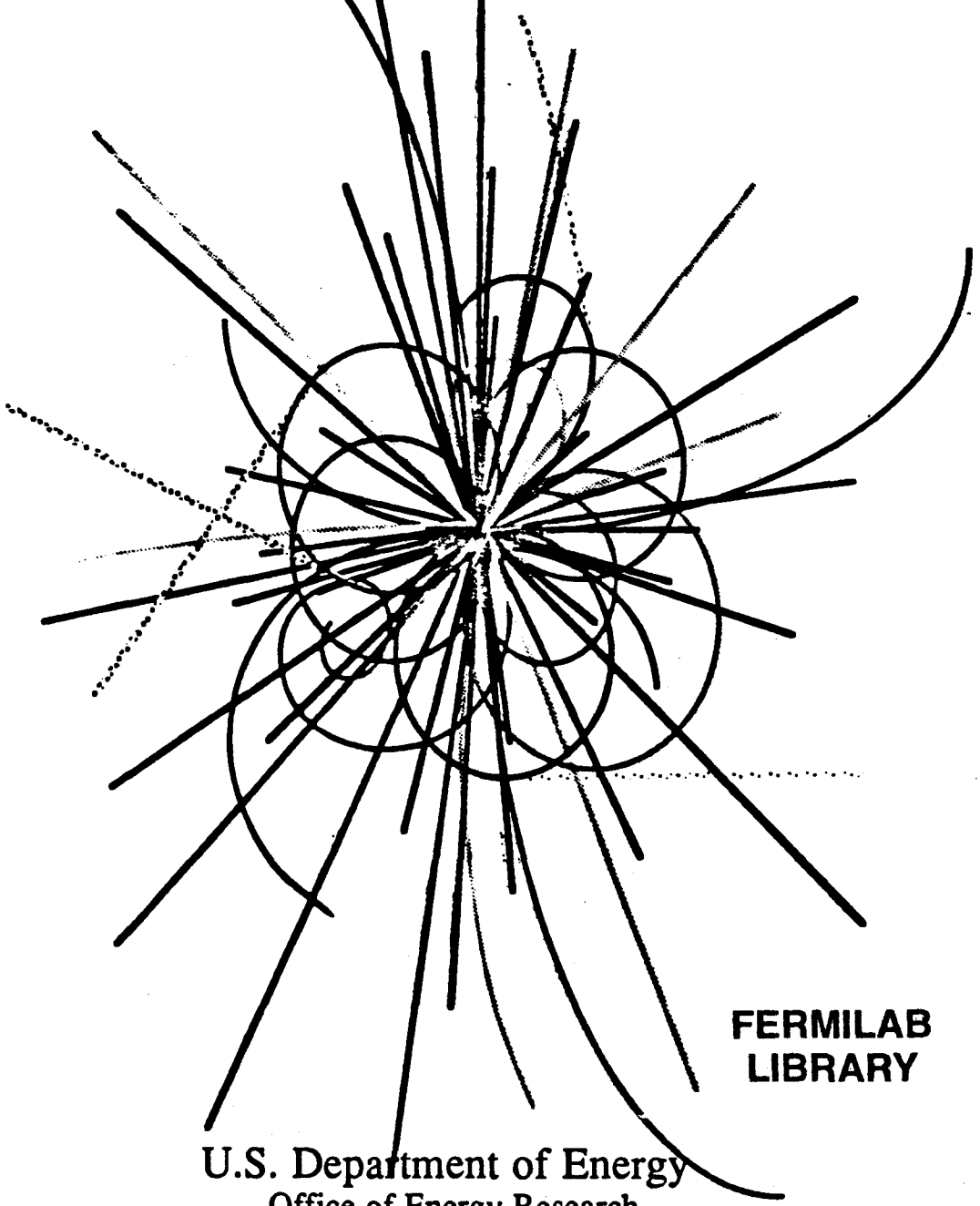
Report on the Superconducting Super Collider Cost and Schedule Baseline

January 1991



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COST AND SCHEDULE BASELINE

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I. INTRODUCTION

This report on the Superconducting Super Collider (SSC) project is a result of Secretary Watkins' statement of March 5, 1990, before the House Science, Space and Technology Committee that the Department would provide a detailed cost and schedule baseline for the SSC upon completing its review of an estimate being prepared by the SSC Laboratory. This report describes the Department's SSC cost and schedule baseline and the review process by which this baseline has been determined.

Establishing this SSC project baseline is a critical milestone in moving forward with the SSC project. With this baseline, the performance, cost, and schedule milestones are set as goals for the project activities and will serve as the reference against which progress during construction is measured and controlled. The SSC, to be a successful project, must meet or exceed this baseline by being completed within the estimated cost and schedule, and by performing technically as designed.

The SSC is one of the largest scientific projects ever undertaken. It involves designing, constructing, and establishing a new high energy physics laboratory of unprecedented size and complexity. The project presents many challenges to both the technical community and to the conventional construction industry. Executing the SSC project to the baseline presented in this report will ensure that the scientific objectives of the SSC will be achieved and that the project will be completed within agreed-upon funding and schedule goals. The Department and the Administration, working with the SSC Laboratory, are committed to ensuring that the SSC project is successful.

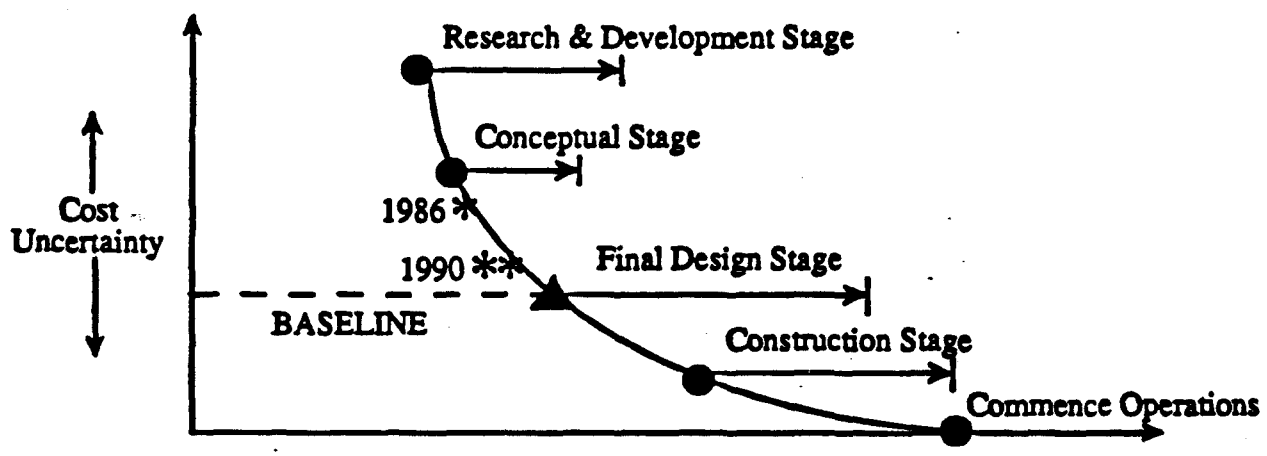
Strong management of the SSC project is key to effectively executing the Department's cost and schedule baseline as outlined in this report. Secretary Watkins has taken a number of steps to strengthen and streamline line management for this project. One of the key steps has been to establish a project office headed by the Department's SSC project director, on-site at the SSC Laboratory, to manage the day-to-day execution of the

project. This project manager reports directly to the program office in Headquarters and, independently, to the Secretary on the status and progress of the project. Further discussion of the project management structure and management responsibilities are outlined in Appendix 1.

SSC DEVELOPMENT AND PREVIOUS COST ESTIMATES

Development of the Department's cost and schedule baseline for the SSC must be viewed in the context of the normal process for the development and definition of any large project. The SSC, a very large and complex project, has evolved through an orderly design and development process to the point where a baseline can be established for final design and construction. This evolution for large projects is depicted in Figure 1.

FIGURE 1
Project Execution Process



* — 1986 Conceptual Design Report for the SSC

** — 1990 Site-Specific Conceptual Design for the SSC

● — Critical steps in project development process

▲ — SSC Baseline established at this point (with prudent contingency allowance) – project managed and controlled to this baseline

The development process starts with a concept of what is to be accomplished and a general approach, with little definition of design or facility details. At this stage, there is a high degree of cost and schedule uncertainty. As the concept is refined and design details are developed, reliable cost and schedule estimates can begin to be developed. At this stage, the cost uncertainty and schedule risk are reduced. The project then moves to the final design stage where more accurate cost estimates and detailed project execution plans are developed.

The SSC Laboratory is presently at the stage of beginning final design and is ready to begin the early stages of construction. The SSC project baseline presented in this report addresses schedule and technical risks, with appropriate allowances for contingencies. Previous cost estimates for the SSC that will be discussed were developed at earlier stages of this development process, as depicted in Figure 1, with a higher degree of cost and schedule uncertainty. Further, the recent experience with the Tevatron collider at the Fermi National Accelerator Laboratory (Fermilab), and the Hadron Electron Ring Anlage (HERA) collider presently under construction at the Deutsches Elektronen-Synchrotron (DESY) in Hamburg, has provided additional information and comparative reference data to assess the reasonableness of the cost and schedule estimate. A chronology for the SSC which reflects this developmental process leading to the SSC cost and schedule baseline is shown in Table 1.

Origin of the SSC

The concept for the SSC originated in a 1982 Summer Study (Reference 1). This and other workshops on detectors and accelerators held in 1983, together with the successful large-scale operation of hundreds of superconducting magnets in the Fermilab Tevatron accelerator, led to a

TABLE 1

CHRONOLOGY OF SSC DEVELOPMENT

1982	Concept of SSC originates from physics summer study.
1983	High Energy Physics Advisory Panel recommendation for immediate initiation of a multi-TeV high-luminosity proton-proton collider.
	DOE initiates research and development on SSC magnets at its laboratories.
1984	Reference Designs Study published (cost estimates extrapolated from historical data).
	SSC Central Design Group formed to coordinate National SSC effort during the research and development and pre-construction phase.
1985	Selection of SSC superconducting magnet design type.
1986	Site requirements established (land, utilities, geology).
	Conceptual Design Report and related documentation on detectors and operating costs published.
1987	Invitation for Site Proposals issued (forty-three proposals received. Proposals addressed geology, real estate, utilities, regional resources, and environment.)
1988	Site selection process (seven best qualified sites reviewed in depth).
1989	Selection of Texas site as best qualified (site-specific geology and infrastructure parameters were established).
	Environmental Impact Statement and Record of Decision for siting signed (environmental impacts and mitigations defined).
	Selection of Universities Research Association as the SSC Management and Operating Contractor (establishment of SSC Laboratory begins).
	Department Office of SSC (Program Office) established.
1990	Site-Specific Conceptual Design Report and related documents completed (technical system criteria and designs, conventional facility criteria and designs, detectors, cost estimates, actual site data, schedule and funding profile estimates).
	Department On-Site Project Office for SSC established in Texas.
	SSC cost/schedule baselines established.

unanimous recommendation by the High Energy Physics Advisory Panel in July 1983, for the ". . . immediate initiation of a multi-TeV[1] high-luminosity[2] proton-proton collider project with the goal of physics experiments at this facility at the earliest possible date." The proposed facility was designated the SSC (Reference 2).

Hearings before the House Science and Technology Committee in October 1983, addressed redirection of high energy physics program resources to initiate research and development for the SSC (Reference 3). The Department did not put forth a cost estimate at this time, noting that a major goal of the R&D and pre-construction phase of the SSC program was to develop a credible cost estimate and that this process would take a number of years.

The SSC Research and Development Program

In December 1983, preliminary research and development was initiated and the Reference Designs Study (RDS) was chartered (Reference 4). This study, published in 1984, addressed alternative designs for an accelerator having a beam energy of 20 TeV and a luminosity of 10^{33} per square centimeter per second. This study developed very preliminary cost estimates for the construction cost for three options for a facility meeting the goals of the SSC. The cost estimates ranged from $2700 million to $3055 million (constant FY 1984 dollars)[3], depending on the different magnet designs and

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[1] TeV - trillion electron volts, a measure of beam energy.

[2] Luminosity is a measure of beam intensity which characterizes the number of events that occur per second.

[3] Estimates in constant dollars reflect base-cost estimates and do not include adjustments for the estimated effects of inflation on funds to be spent in future years. Cost estimates identified as being in as-spent dollars are estimates of the total costs, accounting for actual costs incurred in the year of expenditures. Therefore, cost estimates in as-spent dollars have an escalation factor added to the base cost to account for anticipated inflation on funds to be spent in future years. The as-spent numbers, therefore, are based on an assumed funding profile that would need to be appropriated for the indicated schedule.

the related size and configuration of the collider. These estimates, however, were incomplete and did not include consideration of the cost of detectors or operating costs for research and development and preoperations.

In the fall of 1984, the Universities Research Association, which had been assigned oversight responsibility for the National SSC effort, formed the SSC Central Design Group (CDG). The Central Design Group, located at Lawrence Berkeley Laboratory (LBL), was directed by Dr. Maury Tigner, with staff members drawn from high energy physics, accelerator, and technical groups across the country.

A diversified research and development effort was also undertaken to provide the technical basis for selection of one of five superconducting magnet design types then under study as the basis of the SSC design. The primary magnet type for the SSC was selected in September 1985 (Reference 5). Follow-on efforts in 1986 focused on engineering for development of magnets, the development of a conceptual design and cost estimate, and associated operating costs and detector costs.

The SSC Conceptual Design Report (1986)

The SSC Conceptual Design Report (CDR) in 1986 drew on the SSC R&D efforts, including the work of many different task groups assembled by the Central Design Group to address specific technical issues. In all, about 250 individual scientists and engineers from across the country and around the world participated in the research and development and design studies that led directly to the Conceptual Design Report (Reference 6).

