United States General Accounting Office

GAO

Report to Congressional Requesters

February 1993

FEDERAL RESEARCH

Super Collider Is Over Budget and Behind Schedule

GAO/RCED-93-87

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-227295

February 12, 1993

The Honorable George E. Brown, Jr.
Chairman
The Honorable Robert S. Walker
Ranking Minority Member
Committee on Science, Space, and Technology
House of Representatives

In a May 4, 1992, letter, Representatives Howard Wolpe and Sherwood L. Boehlert, in their capacity as Chairman and Ranking Minority Member, Subcommittee on Investigations and Oversight, House Committee on Science, Space, and Technology, requested that we examine the cost and schedule for the Superconducting Super Collider. As agreed, we are providing our report on this request to you.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the appropriate congressional committees; the Secretary of Energy; and the Director, Office of Management and Budget. We will make copies available to other interested parties upon request.

This work was performed under the direction of Victor S. Rezendes, Director, Energy and Science Issues, who can be reached on (202) 275-1441 if you or your staff have any questions. Other major contributors to this report are listed in appendix I.

J. Dexter Peach
Assistant Comptroller General

Executive Summary

Purpose

The Superconducting Super Collider (SSC) is intended to be the world's largest particle accelerator—a basic research tool for seeking fundamental knowledge about matter and energy. In 1987, the Department of Energy (DOE) provided the Congress with an estimated total SSC project cost of $5.3 billion. Since January 1991, DOE has maintained that the SSC would be completed in 1999 at a total cost of $8.25 billion.

GAO was asked to determine whether DOE's cost and schedule assurances were based on a reliable and accurate assessment of the SSC's current and projected status. Specifically, GAO examined (1) whether the required Cost and Schedule Control System had been implemented, (2) whether the project has realized cost savings when compared with the January 1991 baseline cost estimate, (3) whether cost and schedule changes could increase the project's total estimated cost, and (4) how DOE is implementing its "build-to-cost" strategy—a plan to reduce, defer, or eliminate components to hold construction costs to baseline cost estimates. GAO is also providing its observations on the status of SSC funding.

Background

The SSC is being constructed about 30 miles south of Dallas, Texas. The accelerator complex, called the SSC Laboratory, is to consist of a series of five accelerators. The principal components of the accelerators are magnets that will steer and focus beams of protons, moving in opposite directions, until they collide, at nearly the speed of light. As proposed, the SSC will also include two large general-purpose detectors that will record the collisions for analysis by physicists.

The SSC project's prime contractor is Universities Research Association, Inc. (URA), a nonprofit corporation, which is to design, construct, and manage the SSC Laboratory. In managing the project, URA is contractually required to implement a Cost and Schedule Control System. When fully implemented, such a system shows tasks that are ahead of or behind schedule and/or under or over budget. Trends can be extrapolated from the data to produce a range of cost and schedule estimates at completion of the project or of major project segments. URA has awarded subcontracts for conventional construction and for the production and design of project equipment, such as superconducting magnets. Two collaborations of scientists have been selected to design, construct, assemble, and install the two large detectors.

DOE's 1991 baseline cost estimate of $8.25 billion for the SSC includes $2.6 billion in costs to be funded from nonfederal sources, including $1.7 billion in foreign contributions. However, it excludes some costs expected to be funded by sources other than the DOE appropriation for construction: about $500 million for the detectors, for which the SSC is seeking mainly nonfederal funding, and about $400 million for laboratory preoperations costs, which are to be funded from DOE's High Energy Physics Program.

Results in Brief

The prime contractor still has not implemented a fully functioning Cost and Schedule Control System for managing the project. URA initially gave low priority to implementing this system, and although progress is being made, a fully functioning system—with trend analysis showing the estimated cost and schedule for completing the project—will not be available until July 1993 or later.

It is unlikely that net savings have been realized. Although the prime contractor's accounts indicate that there have been savings, these accounts do not reflect complete, up-to-date records of project savings and cost increases. GAO found that known cost increases not reflected in the contractor's accounts would have offset the recognized savings.

Analyses of the major subcontractors' work in progress show that the SSC project is over budget and behind schedule. For example, trend analyses show that costs at completion for architect and engineering services and conventional construction will be $630 million over the baseline cost estimate of $1.25 billion. However, because DOE does not have a fully functioning Cost and Schedule Control System, it is not clear how much these increases will change the project's total cost and schedule.

To counter cost increases, DOE plans to follow a build-to-cost strategy. This strategy is intended to hold construction costs to baseline cost estimates by eliminating, reducing, or deferring some components, such as the detectors. Such actions would reduce the SSC's experimental capabilities and could adversely affect the experimental research. Furthermore, if such components are added later, the overall cost to the government may increase.

The SSC project has reached a crossroads at which key funding decisions need to be made. Currently, the SSC is over budget and behind schedule. Furthermore, DOE recently advised the Congress that it is confident of obtaining only about $400 million of the $1.7 billion that it is seeking from foreign contributors by 1999—leaving a shortfall of $1.3 billion. As a result, the Congress is now faced with the prospect of having to provide a substantial increase in funding to complete the project.

Principal Findings

Cost and Schedule Control System Not Yet Implemented

Although contractually required to do so, URA has not yet fully implemented the Cost and Schedule Control System. While URA has made progress in implementation, its accounting system has misallocated expenses among its accounts. Without an accurate accounting system, the reports generated by the Cost and Schedule Control System are also inaccurate and cannot be relied upon for monitoring the project's status or progress. It may take several months to refine the system's operations to ensure reliable reporting. At best, the first trend analysis showing the estimated cost and schedule for completing the project will be available in July 1993.

Project Savings Doubtful

URA's accounting records show that the project had a net savings of $2.1 million as of October 1, 1992. However, GAO found that the accounting records were incomplete and all savings and cost increases had not been recorded. If known cost increases had been promptly recorded, URA's account showing a net savings would have had a deficit of $19.9 million.

Cost Growth on Work in Progress

Major subcontractors' reports, including those for conventional construction and magnet development, have identified both cost overruns and schedule delays. DOE's analyses of the subcontractors' reports, done at GAO's request, showed that the conventional construction subcontractor was 19 percent behind schedule and 51 percent over the baseline cost. DOE's projection of this trend to completion showed that the subcontractor would be about $630 million over the $1.25 billion baseline estimate. Trend analyses of the performance by the two major magnet subcontractors predicted that their development contracts will have cost overruns of $53 million (25 percent) and $25 million (37 percent).

DOE Following the Build-To-Cost Strategy

To control cost, DOE and the SSC Laboratory have been using the build-to-cost strategy for constructing the two large detectors, which are being designed to cost a total of about $1.1 billion. The project's baseline cost estimate allows about $596 million for the two large detectors—leaving about $500 million to be funded from other sources. Although most of this additional funding has been expected to come from foreign countries, such funding has been slow to materialize. If the funding from other sources is not received, DOE is considering deleting or deferring the installation of some detector components. Some consideration is even being given to deferring construction of one of the two detectors. Installing these components after SSC construction is completed could increase the SSC's costs and require DOE to shut down the SSC for as long as 2 years.

Observations on SSC Funding

With $1.6 billion invested in the SSC, the Congress faces a critical decision point on funding, especially in light of the uncertainty of foreign contributions. In a January 14, 1993, letter, the Secretary of Energy acknowledged that without a significant contribution from Japan, it is highly doubtful that the goal of $1.7 billion in foreign funding could be met. He also acknowledged that federal funding at a level less than requested has increased the cost of the project and extended its schedule. According to DOE, a 1-year slip in the project's schedule could increase the SSC's cost by about $400 million. To hold the cost increase to $50 million and the schedule slippage to 3 months, the Secretary stated that $1.2 billion in funding would be needed in fiscal year 1994. To ensure that the project is completed on schedule, independent of foreign contributions, the Secretary recommended that in fiscal year 1994 the Congress provide $5.5 billion, representing the full remaining federal funding required, to construct the SSC.

GAO notes that funding of at least the annual amount requested by DOE would be needed if the project is to stay within its current budget and schedule. However, as evidenced by the matters discussed in this report, even providing the full amount of funding requested will not ensure that the project is built within budget and on schedule.

Agency Comments

GAO discussed the facts presented in this report with the DOE SSC Project Director and his staff. The SSC Project Director provided additional facts, such as an update of the implementation status of the Cost and Schedule Control System. GAO incorporated the additional information into this report. DOE also believed that current SSC performance trends are not reliable because the project is in its early stages and major contract modifications are being made to control future construction cost growth. As requested, GAO did not obtain written agency comments.

Contents

Abbreviations

ASST	Accelerator Systems String Test
CCB	Configuration Control Board
DOE	Department of Energy
GAO	U.S. General Accounting Office
GEM	Gammas, Electrons, and Muons
HEB	high-energy booster
LEB	low-energy booster
LINAC	linear accelerator
MEB	medium-energy booster
OIG	Office of Inspector General
PB/MK	Parsons Brinckerhoff/Morrison Knudsen
SDC	Solenoidal Detector Collaboration
SSC	Superconducting Super Collider
TeV	trillion electron volts
URA	Universities Research Association, Inc.

