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Report to the Chairman, Committee on the Budget, U.S. Senate

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FEDERAL RESEARCH

Status of DOE's Superconducting Super Collider

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April 15, 1991

The Honorable Jim Sasser
Chairman, Committee on the Budget
United States Senate

Dear Mr. Chairman:

In response to your March 7, 1990, request we reviewed the status of the Department of Energy's (DOE) Superconducting Super Collider (SSC), which will be located 30 miles south of Dallas, Texas. The SSC will be the world's largest high energy particle accelerator—a research tool used by physicists to seek fundamental knowledge about energy and matter. DOE recently estimated that the SSC will cost $8.2 billion (in current-year dollars).[1] You expressed concern that once the project progressed beyond the design phase, other problems could lead to further cost increases. As agreed with your office, this report provides information on the instability in tenure of DOE and SSC Laboratory project management, uncertainties related to the SSC site geology, uncertainties and risks with magnet development and production, and Texas' proposed contribution to the project's costs.

Results in Brief

Both the SSC Laboratory and DOE's SSC program office have experienced management instability because acting directors that have occupied key positions have frequently changed. In general, instability in key leadership positions can result in frequent changes of direction, diminished accountability, and little long-term operational planning. Although the SSC Laboratory revised its organization and filled its management positions in October 1990, the DOE program office still has not named a permanent manager to a key position—most notably the position of program manager to head the Office of the SSC.

Texas' 1987 site proposal was based on the expectation that the SSC tunnel would be excavated through two types of geologic formations, but a change in the shape and location of the tunnel will require excavation through a third type of geologic formation that has a high shrink-swell potential. To better understand the geology, the SSC Laboratory plans to construct a section of the SSC tunnel before beginning full-scale construction.

[1] As you subsequently requested, we are examining DOE's cost estimates as part of a separate review.

Full-size superconducting collider dipole magnets for the SSC's current design have not yet been built or tested. Dipole magnets, with one north and one south pole, guide the particle beams around the SSC. Because the design of the magnet was changed in December 1989, the tooling to build the full-size magnets is not yet available. In addition, the development schedule for these magnets is compressed and, as such, increases the risk of whether the magnets will work as intended because little time will be available to resolve any problems that may be encountered.

If the magnets do not work, the success of the SSC project will be jeopardized. To reduce the risk for the magnets, the SSC Laboratory has added 5 months to the scheduled time for starting industrial production of the magnets. Nonetheless, the magnet schedule remains compressed from development through the start of production. A critical point in the magnet development schedule is the above-ground string test, which will integrate a series of magnets with technical support systems. The successful completion of this test, currently scheduled for the third quarter of fiscal year 1992, should give reasonable assurance that the magnets and supporting systems will operate as intended.

Although Texas offered to contribute at least $1 billion plus land toward the SSC in its September 1987 site proposal, it did not specify how those funds would be used. In September 1990 DOE and Texas agreed that about $875 million of Texas' contribution would go toward items included in the SSC's $8.2 billion estimated total project cost. The remaining $125 million will be used for SSC-related activities, such as Texas-supported research and development, that are not included in the estimated total project cost.

Background

The SSC is designed to accelerate two beams of protons to nearly the speed of light before they collide with an energy of 40 trillion electron volts (TeV). Physicists will then use particle detectors to analyze the collisions to search for the presence of new subatomic particles and measure their properties. The SSC facility will consist of (1) a series of four injector accelerators to accelerate the proton beams from rest to 2 TeV; (2) an oval tunnel 54 miles in circumference (see app. I) with an average depth of 150 feet into which the beams will be injected and accelerated in opposite directions to nearly the speed of light; (3) four underground interaction halls, which will house the detectors and where experiments will be conducted by colliding the beams; (4) conventional buildings, such as a central laboratory building, industrial buildings, warehouses, and auxiliary support buildings; and (5) an infrastructure of roads and utilities.

The SSC's principal technical components are the approximately 8,600 superconducting collider dipole magnets that will bend the proton beams around the rings. These superconducting magnets, which are to be produced by private industry, have recently been redesigned. Superconducting magnets have never before been produced on such a large scale.