This Conceptual Design Report included both a conceptual technical design for the SSC and a cost estimate, for the construction portion only of the project, of $3010 million (constant FY 1986 dollars), with a schedule duration of 6-1/2 years leading to a completion date of mid-FY 1994. As a site had not yet been selected, construction costs were examined for three

"example" sites from around the country and averaged, to arrive at the estimate of $3010 million (constant FY 1986 dollars). In separate reports (Reference 7), the Central Design Group documented estimates of the operating costs for R&D and preoperations ($261 million in constant FY 1986 dollars) and a range of costs for the initial complement of detectors and computers ($664 to $976 million, again in constant FY 1986 dollars). Thus, the estimate developed by the Central Design Group in 1986 in the Conceptual Design Report and related documents was the first complete project cost estimate and schedule developed for the SSC. It occurred early in the project development process (Figure 1, page 2) and, therefore, possessed a higher degree of cost and schedule uncertainty. This estimate would equate to a total project cost[4] in the range of $3935 million to $4247 million (constant FY 1986 dollars). In as-spent dollars, with estimated escalation added for dollars to be spent in future years, these costs would be larger, approximately $5000 million.

Review of the SSC Conceptual Design

The design and cost estimate for construction from the Conceptual Design Report was reviewed in May 1986, by a team led by the Department's Office of Energy Research which included a large number of technical experts from throughout the world. This review concluded that the design set forth in the Conceptual Design Report was technically feasible and properly scoped to meet the requirements of the U.S. high energy physics program (Reference 8). The Department's review further concluded that the cost estimate of $3010 million (constant FY 1986 dollars) for the construction project was credible and consistent with the scope of the project.

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[4] Total Project Cost (TPC) is defined as that which includes not only the total cost for construction, but also includes supporting R&D, detectors and computers, and certain related operating costs incurred prior to completion of the construction project.

The Department's Independent Cost Estimating (ICE) staff also reviewed the Conceptual Design Report and related costs. They suggested that the construction and detector costs could be somewhat higher than the estimate by the Central Design Group. They also suggested that the construction cost estimate of $3010 million be raised by $428 million (mostly for superconducting magnets) and that the costs for detectors and computers estimated by the Central Design Group to be in the a range of $664 million to $976 million, be raised to $1156 million, (all in constant FY 1986 dollars). The ICE staff believed that the program office estimate of $3010 million (constant FY 1986 dollars) for construction only appeared to be somewhat optimistic; however, they agreed that it was adequately representative of likely SSC costs to support a decision on the project and recommended that project cost estimates be updated after site selection.

In preparing its FY 1988 budget request, the Department decided to base its initial SSC construction request to the Congress on the Central Design Group's construction cost estimate of $3010 million (constant FY 1986 dollars) which equates to $3210 million in constant FY 1988 dollars. The Department adopted an allowance for detectors and computers of $664 million (constant FY 1986 dollars) which equates to $719 million when stated in constant FY 1988 dollars. Although at the low end of the range of the Central Design Group's estimate, the Department deemed this allowance adequate for a viable initial complement of four detectors of varying sizes. The Department used an allowance of $446 million (constant FY 1988 dollars) for research and development and preoperations. This is a substantial increase above the Central Design Group's estimate which equates to about $300 million in constant FY 1988 dollars and reflected a more careful examination of the costs by the Central Design Group and the Department. These considerations led to a total project cost estimate of $4375 million (constant FY 1988 dollars). The Department extended the schedule by 2 years from that envisioned by the Central Design Group to provide for a less aggressive funding profile and, with escalation added, developed the first total project cost estimate submitted to Congress of $5320 million (as-spent).

Prior Budget Requests

To date, all of the Department's requests for the appropriation of SSC construction funding summarized in Table 2, have been based on the non-site-specific conceptual design developed in 1986 by the Central Design Group.

The first SSC budget request discussed above was forwarded to the Congress in early 1987 after President Reagan made the decision to go forward with the SSC as an important National priority. Thus, the initial request for Federal construction funding made in the FY 1988 budget request had a total project cost estimate of $5320 million (as-spent), with construction to begin in FY 1988 and to be completed in mid-FY 1996 (a construction duration of 8-1/2 years).

As discussed previously, the $5320 million (as-spent) was developed from an estimate of $4375 million in constant FY 1988 dollars by adding estimated escalation. It is this $4375 million (constant FY 1988 dollars) which has often been quoted and incorrectly compared to subsequent estimates in as-spent dollars. The Department indicated in Congressional hearings and in SSC information documents DOE/ER-0363 and DOE/ER-0339 (Reference 9) that this cost estimate of $4375 million (constant FY 1988 dollars) was accurate to within 10 percent and that site selection and additional design studies would be required before the estimate could be improved.

The Department's FY 1988 funding request to the Congress for SSC construction was $10 million, but no construction funding was appropriated in FY 1988 (Reference 10).

In FY 1987 and FY 1988, the Department conducted research and development at a pace of about $20 million and $33 million respectively, a significantly lower funding level than the $60 million to $70 million that had been assumed by the Central Design Group for this period.

TABLE 2

SSC Cost Estimates and Federal Budget Requests
Based on the 1986 SSC Conceptual Design

Year	Total SSC Budget[1] (as-spent $M) Requested	Total SSC Budget[1] (as-spent $M) Appropriated	Construction Funds (as-spent $M) Requested	Construction Funds (as-spent $M) Appropriated	TPC (as-spent $M)	Estimated Construction Completion Date
FY 1988	35	33 [2]	10	0	5,320	mid-FY 1996
FY 1989	363	98	283	0	5,320	mid-FY 1996
FY 1990	250	218 [3]	160	127 [4]	5,894 [5]	mid-FY 1998 [5]
FY 1991	318 [3]	243 [3,6]	169	94 [6]	5,894 [7]	mid-FY 1998 [7]

[1] Total SSC Budget includes the construction funds indicated in the next column plus the supporting research and development funds, and DOE Program Direction funds (FY 1990 and FY 1991).

[2] Original appropriation was $25 million. An additional $8 million was approved later through a reprogramming action.

[3] Includes DOE program direction funds not in the total project cost ($3.2 million in FY 1990 and $5.7 million in FY 1991).

[4] Original appropriation provided $129 million (of which $24 million was precluded from expenditure for activities other than tunneling); $2 million was reprogrammed to SSC program direction.

[5] The increase in total project cost reflects the delay in appropriation from earlier budget requests for initial construction funds and a modified funding profile which extended the completion date.

[6] Congress also released restriction on $24 million appropriated in FY 1990 for use in FY 1991.

[7] Estimate from FY 1990 Construction Project Data Sheet was used pending completion of the reviews and reconciliation of cost and schedule estimates that are the subject of this report.

The FY 1989 budget request to Congress reflected a total project cost estimate of $5320 million (as-spent) and included a request for initial Federal SSC construction funding at a level of $283 million, the same level previously indicated in the FY 1988 request as the planned funding level for FY 1989 (Reference 11). The total project cost estimate and the completion date remained the same as in the FY 1988 request, since the $10 million of construction funds that had been requested in FY 1988 would have permitted only minimal preparatory activities. Hence, failure to receive these requested funds caused no appreciable delay or increase in cost. A significant increase in R&D funds (from $33 million to $98 million) was appropriated for FY 1989; however, no construction funds were appropriated. This did cause a schedule delay, making it impossible to hold to the mid-FY 1996 completion date. This delay, along with a stretchout in the funding profile, did result in an increase in the cost estimate of $574 million, which was subsequently reflected in the FY 1990 request of $5894 million (as-spent).

This FY 1990 budget request to the Congress included $160 million for initial Federal construction funds for the SSC (Reference 12). The estimated completion date was extended to mid-FY 1998, with the corresponding increase in the total project cost to $5894 million (as-spent) referred to in the above paragraph. This increase of $574 million in total project cost and the 2-year delay in completion date reflected primarily the delay in appropriation of initial construction funding and a somewhat less aggressive funding profile. A reduced level of construction funding ($127 million) was appropriated for FY 1990. In January 1989, following selection of the Texas site for the SSC, the Universities Research Association, selected as the Management and Operating contractor for the SSC, began to establish the SSC Laboratory.

The FY 1991 budget request to Congress reflected the same total project cost and completion date as that in the FY 1990 request (Reference 13), pending completion of the updated, site-specific conceptual design and cost estimate by the SSC Laboratory (Reference 14) and completion of the reviews by the Department that are the subject of this report

(References 15 and 16). At the time the FY 1991 budget was submitted to Congress, the Department had approved conceptual design changes proposed by the SSC Laboratory, but did not yet have the results of its reviews of the preliminary cost estimate submitted by the SSC Laboratory. Secretary Watkins and other Department officials testified to the design changes at several Congressional hearings and further stated that the SSC cost was going to be greater than the earlier estimate of $5894 million (as-spent), with an increase possibly as much as $1000 million to $2000 million.

Up to this point, the first and only complete estimate, which was set forth in the 1986 Conceptual Design Report and supporting documentation, indicated a total project cost estimate in the range of $3935 million to $4247 million (constant FY 1986 dollars) and completion in mid FY-1994. When the effects of the Department's extension in completion date to mid-FY 1996 and the Department's reevaluation of the research and development and preoperations needs were taken into effect, this led to the total project cost estimate of $4375 million (constant FY 1988 dollars) which equated to the $5320 million total project cost estimate in as-spent dollars in the Department's first SSC construction request to Congress for FY 1988. This basic estimate was subsequently updated to reflect delays in appropriation of initial construction funding and a delay in completion from mid-FY 1996 to mid-FY 1998, leading to the total project cost estimate of $5894 million (as-spent) indicated in the FY 1990 and FY 1991 budget requests.

Congressional Budget Office Report

In October 1988, the Congressional Budget Office (CBO) published a report entitled Risks and Benefits of Building the Superconducting Super Collider, A Special Study by the Congressional Budget Office (Reference 17). This report addressed a number of issues regarding the SSC which are summarized in Appendix 2. Of particular relevance to this report are the CBO comments on the first SSC total project cost estimate of $4375 million (constant FY 1988 dollars). Based on a comparison of estimated costs to

as-built costs for a selected set of high energy physics facilities, the CBO suggested that SSC costs might rise above the Department's estimate of $4375 million (constant FY 1988 dollars) by as much as 46 percent. The Department strongly refuted the CBO suggestion, stating that the CBO analysis was badly flawed (Reference 18).

PRELIMINARY SITE-SPECIFIC CONCEPTUAL DESIGN AND COST ESTIMATE

Changes to the 1986 conceptual design for the SSC were proposed to the Department by the SSC Laboratory in December 1989, in the form of a preliminary draft Site-Specific Conceptual Design Report (SCDR). Although these changes addressed the detailed design of certain systems, there were no changes in performance and design objectives of the SSC, which remained as they were in the 1986 Conceptual Design Report. The SSC Laboratory, in proposing these design changes, noted that in the period of over 3 years since the 1986 Conceptual Design Report, there was substantial new information and an increased understanding of magnet performance and accelerator design for the SSC. Certain system parameters needed to be optimized from the design outlined in the 1986 Conceptual Design Report to ensure that the SSC would readily meet its performance and operational expectations. These changes included a doubling of the energy of the final injector accelerator from 1 TeV to 2 TeV (along with related energy increases in the lower energy injectors); an improvement in the uniformity of the magnetic field of the superconducting dipole magnets, leading to an increase in the magnet coil inner diameter from 4 cm to 5 cm; and an increase in the circumference of the collider ring from 52 to 54 miles (83 km to 87 km). Preliminary information from the SSC Laboratory indicated that costs would likely increase to a total project cost in the range of $7000 million to $8000 million (as-spent).

In light of the impending increase in cost estimated by the SSC Laboratory, Secretary Watkins requested a separate review by the High Energy Physics Advisory Panel to assess the overall scope of the SSC and the scientific potential of the facility as a function of beam energy for beam energies below 20 TeV. The High Energy Physics Advisory Panel formed a blue

ribbon Subpanel on SSC Physics whose members were a group of prestigious scientists, including five Nobel Laureates. This Subpanel recommended strongly that the SSC energy be maintained at 20 TeV and concluded that implementing the design changes proposed by the SSC Laboratory would ensure confidence in reliable and timely operation of the SSC. The Subpanel felt strongly about the need for a flexible and reliable facility at 20 TeV for decades to come and concurred with the SSC Laboratory's logic for making the recommended technical design changes previously described in this section.

The Subpanel report was unanimously accepted by the High Energy Physics Advisory Panel, which in its letter of transmittal to the Department further stated that: "Timely completion of the Superconducting Super Collider (SSC) remains the highest priority of the national High Energy Physics program. The physics research to be done with the SSC is essential to the improvement of present human understanding of the fundamental forces of nature and the underlying constituents of the physical universe in which we live." (Reference 19). After carefully reviewing the High Energy Physics Advisory Panel's advice, Secretary Watkins reaffirmed that the SSC was properly scoped at a 20-TeV beam energy and that the design changes proposed by the SSC Laboratory were necessary. This would certainly result in an increase in the cost estimate, but was in total keeping with the regular project development process (Figure 1, page 2).

Concurrent with this process to reaffirm the basic parameters of the SSC, the Department convened a review team in January 1990, to examine the SSC Laboratory's preliminary design, cost, and schedule estimates. The SSC Laboratory presented a preliminary total project cost estimate of $7235 million (as-spent) based on a site-specific design, with construction completion projected at the end of FY 1998 and the assumption that certain project elements in the areas of cryogenics and utilities could be decapitalized (i.e., the facilities would be built by industry and their capital costs would be amortized within the billing charges for the services provided). They further indicated that if these elements were included, the total preliminary project cost estimate would be $7705 million (as-spent). These estimates did not include the $131 million expended in FY 1988 and

FY 1989. The SSC Laboratory estimate at that time included a 14.5 percent contingency allowance ($720 million on the construction portion of the $7235 million estimate, and $778 million on the construction portion of the $7705 million estimate) on the base construction cost, which was judged by the Department to be low for a project of this type at this stage of development. This very preliminary review indicated a cost estimate in the range of $7000 million to $8000 million (as-spent). As noted in the previous discussion on the FY 1991 budget request, this preliminary estimate of $7000 million to $8000 million was discussed by Secretary Watkins and other Department officials during a number of Congressional hearings on the FY 1991 budget request.