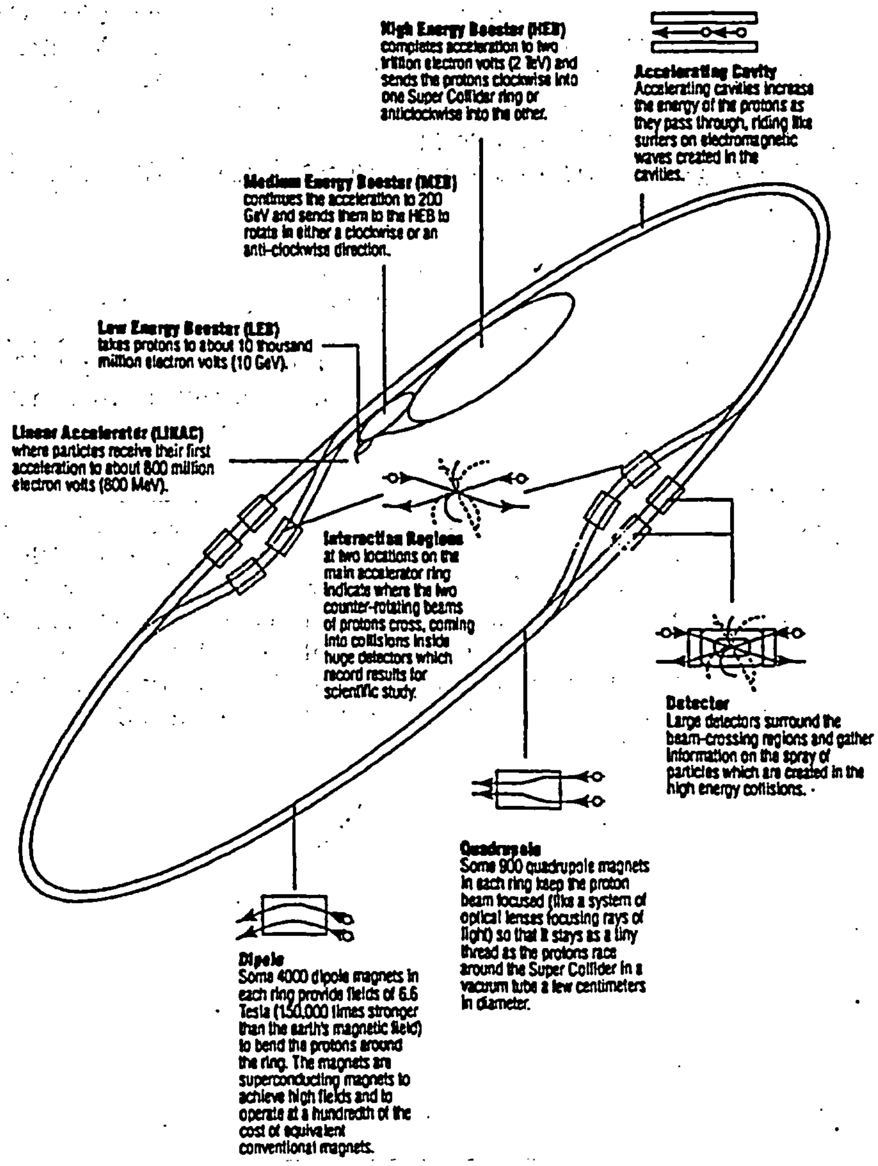
Chapter 1

Introduction

The Department of Energy (DOE) is building the world's largest high-energy particle accelerator—the Superconducting Super Collider (SSC). The SSC is being constructed about 30 miles south of Dallas in Ellis County, Texas. When completed, the SSC will be used as a research tool by physicists seeking fundamental knowledge about energy and matter. The accelerator complex, called the SSC Laboratory, is to consist of a series of five accelerators, each increasing the energy of the particles accelerated: a linear accelerator, a low-energy booster, a medium-energy booster, a high-energy booster (HEB), and the collider itself. The collider will collide two beams of protons at an energy of 40 trillion electron volts (TeV) and provide the initial complement of instruments and facilities to study the results of the collisions.

The collider includes two rings of superconducting magnets operating at temperatures near absolute zero (-452 degrees Fahrenheit). The two principal types of magnets are (1) dipole magnets, with a north and south pole, to bend the proton beams; and (2) quadrupole magnets, with two north poles and two south poles, to focus the proton beams. When completed, the SSC will contain about 8,300 dipole magnets and about 1,700 quadrupole magnets assembled in a 14-foot, concrete-lined tunnel, 54 miles in circumference, with all supporting power and cooling equipment. Figure 1.1 provides a description and diagram of how the SSC will function.

Figure 1.1: How the SSC Will Work



Source: Office of the Inspector General, DOE.

The two superconducting magnet rings will steer and focus the proton beams, which will be moving in opposite directions, until they collide in various interaction regions, where detectors will record the collisions for analysis by physicists. Several detectors are planned: two large, general-purpose detectors and additional smaller detectors. The two large detectors are the Solenoidal Detector Collaboration (SDC) and Gammas, Electrons, and Muons (GEM). These two detectors will be built by collaborations involving over 1,600 scientists who are designing and developing the detectors so that they may carry out high-energy physics experiments.

The SSC Laboratory is operated by Universities Research Association, Inc. (URA), a nonprofit association of 79 major research-oriented universities in the United States and Canada. URA received the prime contract to manage the design and construction of the collider in January 1989. It also reviews and approves, with advice from the laboratory's Program Advisory Committee, the scientific merit and feasibility of proposed experiments.

Project Baseline Cost Estimate

Initially proposed to the Congress in 1987 at a cost of $5.3 billion (in current year or year of expenditure dollars), the cost of the SSC grew to an estimated $8.25 billion by January 1991.[1] DOE has repeatedly assured the Congress that the SSC project will be completed on time and within budget. The SSC project's estimated cost of $8.25 billion (in current year or year of expenditure dollars) was established in January 1991.[2] Table 1.1 shows the January 1991 baseline cost estimates for each of the major program elements.

[1] For information on the history of the SSC cost estimate see Federal Research: Super Collider Estimates and Germany's Industrially Produced Magnets (GAO/RCED-91-94FS, Feb. 12, 1991).

[2] Report on the Superconducting Super Collider Cost and Schedule Baseline, Office of the Superconducting Super Collider, Office of Energy Research, DOE (Dallas: Jan. 1991).

Table 1.1: January 1991 SSC Baseline Cost Estimates

Dollars in millions

Program element	Estimated cost
Accelerator systems[a]	$1,128
Magnet systems[b]	2,040
Conventional construction[c]	1,073
Project management, support, and indirect costs	248
Research and development and pre-operations[d]	875
Experimental systems[e]	760
Escalation[f]	1,282
Contingency[g]	843
Total estimated project cost[g]	**$8,249**

Note: Dollars are fiscal year 1990 dollars, unless otherwise indicated.

[a]Includes the management, design, fabrication, and installation of all accelerator technical systems and equipment except for the superconducting magnets.

[b]Includes the management and industrial development of tooling and manufacturing processes, and the production of the superconducting magnets.

[c]Includes surface and underground structures, such as the tunnels, experimental halls, surface structures around the accelerator rings, office buildings, and industrial and heavy works buildings.

[d]Includes magnet design and fabrication of prototypes, accelerator physics studies, and conceptual design of the various technical systems. Pre-operations includes the personnel, support services, and utilities for start-up and commissioning of the injector accelerators and collider.

[e]Includes detectors and procurement of associated computers.

[f]Costs estimated in constant fiscal year 1990 dollars were escalated to current year dollars for the scheduled year of expenditure.

[g]In current year (year of expenditure) dollars.

Source: DOE.

Other Program Costs

In estimating the SSC project baseline, DOE excluded some costs that are to be funded from sources other than the DOE appropriation for construction. The baseline cost does not include (1) about $500 million for the detectors, for which the SSC project is seeking mainly nonfederal funding; (2) about $400 million for laboratory pre-operations costs not associated with commissioning the four injector accelerators or the collider, which are to be funded from DOE's High Energy Physics Program; (3) about $118 million through fiscal year 1999 for DOE program direction costs; and (4) about