In April 1987 DOE issued an invitation for site proposals, asking states and others to provide the U.S. government with land on which to build and operate the SSC. In January 1989 DOE selected the site for the SSC in Ellis County, Texas, about an hour's drive south of Dallas. At the same time, DOE established the SSC Laboratory in Dallas, Texas, and selected Universities Research Association as the management and operations contractor.[2]

In January 1989 DOE also established an Office of the SSC within its Office of Energy Research. According to DOE's SSC management plan, the Office of the SSC is to be a strong centralized office responsible for the overall management of the program. More specifically, the office is responsible for, among other things, formulating SSC policy; negotiating collaborative arrangements with foreign governments; and overseeing safety, environmental, managerial, and financial matters. The Office of the SSC consists of a headquarters program office and an on-site project office located in Dallas, Texas. This project office, established in July 1989, performs on-site technical, financial, and construction monitoring and serves as the focal point for day-to-day management issues and activities with the contractor-operated SSC Laboratory.

In December 1989 the SSC Laboratory made several major design changes to increase the chances that the SSC will work. The energy of the 1-TeV injector was increased to 2 TeV, the circumference of the collider rings was increased from 52 miles to 54 miles, and the aperture size of the collider dipole magnet was increased from 40 to 50 millimeters.[3] These changes were made on the basis of new information resulting from the operation of an accelerator using superconducting magnets at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois,

[2]Universities Research Association, a consortium of 66 universities, has been DOE's contractor for the SSC national research and development program since 1984.

[3]The aperture is the diameter of the magnet's inner coil.

and magnet development for an accelerator built in Germany.[4] In January 1990 a subpanel of DOE's High Energy Physics Advisory Panel (HEPAP)[5] reported that it had reviewed the design changes and concurred with them in light of the new information.[6]

Management Instability at the SSC Laboratory and DOE's Program Office

Key positions at the SSC Laboratory and in DOE's Office of the SSC have been filled by acting directors, who have frequently changed. Acting managers in key leadership positions tend to have reduced authority and accountability over a program. For example, in a study of management at the Social Security Administration over a 10-year period, we found problems with having acting managers, with an average tenure of 17 months, in key leadership positions.[7] Short tenures, along with the acting managers' differing priorities and management approaches, resulted in frequent changes of direction, diminished accountability, and little long-term operational planning. We further reported that the majority of the agency's managers noted the reduced "clout" or effectiveness of acting officials. The SSC Laboratory recently appointed permanent directors to key positions, but DOE has not yet named a permanent program manager to direct the Office of the SSC.

SSC Laboratory Management

The SSC Laboratory has experienced management instability; it operated with acting managers in three out of six key positions until October 1990 (about 22 months after it was established in January 1989). In July 1990 the HEPAP subpanel reported that the establishment of stable management at the SSC Laboratory needed close watching.[8] The subpanel was concerned that a number of critical management positions either were not filled or were filled by acting or temporary people. In the view of the subpanel, in order for managers to work together effectively as a team dedicated to the single objective of creating a working SSC, they needed enough time to develop respect for each other.

[4] Federal Research: Super Collider Estimates and Germany's Industrially Produced Magnets (GAO/RCED-91-94FS, Feb. 12, 1991).

[5] In 1967 DOE established the High Energy Physics Advisory Panel to review DOE's high energy physics program and provide advice on overall program balance, scientific priorities, and special problems.

[6] Report of the 1990 HEPAP Subpanel on SSC Physics, DOE, Jan. 1990.

[7] Social Security Administration: Stable Leadership and Better Management Needed to Improve Effectiveness (GAO/HRD-87-39, Mar. 18, 1987).

[8] Report of the 1990 HEPAP Subpanel on SSC Cost Estimate Oversight, DOE, July 1990.

In October 1990 the SSC Laboratory revised its organization when, according to a laboratory official, the SSC moved from a design to a construction phase. The laboratory named as general manager a former vice president for a large architectural/engineering firm, with experience in managing large construction projects. At the same time, it appointed several other permanent managers by transferring managers to some divisions and hiring new managers for others. By filling these positions, the laboratory has taken action toward resolving its management instability problem.

DOE Program Management

Because of the absence of a permanent program manager to direct it, the Office of the SSC has lacked stable leadership since it was created in January 1989. The program manager's position is critical because he is responsible for the management and oversight of the planning, implementation, and direction of the construction and operation of the SSC. For the first 4 months, the office had neither a director nor an acting director. In May 1989 the Deputy Associate Director of DOE's Basic Energy Sciences Office was detailed to the position as acting director for 15 months. The current acting director, who is also the deputy associate director for the Office of the SSC, was placed in the acting position in July 1990.