SITE-SPECIFIC CONCEPTUAL DESIGN AND COST ESTIMATE

As a result of this January review, the Department charged the SSC Laboratory to refine the proposed design changes and to critically reexamine the cost estimate and schedule that had been submitted to the Department in December 1989. Following a major effort during the spring of 1990, the SSC Laboratory completed draft documentation of the Site-Specific Conceptual Design Report, total project cost, schedule, and funding profile in June 1990, well after the FY 1991 budget request was before the Congress. This represented the second complete total project cost estimate for the SSC project. This estimate, developed by the SSC Laboratory, reflected an increase in the total project cost to $7837 million (as-spent) and project completion by the end of FY 1998. This total project cost estimate included an increase of about $200 million in the contingency allowance over that in the earlier January 1990 estimate. The Site-Specific Conceptual Design Report, which, along with documentation presented to the Department and its review teams in June 1990, forms the basis for the Department's cost and schedule baseline, is discussed in greater detail in Chapter II.

INDEPENDENT COST REVIEWS

In order to ensure a thorough evaluation of the SSC design, cost, and schedule to be submitted by the SSC Laboratory in June 1990, the Department organized three reviews, compared to the two reviews that are normally conducted. These reviews included the customary program office (the Office of Energy Research) review and the Department's Independent Cost Estimating staff review. To ensure that the SSC Laboratory estimate would receive a completely independent and critical review and that the Department's review process would also be examined, Secretary Watkins requested a third, special review, by the High Energy Physics Advisory Panel.

The first was the *Office of Energy Research Review Committee (ERC)*, chaired by Dr. L. E. Temple, Jr., Director of the Division of Construction Management Support within the Office of Energy Research. It had a membership which included 16 DOE staff and 46 outside technical experts, along with 20 support staff consisting of report writers and coordinators, and observers. The outside technical experts were drawn from DOE laboratories, foreign laboratories, universities, the industrial sector, and the private sector. The members included persons with technical and engineering experience with accelerator and tunneling construction, as well as persons with experience in managing large projects. This committee was divided into 11 subgroups, each of which conducted in-depth analyses of specific aspects of the project.

The *Office of Energy Research Review Committee* was given the following charge:

> The ERC should assess the technical design proposed; in particular, whether the design is consistent with the SSC performance objective. The ERC should carefully review the cost estimates for the conceptual design, understand in detail the basis for the estimates, note identified uncertainties, and judge the overall validity of the estimates. The realism of the proposed construction schedule and funding profile should be addressed. The manner in which the work will be accomplished, including how it will be managed, should be reviewed and assessed. Thus, in summary, the ERC is to review and assess the proposed SSC design and the credibility of the associated cost and schedule estimates, as well as the adequacy of present and planned management arrangements to accomplish the scope of work.

The results of this review are documented in: Report of the DOE Office of Energy Research Review Committee on the Site-Specific Conceptual Design of the Superconducting Super Collider, dated September 1990 (Reference 16).

The second was the review team organized under the direction of Mr. Bobby R. Scarlett, Director, Office of Independent Cost Estimating (ICE). The ICE review team consisted of 2 DOE staff and 11 outside technical experts, primarily in the areas of superconducting magnets and conventional construction. This review assessed the overall scope of the project, the cost estimate, proposed schedule, and high risk technical issues. The ICE staff functions independently of the Office of Energy Research, develops independent cost and schedule estimates for all DOE major systems acquisitions and major projects, and reports its findings directly to the DOE Acquisition Executive (Deputy Secretary Moore in the case of the SSC). Results of the ICE review have been provided to the program and are incorporated in Chapter II of this report.

The third was the High Energy Physics Advisory Panel's *Subpanel on SSC Cost Estimate Oversight*, which was chaired by Dr. John W. Townsend, former Director of the Goddard Space Flight Center in Greenbelt, Maryland. The other five members included senior experts in civil construction, detectors, accelerator design and operation, laboratory management, and industrial management of R&D and technical programs. This Subpanel not only reviewed the SSC Laboratory's estimate but also assessed the Department's review process. The charge to the Subpanel follows:

> Provide a report documenting an independent assessment of the SSC cost estimate. The Subpanel should evaluate and address the appropriateness of the cost estimating methodology; the completeness, and credibility of the cost estimate; the realism of the proposed schedules and funding profiles; and the degree of risk involved in completing the SSC within the estimated cost, including the proposed contingency. The Subpanel should be established as soon as possible and begin immediately to interact with the SSC Laboratory.

The conclusions and recommendations of the Subpanel are documented in the Report of the 1990 HEPAP Subpanel on SSC Cost Estimate Oversight (Reference 15).

All three review groups received in-depth presentations by the SSC Laboratory and had the opportunity to interact with Laboratory staff during the week of June 25-30, 1990. They also held additional meetings to gather data, formulate their findings, and develop recommendations. The Laboratory's cost estimate, the cost estimates resulting from the three reviews, and an analysis of their variations are discussed in Chapter II.

THE DEPARTMENT'S BASELINE

Since receipt of the results of the reviews, the Department has undertaken a detailed reconciliation of the differences. Subsequently, the Department considered three cost and schedule scenarios:

Scenario 1 - The proposed baseline submitted by the SSC Laboratory, with a total project cost of $7837 million (as-spent) and completion by the end of FY 1998.

Scenario 2 - An adjusted baseline developed by the Department, with a total project cost estimate of $7873 million (as-spent) and completion by the end of FY 1998.

Scenario 3 - An alternative baseline developed by the Department, with a total project cost of $8249 million (as-spent) and completion by the end of FY 1999.

Based on its assessment of all the data, **the Department has concluded** that the third scenario establishes the most appropriate cost and schedule baseline for the SSC. Details on these three scenarios and the Department's final baseline cost, schedule, and funding profile are provided in Chapter III.

This development and history of early cost estimates and the baseline cost estimate for the SSC project reflect the natural maturation of design and cost uncertainty for any large project. The cost estimates discussed for this project have evolved since the inception of the concept for SSC in the 1982-1984 time period to the first complete estimate of total project cost at the time of the Conceptual Design Report of 1986. The subsequent Site-Specific Conceptual Design Report in 1990 further refined the design and developed the second complete cost estimate while maintaining the performance objectives of the SSC as earlier conceived.

II. DISCUSSION OF THE SSC COST ESTIMATES

This chapter summarizes the performance goals and technical design of the SSC and addresses in depth the SSC Laboratory cost estimate that was the basis for the deliberations of the three Department review groups. The findings and recommendations of each review group are summarized. In key areas where the review groups differed from the SSC Laboratory estimate, a detailed discussion of the recommendations of each of the review groups is provided along with the Department's evaluation and conclusion.

DESIGN OBJECTIVES AND MODIFICATIONS

The primary design objectives of the SSC are an energy of 20 TeV for each of the two beams and a luminosity (a measure of the rate of useful collisions) of 10^{33} per square centimeter per second, which results in a total of about 100 million interactions per second.

As noted earlier in Chapter I, the design objectives of the SSC remain as they were in the 1986 Conceptual Design Report. However, certain system parameters have been modified and optimized to meet these goals. The revised design reflects: an updated assessment of the physics to be explored by the SSC; advances in accelerator and detector design and technology; recent experience with other high energy physics facilities around the world; and the characteristics of the Texas site. Changes of this nature are not unexpected and are normal for a project moving from the conceptual design stage to more detailed design, as was done in this case as the SSC moved from the 1986 conceptual design to that now proposed by the SSC Laboratory.

The revised design is somewhat more conservative than that proposed in the 1986 Conceptual Design Report, with a particular focus on reducing the commissioning time for the collider, ensuring highly reliable operation, and maintaining flexibility in operations and experimental capability. The

primary design changes from the 1986 Conceptual Design Report are summarized as follows:

- an increase in energy for the injector accelerators from an energy of 1 TeV to 2 TeV for the High Energy Booster, along with related increases in the energy of the Medium Energy Booster and Low Energy Booster;
- an increase of the magnetic focusing strength in the collider ring, requiring a slight increase in the circumference of the collider ring from 83 km (52 miles) to 87 km (54 miles);
- an improvement in the field uniformity and design margin of the collider superconducting dipole magnets, related to an increase of the coil inner diameter from 4 cm to 5 cm;
- adaptation of the facility to the site, including the depth of the accelerator tunnels, to take into account the local environment, topography, and geology;
- incorporation of flexibility in the baseline design to permit later installation of beam bypasses which would allow for potential future detector installation without lengthy shutdowns;
- an increase in the size allowance for the experimental halls in view of the latest understanding of the size, complexity, and technical sophistication of the detectors required for the SSC energy range; and
- improved definition of the test and calibration beam capability needed to meet the requirements of the detector program.

The revised conceptual design will provide for a flexible and reliable SSC facility that will meet the scientific goals of the SSC program and the scientific community well into the next century.

DESCRIPTION OF THE FACILITY

The SSC accelerator complex, as described in the Site-Specific Conceptual Design Report, consists of five cascaded accelerators including a 600-MeV linear accelerator; an 11-GeV Low Energy Booster synchrotron; a

200-GeV Medium Energy Booster synchrotron; a 2-TeV High Energy Booster synchrotron; and finally, the 20-TeV collider (two synchrotrons located in a common tunnel). The accelerators are housed in underground enclosures. Located around the circumference of each accelerator will be surface structures to provide cryogenics, utilities, other necessary support services, and access to the underground structures. The detectors will be located in underground experimental halls at four primary interaction points. Also included are offices, laboratories, work spaces, and technical support facilities in a campus-like arrangement to house and support the estimated 2200 staff and 500 visiting scientists from throughout the world.

The dominant element of the SSC is the collider in which oppositely directed beams of protons, each with an energy of 20 TeV, are caused to collide head-on. The two accelerator rings confining the proton beams are housed one above the other in an underground tunnel that includes the interaction points. The beams are guided around the desired paths through evacuated tubes by superconducting dipole magnets, which bend the beams around the ring, and by superconducting quadrupole magnets, which focus the beams to a narrow region about the desired orbit. The superconducting magnets for the collider, as well as those for the High Energy Booster, must be held at a temperature of 4.35 Kelvin (-451.8° Fahrenheit) by a large cryogenic liquid helium system.

THE SSC LABORATORY ESTIMATE

This second complete estimate of the total project cost for the SSC project, done in 1990 by the SSC Laboratory, proposed a total project cost of $7837 million (as-spent) under the scenario of an aggressive, best-case schedule and funding profile, leading to project completion by the end of FY 1998. This cost estimate is based on the Site-Specific Conceptual Design Report discussed previously in Chapter I, along with the associated documentation on design, schedule, funding profile, and management presented by the SSC Laboratory to the Department and its review teams in June 1990. In preparing its documentation, the SSC Laboratory carried out extensive studies on the design of the collider, injector, detectors, and related

facilities and structures, using the 1986 Conceptual Design Report as a starting point.

A summary of the changes in the base-cost estimate from the time of the 1986 Conceptual Design Report to the 1990 Site-Specific Conceptual Design Report and the primary reasons for the changes are given in Table 3. For purposes of comparison, both base cost estimates are shown first in constant FY 1990 dollars. The $5815 million base-cost total (constant FY 1990 dollars) indicated in Table 3 leads to the SSC Laboratory's total project cost estimate of $7837 million when a contingency allowance of $920 million and an escalation allowance of $1102 million are added. The $4270 million base-cost total (constant FY 1990 dollars) indicated in Table 3 leads to the Department's prior estimate of $5894 million when a contingency allowance of $757 million and an escalation allowance of $867 million are added.

COST-ESTIMATING METHODOLOGY

The general philosophy of the SSC Laboratory's cost estimate, which is the primary basis for the Department's SSC baseline, is to include the costs needed to bring the SSC to a state of operational readiness and to create a laboratory suitable for conducting high energy physics experiments at the facility. In addition to the base construction cost of the technical systems and conventional facilities, the total project cost estimate includes the costs of: engineering, design, inspection, and administration (EDIA) for all technical systems; architect-engineering/construction management (A-E/CM) services for conventional systems; an allowance for contingency; the research and development program for accelerators and components; preoperating commissioning activities; the U.S. share of detector research and development and fabrication; computers; and required management and administration.

TABLE 3

Cost Comparison Summary of 1986 CDR and 1990 SCDR
(Dollars in Millions)

	SCDR 1990	CDR 1986[1]	INCREASE
Accelerator Systems [2]	1082	758	324
Magnet Systems [3]	1904	1186	718
Conventional Construction [4]	1052	776	276
Project Management [5]	49	26	23
Preops, R&D, Admin. Support [6]	976	772	204
Experimental Systems	752	752	-
BASE COST (FY 1990 Dollars)	**$5815**	**$4270**	**$1545**
Escalation	1102	867	235
Contingency	920	757	163
TOTAL PROJECT COST (AS-SPENT)	**$7837**	**$5894**	**$1943**

1 Conceptual Design Report (CDR) estimates have been recast in the Site-Specific Conceptual Design Report (SCDR) format to permit comparisons. Total project cost is as presented in the FY 1990 and FY 1991 budget requests to Congress.

2 The two largest circular injectors (the High Energy Booster and the Medium Energy Booster) have been increased in energy by a factor of two. The collider cost has increased due to additional refrigeration required for the larger aperture dipoles and increased power supply and distribution costs for the warm power leads.

3 The superconducting magnets for the collider are now of larger aperture than considered in the CDR and the estimated cost per magnet has increased. In addition, more magnets are needed due to the larger circumference of the collider and High Energy Booster.

4 The increase is largely due to the longer length of injector facilities resulting from their increased energies, the larger circumference of the collider ring, and the larger inside diameter of the tunnels. In addition, the experimental areas have an internal volume that is two to three times larger than in the CDR due to the requirements of the physics program.

5 The effort required to manage the project according to current requirements is now judged to be larger than was estimated at the time of the CDR.

6 Current assessment indicates larger R&D needs, including those driven by the technical changes such as magnet aperture. The wage costs per full time equivalent are larger than anticipated in 1986.