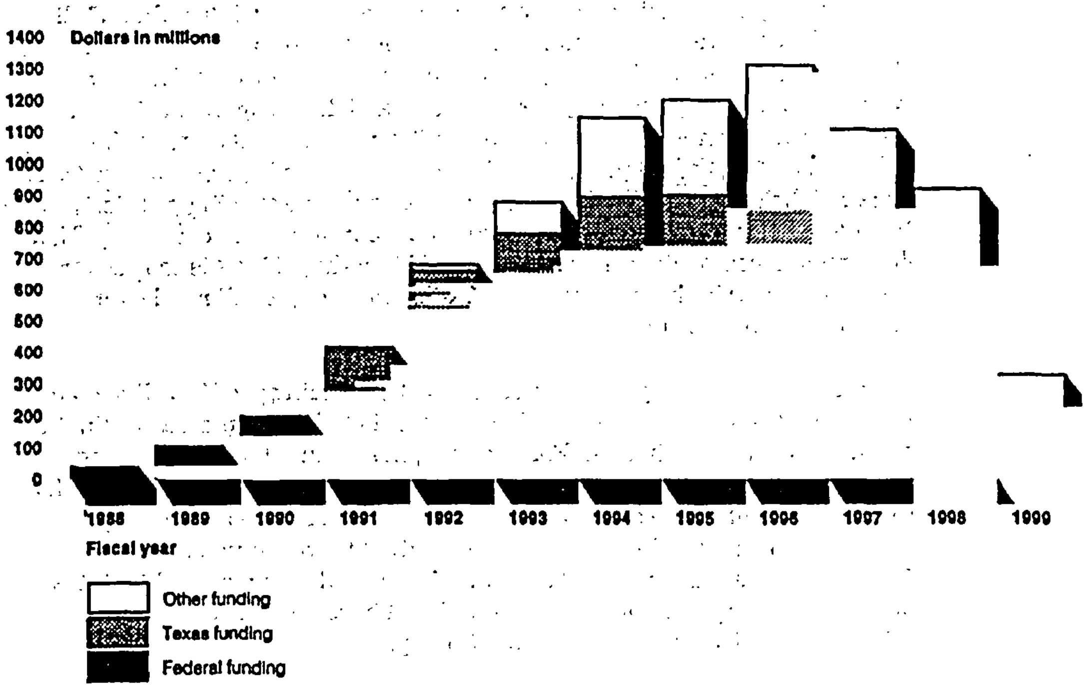
$60 million in land costs and $125 million in infrastructure and general support, which the state of Texas is contributing.

Project Baseline Funding Profile

DOE's January 1991 estimate assumes that the SSC would be completed in 1999. Therefore, the $8.25 billion needs to be provided to DOE in a time frame that will allow construction to proceed in a timely manner. Texas has pledged to contribute up to $1 billion, plus land, to the SSC. Of this amount, $875 million will be provided toward the funding of the project's baseline cost. Texas has tied its contributions to the rate of federal funding, but in a separate report, we recently pointed out that few commitments to provide funds have been made by foreign countries.[3] Figure 1.2 shows the amounts DOE expects the federal government, the state of Texas, and others, primarily foreign sources, to provide over this period.

[3]Federal Research: Foreign Contributions to the Superconducting Super Collider (GAO/RCED-93-75, Dec. 30, 1992).

Figure 1.2: January 1991 SSC Baseline Funding Profile



Source: DOE.

As shown in figure 1.2, the project's peak funding is expected to occur between fiscal years 1994 and 1997, when about 56 percent of the construction funds are to be spent.

Effects of Reduced Federal Funding

The Congress has not fully funded each year's budget request for the SSC project. In its oversight of the project, the Congress has expressed concern over the relative scientific merits of the SSC project versus other science, as well as with the SSC's technical uncertainties, particularly the superconducting magnets. Accordingly, funding has not been available as planned in the SSC project's funding profile. The SSC received \$182 million, or 15 percent, less in federal appropriations than requested for fiscal years 1992 and 1993. The SSC program received \$517 million in fiscal year 1993 appropriations, for example, compared with the SSC baseline funding profile of $650 million requested by DOE. As a result of the lower fiscal year 1993 funding, total project cost would increase by about $50 million if all federal funds were restored in fiscal year 1994 (the $133 million added to the funding profile for the year), according to the DOE Project Director, who has overall responsibility for managing and directing the project. If the funds are not restored in fiscal year 1994, the cost will increase by $200 million and the project would likely be completed 6 months later than scheduled, the Project Director said. The SSC baseline funding profile, including DOE program direction, calls for $723 million in fiscal year 1994, a 40-percent increase over the fiscal year 1993 funding. If DOE is to recover the $133 million in the fiscal year 1994 appropriation, it will need over $850 million in appropriations.

With the peak funding period approaching, the funding profile will need to be met or closely approximated if the project is to be completed within the estimated cost and schedule. For example, at an annual federal funding level of $650 million, the SSC project would require an additional 18 months to complete, with a cost increase over baseline of about $570 million, according to an SSC Laboratory funding study. At levels much below $650 million annually, the SSC Laboratory's General Manager said that it is doubtful the project could be ever completed because the construction schedule would be stretched out indefinitely.

Program Management Systems

DOE requires that the cost and schedule of the program be monitored using a Cost and Schedule Control System.[4] This system is intended to be an early warning system for identifying cost and schedule problems for the SSC project. When fully implemented, such a system provides information essential for managing a large construction project and forms the basis for reporting progress by comparing actual costs and schedule with the program's baseline. DOE's ability to keep track of the schedule for the SSC construction project is critical. According to DOE, a 1-year slip in the project's overall completion schedule would increase the project's costs by about $400 million, or roughly $1 million a day.

Major Subcontracts

URA has five major subcontracts, each of which is a cost-reimbursable contract. One subcontract is for the architecture and engineering services and the management of the conventional construction. The other four are for various superconducting magnets. The superconducting dipole magnet

[4]DOE also refers to the Cost and Schedule Control System as the Project Control System.

development program is operated under the leader/follower procurement concept. This concept is intended to introduce competition into the procurement of dipole magnets during the production phase. The lead contractor agrees to develop the follower subcontractor's capability to produce magnets by providing design, tooling, and technical assistance. This is to enable the follower to independently compete to produce the dipole magnets. The winner of the dipole magnet competition is expected to produce all of the full-rate production dipole magnets under a firm-fixed price subcontract. The full-rate production subcontract for about 7,750 dipole magnets is scheduled to be awarded in fiscal year 1995. Table 1.2 presents the subcontractors, their functions, and the dollar value and performance period of their contracts as of November 20, 1992.

Table 1.2: Major Subcontractors, Their Functions, and the Value and Period of Their Subcontracts

Dollars in millions

Subcontractor	Function	Subcontract face value	Period of performance
Parsons Brinckerhoff/ Morrison Knudsen (PB/MK)	Project architect, engineering and conventional construction manager	$1,208	6/90 to 9/98
General Dynamics	Collider dipole magnet product development leader in leader/follower program	207	5/91 to 6/95
Westinghouse	Collider dipole magnet product development follower in leader/follower program	104	5/91 to 6/95
Westinghouse	Full-scale development and low-rate initial production of HEB dipole magnets	84	1/92 to 7/96
Babcock and Wilcox	Collider quadrupole magnet product development	71	6/91 to 9/95
Total		**$1,675**[a]	

[a]Total does not add due to rounding.

Source: URA.

Objectives, Scope, and Methodology

The Chairman and Ranking Minority Member, Subcommittee on Investigations and Oversight, House Committee on Science, Space, and Technology, asked us to examine the effect of current and future cost and schedule changes on the SSC project's total cost. Specifically, we were asked to determine (1) whether the project contractor had implemented the required Cost and Schedule Control System, (2) if the project had realized cost savings, (3) whether cost and schedule changes could increase the project's total estimated cost, and (4) how DOE is implementing its build-to-cost strategy—a plan to reduce, defer, or eliminate components to hold construction costs to baseline cost estimates. We conducted our work primarily at the SSC project sites in Dallas and Waxahachie, Texas. We also observed the status of magnet development and production facilities being built in Hammond, Louisiana, and Lynchburg, Virginia.

To determine the implementation status of the Cost and Schedule Control System, we examined available SSC Laboratory reports and major subcontractors' documents. We examined the documents and interviewed cognizant DOE and laboratory officials to gain an understanding of the project's accounting and control systems, the design of relevant policies and procedures, and the status of their implementation.

To determine the savings realized, as well as the potential cost increases, we examined the project's cost performance reports and related configuration control and accounting systems, and we interviewed key project and contractor personnel concerning the issues identified. We also examined major project elements that had work in progress, including the work performed under the conventional construction and superconducting magnet subcontracts. Because the project did not have a functioning cost performance reporting system, we were unable to fully assess the effects of cost overruns and schedule slips on the estimated cost to complete the total SSC project. However, at our request, DOE provided analyses of the cost performance reports of four major subcontractors that do have functioning reporting systems: (1) PB/MK, (2) General Dynamics, (3) Babcock and Wilcox, and (4) Westinghouse. In providing these analyses, DOE cautioned that the analyses may provide a distorted picture because of the early stage of the project.[5]

To examine the build-to-cost strategy, we focused on the use of this approach in planning the construction of the two large, general-purpose detectors. We examined the project's budget and accounting records and interviewed cognizant DOE and SSC Laboratory officials. We also attended

[5]Although DOE provided us trend analyses of Westinghouse's subcontracts for the dipole magnet development follower and for the HEB magnets, we did not include them in this report because a meaningful analysis could not be made. The dipole follower contract is a level-of-effort contract, meaning that budget equals money (or effort) expended. The HEB magnet contract had just started, with only 6 percent of the monies spent.

the SSC Laboratory's Program Advisory Committee meetings and interviewed the director of the Texas National Research Laboratory Commission,[6] the spokesmen for the two large detector collaborations, and senior officials of the project's subcontractors.

In providing our observations on SSC funding, we relied primarily on observations made in carrying out this assignment. However, we also included information from our December 1992 report on foreign contributions to the SSC and recent DOE correspondence on this subject.

