the Doubler at Fermilab—had produced significant advances in the technologies of superconducting magnets. In 1991, Lederman testified to the House Budget Committee that these advances had "enabled" the deployment of the "powerful medical diagnostic tool called magnetic resonance imaging," continuing, "Some 25 companies are making these things in a new industry that is approaching $1 billion a year."[19]

Advocates of the SSC declared that it, too, would assist in the battle

[17] Ibid., p. 62; Irwin Goodwin, "Reagan Endorses the SSC, a Colossus among Colliders," *Physics Today*, 40 (March 1987), 48.

[18] House, *SST Hearings*, 1987, p. 263.

[19] U.S. Congress, House, *Hearing before the Task Force on Defense, Foreign Policy and Space, Committee on the Budget, Establishing Priorities in Science Funding*, 102nd Cong., 1st Sess., July 11 and 18, 1991, p. 78 (hereafter, House, *Hearing, Task Force*, 1991.)