The SSC Laboratory's cost estimate has been developed by a bottoms-up approach utilizing a comprehensive Work Breakdown Structure (WBS) division of the SSC tasks. The total cost is built up as the sum of many individual cost elements at the WBS sublevels. Where possible, the cost estimates for the SSC components and systems are based on previous experience with similar accelerator systems and standard conventional construction practices. The development of the cost estimate for the collider superconducting magnets, which are a major fraction of the total project cost, has received very detailed attention. In the conventional facilities category, the underground construction, including the tunnel and experimental halls, represents the largest portion of the cost. In the case of the tunnel, the SSC Laboratory has selected the most conservative of several estimates developed by different architectural-engineering firms.

The SSC Laboratory estimate includes an allowance of $842 million (as-spent) of Federal funds for the detectors, which the SSC Laboratory believes is sufficient for a viable and productive initial physics program with the SSC. This cost envelope is based on a build-to-cost approach which has been successfully used in the past for other high energy physics accelerator programs.

Cost estimates are based on vendor quotes (approximately 30 percent), engineering estimates with vendor and SSC Laboratory input (approximately 30 percent), and estimates by the SSC Laboratory based on experience and engineering standards (approximately 40 percent). In some cases, consultants have been used to verify cost estimates and to estimate specialty areas. Current Davis-Bacon labor rates are used in the estimate where appropriate.

An estimate of engineering, design, inspection, and administration (EDIA) is provided for each technical system cost element, based on an assessment of the complexity, uniqueness, and criticality of each element. The EDIA cost is derived from estimated man-hours, rates, and overhead estimates. An architect-engineering/construction management (A-E/CM)

estimate has been developed for each conventional facility cost element using a process similar to the EDIA estimate.

Contingency allowances are assigned to each of the technical and conventional construction cost elements. For each WBS element, technical, cost, and schedule risk weighting factors are estimated and used to calculate an appropriate contingency allowance. Contingency is not included for research and development and preoperating commissioning activities and was considered to be a part of the total allowance of $842 million (as-spent) for the initial complement of detectors.

Because a major new National laboratory is being established, in addition to construction of the SSC collider facilities, there are some laboratory costs that were not included in the SSC Laboratory estimate of the total project cost. For example, costs for the general laboratory facilities and services not specifically related to the construction project, and operating costs for the injectors and collider sectors once these facilities have been commissioned, were assumed to be funded separately outside of the total project cost. The SSC Laboratory estimate also did not include funding for the initial complement of spares. The SSC Laboratory assumed, and the Department agreed, that the costs of the SSC Laboratory physics research groups will be provided outside of the total project cost, from high energy physics program funding.

All costs are estimated in constant FY 1990 dollars, which were escalated to as-spent dollars on the basis of a schedule and funding profile developed by the SSC Laboratory using escalation rates provided by the Department. The Department's construction project escalation rates are used for the construction portion of the SSC, and the Office of Management and Budget (OMB) escalation rates are used for those portions of the SSC project that are funded with operating and equipment funds within the total project cost.

SUMMARY OF REVIEW FINDINGS

A summary of the costs calculated by the SSC Laboratory and the increments estimated by the three review teams are shown in Table 4. The Energy Research Review Committee (ERC) recommended a $46 million (constant FY 1990 dollars) increase in the base-cost estimate (plus an associated escalation increase of $10 million) and a $494 million (as-spent) increase in contingency, leading to a total project cost estimate of $8387 million (as-spent). The High Energy Physics Advisory Panel (HEPAP) Subpanel recommended an increase in contingency of $500 million (as-spent) for technical uncertainties and $300 million (as-spent) for a 6- to 12-month addition to the schedule to reduce risk, leading to a total project cost estimate of $8637 million (as-spent). They also suggested an increase of $300 million (as-spent) to enhance the scope of the initial set of detectors.

The Independent Cost Estimating (ICE) staff recommended an increase of $558 million (constant FY 1990 dollars) in the construction project base-cost estimate, an increase of $674 million (as-spent) in contingency, and an increase of $260 million (as-spent) for additional escalation, leading to an estimate for the total project cost of $9329 million (as-spent). They also suggested that certain additional cost elements, totalling an additional $2492 million (as-spent), be considered for inclusion in the total project cost.

The ERC and HEPAP Subpanel were in basic agreement with the cost-estimating methodology and base-cost estimates presented by the SSC Laboratory. The ERC suggested overall adjustments to the base-cost estimates at the level of about 1 percent, while the HEPAP Subpanel suggested none. The HEPAP letter forwarding the Subpanel report to the Department states that: ". . . the study validates the baseline cost arrived at by the SSC Laboratory." The ICE staff, on the other hand, recommended an overall increase in the construction project base-cost estimate of about 14 percent.

TABLE 4

SSC Cost Estimates
(Millions of Dollars)

		Adjustments Suggested by Reviews		
	SSCL Estimate	ERC	HEPAP Subpanel	ICE
Construction Project				
Accelerator Systems	$1082	+ 27		+ 15
Magnet Systems	1904			+ 368
Conventional Construction	1052	+ 19		+ 175
Project Management & Support	49			
Subtotal (FY 1990 $)	4087			
Escalation	906	+ 10		+ 123
Subtotal (As-spent)	$4993			
Contingency (As-spent)	920	+ 471	+ 800	+ 576
Total Estimated Cost (TEC)	**$5913**	**$6440**	**$6713**	**$7170**
Other Related Costs				
R&D and Preoperations	$ 976			
Experimental Systems	752			
Subtotal (FY 1990 $)	1728			
Escalation	196			+ 137
Subtotal (As-spent)	$1924			
Contingency (As-spent)	---	+ 23		+ 98
Total Project Cost (TPC)	**$7837**	**$8387**	**$8637**	**$9329**
Additional Cost Items (As-Spent)				
Schedule Risk				+ 476
Spares				+ 110
Lab Operations				+ 494
DOE Site Office				+ 31
Land				+ 70
Detector Scope			+ 300	+1180
FY 1988 and FY 1989				+ 131

The suggested increases to the total project cost by the review groups were largely in the area of contingency allowances to cover estimated costs for technical uncertainties and for schedule delays that could possibly occur during the course of the project. Increases in contingency accounted for all of the changes recommended by the HEPAP Subpanel, 85 percent of those recommended by the ERC, and 45 percent of those recommended by the ICE staff (excluding the suggested additional cost items). Although the ERC and HEPAP Subpanel did express their judgment on what the cost and schedule impact might be if these contingent difficulties occurred as the project proceeds, both groups concluded that the SSC was technically feasible, and neither group advised that the SSC could not be built and commissioned as proposed by the SSC Laboratory. The ICE staff, on the other hand, expressed its judgment that the schedule was unrealistic and unachievable and that a slippage of at least 1 year was likely. The differences among the four cost estimates occur largely in the following seven areas which are discussed separately below: superconducting magnets; accelerator systems and conventional construction; detectors; schedule risk; operating costs for completed facilities and spares; contingency; and additional cost items, primarily suggested by the ICE staff.

ANALYSIS OF COST-ESTIMATE VARIATIONS

This section provides a discussion of the findings of the review groups for the areas of the project where there were differences in the total project cost estimates, and it gives the Department's evaluation in each case.

Superconducting Magnet Costs

The SSC Laboratory estimated the cost of superconducting magnets at $1904 million (constant FY 1990 dollars) and proposed a contingency allowance of 19.3 percent which, with appropriate escalation added, leads to a total estimate of $2776 million (as-spent).

The ERC and HEPAP Subpanel expressed concerns about different aspects of the magnet procurement strategy, particularly with regard to whether the leader-follower concept provided adequate competition. **The Department believes** that the magnet Request for Proposal (RFP) issued on July 25, 1990, allows sufficient flexibility to accommodate these concerns (Reference 20). The SSC Laboratory and the Department are considering specific ways to deal with these concerns, and the SSC Laboratory has already issued a letter to potential bidders inviting them to propose activities that would enhance competition.

The ICE staff expressed concern about the high degree of concurrency in schedule between the testing of prototype dipole magnets and the fabrication of production magnets. **The Department believes** that the concurrency of the design and prototyping activities in the magnet program schedule are desirable to effectively optimize the design on the basis of test results. The concurrency will allow the incorporation of results from the testing of prototypes into the design in a timely manner. **The Department notes** that while there is concurrency in the development phases of the magnet program (which includes the 502 low-rate production magnets), there is no concurrency between prototype testing and full-rate production.

The ERC and ICE groups each recommended that the contingency for superconducting magnets be raised to about 35 percent (an increase of about $350 million as-spent). The HEPAP Subpanel discussed a similar increase in their deliberations. The ERC and HEPAP Subpanel were concerned about the possible need to cold test all superconducting magnets prior to installation in the tunnel and reflected this concern in their recommendations on contingency allowances. **The Department notes** that the SSC Laboratory estimate includes funding to permit cold testing of all of the first 10 percent of the superconducting magnets and of 10 percent of the remaining magnets. The ICE staff, as well as the ERC and HEPAP Subpanel, were concerned that the SSC Laboratory estimate did not allow adequate indirect cost loading on materials purchased by subcontractors to cover materials handling, corporate overhead, and profit. While the ERC and HEPAP Subpanel

did not identify a separate increase for this purpose outside of their proposed increase in contingency, ICE recommended an increase of about $368 million (constant FY 1990 dollars) to the base cost of the magnets, primarily for these materials-loading costs, and indicated their concern that magnet costs could increase even further.

The Department evaluated the concerns about magnet contingency and has concluded that the contingency allowance in the baseline estimate is adequate to cover a reasonable array of uncertainties that could arise during magnet development and production. Following a reevaluation of materials-loading cost estimates by the SSC Laboratory, the Department has concluded that the base-cost estimate of the magnets should be increased by $84 million (constant FY 1990 dollars) to accommodate potentially higher materials-loading costs; the Department believes that the remainder of the concern in this area can be mitigated by direct government purchase of materials should the magnet fabrication bids from industry include the larger materials-loading factors. This increase is reflected in Table 6 on page 53.

Accelerator Systems and Conventional Construction

The ERC proposed adding $46 million (constant FY 1990 dollars) to the base-cost estimate for these items, including $27 million for accelerator systems and $19 million for conventional facilities. In addition, the ERC recommended an increase of about $97 million (constant FY 1990 dollars) in contingency. The HEPAP Subpanel, in its deliberations, suggested that contingency on underground construction should be increased to 25 percent because of the possibility of encountering unforeseen conditions during tunneling. The ICE staff recommended more substantial changes to the base estimate, totalling $190 million (constant FY 1990 dollars). This recommended increase was mostly for higher estimated costs of the tunnel liner and of 69 kilovolt cables installed in the tunnel; for higher unit cost estimates for surface facilities; for increased labor estimates for

experimental halls; and for larger architect-engineering/construction management expenses, particularly in the area of inspection.

The SSC Laboratory has reexamined its cost estimates for each of the areas of concern identified by the review groups. As a result, **the Department concludes** that the base-cost estimate will be increased by $25 million (constant FY 1990 dollars) for accelerator systems to cover costs of a variety of small items including changes in estimates of vendor wage rates, freight for shipping of conventional magnets, and the cost of septum magnets. The base estimate will also be increased by $21 million (constant FY 1990 dollars) for conventional construction to cover increased estimated costs for the Accelerator String Test Facility and the Prototype Installation Facility and a variety of minor additions to other structures. Cost estimates for the tunnel liner, 69 kilovolt cables, labor, and architect-engineering/construction management expenses were revalidated by the SSC Laboratory, and no changes in the estimates for these items have been made. **The Department has concluded** that any additional uncertainties in these areas can be controlled by effective project management, either within the contingency allowance for these activities in the baseline estimate or in final design optimization. These increases are reflected in Table 6 on page 53.

Schedule Risks

The SSC Laboratory presented a schedule which projected completion of the SSC by the end of FY 1998. This schedule required a rapid ramp-up of funding and project activities beginning in FY 1992. The ERC judged that the schedule was very aggressive, but achievable if a number of critical factors fell into place properly. The ERC recognized that such an aggressive schedule entailed schedule and cost risks, but did not recommend a specific cost increase for this item. The HEPAP Subpanel had concerns about the ability to achieve the schedule and the realism of the associated funding profile. They suggested adding 6 to 12 months up front in the schedule to give the SSC Laboratory more time to enhance its staffing, to

reduce perceived risks in the magnet program, and to permit a more realistic funding profile. They recommended a $300 million (as-spent) contingency increase for schedule risk. The ICE staff had concerns that the schedule was unrealistic and unachievable. They estimated that a slippage of at least 1 year in completion was likely. They suggested an overall increase of $476 million (as-spent) to cover a schedule extension of 1 year.

The Department has concluded that an overall schedule extension of 1 year (completion extended from the end of FY 1998 to the end of FY 1999) will: reduce schedule risk, provide for a more conservative scheduling of major project activities. facilitate a more realistic funding profile with a more prudent buildup beginning in FY 1992, and reduce technical risk by allowing more time to firm-up designs before entering into production of major components. Such a schedule extension, coupled with a less aggressive funding profile, will require an addition of $376 million (as-spent) to the cost estimate provided by the SSC Laboratory, but it will significantly reduce overall cost and schedule risk. This is reflected in Table 6 on page 53.

Detectors

Detectors for high energy collider experiments are generally quite large and very complex. Their design and fabrication takes many years. These detectors are traditionally built by large "collaborations" of scientists and institutions from throughout the world contributing manpower, materials, and equipment. The design of the detectors and the scope and composition of the collaborations is defined later in the project development process than that for the accelerator which is centrally managed by the Laboratory. The detector designs, therefore, generally mature over several years and involve a number of reviews before final approval.

This process of selecting detectors involves a peer evaluation of both the scope and technical approach of the collaborators as well as the physics to be derived from the collider being built. Its focus is on the

experiments to be performed, with the "user" community defining and developing the instrumentation and diagnostics for the experiments separate from the Laboratory which builds the large machine. The process is evolutionary and requires constraints on the design and scope of each detector and a cost discipline to provide for tradeoffs of cost and performance. This is usually accomplished by imposing a cost ceiling for design and fabrication that serves to fix the overall scope of the detectors and to impose cost discipline.