Because the project did not have complete cost performance reports and the project's control and accounting systems were incomplete, we had to rely to a large extent on interviews with both subcontractors and project managers to obtain complete and current information on activities that could affect project cost and schedule status but that were not yet included in project reports. Such activities included investigations of site conditions, trade-off studies of various construction and manufacturing options, technical results, and internal cost and schedule estimates on project completion.

DOE and URA established policies and practices to monitor our interviews with subcontractor and project personnel during this review. Both DOE and URA followed a practice of having internal review staff present during interviews with project employees. This practice, we believe, created conditions under which employees might not have spoken freely or provided candid views of transactions and events within their knowledge—unreported results of site investigations, trade studies, tests, design reviews, or internal estimates. We objected to these policies and practices but were unsuccessful in removing these restrictions.

These practices were most restrictive in the SSC Laboratory's Magnet Systems Division, which also inappropriately marked documents to restrict public disclosure with a legend, "Government Commercial Confidential Information and Proprietary and Trade Secret Information." The practice unreasonably delayed receipt of some documents, which, in turn, limited the time available to analyze them and follow up on the issues identified. Except for some procurement-sensitive documents, restrictions against public disclosure were removed during our exit meetings with URA and DOE officials.

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

We discussed the facts presented in this report with the DOE SSC Project Director and his staff. The SSC Project Director provided additional facts regarding the effects of reduced funding levels on the project's cost and schedule, an update on the status of the implementation of the Cost and Schedule Control System, and possible deferrals of buildings and detector components under DOE's build-to-cost strategy. We incorporated that information into this report. In addition, the Project Director believed that current SSC performance trends are not reliable because the project in its early stages and major contract modifications are being made to control future increases in construction costs. (See ch. 4 for a further discussion of DOE's concerns.) As asked by the requesters' office, however, we did not obtain written agency comments.

We performed our work in accordance with generally accepted government auditing standards. Our work was conducted from May 1992 to February 1993.

Cost and Schedule Control System Has Not Been Fully Implemented

Although required by regulation and contract, URA, DOE's prime contractor, has not yet fully implemented a Cost and Schedule Control System for managing the SSC project. Without such a system, DOE lacks information to assess on a timely basis whether the project has encountered problems affecting its cost and schedule. In July 1992 we reported on the system's status and some of the reasons for the delay in implementing the system.[1] In that report we pointed out that the first meaningful trend analysis showing the estimated cost for completing the project might not be available until June 1993. While URA continues to make progress in implementing its Cost and Schedule Control System, further delays have been encountered, and the first meaningful trend analysis showing the estimated cost of completing the project may not be available until July 1993—about 4-1/2 years after DOE awarded URA the prime contract requiring the Cost and Schedule Control System.

Although the system is not in place, DOE officials advised us that they are using alternative methods to monitor the program's performance by comparing it with the cost and schedule baseline. These alternate methods include subjective assessments of task completions that are based on oral reports by task supervisors during frequent meetings. Because these assessments were not adequately documented, we could not independently assess the effects of known cost and schedule changes on the project baseline. Additionally, URA's cost accounting records misstate the costs of tasks and do not provide reliable records for comparisons with the project's baseline cost estimate.

Purpose of Cost and Schedule Control Systems

DOE's Cost and Schedule Control System is intended to act as an early warning system for identifying cost and schedule problems for the SSC project. When fully implemented, the system will provide information essential for managing the SSC project and form the basis for reporting progress. URA is required by its contract with DOE, DOE's acquisition regulations, and the SSC project management plan to implement this system. Two key products of such a system are a monthly cost performance report and an integrated project schedule. Information from these reports are used by contract administrators and project managers, who develop trend analyses of the total cost and of the schedule for completing the project, to further assess the project's progress.

[1] Federal Research: Implementation of the Super Collider's Cost and Schedule Control System (GAO/RCED-92-242, July 21, 1992).

Cost performance reports periodically compare work planned over the project's entire 10-year construction period with actual work performed in terms of budget and schedule. The amount of work completed in terms of the SSC project's cost estimate for that work is called the earned value. A hypothetical example may help to illustrate earned value. Suppose 10,000 feet of tunnel was to be completed in a month's time and cost $10 million. By the end of that month's time, suppose 7,000 feet of the tunnel segment, or 70 percent, was actually completed. The value of that work, or earned value, would be $7 million. Knowledge of the earned value is essential to monitoring project progress because it provides insights into the status of tasks being performed in terms of schedule and cost. Using the above illustration, $10 million in work on the tunnel was scheduled for a month, but only $7 million worth of work on the tunnel (earned value) was accomplished; therefore, the tunnel would be behind schedule by $3 million. If that $7 million worth of work had cost $8 million, then, at that point in time, the tunnel would cost $1 million more than planned. Further, by using the reports, managers can project the effect of cost and schedule shortfalls on the overall project and can assess the reasonableness of the contractor's plan to recoup cost and schedule losses. One major product of the system is the project's current "estimate at completion", which is based on cost and schedule trends to date.

An integrated project schedule shows the interrelationships of the scheduled dates of the various major project components. Such a schedule enables managers to evaluate the adequacy of planned schedules and to determine "critical path" items. Items are considered on the critical path if a delay in their schedule can delay project completion.

Complete reports on cost performance and integrated project schedule enable contract administrators and project managers to properly evaluate factors associated with cost, schedule, and technical performance. This information can be used to predict trends in work performance, identify critical areas that may be behind schedule or over budget, and monitor the overall status of the project, including its current estimate at completion.

Implementation Initially Given Low Priority

Our July 1992 report pointed out that URA management had given low priority to implementing the Cost and Schedule Control System but had begun training its managers on the importance and use of the system in May 1992. This low priority resulted in insufficient staff being committed to implementing the system. The system had low priority in part because URA was in the midst of revising the work breakdown structure, which outlines the work to be done. If the integrated project schedule had been completed before the work breakdown structure was revised, then the integrated project schedule would need to be later revised to reflect the new work breakdown structure. We reported that progress was being made in implementing the system but that it might be June 1993 before URA would be able to provide a meaningful trend analysis of the SSC's cost and schedule.

Current Implementation Status

Since our July 1992 report, URA has made progress in implementing the system, but some of its critical aspects are still not in place or rely on inaccurate data. DOE has not yet reviewed and approved URA's Cost and Schedule Control System. By the end of fiscal year 1993, URA estimates that the project will have spent 22 percent of its total budgeted cost of $8.25 billion.

As we noted in our earlier report, since May 1992 URA has been training its managers on the importance and use of the Cost and Schedule Control System. This training includes instruction on the various methodologies for calculating earned value. Using this training, cost account managers are to determine the appropriate methodologies for determining earned value for their tasks.

As of November 1992, URA expected to release the first complete cost performance report in early December 1992, which is 2 months later than it had expected as of our July 1992 report. All elements of the report were expected to be included—program budgeted costs, earned value, and actual costs. However, because of errors within the accounting system, it may be some time before URA's Cost and Schedule Control System will generate valid data.[2]

Data Are Inaccurate

When inaccurate accounting data are used, the reports generated by the Cost and Schedule Control System will also be inaccurate. During this review, we noted accounting errors that raise doubts about whether recorded program costs are reliable. For example, in comparing URA's program management costs with the program management baseline estimate for fiscal years 1990 and 1991, we found cost increases that URA

[2]URA provided a complete cost performance report to DOE in Jan. 1993. In transmitting the report, URA pointed out that the numbers presented are inaccurate and should not be used for analysis.

officials attributed to accounting errors.[3] Management costs for 1990 exceeded the $26.8 million baseline estimate by $9.4 million, or 35 percent; the 1991 costs exceeded the $13.9 million baseline estimate by $12.5 million, or 89 percent.

URA's Cost and Schedule Manager explained that some recorded costs for 1990 through 1992 are incorrect. Some direct program costs were incorrectly charged to the management accounts when they should have been charged directly to the tasks on which work was being performed. As a result, program management costs are overstated and direct program costs are understated. For example, the Accelerator Systems Division and the Magnet Systems Division had charged expenses to the management accounts; those amounts should have been charged directly to the cost of the accelerators and magnets.

The URA Cost and Schedule Manager had not corrected the accounts because how the costs would be reallocated was unknown. As of January 1993, URA was developing a policy on how to allocate costs. Until the policy is developed, fiscal year 1993 costs will also be incorrectly allocated.

In addition, the quadrupole subcontractor's, Babcock and Wilcox's, cost performance reports for the quadrupole magnet program, were incorrect until August 1992 and a meaningful trend analysis could not be projected from them. Officials for Babcock and Wilcox explained that until August 1992, changes made to magnet quantities had not been correctly reflected in the baseline cost estimates used in preparing the company's cost performance reports.[4] As a result, the cost performance reports through July 1992 had been showing cost overruns and schedule slips that were not accurate.

Compliance Review Planned

DOE plans to conduct a compliance review of URA's cost and schedule system as soon as it receives a complete system description and cost

[3]Our analysis did not include program management costs for the Accelerator Design and Operations Division or the Physics Research Division because baseline cost figures for those organizations were not available. We did not make comparisons for fiscal year 1992 because the costs had not yet been summarized at the time of our review.