DOE did not name a project manager for its on-site project office until May 1990—over 9 months after the office was established. According to the project manager, communication between the SSC Laboratory and DOE had been scattered before his appointment because a focal point for communication was lacking. The project manager believed he could become the focal point. He told us that, upon his appointment, he was able to get the SSC Laboratory and DOE management to agree within 2 weeks on a draft request for proposal for superconducting magnets that they had been discussing for about a year.

In November 1990 DOE's Inspector General also reported on key vacancies in the headquarters office—the most prominent being the position of program manager.[9] The Inspector General said that the staff vacancies contributed to delays in resolving certain critical issues and to a general lack of program direction. In response, DOE management pointed out that the staffing has increased during fiscal years 1990 and 1991 and attributed the delays to technical changes.

[9] Special Report on the Department of Energy's Superconducting Super Collider Program, Office of Inspector General, DOE, Nov. 16, 1990.

A DOE Office of Energy Research official told us that the program manager position has not been filled with a permanent director because DOE has not been able to recruit a person with the unusual set of skills needed for this position, in part because of the relatively low salary and post-employment conflict-of-interest restrictions. According to this official, the December 1990 pay increase of approximately 25 percent for Senior Executive Service positions greatly alleviated the salary problem. While the conflict-of-interest restrictions are of continuing concern to applicants, this official said that no major barriers remained to filling the program manager position on a permanent basis. In March 1991 the official said that the Office of Energy Research plans to select a permanent program manager "soon," but he was uncertain about the date.

Site Geology Adds Complexity to Construction

In March 1990 DOE approved the "footprint" (the shape and location of the land that the laboratory and accelerator will occupy) for the SSC site, allowing Texas to begin acquiring land. As originally proposed by Texas, the SSC's tunnel would have been excavated through two types of geologic formations—70 percent Austin chalk and 30 percent Taylor marl.[10] However, the site-specific footprint has been changed to include three geologic formations: approximately 29 miles of Austin chalk (about 54 percent), 18 miles of Taylor marl (about 33 percent), and 7 miles of Eagle Ford shale (about 12 percent).[11]

Although the Eagle Ford shale formation makes up only 12 percent of the SSC's tunnel, construction through the formation poses risks because of the shale's high shrink-swell potential, causing possible unstable geologic conditions. According to SSC Laboratory officials, the shale is expected to swell when the overburden of earth is removed and settle when pressure is reapplied. He added that to better understand the reaction of the shale, in December 1989 the SSC Laboratory proposed digging a large-diameter drill hole through the geologic formations. According to the SSC Laboratory's Underground Technology Advisory Panel, information on ground behavior in the Eagle Ford shale is needed at the earliest

[10] Austin chalk (primarily calcium carbonate) and Taylor marl (a gray claystone) are soft, sedimentary rocks.

[11] Eagle Ford shale is a soft rock composed of laminated layers of claylike, fine-grained sediments. A property of shale is its potential to become compressed, or shrink, under pressure and to expand, or swell, when the pressure is removed.

possible date for inclusion in preliminary and final designs.[12] However, according to DOE officials, in June 1990 the drill hole was canceled as too costly—$3 million to $5 million—because the information could be obtained elsewhere.

Instead, the laboratory planned to obtain the information by constructing a prototype installation facility—a separate underground tunnel for studying the below-ground installation of magnets and cooling systems. The advisory panel stated that field measurements at the prototype installation facility could be substituted for the drill hole data, provided the start of the facility was not delayed. In August 1990 the proposed prototype installation facility was eliminated because DOE and the SSC Laboratory decided it would be more cost effective to build a 2.6-mile section of the SSC tunnel as a prototype. According to a DOE official, this approach will also enable the SSC Laboratory to resolve more quickly the uncertainties arising from the geology. The SSC Laboratory proposes to start planning, measuring, and digging test holes for the prototype section in October 1991. The section will be dug through the Eagle Ford shale formation, and the section and its access shaft will be instrumented to measure the shale's expansion and movement characteristics.

Collider Dipole Magnets Remain a Significant Risk

The SSC Laboratory has not yet built or tested full-size collider dipole magnets of the current design. Because of the December 1989 change in design from a 40- to 50-millimeter aperture, the tooling for building these magnets is not yet available. Although testing continues on the 40-millimeter magnet, much of the needed data on the magnets' mechanics and performance will not be available until the 50-millimeter magnets are built and tested. In addition, the magnet development schedule is compressed, with many overlapping tasks. The above-ground string test scheduled for the third quarter of fiscal year 1992 is a critical milestone for determining whether the magnets and supporting systems will work together.