Because of the evolving nature of the detector designs and the tradition of relying on the individual contributions of foreign scientists and institutions, the foreign contributions to the detectors for high energy physics facilities have not generally been included as part of the estimated cost. These contributions have not been used to offset Federal funds required for the project, but rather to augment those funds and, thus, are not considered part of the total project cost.

A number of successful collaborations can be cited that have had international participation and cost-sharing of this type. For example, approximately one-third of the total cost of the Collider Detector at Fermilab was contributed by foreign scientists and institutions, primarily from Japan and Italy. Also there has been strong U.S. participation in the fabrication of all four of the detectors for the Large Electron-Positron (LEP) collider at the European Laboratory for Particle Physics (CERN) near Geneva, Switzerland. In particular, the L3 detector project at LEP is led by a U.S. physicist, and the U.S. provided approximately one-quarter of the total cost of that detector.

Detector Proposals. Proposals for detector concepts were submitted by teams of collaborators to the SSC Laboratory in May 1990; 15 proposals were submitted, including four for large, general-purpose detectors. The scope and preliminary cost estimates for these large detectors were further refined and submitted to the Laboratory in December 1990. The SSC Laboratory subsequently identified two large, general-purpose detectors (the

Solenoidal Detector Collaboration (SDC) and the L* detector) for further consideration. Final approval is expected in late 1992.

Earlier Detector Estimates. The initial cost estimate for detectors submitted to Congress as part of the FY 1988 budget request was $815 million (as-spent). This estimate included funds for detector research, computers, and detector design and fabrication. It was based on a 1986 scenario for two large, general-purpose detectors; one medium-sized detector; and a smaller experiment. This estimate was judged to permit a vigorous SSC physics program at turn-on, while leaving flexibility to incorporate new detector technologies as they became available. This estimate also assumed that there would be substantial participation by foreign scientists and institutions in the detector collaborations and, thus, significant foreign contributions to the design and fabrication of these detectors.

The cost estimate for SSC detectors was updated in the FY 1990 budget request to $842 million (as-spent). This change in the estimate of cost reflected the cost impact of escalation due to the extension in schedule for project completion. There was no change in the scope of the detectors or the estimate of the contributions by foreign collaborators.

SSC Laboratory Proposal (June 1990). In its proposed cost estimate, the SSC Laboratory retained the same $842 million (as-spent) allowance that previously had been provided to Congress. This allowance, which corresponds to $752 million in constant FY 1990 dollars, continues to reflect the Laboratory's expectation that sizeable contributions from the detector collaborations (scientists and institutions) would supplement U.S. funds as has been the tradition in high energy physics. Subsequent technical reviews and advice of the SSC Laboratory's Program Advisory Committee supported this position, concluding that ". . . while increased detector funds would clearly allow a broader and more varied program, a viable and productive initial program can be implemented with the $842 million (as-spent) U.S. funding allocation plus expected significant foreign contributions." (Reference 21)

Department Reviews of the SSC Laboratory Proposal. The ERC expressed concern that the SSC Laboratory allowance of $842 million (as-spent) of U.S. funds for detectors, along with anticipated foreign contributions, would not be adequate to permit an initial SSC physics program consisting of two large, general-purpose detectors, one medium-sized special-purpose, detector, and one or more small experiments. However, the ERC concluded that the $842 million (as-spent) allowance provided in the SSC Laboratory estimate for experimental systems, along with the anticipated significant level of non-Federal contributions for detectors, could permit a balanced initial physics research program, although one of somewhat reduced scope. The Subpanel of the High Energy Physics Advisory Panel also had concerns that the SSC Laboratory allowance was inadequate and suggested adding $300 million (as-spent).

The ICE staff developed their estimate of the cost on a more broadly scoped initial set of detectors, which included two fully-scoped, large, general-purpose detectors. They concluded that the cost estimate for these detectors should be larger than that permitted by the SSC Laboratory allowance, and closer to that indicated in the Expressions of Interest. They further concluded that the full cost of the detectors, independent of funding source, should be included in the total project cost estimate and that a contingency allowance of 40 percent should be added. ICE also suggested that the Department's construction project escalation rates, rather than the Office of Management and Budget escalation rates for capital equipment, should be used. In view of these considerations, the ICE staff suggested an increase of $1180 million (as-spent) for detectors, detector research and development, and computers.

The cost estimates and U.S. funding requirements presented by the collaborations, and accepted by the SSC Laboratory, are consistent with the estimate in the baseline of funds for large, general-purpose detectors. The overall allocation for detectors in the baseline is $752 million (constant FY 1990 dollars). The estimates presented to the Program Advisory Committee

reflect Federal funding requirements of about $310 million for SDC and $260 million for L* detector (constant FY 1990 dollars).

The Department's Baseline. On the basis of its evaluations, and the recent affirmation of the detector cost estimates, the Department is retaining the $752 million allowance in FY 1990 dollars for detectors and computers. An adjustment of $8 million for the FY 1988 and FY 1989 costs that were not included in the initial SSC Laboratory estimate, along with a revised estimate of escalation to reflect the latest escalation rates provided by the Office of Management and Budget and the schedule extension in the baseline, brings the total allowance in the cost baseline to $910 million (as-spent).

The Department has decided that this allowance of $910 million (as-spent) Federal funds is adequate, along with expected significant foreign detector contributions, to provide two large, general-purpose detectors of appropriate scope for the initial SSC physics program as well as two or more smaller experiments. **It is the judgment of the Department** and the SSC Laboratory that a strong SSC physics program, consistent with manpower and technical resources available both in the U.S. and abroad, can be achieved within this allowance of U.S. funds, plus anticipated significant foreign contributions. This judgment also reflects the need for a well-balanced, overall U.S. high energy physics program and the appropriate allocation of National resources over the next decade, prior to the time of SSC turn-on.

The Department further notes that the SSC Laboratory is committed to a design-to-cost approach for detectors and that there is a history in the high energy physics program of successfully building large detectors with this approach. Furthermore, any additional funds that might be required for detectors will be obtained from foreign collaborations and their contributions. The detector proposals submitted to the SSC Laboratory in December 1990, validate the viability of this approach by identifying significant foreign contributions.

International Participation. The Department is committed to establishing the SSC Laboratory as a truly international laboratory and is seeking strong participation in both the accelerator construction and the experimental program by foreign partners. Thus, in the case of SSC, there are two components to foreign contributions: (1) those funds deriving from traditional collaborations where contributions to the detectors by foreign scientists and institutions do not offset a portion of the total project cost and are not included as part of the estimated cost to build the project, and (2) those contributions from foreign partners to the construction of the SSC that will directly offset a portion of the total project cost, thereby reducing the total Federal funds required to build the SSC. As mentioned earlier, this allocation of foreign contributions to the detectors is not unique to SSC, but has been applied in other projects (e.g., Fermilab, LEP, etc.).

A unique feature of the SSC project is to approach foreign countries at the government-to-government level with an offer of partnership in return for contributions to building and operating the SSC as a truly international laboratory. These contributions and international participation are further discussed in the following chapter of the report, dealing with the reconciliation of the baseline cost estimate for the SSC and the cost of some of its operations.

Operating Costs for Completed Facilities and Spares

The HEPAP Subpanel and the ERC review group did not address the issue of how to fund operating costs for facilities after their commissioning had been completed, for general laboratory operating overhead for activities not directly related to the construction project and for spares. This was viewed as a matter for a Department policy decision. They did, however, support the need for funding such activities. The ERC expressed its judgment that the SSC Laboratory estimate for these costs was reasonable. The ICE staff suggested that approximately $460 million (as-spent) for these costs should be included as part of the total project cost. (The ICE staff

also suggested that approximately $144 million (as-spent) be added for the costs of SSC Laboratory physics research groups which the Department had already decided would be appropriately covered with high energy physics program funding.) **The Department notes** that the SSC Laboratory estimate does include, within its total project cost estimate, funds for preoperation of facilities through the completion of their individual commissioning and any funds necessary for completion of commissioning of the collider. The estimate also includes funds for administrative and technical support for personnel directly involved in project design and construction activities.

In the past, laboratory operating costs for the types of activities discussed in this section have been met from program operating budgets rather than from within the total project cost for high energy physics facilities constructed at *existing* laboratories. The Department has reviewed ways to provide operating costs for these purposes, taking into account that the SSC is unique and involves the establishment of a new laboratory on a greenfield site. **It is the Department's conclusion** that the funding for these operating costs, which are estimated to total approximately $460 million (as-spent), should be provided outside the total project cost. These costs will begin at a low level in FY 1993, with a slow ramp-up during the remainder of the construction project. This is consistent with the approach used at other laboratories and is a logical decision since the costs are more endemic to operations after construction than to preparations for operations during construction. These funds for laboratory operations should be provided by additional appropriations for the high energy physics program which has the ultimate responsibility for operation of the SSC. This position is further supported by the goal set for the SSC program to obtain foreign participation and partnership contributions by formal agreements with foreign partners for the operation of an international SSC Laboratory.

Contingency

The ICE staff stated their judgment that the contingency allowance in the SSC Laboratory estimate was not in accordance with Departmental guidelines for a project at this stage of design development. As noted in previous sections of this report, the ERC and HEPAP Subpanel also had concerns about the contingency allowance in the SSC Laboratory baseline estimate. **The Department has concluded** that an addition of $142 million (as-spent) to the total project cost to bring the overall contingency to $1062 million, 20 percent of the base construction cost, compared to the 18 percent in the SSC Laboratory estimate, is an appropriate allowance to reduce cost risk. This is reflected in Table 6 on page 53. In addition, part of the $125 million of the $1000 million Texas contribution that is not currently allocated to offset costs within the total project cost could be available for contingency which may be applied to offset additional costs within the total project cost.

The Department believes that the concept of contingency allowances for large projects, involving large quantity procurements and highly repetitive fabrication requirements, should be different than for smaller projects. In particular, it is not clear that there is any basis to set contingency allowances as a straight percentage of total cost, independent of the size of the project or the number of items that are to be procured or fabricated. For example, in the superconducting magnet area of the SSC, the engineering cost for correcting design problems would be amortized over a base ten times larger than that of the Fermilab Tevatron accelerator, and the duration of the magnet production schedule provides greater capacity for making up schedule problems. A similar argument can be made for tunneling cost contingency. With the length of tunnel that will be constructed for the SSC, it is more likely that the average distribution of geological characteristics typical of the area will be encountered than for a much smaller tunnel where the effect of local aberrations could overwhelm the initial tunneling cost estimate.

The Department concludes that a contingency allowance of $1062 million is in the mid-range of the Department's guidance on contingency allowances (15 to 25 percent), and is highly appropriate at this stage of design for a project of the size and type of the SSC. **The Department notes** that both its cost baseline and the contingency allowance included therein are larger than those proposed by the SSC Laboratory which was willing to commit to deliver the SSC at their proposed cost estimate of $7837 million (as-spent). **The Department further believes** that if either the cost baseline or contingency allowance therein is made too large, this will guarantee a higher cost at completion.

The Department further concludes that an adjustment to the estimated overall project contingency is appropriate to remove the contingency allowance on the production of technical components that are expected to be provided as in-kind contributions by foreign sources. A reduction of $219 million was made for this purpose. This figure reflects an estimate of the contingency on the production of technical components and magnets that are expected to be provided as in-kind foreign contributions. The commitment of foreign sources by formal agreement to deliver these items as in-kind contributions would obviate the need for Federal contingency funds on the production of these items. Contingency will be maintained, however, on the design and development portion of these components, which is a U.S. responsibility. With the adjustment discussed in this paragraph, the contingency allowance in the baseline becomes $843 million (Table 7, page 55).

Additional Cost Items

The ERC and HEPAP Subpanel did not address how to deal with these matters which were viewed as DOE policy issues. Most of the items in this category were raised by the ICE staff.

Escalation Rates. The SSC Laboratory estimate used Department construction project escalation rates for the total estimated cost of the

construction portion of the SSC and used Office of Management and Budget escalation rates for operating and equipment funds for the remainder of the project cost elements. This combination of construction cost elements in the total estimated cost, together with other related project costs funded with operating and capital equipment funds, make up the total project cost. The ICE staff questioned the use of Office of Management and Budget escalation rates for the portions of the total project cost covered with operating and equipment funding, noting their judgment that the Department construction project rates should be used for all costs within the total project cost. **The Department concludes** that the application of the Office of Management and Budget escalation rates to the operating cost elements for general laboratory operations, accelerator commissioning, and research and development is appropriate since these cost elements include largely salaries, utility service charges, and small materials and supplies expenses. Since the fabrication of detectors will be done within a fixed allowance using a build-to-cost approach, the application of additional escalation is not considered to be appropriate in this area. **The Department's baseline** increases the SSC Laboratory estimate by $49 million to reflect the latest (May 1990) Office of Management and Budget escalation rates which are higher than the previous rates used by the SSC Laboratory in their estimate. Application of the August 1990 update of the Department's construction project escalation rates, which are lower than the previous rates, results in a savings of $226 million in estimated construction cost compared to the SSC Laboratory estimate. This is reflected in Table 6 on page 53.

FY 1988 and FY 1989 Costs. The ICE staff expressed concern that FY 1988 and FY 1989 costs ($131 million), which were included in the total project cost in all previous budget submissions, had been excluded from the SSC Laboratory estimate. **The Department has concluded** that these costs should be included in the baseline total project cost. Accordingly, the baseline total project cost has been increased by $131 million for costs in those two previous fiscal years. This is reflected in Table 6 on page 53.

Land. Neither the 1986 estimate nor the SSC Laboratory estimate included the costs of land. The ERC and HEPAP Subpanel did not consider land costs. ICE expressed their interpretation of Department Orders that land costs should be included in the total project cost and suggested a $70 million increase for this purpose. The SSC presents a unique situation within the Department with regard to land costs. The Department's Invitation for Site Proposals for the SSC specifically required that the land be provided by the proposer at no cost to the Federal government. Since this is a non-cost item to the Federal government and the Federal government is not involved in the acquisition of the land, **the Department has concluded** that land costs to the State of Texas will not be included in the government's baseline total project cost estimate.