[4]In Nov. 1991, shortly after awarding Babcock and Wilcox the quadrupole contract, URA reduced the number of prototype magnets from 11 to 7 and shifted those costs to build 9 model magnets. URA and Babcock and Wilcox officials explained that producing model magnets before prototype production will enable the program to obtain more information sooner and for less cost than with a prototype. Information obtained from the model magnets may be incorporated into the design of later prototype magnets.

performance report from URA. As of November 1992, DOE had only received descriptions of the parts of the system as they had been developed. The compliance review initially compares the system description with DOE guidelines. A compliance review is then conducted to ensure that URA is following the procedures outlined in the system description and to assess the validity of the data. DOE officials expect to have the review completed and approval given by November 1993. DOE will then continue such compliance reviews on a routine basis.

Alternative Program Monitoring Methods Used

Acknowledging that the Cost and Schedule Control System was not yet in place, DOE managers stated that they used alternative methods for monitoring the program. The DOE Project Director stated that although the methods used may not be as timely as a fully implemented Cost and Schedule Control System, the alternative methods are adequate for monitoring the program. DOE has been reviewing monthly progress reports from URA managers and holding meetings as often as once a week with managers. However, because such meetings are either not recorded or are recorded with minimal information, we could not independently assess potential impacts of cost and schedule changes to the program. Furthermore, the accounting errors make it difficult to reliably compare recorded costs with baseline estimates for specific tasks. We also noted that these alternative methods have not included analyses of available cost performance reports prepared by the major subcontractors. In November 1992 the DOE Project Director advised us that DOE will start reviewing these reports on a monthly basis.

Impact of Delayed Implementation of the Cost and Schedule Control System Not Yet Clear

DOE and URA managers stated that the delay in fully implementing the Cost and Schedule Control System has affected their ability to prepare overall trends in program costs and schedule. However, they asserted that such analyses would not be meaningful in any case because the program is still in its early stages.

According to a DOE official responsible for analyzing the trends, he needs 6 months of accurate data to produce meaningful trend analyses. Once cost performance reports are produced, it typically takes 6 to 9 months to make them complete and accurate. Conceivably, accurate data and trend analyses could be available sooner. However, as noted earlier, the accounting systems that the cost performance reports rely on were not corrected as of mid-January 1993. Therefore, assuming that no additional problems or delays are encountered, the first trend analysis showing the estimated cost and schedule for completing the project will be available in July 1993 at the earliest.

Conclusions

URA still does not have a system in place that would allow it to objectively monitor the SSC project's cost and schedule. Such a system is contractually required and essential for monitoring a construction project of this magnitude. Without a complete and accurate system, URA and DOE lack information to assess on a timely basis whether planned project changes will adversely affect cost and schedule. Since our July 1992 report, additional delays have been encountered. We noted a problem with inaccurate cost information in URA's accounting records because of incorrect cost allocations that had not been corrected as of mid-January 1993. Since it takes at least 6 months of accurate data to produce meaningful trend analyses, the earliest date for full implementation has slipped at least another month to July 1993. Implementation may be delayed further because problems are typically encountered and because DOE's initial compliance review of the system, which may disclose additional problems, is not expected to be completed until November 1993.

Net Savings Are Unlikely

As of October 1, 1992, URA had reported savings totaling about $24.4 million—$10.3 million of which went to DOE's contingency fund and the remaining $14.1 million to URA's management reserve account. According to DOE, cost increases that result from scope increases or other project enhancements may be funded from DOE's contingency fund; cost increases from overruns are funded from URA's management reserve. The URA management reserve therefore has been used to cover cost increases on tasks estimated in the baseline cost, leaving a balance of $2.1 million as of October 1, 1992. However, if additional known cost increases were promptly recorded, the management reserve account would have shown a deficit of about $19.9 million.

Other potential future savings have been publicly claimed. These savings are expected if actual costs are lower than the baseline estimates or if changes are made in the project design to reduce cost. The validity of these savings cannot be readily determined because the tasks have not been accomplished in sufficient detail for the costs to be recorded in the formal accounting system. The division managers, we found, were reluctant to officially report potential savings as actual savings because of concerns about anticipated but unknown cost increases.

URA Has a Formal System for Recording Cost Changes

URA has developed a formal system, the Configuration Control Board (CCB), for tracking project savings and cost increases. The CCB matches the estimated cost of changes to the related baseline cost estimate. DOE considers deferred or deleted tasks to be cost savings because the estimated cost of those tasks can be used to cover the cost of other tasks. Savings realized by the SSC project are officially recognized by DOE and URA project management only when a change in the baseline has been approved by the CCB. Although all proposed changes to the SSC cost and schedule baseline are supposed to be reviewed by the CCB, the SSC project may realize other savings if or when actual costs are lower than baseline estimates. The CCB system does not specifically provide for costs lower than the baseline estimate to be officially recognized as savings, but URA plans to revise the system to capture such savings.

When CCB changes result in a savings, the general practice is to place the amounts into URA's management reserve account to fund cost overruns in other areas of the project. However, savings can also be transferred to DOE's contingency fund.

Some Known Cost Increases Not Yet Charged to URA or DOE Funds

We noted that some cost increases were known but had not yet been charged to the URA management reserve or the DOE contingency fund. Timely recording of known cost changes is needed to provide managers with an accurate understanding of the project's costs. Had the known increases been recorded, the savings would have been more than offset.

The Central Facility is a case in point. The Central Facility is an SSC complex in Waxahachie, Texas, that was converted from a warehouse. DOE and URA reported $13.8 million in savings from the purchase of the warehouse because the purchase enabled them to remove seven buildings, that were to be built, from the project's baseline costs. After the baseline was changed to account for the savings from the Central Facility, other changes occurred that will reduce the Central Facility's savings. Although the Central Facility was initially projected to save $13.8 million, three subsequent CCB actions totaling $6.3 million have been initiated to cover the additional costs of preparing the building for use and for expanded user requirements. As of November 1992, DOE was still considering two of these CCB actions and had approved one for $2.9 million to be funded by the DOE contingency fund.

Similarly, with regard to tunneling costs, in July 1992 DOE approved a CCB action of $22 million for additional tunneling work to be funded from URA's management reserve. However, as of October 23, 1992, this amount had still not been recorded against the management reserve. According to the URA official responsible for this account, he had the information needed to record this cost increase but had not yet done so. Had he done so, the management reserve's reported balance of $2.1 million would have changed to a deficit of about $19.9 million.

Total Savings Are Difficult to Determine

In congressional testimony and public statements, DOE and the SSC Laboratory have claimed potential savings other than those officially recorded in URA's management reserve or the DOE contingency fund. According to URA management, these savings occurred because contract costs were lower than the baseline estimates. URA plans to implement a policy to formally recognize such savings through the CCB process. However, these savings have not yet been formally documented because (1) there are no formal procedures in place that specify when to record such savings and (2) division managers are reluctant to report savings to project management for fear of having their budgets reduced, according to a URA official.

For example, the SSC Laboratory's Conventional Construction Division has unofficially reported approximately $31 million in net savings for the first five tunnel segments. These contracts were fixed-price contracts.[1] The contract for the first tunnel segment was awarded for about $4 million above the baseline cost of $17 million; the second tunnel segment was awarded for about $1 million below the baseline of $15 million; the third contract was awarded for about $11 million below the baseline of $37 million; the fourth contract was awarded for about $10 million below the baseline of $38 million, and the fifth was awarded for about $13 million below the baseline of $39 million. On the basis of this trend, URA project management estimated a savings of about $58 million for all 10 tunnel contracts. URA project management therefore has been considering generating a CCB action to officially record the $58 million as savings and add that amount to URA's management reserve. However, an additional $56 million of costs associated with the tunnel construction will offset these savings: In addition to the $22 million increase for tunnel shafts that DOE approved in July 1992, an estimated $34 million will be needed for additional tunnel cooling systems.

Moreover, costs for the first tunnel segment, with a contract cost of about $21 million when awarded, have increased. As of August 1992, PB/MK reported a cumulative cost increase of $500,000 for tunnel construction management for the first tunnel segment. PB/MK attributed the increase to having to provide more support than planned to the construction subcontractor because of schedule delays. The SSC Laboratory's Conventional Construction Division Director explained, however, that the increased cost reported by PB/MK resulted from the disproportionate allocation of staffing costs to the initial tunnel contract and was not a true cost increase. Whether the cost increase should have been allocated to the first contract or to subsequent contracts, the increase would reduce cumulative projected savings for the 10 tunnel contracts.

[1]According to the Director for the SSC Laboratory's Conventional Construction Division, about 35 percent of the value of the fixed-price contracts is based on fixed unit prices for material used, such as a fixed price for each foot of steel-reinforcing bar. Under this type of contract, the contractor will be paid for the actual quantity of material used, which can result in higher or lower final costs for the contract.