Collider Dipole Magnets Are Untested

To develop the superconducting magnets, the SSC Laboratory will build and test both model (1.8 meters in length) and full-size 50-millimeter (15 meters in length) magnets. Model magnets are used to test tooling and

[12]The Underground Technology Advisory Panel was convened at the request of the SSC Laboratory to review various aspects of conventional construction. The panel consists of geology and geotechnical consultants.

magnet design features for their incorporation into the design and production tooling for full-size magnets. Under this approach, the subsequent proven design is to be detailed in a series of process and performance specifications for use by private industry.

DOE's Fermilab has the lead responsibility for the research and development of the collider dipole magnet. Fermilab has continued to build magnets of the original 40-millimeter design in order to test various components, such as insulation and the superconducting wire. However, according to Fermilab officials, the 40-millimeter magnet program was reduced for fiscal year 1990 because of the design change to the 50-millimeter magnet and because budget constraints limited the amount of superconducting wire bought for 1990. As a result, two out of six proposed full-size 40-millimeter magnets were not built. According to the Magnet Systems Division Director at the SSC Laboratory, building fewer 40-millimeter magnets resulted in having less test information, but the impact on the program will be minimal because development planned for the 40-millimeter magnets will be done on the 50-millimeter magnets.

Fermilab received the tooling for the model 50-millimeter magnets in October 1990. It completed and began testing the first model magnet in December 1990. Fermilab cannot build a full-size 50-millimeter magnet because it is still procuring the tooling for the larger aperture magnets specified in the design change. Fermilab officials expected to receive the tooling for the full-size 50-millimeter magnets in April 1991, at which time they will start building them.

Collider Dipole Magnet Development Schedule Compressed

The magnet development schedule is compressed, with overlapping development stages and little or no time available between stages for resolving problems. According to an SSC Laboratory official, when problems arise in one development stage, they will be resolved in the next stage.

However, such an approach increases the magnets' risks. The HEPAP subpanel noted that the magnets are costly (about $2 billion), require additional development to achieve a proven design for a 50-millimeter aperture, need tooling and assembly methods for mass production, and must be thoroughly tested before they are committed to production. The subpanel concluded that the schedule was "not realistic" and recommended adding 6 to 12 months to the early part of the schedule to, among other things, provide more time to reduce risk for the magnets. In response to the HEPAP recommendation, the SSC Laboratory added 5 months to the time planned for industry delivery of the first production magnets.

Despite the time extension, the magnet development schedule is still compressed. For example, in July 1990 the SSC Laboratory issued a request for proposal for collider dipole magnets. According to a DOE official, in October 1990 the SSC Laboratory announced that General Dynamics and Westinghouse had been selected to enter into negotiations for the contract. Thus, the SSC Laboratory requested bids even before Fermilab began building the first model 50-millimeter magnet in October 1990.

In addition, each subsequent phase of development overlaps the preceding phase. For example, before Fermilab completes building and testing its first full-size 50-millimeter dipole magnet in November 1991, industry is scheduled to build the first full-size demonstration magnet at Fermilab in June 1991.

The first group of demonstration magnets will be tested in the above-ground string test scheduled for the third quarter of fiscal year 1992. According to SSC Laboratory officials, this above-ground string test will determine whether the 50-millimeter dipole magnets will work together and with the other SSC components, including the electrical power supply and cooling systems. If the magnets do not work, the success of the SSC project will be jeopardized. For example, in 1983, DOE terminated a collider called ISABELLE because its superconducting magnets did not work as intended. At the time 75 percent of the project's construction was completed. Therefore, the SSC Laboratory plans to ensure that the SSC magnets work before starting tunnel construction.

Following the successful completion of the string test, magnets are to be installed in the first tunnel sector to further demonstrate the underground installation and performance of the magnets when integrated with the cooling systems. The construction of the first tunnel sector of about 8 miles is scheduled to begin in the fourth quarter of fiscal year 1992.

Texas' Contribution Toward SSC's Project Cost Is Less Than $1 Billion

Texas' September 1987 site proposal stated that Texas would contribute about $1 billion plus land toward the SSC, but did not specify how much of the $1 billion would be designated for the SSC project's cost. In September 1990 DOE and Texas agreed that about $875 million of this amount will offset the SSC's total project cost. The remaining $125 million is for SSC-related costs, such as research and development, that are not included in the project's $8.2 billion estimated cost.