DOE On-Site Project Office. ICE indicated their interpretation of Department Orders that the costs of the Department's SSC On-Site Project Office (OPO), which they estimated to be $31 million, should be included in the total project cost estimate. The SSC situation is again unique in that the On-Site Project Office is a direct extension of the headquarters' Office of SSC (OSSC), with only supporting activities provided to the On-Site Project Office by the Chicago Operations Office. Hence, there is not the clear distinction between the headquarters' program office and field project office that has existed in the Department for other projects. Since the normal procedure is not to apportion Department headquarters or operations office administrative support overhead to the total project cost, it should not be done so for the SSC. The On-Site Project Office has a broader and more complex role than a typical field project office, particularly with its interactions and coordination with the Texas National Research Laboratory Commission. Because of the special circumstances prevailing for the SSC, **the Department has concluded** that the funds for the On-Site Project Office will not be included as part of the total project cost, but will be funded as an integral part of the program direction portion of the SSC appropriation, outside the total project cost.

III. THE SSC BASELINE

This chapter presents three alternative scenarios considered by the Department in determining SSC cost estimates and in establishing the Department's cost and schedule baseline for the SSC project.

SCENARIOS LEADING TO THE SSC BASELINE

Earlier Department budget requests to Congress for the SSC project indicated a total project cost estimate of $5894 million (as-spent), with a projected completion date of mid-FY 1998. These estimates for cost and schedule were based on the 1986 SSC Conceptual Design Report and supporting documentation on detectors, computers, research and development, and preoperations. In June 1990, the SSC Laboratory presented a Site-Specific Conceptual Design Report based on the characteristics of the Texas site that had been selected and on additional technical information that had become available over the intervening 4 years on the performance of superconducting magnets and accelerators. The resulting cost and schedule estimates developed by the SSC Laboratory were examined in detail by the Department, including three separate reviews in June 1990, as discussed in Chapter II.

As a result of this evaluation of the cost and schedule baseline proposed by the SSC Laboratory and the recommendations and comments of the review committees, **the Department has reconciled the major differences and developed a baseline cost and schedule estimate for the SSC project.** In arriving at this baseline, the Department considered the following three total cost and schedule scenarios. The cost estimates for each are summarized in Table 5 on page 49.

Scenario 1 - The proposed baseline submitted by the SSC Laboratory, with a total project cost of $7837 million (as-spent) and completion by the end of FY 1998.

Scenario 2 - An adjusted baseline developed by the Department, with a total project cost estimate of $7873 million (as-spent) and completion by the end of FY 1998.

Scenario 3 - An alternative baseline developed by the Department, with a total project cost of $8249 million (as-spent) and completion by the end of FY 1999.

Scenario 1

This scenario, proposed by the SSC Laboratory in June 1990, has an estimated total project cost of $7837 million (as-spent) and project completion by the end of FY 1998. It requires a rapid buildup in total funding (both Federal and estimated non-Federal funds) from assumed FY 1991 levels to a total funding level of $1250 million (both Federal and estimated non-Federal funds) in FY 1992.

Although the Energy Research Review Committee and the HEPAP Subpanel both expressed concerns about the realism of the schedule and the aggressiveness of the funding profile, neither advised that the SSC could not be built and commissioned as proposed by the SSC Laboratory. The ICE staff took the position that the schedule and funding profile were unrealistic and unachievable. Clearly this scenario is very aggressive and it entails significant cost and schedule risks. The review groups recommended minor adjustments in several of the base-cost estimates and pointed out that there are several cost elements that need to be considered for inclusion in the total project cost estimate, particularly the FY 1988 and FY 1989 costs that were included in previous budget requests submitted to Congress.

Scenario 2

This scenario developed by the Department has an estimated total project cost of $7873 million (as-spent) and project completion by the end of FY 1998. It provides for adjustments to the estimate initially proposed

by SSC Laboratory to address most of the major concerns expressed by the independent review groups. It is presented in the same terms of reference as the SSC Laboratory proposal of June 1990. These are the Department baseline increases discussed in Chapter II, except for the increase related to a schedule extension. This scenario raises the overall contingency allowance to $1062 million (as-spent), to a level of 20 percent of the base construction cost, which is in the mid-range of Department guidelines. This scenario also incorporates a reduction of $219 million in the project contingency allowance because the Department does not believe that contingency is needed or appropriate for the production of expected foreign in-kind contributions. This reduction results in an overall contingency allowance for the project that is still at a level of $843 million. Escalation estimates were also updated to reflect the latest Department and Office of Management and Budget escalation rates. This scenario also incorporates increases totalling $130 million (constant FY 1990 dollars) in the base cost estimate for some elements of the construction project. This increase results from a reevaluation of the estimate by the SSC Laboratory in all areas where there were significant cost variations with the review groups. This scenario includes $131 million for the FY 1988 and FY 1989 funding to properly account for prior year funding and to be consistent with prior estimates provided to the Congress.

While this scenario reduces cost uncertainties in the base estimate and contingency allowance, it does not adequately address the concerns raised by the review groups about schedule risk and the aggressive funding profile. It maintains the same aggressive ramp-up in funding profile for FY 1992 and the projected completion date by the end of FY 1998 as in Scenario 1.

Scenario 3

This alternative scenario developed by the Department has an estimated total project cost of $8249 million (as-spent) and project completion by the end of FY 1999. It incorporates all the adjustments outlined for Scenario 2 and incorporates the FY 1992 budget request and out-year funding profile to project completion. It includes a much reduced ramp-up of Federal funding

in FY 1992 and during the period through FY 1997, and extends the schedule for completion by 1 year, with a related overall cost increase of $376 million relative to Scenario 2.

This scenario reflects a restructuring of SSC project activities and schedules in a way that balances Total Project Cost, schedule, and annual funding requirements within the restraints imposed by overall budget deficit reduction agreements. After careful examination and reevaluation of budget authority and cost profiles, the Department and the SSC Laboratory have concluded that the SSC project can be executed with a less aggressive funding profile than required by Scenarios 1 and 2, but still retain the plan of completion by the end of FY 1999. This is achieved by a prudent optimization of the time between commitment of budget authority and the actual costs to execute project activities. This approach will require careful management of project resources and phased funding of multi-year contracts with attendant cost risks. Both the SSC Laboratory and the Department's On-Site Project Director are confident that any cost risks with this approach are manageable.

The schedule extension and less aggressive funding profile of this scenario developed by the Department address the concerns of the review groups about schedule risk and the realism of the rapid buildup in the project in FY 1992. This scenario also addresses the Federal funding restraints of overall budget deficit reduction agreements with a profile beginning with $522 million of Federal funds in FY 1992 that rises to $638 million in FY 1993 and $710 million in FY 1994 and then remains approximately constant, with annual escalation adjustments, through FY 1996.

This scenario also incorporates an allocation of $199 million of indirect charges and $73 million of accelerator and magnet product development costs to the Total Estimated Cost for construction. This allocation is different from that originally presented by the SSC Laboratory; it reflects the decision by the Laboratory to implement an accounting system in FY 1991 that allocates indirect costs to both construction and operating activities. This decision is consistent with

independent audit findings and recommendations and is a change from the direct charge of Laboratory and administrative support costs reflected in the original Laboratory proposal. This allocation approach, with $30 million of escalation, results in an increase in the Total Estimated Cost by $302 million compared with that proposed by the Laboratory, with an offsetting decrease in Other Project Costs in the same amount, thereby maintaining the Total Project Cost at $8249 million.

The funding profiles of Federal funding requirements for this scenario (both for budget authority and costs) are shown in Figure 2 on page 50.

TABLE 5

SSC Cost Scenarios
(Millions of Dollars)

	Scenario 1 SSC Estimate	Scenario 2 DOE Adjusted Estimate	Scenario 3 DOE Baseline
Construction Project			
Accelerator Systems [1]	$1082	$1107	$1128
Magnet Systems [1]	1904	1988	2040
Conventional Construction [1]	1052	1073	1073
Project Management, Support, and Indirects [1, 3]	49	49	248
Subtotal (FY 1990 $)	4087	4217	4489
Escalation	906	709	1019
Subtotal (As-spent) [2]	$4993	$4926	$5508
Contingency (As-spent) [2]	920	843	843
Total Estimated Cost (TEC) [2]	**$5913**	**$5769**	**$6351**
Other Related Costs			
R&D and Preoperations [1]	$ 976	$1099	$ 875
Experimental Systems [1]	752	760	760
Subtotal (FY 1990 $)	1728	1859	1635
Escalation	196	245	263
Total Other Related Costs [2]	**$1924**	**$2104**	**$1898**
Total Project Cost (TPC) [2]	**$7837**	**$7873**	**$8249**

[1] Gives base cost estimates for these project elements in constant FY 1990 dollars.

[2] Gives estimates in as-spent dollars (projected escalation for the year of expenditure is added to the base cost expressed in constant FY 1990 dollars).

[3] Indirect costs of $199 million apply only to Scenario 3, the DOE Baseline.

Figure 2

SSC Baseline Funding Scenario

Total Budget Authority and Cost Requirements
(In Millions of As-Spent Dollars)

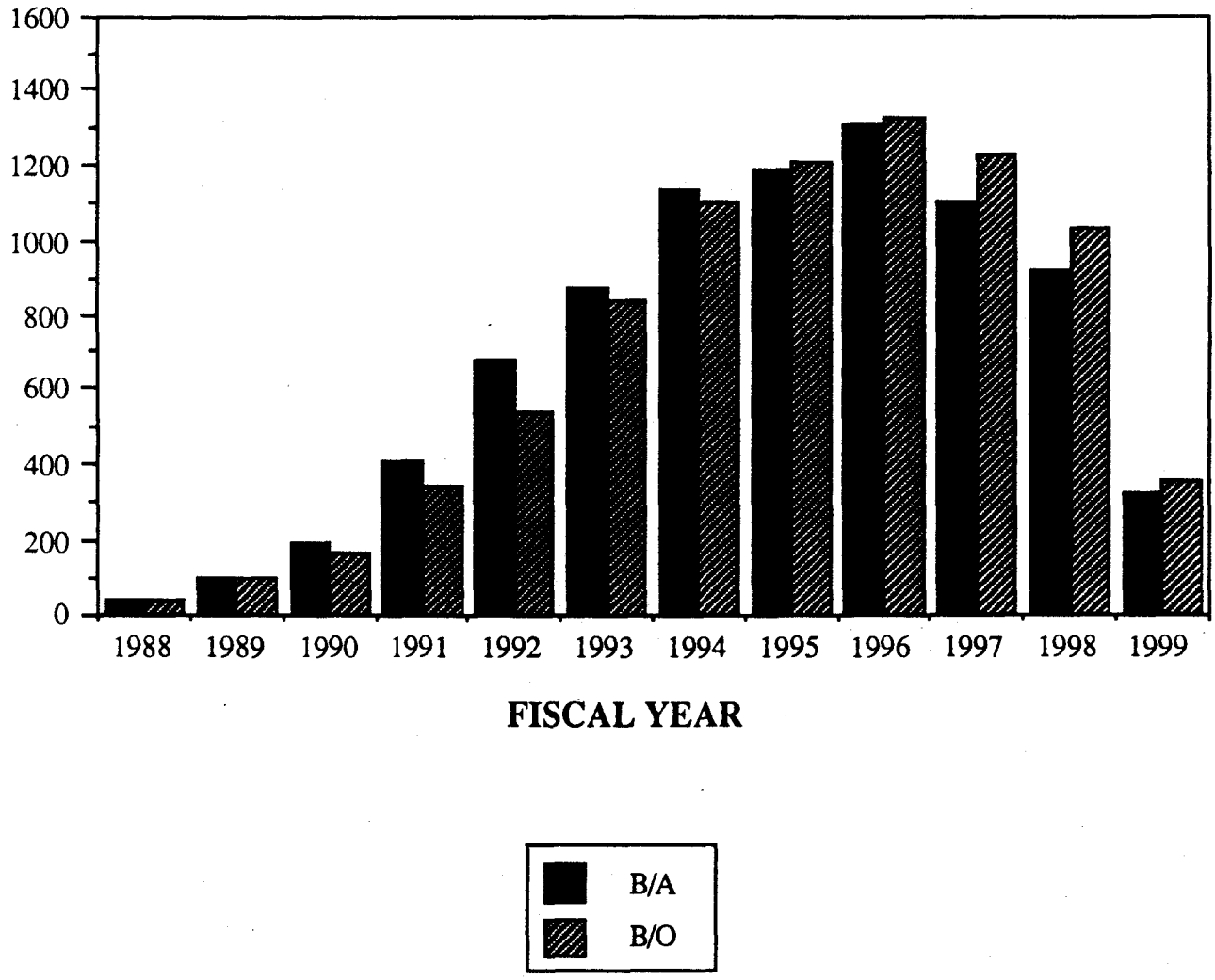

FIGURE 2
MacD:ab:1-29-91

DEPARTMENT COST AND SCHEDULE BASELINE

Cost Baseline

Based on its assessment of all of the data and the judgments provided by the SSC Laboratory and the three review groups, **the Department concludes that Scenario 3 provides the most appropriate cost and schedule baseline for the SSC project. This baseline total project cost is $8249 million (as-spent) with project completion by the end of FY 1999.** This estimate is built up from the SSC Laboratory proposal, with adjustments to reconcile most of the differences suggested by the review groups as discussed in Chapter II (Table 6 on page 53). The key adjustments are outlined as follows:

- an increase in the SSC Laboratory base construction cost estimate for a number of project elements ($130 million plus $29 million of associated escalation, for a total of +$159 million);
- an increase in the overall project contingency to 20 percent of the base construction cost (+$142 million);
- a decrease in the contingency allowance associated with those items expected to be provided as foreign in-kind contributions (-$219 million);
- an overall increase for the estimated cost impact of a schedule extension of 1 year and a less aggressive funding profile (+$376 million);
- inclusion of FY 1988 and FY 1989 costs which had been included in previous estimates provided to the Congress (+$131 million);
- an allocation of $199 million of indirect costs, $73 million of accelerator and magnet product development costs, and $30 million of associated escalation to the Total Estimated Costs (no change in Total Project Cost);
- a decrease in the escalation estimate for construction resulting from use of the latest (lower) DOE construction project rates (-$226 million);

- an increase in the escalation estimate for other related costs resulting from use of the latest (higher) OMB escalation rates for operating and capital equipment funds (+$49 million).