Work-In-Progress Is Over Budget and Behind Schedule

Each of the conventional construction facilities completed to date has had cost overruns and schedule delays.[1] However, without a functioning system for reporting cost performance, we cannot fully assess the effects of cost overruns and schedule slips on the estimated cost to complete the total SSC project. Nevertheless, DOE's analyses of major subcontractors' cost performance reports raise concerns about future cost growth in the project.

DOE Trend Analyses of Subcontractor Reports Show Cost Overruns and Delays

At our request, DOE analyzed the cost performance reports for the architect and engineering/conventional construction subcontractor, PB/MK; the dipole magnet subcontractor, General Dynamics; and the quadrupole magnet subcontractor, Babcock and Wilcox. The analyses showed that each subcontractor was running over cost and behind schedule as of August 1992. In providing the analyses, DOE cautioned that "the data currently available is not sufficiently mature to provide quality projections." DOE noted that each of the subcontractors had spent less than 20 percent of its total budget, cost performance reports do not incorporate all the completed major contract modifications, and excessive spending during start-up or engineering phases of the magnet contracts does not translate into continued cost increases. The least costly projection for each of these subcontractors is shown in table 4.1.[2]

Table 4.1: Trend Analyses of Cost at Completion for Selected Subcontractors

Dollars in millions

Subcontractor	Baseline cost estimate at completion	Projected cost at completion	Projected cost increase[a]
PB/MK	$1,250	$1,881	$631
General Dynamics	207	260	53
Babcock & Wilcox	68	93	25

Note: Based on work in progress through August 1992.

[a]The projected cost increase for each subcontractor exceeds the DOE-held contingency for the respective subcontracts. The amounts of contingency held for these subcontracts are not shown because DOE considers those amounts to be procurement-sensitive information.

Source: Prepared by GAO from trend analyses provided by DOE.

[1]We define a cost overrun as actual costs that exceed the baseline cost estimate for the task worked upon. However, DOE does not recognize a project cost overrun until the cumulative cost of work performed exceeds the cumulative baseline cost estimate for that work, including contingency funds. Because the baseline cost estimate was based on a conceptual design, some elements will have cost overruns and some will have underruns. DOE expects these costs to balance out over time.

[2]DOE also provided us with projections using different assumptions that indicated larger cost increases and additional schedule delays.

At DOE's request, URA subsequently prepared special trend analyses that assumed that no further cost increase would occur and indicated that the subcontracts will come within their respective baseline estimates. Although the subcontractors are currently behind schedule, the overall schedules for conventional construction and superconducting magnets have enough slack to absorb all known delays, according to URA officials.

Conventional Construction Is Over Budget and Behind Schedule

DOE's analysis of PB/MK's cost performance reports shows that, as of August 1992, conventional construction was $47 million, or 51 percent, over budget and 19 percent behind schedule. PB/MK had spent about $141 million, or about 12 percent, of the estimated contract amount. Compared with the baseline cost of $1.25 billion for the work to be performed under PB/MK's contract, the trend analysis for the least costly case projects a $630 million cost overrun at completion.

Two areas of increased costs for the conventional construction subcontractor have been (1) architect and engineering services and (2) the design and construction of facilities.

Architect and Engineering Services

Through fiscal year 1991, about the first 16 months of the contract, PB/MK exceeded its architect and engineering services baseline cost of $24.8 million by $13.8 million, or 56 percent. The total 10-year baseline cost for architect and engineering services is $126.7 million (in fiscal year 1990 dollars). These services are to include preparing designs for buildings, tunnels, and infrastructure; providing engineering and inspection services during construction; and providing construction management and related work.

In July 1992 DOE's Office of Inspector General (OIG) reported that the excessive costs for architect and engineering services were due to the lack of strong program management by URA.[3] The report noted that URA did not approve the subcontractor's annual work plans and allowed subcontractor expenditures in excess of the baseline. URA has an approved PB/MK work plan for fiscal year 1993, according to a URA official.

In addition, PB/MK incurred costs for program management and administration services not originally included in the baseline. These services included community relations; protection of workers' safety and

[3] Report on Department of Energy's Superconducting Super Collider (SSC) Conventional Construction Program, Office of Inspector General, DOE, (Germantown, Md.: July 7, 1992).

health, protection of the environment at the work site, and quality assurance. According to DOE's OIG, because these services could not be compared with the baseline, the account for these services became a catchall for miscellaneous costs and masked the full extent of cost overruns. Many costs that should have been included in design or construction management costs, which were already exceeding baseline costs, were included in program management and administration.

Design and Construction of Facilities

Both the facilities completed as of November 1992—the Magnet Development Laboratory and the Accelerator Systems String Test (ASST) Facility—have had cost overruns. The Magnet Test Laboratory was partially completed and was over its baseline cost and behind schedule as of November 1992. Table 4.2 shows the initial baseline cost estimate and the revised baseline cost estimate for the three facilities.

Table 4.2: Facility Cost Estimates and Actual Costs

Dollars in millions

Facility	Baseline cost estimate[a]	Revised baseline cost estimate[b]	Actual costs[c]
Magnet Development Laboratory	$ 9.5	$12.1	$12.2
ASST Facility	3.8	4.6	6.5
Magnet Test Laboratory	4.8	9.1	[d]
Total	**$18.1**	**$25.8**	

[a]The baseline cost estimate includes amounts for the construction and design of each facility. The design cost estimate is 8 percent of the construction cost estimate.

[b]The revised baseline estimate includes escalation and changes approved by the CCB.

[c]Expenditures to complete the facility as provided by the SSC Laboratory.

[d]The Magnet Test Laboratory was not completed as of November 23, 1992.

Source: Prepared by GAO from SSC Laboratory data.

URA revised the baseline cost estimates for the Magnet Development Laboratory, the Magnet Test Laboratory, and the ASST Facility to include $7.7 million in additional costs for escalation, omitted baseline items, design changes, and unforeseen site conditions. Using CCB actions, URA increased the baseline cost estimate for each of the three major facilities. URA generated the majority of the CCB actions after incurring the increased costs but is attempting to produce and approve CCB actions prior to work being performed on future contracts.

The facilities' cost increases resulted from design changes, baseline omissions, and unforeseen site conditions encountered during construction. Each of the three major facilities had cost increases because of design changes. For example, the Magnet Development Laboratory's baseline estimate increased by $2.3 million because of numerous design changes. While it was being designed, changes included having to re-site the facility four times because of changes in the availability of land. Design changes continued while the facility was being built. The DOE OIG reported that 18 changes to building contracts resulted in contract modifications that added $450,000 to the cost.

Omissions of items from the baseline estimates increased costs for the Magnet Test Laboratory and the ASST Facility. The baseline estimate for the Magnet Test Laboratory increased by $1.5 million to include costs for two buildings and systems omitted from the original baseline. Similarly, the baseline estimate for the ASST Facility omitted two buildings that cost $1.1 million.

Unforeseen site conditions also increased facility costs. For example, during the construction of the Magnet Development Laboratory, an artesian spring was discovered. Costs associated with this condition totaled $241,000.

To cover the $7.7 million increase in estimated costs, funds from DOE's contingency fund, URA's management reserve, or other SSC Laboratory accounts were used. For example, DOE's contingency fund was used to cover $2.3 million of the Magnet Development Laboratory's cost increase and $1.5 million of the Magnet Test Laboratory's cost increase. URA's management reserve covered the remaining cost increase for the Magnet Test Laboratory. URA transferred about $700,000 from the Accelerator Systems Division to cover the increase in design cost for the ASST Facility. Although not recorded formally in a CCB action, another $1.1 million for the ASST was transferred from an account within the Conventional Construction Division. The balance of about $1 million came from funds set aside for escalation in the baseline estimate.

While the three facilities were completed behind schedule, the delays did not affect critical milestones, according to SSC Laboratory officials. However, because the Magnet Test Laboratory is scheduled to be completed about 4 months late, the Magnet Systems Division spent about $1 million in DOE contingency funds to continue testing at another laboratory.

DOE and URA Actions to Control Costs

In November 1992, in response to these cost overruns, DOE and URA changed the SSC Laboratory's work processes and modified PB/MK's architect-engineering/construction management subcontract. According to DOE officials, the contract changes will contain the cost increase for construction at below $50 million. DOE officials advised us that the project's baseline cost estimate has sufficient contingency funds for construction to absorb the anticipated cost overruns. In addition, they pointed out that they are committed to a build-to-cost approach; that is, if costs do increase, conventional construction projects will either be eliminated or deferred until after the accelerator is "completed," in order to stay within the budget.

Dipole Magnet Development Is Over Budget and Behind Schedule

General Dynamics' cost performance reports for the dipole magnet subcontract showed that as of August 1992 it was $7 million, or 26 percent, over budget and 10 percent behind schedule. However, General Dynamics has a management reserve with enough funds to cover $6 million of the overrun. The subcontractor had spent $34 million, or 16 percent, of its $207 million budget. DOE's least costly trend analysis for this work projected a $53 million overrun, about 25 percent above baseline, at completion.