DOE's memorandum of understanding with Texas, effective September 1990, states that the September 1987 proposal serves as the basis for Texas' contribution to the SSC unless and until otherwise agreed to by DOE and the Texas National Research Laboratory Commission (TNRLC).[13] The memorandum of understanding does not specify what the funds will be used for other than stating that they will be dedicated to reducing the overall cost of the SSC program to the federal government.

The Acting Program Manager, Office of the SSC, and a representative of the TNRLC told us that in September 1990 DOE and the TNRLC separately agreed that Texas would contribute $875 million toward the total project cost. According to DOE's January 1991 report on the SSC baseline cost estimate, Texas will use the balance of $125 million for activities, such as Texas-supported research and development, that are not included in the total project cost.

Conclusions

DOE did not name an on-site project manager for over 9 months and has not yet named a permanent program manager for the Office of the SSC. Thus, DOE's multibillion dollar SSC program has been underway for over 2 years without stable management leadership. We recognize that it takes time for any new program to assemble personnel with the needed talents and experience. For the SSC project, this task has been particularly difficult for the top management positions because of the unique skills and experience needed to manage such a large, technically complex project. According to an official in the Office of Energy Research, with the December 1990 increase in federal executive pay rates, no major barriers remain to filling the program manager's position.

Because reliance on acting managers tends to diminish accountability, adversely affect long-term planning and decision-making, and reduce the "clout" or effectiveness of acting officials, we believe that DOE needs

[13]The Commission represents Texas in the development, financing, construction, and operation of the SSC.

to follow through on its plans and to select a permanent program manager as soon as possible.

Of the many uncertainties and risks associated with the construction of the SSC, the major technical risk concerns the collider dipole magnets. Whether the magnets will work as intended is uncertain because no full-size magnet of the current design has been built and tested. Although DOE has taken some action to reduce the risk, such as delaying the start of magnet production, uncertainties and risks remain. The schedule for developing the magnets is still compressed, and the overall risks for the magnets are high because little time will be available to resolve any problems that may be encountered. A critical test in determining whether the magnets will work as intended is the above-ground string test scheduled for the third quarter of fiscal year 1992. Following the string test, tunnel construction is scheduled to start in the fourth quarter of fiscal year 1992. The government could therefore limit its risk by not funding the tunnel construction until after the string test shows that the magnets work as intended.

Recommendation to the Secretary of Energy

We recommend that the Secretary of Energy provide the SSC program greater management stability by expeditiously following through on its plans to appoint a permanent program manager to direct the Office of the SSC.

Matter for Congressional Consideration

In deliberating the fiscal year 1992 funding for the SSC, the Congress may want to limit the risk to the federal government by making the funding of tunnel construction contingent on the successful completion of the above-ground string test of collider dipole magnets.

The objective of our review was to examine the status of DOE and SSC Laboratory project management, SSC construction, magnet development and production, and Texas' proposed $1 billion contribution. We reviewed pertinent GAO reports and DOE and SSC Laboratory documents on construction and magnet development and production. We interviewed DOE officials at headquarters and in Dallas, Texas, and SSC Laboratory officials in Dallas, to determine the status of program management, construction, and magnet development and production. We discussed magnet development and production with Fermilab officials.

We interviewed TNRLC officials in Dallas concerning Texas' contribution to the SSC.

Our review was performed between May 1990 and February 1991 in accordance with generally accepted government auditing standards. We discussed the facts in this report with DOE officials and matters related to Texas' contribution with a representative of the TNRLC. They generally agreed with the facts presented, and their comments have been incorporated where appropriate. However, as requested by your office, we did not obtain official DOE comments on a draft of this report.

As agreed with your office, we are sending copies of this report to the Secretary of Energy and other interested parties. This work was conducted under the direction of Victor S. Rezendes, Director, Energy Issues, who may be reached at (202) 275-1441 if you or your staff have any further questions. Other major contributors to this report are listed in appendix II.