The major elements of the Department's baseline cost estimate are given in Table 7 on page 55. Table 8 on page 57 presents a more detailed breakdown of the cost estimate by Work Breakdown Structure (WBS) elements.

Schedule Baseline

Figure 3 presents the baseline project schedule at a very summary level. This project schedule reflects the major project activities and milestones for technical systems, conventional construction, and the detectors. This baseline schedule incorporates a schedule extension of 1 year (completion scheduled by the end of FY 1999) to reduce schedule and cost risks and to provide a more prudent and achievable ramp-up in the funding profile beginning in FY 1992. This schedule is still aggressive, but it is cost effective and strikes a balance between risk and total project cost.

Integration of all the major activities is being carefully planned and will be controlled through a disciplined systems integration process and formal configuration management and change control procedures. An inclusive set of project milestones has been established to provide goals for project activities and to provide a basis for measuring progress against the baseline.

The Supplemental Environmental Impact Statement (SEIS) and Record of Decision (ROD) are scheduled for completion early in the second quarter of FY 1991. Most construction activities are scheduled to begin with detailed design in FY 1991. Design and construction of the injectors will proceed sequentially starting with the Linac and moving through the injector chain to the High Energy Booster. Superconducting magnet and collider technical systems development will proceed in parallel. The magnet development and prototype testing will culminate in the magnet "string test" scheduled for late FY 1992.

TABLE 6

SSC Baseline
(Millions of Dollars)

	SSCL Estimate	Changes	DOE Baseline
Construction Project			
Accelerator Systems	$1082	+ 46 [1]	$1128
Magnet Systems	1904	+136 [2]	2040
Conventional Construction	1052	+ 21 [3]	1073
Project Management, Support, and Indirects	49	+199 [4]	248
Subtotal (FY 1990 $)	4087		4489
Escalation	906	-167 [5]	739
Subtotal (As-spent)	$4993		$5228
Contingency (As-spent)	920	+142 [6]	1062
Contingency Adjustment (As-spent)		-219 [7]	-219
Schedule and Funding Profile Adjustment (As-spent)		+280 [8]	280
Total Estimated Cost (TEC)	**$5913**	**+438**	**$6351**
Other Related Costs			
R&D and Preoperations	$ 976	-148 [9,10]	$ 828
Experimental Systems	752 [12]	+ 8 [9]	760
Subtotal (FY 1990 $)	1728		1588
Escalation	196	+ 18 [11]	214
Subtotal (As-spent)	$1924		$1802
Schedule and Funding Profile Adjustment (As-spent)		+ 96 [8]	96
Total Other Related Costs	**$1924**	**- 26**	**$1898**
Total Project Cost (TPC)	**$7837**	**+412**	**$8249**

[1] *Increased by $25 million to include costs for higher estimated vendor wage rates, freight for conventional magnets, and septum magnets. Also includes $21 million to the Total Estimated Cost for accelerator system product development costs.*

[2] *Increased by $84 million to provide for higher materials handling costs. Also includes $52 million to the Total Estimated Cost for magnet system product development costs.*

[3] *Increased to include additional costs for the Accelerator Systems String Test Facility, the Prototype Installation Facility, and additions to other surface buildings.*

[4] *Allocation of $199 million for indirect costs to the Total Estimated Costs.*

[5] *Increased by $59 million for escalation on add-ons to the base cost estimate and decreased by $226 million to incorporate August 1990 update of DOE construction project escalation rates. This results in the net reduction of $167 million.*

[6] *Increased to achieve a 20 percent contingency allowance on base construction cost (prior to the adjustment to remove contingency on foreign in-kind contributions).*

[7] *Adjustment to remove contingency on foreign in-kind contributions.*

[8] *Increased to reflect the overall cost impact of a schedule slip of approximately 1 year and a less aggressive funding profile. This includes an increase of $280 million for construction and $96 million for other related costs for a total increase of $376 million.*

[9] *FY 1988 and FY 1989 costs which were not included in SSCL estimate. Includes an increase of $123 million for R&D and Preoperations and $8 million for experimental systems, for a total increase of $131 million.*

[10] *Includes a reduction of $271 million allocated to the Total Estimated Cost to reflect indirect costs and accelerator and magnet system product development costs.*

[11] *Increased by $49 million to incorporate the latest OMB escalation rates for operating and equipment funding and decreased by $31 million for escalation on costs allocated to the Total Estimated Cost.*

[12] *This figure is in FY 1990 dollars. When $8 million is added for FY 1988 and FY 1989 costs and $158 million is added for escalation, this equates to the $910 million (as-spent) allowance referenced in Chapter II.*

TABLE 7

SSC Cost Baseline
(Millions of Dollars)

Construction Project	
Accelerator Systems [1]	$1128
Magnet Systems [2]	2040
Conventional Construction [3]	1073
Project Management, Support, and Indirects [4]	248
Subtotal (FY 1990 $)	4489
Escalation	1019
Subtotal (As-spent)	$5508
Contingency (As-spent)	843
Total Estimated Cost (TEC)	**$6351**
Other Related Costs	
R&D and Preoperations [5]	$ 875
Experimental Systems [6]	760
Subtotal (FY 1990 $)	1635
Escalation	263
Total Other Related Costs	**$1898**
Total Project Cost (TPC)	**$8249**

[1] *Includes the management, design, fabrication, and installation of all accelerator technical systems and equipment except for the superconducting magnets for the Collider and the High Energy Booster. Included are the accelerator systems for the Linac; the Low, Medium, and High Energy Boosters; the Collider; beam transfer lines; and test beams. The types of systems to be provided include: conventional magnets, injection and extraction systems, cryogenics, rf accelerating cavities, power supplies, vacuum, and instrumentation and controls.*

[2] *Includes the management and industrial development of tooling and manufacturing processes and the production of the superconducting magnets for the Collider and the High Energy Booster.*

[3] *Includes the surface and underground structures to house and support the technical components as well as those required to house the staff and support functions. Included are: the tunnels, experimental halls, surface structures around the accelerator rings, office buildings, industrial and heavy works buildings, utilities, roads, site preparations, etc.*

[4] *Includes: project supervision, planning, monitoring, reporting, and indirects; management of environmental, quality assurance and safety functions; system engineering and integration; management of the configuration control process; and, management of contingency funds allocated to the SSC Laboratory.*

[5] *Research and development includes: magnet design and fabrication of prototypes at the SSCL, other DOE laboratories, and contractor facilities; accelerator physics studies such as beam dynamics calculations; 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 sectors.*

[6] *Includes research and development, fabrication, and installation of detectors and procurement of associated computers.*

TABLE 8

Detailed Breakdown of Baseline Cost Estimate
(Dollars in Thousands)

WBS #	WBS DESCRIPTION	BASELINE
1.0	**TECHNICAL SYSTEMS**	**3,095,110**
1.1	**ACCELERATOR SYSTEMS**	1,106,773
1.1.1	Management/Support	30,230
1.1.2	Linac System	37,031
1.1.2.1	Linear Accelerator	33,102
1.1.2.2	Linac Beam Transfer Line & Dump	3,930
1.1.3	LEB System	42,967
1.1.3.1	LEB Accelerator	37,497
1.1.3.2	LEB Beam Transfer Line & Dump	5,470
1.1.4	MEB System	118,161
1.1.4.1	MEB Accelerator	91,705
1.1.4.2	MEB Beam Transfer Line & Dump	26,456
1.1.5	HEB System	162,612
1.1.5.1	HEB Accelerator	128,230
1.1.5.2	HEB Beam Transfer Line & Dump	34,382
1.1.6	Collider System	647,106
1.1.7	Test Beams	11,231
1.1.7.1	Test Beams System	10,208
1.1.7.2	MEB Transfer Line	1,024
1.1.8	Global Accelerator System	57,435
1.2	**MAGNET SYSTEMS**	**1,988,337**
1.2.1	System Management	26,944
1.2.2	HEB Magnet Production	177,856
1.2.2.1	HEB - Dipole Magnets	143,877
1.2.2.2	HEB - Quadrupole Magnets	33,979
1.2.3	CR - Magnet Production	1,744,916
1.2.3.1	CR - Dipole Magnets (15M)	1,361,376
1.2.3.2	CR - Dipole Magnets (13M)	82,716
1.2.3.3	CR - Quadrupole Magnets	165,958
1.2.3.4	CR - IR Vertical Dipoles	20,404
1.2.3.5	CR - IR Low Beta Focussing	18,492
1.2.3.6	CR - IR Medium Beta Focussing	12,865
1.2.3.7	CR - IR Dispersion Suppressor	12,122
1.2.3.8	CR - IR Special Utility	11,806
1.2.3.9	CR - IR M-1 Magnets	41,668
1.2.3.10	CR - IR Vertical Dipoles	17,509
1.2.4	SSCL Equipment/Tooling	38,621
1.2.4.1	Magnet Development Lab (MDL)	7,569
1.2.4.2	Magnet Test Lab (MTL)	29,133
1.2.4.3	Magnet Acceptance & Area Storage	1,919

WBS #	WBS DESCRIPTION	BASELINE
2.0	**CONVENTIONAL CONSTRUCTION**	**1,072,894**
2.1	Conventional Construction Accelerator	642,865
2.1.1	Support Function	37,662
2.1.2	Linac	2,878
2.1.3	LEB	5,172
2.1.4	MEB	34,781
2.1.5	HEB	74,237
2.1.6	Collider	470,990
2.1.7	Test Beams	17,146
2.2	Conventional System, Experimental	127,071
2.2.1	WN Region	29,819
2.2.2	WS Region	39,053
2.2.3	EN Region	21,368
2.2.4	ES Region	28,631
2.2.5	Support Function	8,200
2.3	Site & Infrastructure	115,580
2.3.1	Primary, Offsite	0
2.3.2	Primary, Onsite	72,018
2.3.3	Secondary	43,562
2.4	Campus	60,666
2.4.1	Central Lab/Office Area	32,182
2.4.2	Magnet Laboratory	16,477
2.4.3	Accelerator Facilities	6,129
2.4.4	Environmental Health Facilities	5,878
2.5	Conventional Construction Management	126,712

3.0	**PROJECT MANAGEMENT & SUPPORT FUNCTION**	**48,692**
3.1	Project Management	25,050
3.2	Project Systems Engineering	23,642

4.2.1	Accelerator Development	21,600
4.2.2	Magnet Development	52,100
	Indirects	199,210

SUBTOTAL	4,489,606
ESCALATION	1,018,600
CONTINGENCY (AS-SPENT)	842,997
TOTAL ESTIMATED COST (TEC)	**6,351,203**

WBS #	WBS DESCRIPTION	BASELINE
4.0	**R&D & PRE-OPERATIONS**	**875,193**
4.1	Accelerator Pre-Ops	130,764
4.2	R&D	322,382
4.2.1	Accelerator R&D	170,680
4.2.2	Magnet R&D	151,702
4.6	Lab Experimental Support	67,306
	Indirects	231,656
	FY88 & FY89 COST	123,085

5.0	**EXPERIMENTAL SYSTEMS**	**759,620**
5.1	R&D	40,000
5.2	Detectors	637,730
5.3	Experimental Systems Computers	74,390
5.4	FY88 & FY89 COST	7,500

SUBTOTAL	1,634,813
ESCALATION	263,046
TOTAL OTHER PROJECT COSTS	**1,897,859**
TOTAL PROJECT COST (TPC)	**8,249,062**

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Superconducting Super Collider
Summary Baseline Schedule