URA does not consider the dipole magnet's development schedule to be on the project's critical path. Nevertheless, the dipole magnet program contains a very ambitious schedule with concurrent design, engineering, testing, and production efforts taking place—especially through 1994. Because these phases occur simultaneously, cost and schedule risk are increased. URA and General Dynamics officials said that they have developed strategies to ensure that delays will not affect internal and contract milestones. These strategies include employing additional staff, allowing overtime, and using URA manufacturing facilities to accomplish minor tasks.

Prototype Magnet Production

Of the $7 million in cost overruns, $1.9 million, or 27 percent, occurred during the development of the prototype for the dipole magnets. Problems encountered during this development included (1) transmission errors in the dipole magnet data transferred from DOE's Fermi National Accelerator Laboratory to the prototype subcontractor;[4] (2) the need to redesign magnet components; and (3) the need to revise drawing schedules. To

[4]The Fermi National Accelerator Laboratory, located in Batavia, Illinois, had a lead role in developing the dipole magnets' design.

minimize the impact of these problems on its schedule, General Dynamics incurred additional costs from overtime. Despite these efforts, some items were behind schedule. For example, release of the completed tooling and equipment designs for prototype magnet production was delayed from May to August 1992. The delay in the design releases has compressed the time for production, delivery, and installation of tooling and equipment needed for prototype production.

In addition to compressing the schedule for delivery of equipment to help meet the prototype production schedule, URA will perform the manufacturing processes for two of General Dynamics' work stations. As of November 1992, URA and General Dynamics were negotiating the terms of the changes to the subcontract, and the impact of these changes on cost and schedule, if any, is unknown at this time.

General Dynamics has incurred increases in the cost of producing and delivering its tools and equipment for the prototype magnet. For example, the subcontractor's August 1992 cost performance report indicated that tool production and delivery was $1.3 million, or 68 percent, over the contract budget of $1.9 million. To keep tools and equipment delivery on schedule, General Dynamics incurred costs for additional staff and travel expenses.

Aggressive Magnet Development Schedule

The Director for the SSC Laboratory's Magnet Systems Division said that he is maintaining an aggressive development and production schedule, although the dipole magnets are not on the critical path now. The Director asserted that an aggressive schedule was the lowest-cost solution and would provide an inventory of magnets for installation if the construction schedule for the collider tunnel improved. The current magnet delivery schedule would make 600 magnets available for installation but may create a storage problem if they cannot be installed in the tunnel shortly after delivery. The SSC Laboratory's General Manager noted that the estimated costs for storing such a quantity of magnets is not currently in the baseline.

Quadrupole Magnet Development Costs Have Increased

According to DOE's trend analysis, the subcontract for quadrupole magnets will be $25 million, or 37 percent, higher than its $68 million baseline cost estimate. As of August 1992, the quadrupole magnet program is $3.8 million, or 36 percent, over cost and 12 percent behind schedule. Babcock and Wilcox had spent $14 million, or 21 percent, of its subcontract, which was valued at $71 million. Babcock and Wilcox attributed part of its current overrun to using about $1.4 million more in labor than planned. The balance of $2.4 million was attributed to various factors, such as increased resources for testing and unfavorable changes in currency exchange rates for dealing with foreign subcontractors. SSC Laboratory officials noted that costs were also higher because Babcock and Wilcox's overhead rates were higher than expected.

Conclusions

The SSC's conventional construction is an early and visible test of whether the cost and schedule of the SSC can be successfully managed. To date, each of the facilities completed has been over budget and behind schedule.

According to trend analyses of cost and schedule performance reported by major subcontractors through August 1992, cost overruns in both conventional construction and magnet development could deplete the project's contingency funds. Although DOE stated that it is too early in the project to obtain reliable trend data, the subcontractors for conventional construction and the dipole and quadrupole magnets had incurred 11, 16, and 21 percent of their respective subcontract costs, respectively, as of August 1992. We agree that more reliable cost trends can be established as more project work is completed. Nonetheless, significant portions of the subcontracts have been completed, and in one case, even exceeded DOE's criteria of 20 percent. Therefore, the early cost trends are, we believe, reason for concern about the project's outcome.

DOE Will Follow a Build-To-Cost Strategy

To counter increased project costs, DOE intends to follow a build-to-cost strategy—a plan to hold construction costs to baseline cost estimates, revised as necessary to include previously omitted baseline costs and changing site conditions. The build-to-cost strategy, we believe, can result in a major downsizing of the project if costs continue to increase. Also, future SSC operating costs may be increased because items omitted during project construction may be added later.

According to DOE, the greatest potential for reducing costs through the build-to-cost approach is with the large, general-purpose detectors. Building the two large, general-purpose detectors—the Solenoidal Detector Collaboration (SDC) and Gammas, Electrons, and Muons (GEM)—with available funds may require a major project change because expected nonfederal funding for about half of the estimated cost of large, general-purpose detectors has been slow to materialize. Officials developing the detectors are seeking additional funds from other sources, primarily foreign countries, and deferring the construction of any unfunded detector components until after the collider has been commissioned. Still another option suggested by the DOE Project Director is to defer the building of one of the large detectors.

Several Sources Needed for Large Detector Funding

DOE established an upper limit of $541 million in 1992 dollars for the estimated cost of each large, general-purpose detector. Therefore, if each detector was built to that cost, a total of about $1.1 billion would be needed. However, the SSC only has $596 million of baseline funds available for the large, general-purpose detectors—leaving the two collaborations of scientists building the detectors to obtain the remaining funds from other sources.

The estimate for the SDC detector has exceeded the DOE limit, and neither collaboration has identified funding sources to meet all detector costs. As of October 1992, the cost estimates for the SDC and GEM detectors were $609 million and $530 million, respectively, for a total of about $1.1 billion. To meet the additional funding requirements, the detector collaborations are seeking funds from DOE's High Energy Physics Program, the state of Texas, and foreign countries. Table 5.1 shows the collaboration's proposed funding and sources as of October 1992.

Table 5.1: Large Detectors' Estimated Cost and Proposed Funding Sources as of October 1992

1992 dollars in millions

Estimated costs and sources of funding	SDC	GEM	Total
Estimated cost	$609	$530	$1,139
Proposed source of funding			
SSC	298	298	596
High Energy Physics Program	40	40	80
Foreign funding	231	98	329
State of Texas	20	15	35
To be determined	20	79	99
Total	**$609**	**$530**	**$1,139**

Source: GAO analysis of SDC and GEM detector estimates.

Up to $596 million in SSC funds has been allocated to the detectors, leaving $543 million to be funded from other sources. Few funds have been committed by foreign countries. As of November 1992, Taiwan was the only foreign country to contribute funds to a detector; it had committed about $65 million toward the SSC, including an unspecified amount for GEM's central tracker, a key detector component.[1] Moreover, neither the state of Texas nor DOE's High Energy Physics Program has yet approved funding for the detectors.[2] Despite this, SDC and GEM collaboration officials have assumed that all the funding will be received from the sources identified and only acknowledged needing additional funding of $20 million and $79 million, respectively.

According to officials of the SDC and GEM collaborations, additional funding sources are unlikely and the detectors' designs cannot be reduced further to cut costs without affecting the detectors' physics capabilities. Therefore, the collaborations have proposed to defer installing some detector components to reduce the estimated cost of the detectors. For example, the SDC collaboration is considering deferring components costing $50 million until the collider is expected to attain its full design capabilities, about 3 or 4 years after commissioning. At that time, the components will be added, presumably with operating funds. Similarly, the GEM collaboration is considering deferring components costing $60 million.

[1] The Associate Director, Physics Research Division, SSC Laboratory, advised us that foreign collaborators have been conducting research and development on the detectors with their own funds.

[2] Texas funding, if any, would come out the state's commitment of up to $1 billion.

Although SDC and GEM collaboration officials have not assessed the total effect on costs of deferring components, they acknowledged that deferring installation will require the shutdown of the collider for later installation. The proposals discussed above would require shutdown for about 9 to 12 months for the SDC and up to 3 months for the GEM. The proposed deferrals of SDC components until the collider is expected to attain its full design capabilities could mean that the collider would be shut down when the physicists can first fully explore the new energy levels. The deferrals will also result in yet uncalculated increased costs to remove and reinstall components and to install the omitted components.

The effects of cost-cutting on physics experiments, according to the SSC Laboratory's Associate Director, Physics Research Division, is difficult to determine until the amount of required reduction is known. The effect of shutdowns is also unknown. However, URA considers detector shutdown and upgrade costs to be normal operating costs. Experimental physicists frequently require upgrades to improve or change the focus of the detectors, depending on what they encounter in their experiments.

DOE Proposal Would Defer One Detector

The DOE Project Director has suggested deferring one detector until after the collider has been commissioned. The Director said that his suggestion has not been very popular among experimental physicists, but a decision on the scope and funding of the detectors needs to be made soon.

The physics community has expressed reservations about deferring one of the detectors. The detectors are the heart of the collider. According to the SSC Laboratory's Program Advisory Committee, a healthy initial program requires two detectors with complementary as well as overlapping strengths to address the physics experiments expected at the high-energy levels of the SSC. Two detectors are needed to provide for independent confirmation of discoveries and for the competition and breadth that will ensure effective exploration of the full potential of the SSC. Two detectors also provide broader opportunities for research by the physics community. The URA General Manager said that URA intends to buy as much detector capability as possible with available funds.