Sincerely yours,

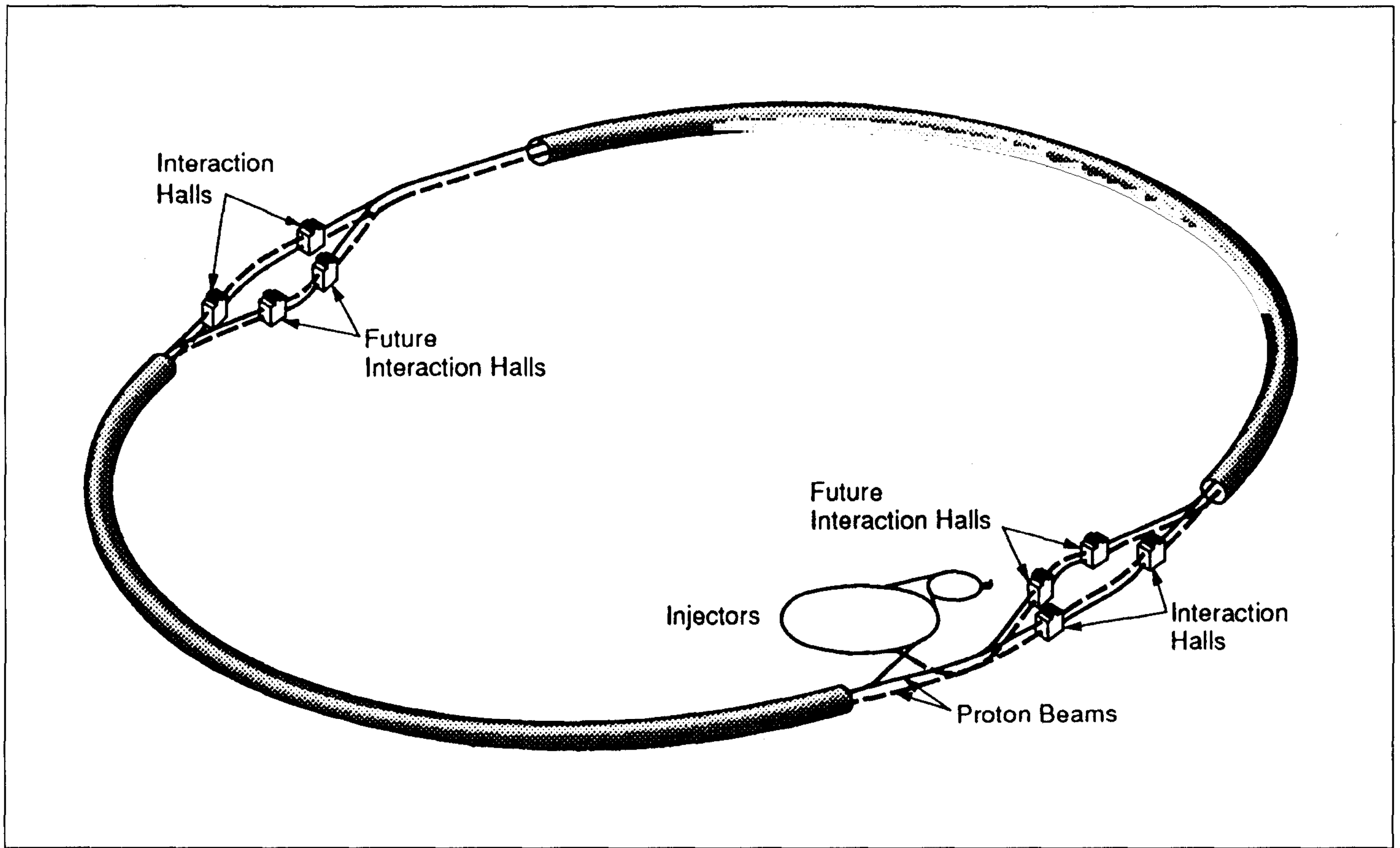
J. Dexter Peach
Assistant Comptroller General

Contents

Abbreviations

DOE	Department of Energy
GAO	General Accounting Office
HEPAP	High Energy Physics Advisory Panel
SSC	Superconducting Super Collider
TeV	trillion electron volts
TNRLC	Texas National Research Laboratory Commission

Diagram of the SSC



Source: SSC Laboratory.

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Related GAO Products

Federal Research: Super Collider Estimates and Germany's Industrially Produced Magnets (GAO/RCED-91-94FS, Feb. 12, 1991).

Energy Reports and Testimony: 1990 (GAO/RCED-91-84, Jan. 1991).

Energy: Bibliography of GAO Documents January 1986 — December 1989 (GAO/RCED-90-179, July 1990).

Federal Research: Information on Site Selection Process for DOE's Super Collider (GAO/RCED-90-33BR, Oct. 4, 1989).

Federal Research: Final Site Selection Process for DOE's Super Collider (GAO/RCED-89-129BR, June 16, 1989).

Federal Research: Determination of the Best Qualified Sites for DOE's Super Collider (GAO/RCED-89-18, Jan. 30, 1989).

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