Collaboration officials have expressed concern that deferral could ultimately mean cancellation of that detector, because of the costs involved in deferring one of the detectors—in terms of delayed operations as well as money. Collaboration officials explained that in addition to escalation costs, a deferral would mean that collider operations could be shut down for 2 years while another complete detector was installed. Furthermore, deferring one of the detectors could reduce the likelihood of obtaining foreign funding.

To address the issue of collider shutdown while deferred components are installed after the accelerator is commissioned, DOE and URA have considered constructing a tunnel bypass around both large detectors, allowing continued experiments at the two small detectors. Rough estimates have put the cost of the bypass at between $50 million and $150 million, depending on how much is completed and whether magnets were installed during project construction or after commissioning.

In November 1992 the DOE Project Manager told us that, regardless of how much project funding is ultimately available for the large detectors, the costs will not exceed the baseline estimate because of the build-to-cost approach. To help decide what should be built with the available funding, he is considering asking DOE's High Energy Physics Advisory Panel to study the situation and provide advice on how to resolve the issue of building the detectors with the limited funds available.[3]

Conclusions

DOE's use of a build-to-cost strategy to counter increased project costs could result in a major downsizing of the SSC if costs continue to increase. The collaborations are considering deferring needed components of large detectors with the expectation that the components would be added later. This approach will not save funds in the long run. Since the omissions are actually deferrals, the costs of adding them at a later date will still need to be met. Moreover, the addition of the components or a detector after commissioning may require the accelerator to shut down for extended periods, thereby impairing any ongoing physics research experiments.

[3]DOE's High Energy Physics Advisory Panel is composed of scientists who provide advice and guidance on high-energy physics research to DOE on a continuing basis.

Observations on SSC Funding

The SSC project has reached a crossroads at which key funding decisions need to be made. In December 1992, we reported that the uncertainty of foreign contributions made funding decisions more critical and suggested that the Congress obtain updated information on the status of foreign contributions. DOE subsequently told the Chairman, House Committee on Science, Space, and Technology, that it is only confident of obtaining about $400 million of the $1.7 billion it is seeking from foreign contributors by 1999.[1] Under this scenario, the project would have a shortfall of $1.3 billion. As a result, the Congress is now faced with the need to provide increased funding in an effort to keep the project within its current budget estimate and completion schedule. The Congress should recognize, however, that even if it increases funding to cover the shortfall in foreign contributions, the project may still be over budget and behind schedule because of the matters discussed in this report.

Decision on Whether to Rely on Foreign Contributions Needs to Be Made

DOE still needs nearly all of the $1.7 billion in foreign contributions it has been seeking to meet the goal it established in January 1991. In December 1992 we reported that only about $15 million in foreign contributions had been received. We noted that the Congress faces a critical decision point on its funding of the SSC. As of the end of fiscal year 1993, about $1.6 billion will have been invested in the project. Starting in fiscal year 1994, the peak funding period for the project begins.

For fiscal year 1994, the funding profile for the SSC project showed that about $700 million in federal funds and about $250 million in foreign contributions were needed. We reported that without a major contribution from Japan in fiscal year 1994, the Congress will, in all likelihood, be faced with deciding whether to increase U.S. funding to make up for the shortfall in foreign contributions or to let the project fall behind schedule. A 1-year slip in the project's schedule could increase the SSC's cost by about $400 million. Furthermore, the Congress will have to decide whether it will be willing to ask the U.S. taxpayer to bear a substantially larger portion of the SSC's cost in future years should Japan decide not to contribute to the project.

With $1.6 billion invested in the SSC, the Congress faces a critical decision point on funding, especially in light of the uncertainty of foreign contributions. We advised the Congress that, as part of its fiscal year 1994 funding decision on the SSC, it should require DOE to provide it with the

[1] Letter from Adm. James D. Watkins, Secretary of Energy, to the Chairman, House Committee on Science, Space, and Technology, Jan. 14, 1993.

most complete, accurate, and up-to-date information available on the status of DOE's efforts to obtain contributions for the SSC from Japan and other foreign countries.

DOE Advised the Congress That Increased Funding Is Needed

According to DOE, a significant increase in funding will be needed in fiscal year 1994. In a January 14, 1993, letter, DOE provided the Congress with updated information on the funding status of the SSC project, including information on the amount of anticipated foreign contributions. DOE acknowledged that without a significant contribution from Japan, it is highly doubtful that the goal of $1.7 billion in foreign funding could be met; DOE was only confident of obtaining foreign commitments of $400 million by fiscal year 1999. DOE also noted that fiscal year 1993 funding was at a level that was lower than requested, and as we noted in chapter 1 of this report, the reduced funding increased the cost of the project and extended its schedule. To hold the cost increase to $50 million and the schedule slippage to 3 months, DOE stated that $1.2 billion in funding would be needed in fiscal year 1994. To ensure that the project is completed on schedule, independent of foreign contributions, DOE recommended that in fiscal year 1994 the Congress provide $5.5 billion, representing the full remaining federal funding required to construct the SSC.

Observations

As we and DOE have previously pointed out, providing the SSC project with less funding than the amounts set forth in the funding profile increases project costs and extends the schedule. Therefore, funding of at least the annual amount requested by DOE would be needed if the project is to stay within its current budget and schedule. However, as evidenced by the matters discussed in this report, even providing the full amount of funding requested will not ensure that the project is built within budget and on schedule. DOE still does not have a fully functioning Cost and Schedule Control System in place that would help it better monitor the cost and schedule changes. A fully implemented system would identify significant problems earlier and enable managers to take more timely corrective actions. Such a system would also disclose cost increases and savings. We found that the savings reported have been exceeded by cost increases, and as a result, net savings are unlikely. Work-in-progress by major subcontractors has incurred increased costs and is behind schedule. Early projections of the major subcontractors' progress indicate that the cost growth could be substantial. To combat increased costs, DOE is pursuing a build-to-cost strategy, which appears to be merely deferring costs to a date after the completion of SSC construction.

Therefore, we caution that completion of the SSC project may require more than the annual amounts provided for in the project's funding profile or more than the $5.5 billion total that DOE recently reported to the Congress.

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.	Jim Wells, Associate Director Robert E. Allen, Jr., Assistant Director Sumikatsu J. Arima, Assignment Manager
Office of General Counsel	Susan W. Irwin, Attorney Advisor
Dallas Regional Office	Joe D. Quicksall, Regional Management Representative Hilary C. Sullivan, Evaluator-in-Charge Sally S. Leon Guerrero, Staff Evaluator Cary B. Russell, Staff Evaluator Michael J. Coy, Staff Evaluator

Glossary

Absolute Zero	The lowest possible temperature defined by the cessation of vibration of molecules. Zero degrees Kelvin.
Accelerator	A device that increases the energy of charged particles such as electrons and protons.
Beam	A stream of particles or electromagnetic radiation going in a single direction.
Collider	In a collider, collisions take place between high-energy particles that are moving toward each other. In such an arrangement, most of the energy is available for creating new particles. In contrast, when a high-energy particle collides with a stationary target, a large portion of the energy resides in the continuing forward motion. Only a small portion of the energy is available for creating new particles.
Detector	A device that can "observe" the presence of a particle or nuclear fragment and measure one or more of its physical properties.
Electron	An elementary particle with a single negative unit of electrical charge and a mass 1/1,840 that of the proton. Electrons surround an atom's positively charged nucleus and determine the atom's chemical properties.
Electron Volt	The amount of energy acquired by an electron accelerated by an electric potential of one volt; MeV, million electron volts; GeV, billion electron volts; TeV, trillion electron volts.
Elementary Particle	A particle (piece of matter) that has no other kinds of particles inside it and no sub-parts that can be identified. Hence, the simplest kind of matter.
Kelvin	A scale of temperature. Zero degrees Kelvin (absolute zero) is equivalent to minus 273 degrees Celsius or minus 523 degrees Fahrenheit.

Linear Accelerator	In this type of accelerator, particles travel in a straight line and gain energy by passing once through a series of electric fields.
Magnet	A device that produces a magnetic field and thus causes charged particles to move in curved paths. Magnets are essential elements of all circular accelerators and colliders, as well as of many particle detectors.
Muon	A particle with a mass 207 times that of the electron and having other properties similar to those of the electron. Muons may have a positive or negative electrical charge.
Particle	A small piece of matter. An elementary particle is a particle so small that it cannot be further divided; it is a fundamental constituent of matter.
Proton	A particle with a single positive unit of electric charge and a mass approximately 1,840 times that of the electron. It is the nucleus of the hydrogen atom and a constituent of all atomic nuclei.
Superconductivity	The ability of some materials at super-cold temperatures to lose all electrical resistance so that electricity will pass through them with no measurable loss of current.
TeV	Tera electron volt, a unit of energy equal to one trillion (10^{12}) electron volts.

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20884-6015

or visit:

Room 1000
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (301) 258-4066.

United States
General Accounting Office
Washington, D.C. 20548

Official Business
Penalty for Private Use $300

First-Class Mail
Postage & Fees Paid
GAO
Permit No. G100