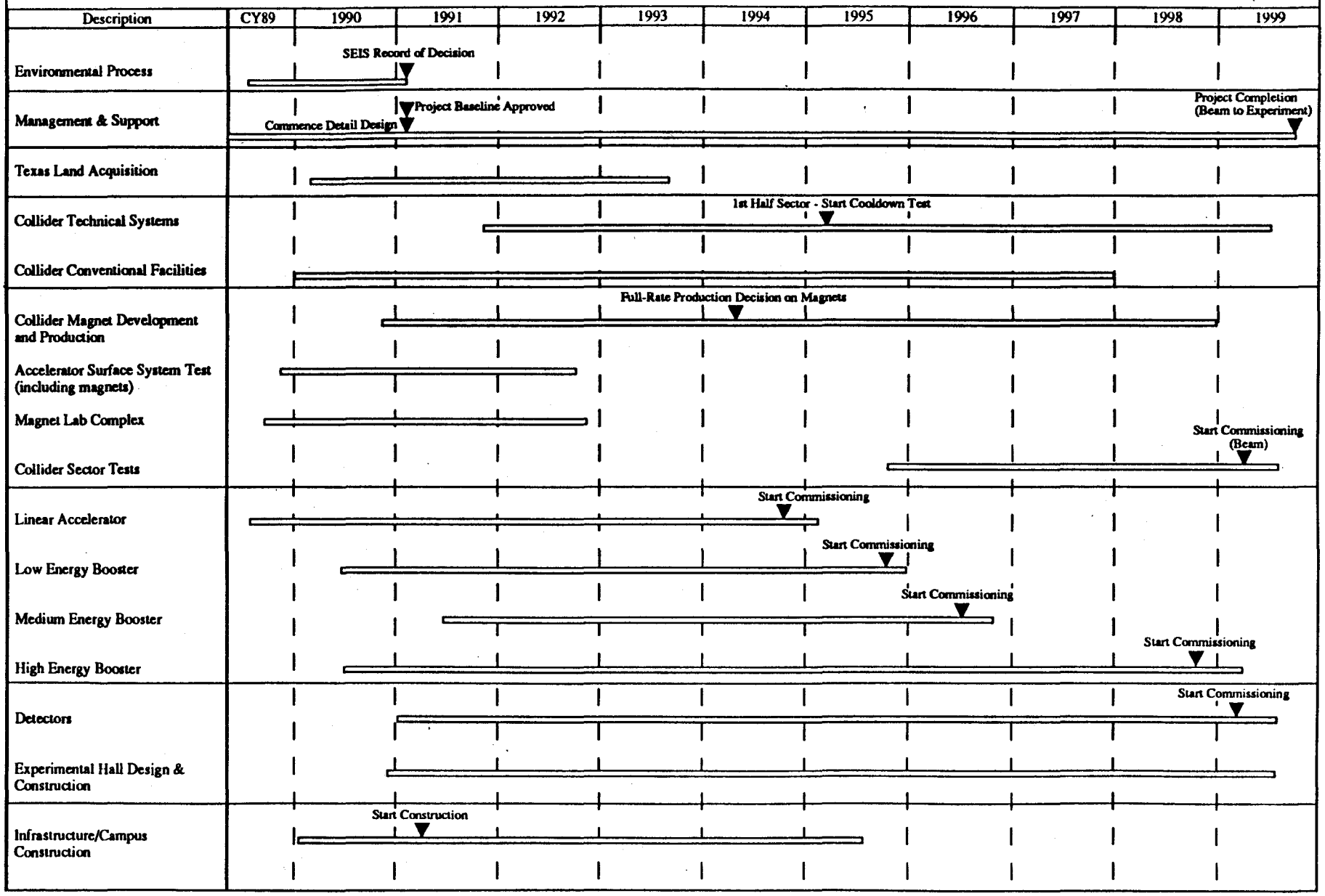

Figure 3

This "string test" will involve operating a series of prototype superconducting magnets (five dipole magnets, one quadrupole magnet, and a spool piece), along with associated cryogenics, quench protection, and control systems to demonstrate their performance. Following successful completion of the string test milestone, magnets will subsequently be installed in an underground facility, the first tunnel sector, to further demonstrate the underground installation and performance of the magnets when integrated with the cryogenic cooling system. Construction of the first tunnel sector will begin in the fourth quarter of FY 1992.

Commissioning of technical systems will begin in FY 1995 for the linear accelerator; followed by the Low Energy Booster in FY 1996, the Medium Energy Booster, which is the source of protons for the test beams in FY 1996; and the High Energy Booster in FY 1998. In a parallel fashion, the collider sectors will be commissioned beginning in FY 1995 and extending into mid-FY 1999, leading to turn-on of the SSC by the end of FY 1999. Magnet delivery schedules, tunnel completion, and magnet installation are being carefully coordinated and integrated into a detailed logistics plan.

The experimental detectors will be designed and fabricated in parallel with the construction of the experimental halls and interaction regions around the collider ring, with final installation and check-out prior to turn-on of the collider by the end of FY 1999.

Funding Profile

Table 9 shows the Department's baseline funding profile for the baseline total project cost of $8249 million (as-spent). This table also reflects estimates of both Federal and non-Federal contributions to the SSC. The same information is displayed pictorially in Figure 4. The estimates of non-Federal contributions are based on agreements with the State of Texas and on obtaining one-third of total SSC funding from non-Federal sources, including Texas and foreign partners. The State of Texas is committed to provide $1000 million plus the land for the SSC, with the details of their

TABLE 9

SSC Baseline Funding Profile[1]
(Millions of As-Spent $)

	Total Project Cost [2]	Estimated Federal	Estimated Non-Federal [3]
FY 1988	33	33	-
FY 1989	98	98	-
FY 1990	191	191 [4]	-
FY 1991	409	260 [5]	149
FY 1992	672	522	150
FY 1993	871	638	233
FY 1994	1137	710	427
FY 1995	1194	728	466
FY 1996	1303	733	570
FY 1997	1102	852	250
FY 1998	916	666	250
FY 1999	323	218	105
TOTAL	8249	5649	2600 [6]

1 This profile presents multi-year funding requirements and, as such, is subject to annual Administration submission of budget requests and Congressional appropriation of funds.

2 Includes all cost elements identified as part of total project cost; does not include cost for Department Program Direction which is also funded as part of the SSC appropriation.

3 Assumes that the $875 million of Texas funds which offset cost elements within the total project cost are provided on a pro-rata basis in FY 1992 and subsequent years. This is a minimum estimate of Texas' contributions in these years, as the Texas National Research Laboratory Commission has indicated that it would consider larger annual contributions on the basis of specific requests and justification from the Department. The FY 1991 Texas contribution reflects $60 million above the pro-rata share approved to offset the shortfall in appropriated Federal funds. In addition, there is also an amount of $125 million of Texas funds that are planned to be used for detector R&D, science education, and other support of the SSC project. A portion of these funds could be made available, if needed, to offset additional cost elements within the total project cost.

[4] FY 1990 appropriation of $218 million, included $191 million available for SSC project in FY 1990, $3 million for the Department's program direction costs, and $24 million appropriated for tunnel construction which was held in the Department's reserve.

[5] Consists of FY 1991 appropriation of $236 million for SSC project costs and the $24 million of FY 1990 funds held in the Department's reserve for which Congress has now released the tunnel construction restriction. (Appropriation of $243 million included $7 million of Department program direction in addition to the $236 million of project funds.)

[6] Reflects estimated contributions of up to $2800 million, reduced by approximately $200 million for the allowance for contingency on foreign in-kind contributions.

Figure 4

SSC Baseline Funding Profile

(Millions of As-Spent Dollars)

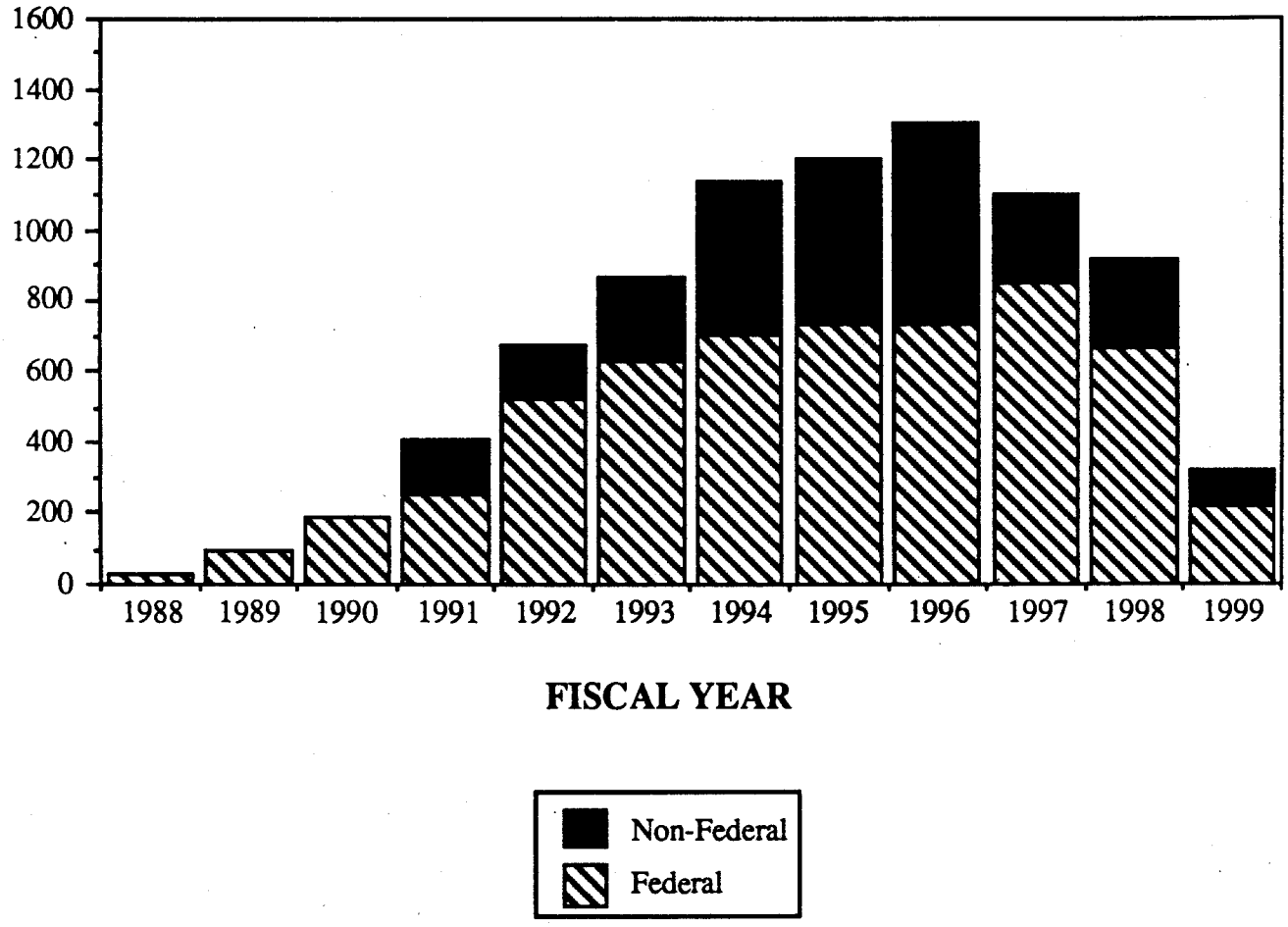

FIGURE 4
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contributions for each upcoming year to be determined annually by mutual agreement to the benefit of the SSC project. Of the $1000 million Texas contribution, agreement has been reached for the Department to allocate $875 million to be used to offset costs within the total project cost. Part of the additional $125 million of Texas funds may be available for contingency to be applied to the total project cost in addition to planned uses for Texas-supported detector R&D and other socio-economic and mitigation activities which are of overall benefit to the SSC in accordance with the Texas site proposal.

The Administration is seeking international participation in the SSC to share the benefits and the responsibility of the construction and operational phases of the SSC program with other nations. This participation can take many forms, commensurate with the scientific and technological strengths and resources of foreign partners. Such cost sharing is appropriate for a program of this magnitude and one that has the objective of building a truly international SSC Laboratory.

Official discussions with potential foreign partners have begun and are encouraging; however, the overall magnitude and timing of foreign contributions remain to be determined as part of formalized agreements to be negotiated with individual countries. The data presented in Table 9 are estimates, based on obtaining one-third of the total project cost from non-Federal sources. Additional benefits are expected to be forthcoming with foreign partners also contributing to the operations of the SSC Laboratory as experiments begin, involving international detector collaborations and teams of scientists.

CONCLUSION

The Department has adopted a cost baseline for the SSC project of $8249 million (as-spent) and a baseline schedule with completion by the end of FY 1999. This cost and schedule baseline will provide a high energy physics laboratory capability that meets the science objectives of the SSC

and that results in a facility that can be commissioned readily, while operating with high reliability.

The increases in estimated total project cost that have been outlined in this report for the SSC project are not the result of cost overruns or underestimates. Rather, they are the result of normal changes in cost that occur as a large project is better scoped and defined. In this case, there have also been adjustments in schedule to provide a less aggressive funding profile and to reflect delays in appropriations (FY 1988 and FY 1989) to begin construction. At this stage of the SSC project, the cost uncertainty has been substantially reduced and is managed through contingency allowances that have been included in the overall estimate of total project cost. Having established the project baseline design, cost, and schedule estimate (which includes a prudent level of contingency), and strong management for the SSC, the Department is confident in moving forward at this time with the SSC project as outlined in this report.

The baseline is technically feasible. It involves an aggressive but cost-effective schedule, and it establishes a credible total project cost estimate. The associated funding profile is prudent and reflects obtaining one-third of the total project cost from non-Federal sources. The combination of the revised schedule and the increased contingency allowance from that initially proposed by the SSC Laboratory prudently reduces cost and schedule risks. The baseline furthermore ensures reliable and flexible operation through a more conservative design approach by the SSC Laboratory than that of the conceptual design of 1986.

The baseline cost includes a contingency allowance of $843 million (as-spent), which should provide a more than adequate contingency envelope for effective execution of the SSC project. This contingency allowance should provide for appropriate tradeoffs and responses to any reasonable set of technical and schedule uncertainties that might arise. The extension of 1 year in the baseline schedule to FY 1999 provides schedule flexibility and a more prudent ramp-up of funding. The schedule flexibility will allow more time to firm-up designs before entering into construction and magnet

production, thereby reducing schedule and technical risks noted by the review groups.

This baseline provides a cost-effective basis for planning and managing a project of this size and complexity. Executing the SSC project to the baseline presented in this report will ensure that the scientific objectives of the SSC will be achieved and that the project will be completed within agreed-upon funding and schedule goals. Establishing these cost and schedule goals and ensuring strong Department and SSC Laboratory management teams are essential to building the SSC at the lowest possible cost. To this end, the Department is moving rapidly to build up staffing of its On-Site Project Office, with all key leadership positions now filled. The SSC Laboratory has made recent management changes to strengthen its management of the project, including the creation of a new position of General Manager and the naming of an experienced Project Manager.

The Department and the SSC Laboratory are committed to manage the project to this baseline. The Department will hold the contractor to this baseline and is requiring that appropriate project controls and management techniques be incorporated as an integral part of the SSC project management. Any proposed future changes will be quickly evaluated and carefully assessed against the baseline before being approved by senior management officials of the Department. This strong SSC project management, combined with additional measures already implemented throughout the Department for managing major projects, will serve as the basis for the Department and the SSC Laboratory to ensure that the SSC is built successfully.

APPENDICES

APPENDIX 1

MANAGEMENT OF THE SSC PROJECT

The SSC is one of the largest scientific projects ever undertaken. To manage this project effectively requires that the Department: institute a formal process for review, control, and decision making by senior officials of the Department; streamline SSC program and project management; and ensure the development of a well-engineered technical design together with an aggressive but realistic cost and schedule baseline. Effectively executing the project to meet this baseline will ensure that the scientific objectives of the SSC will be achieved and that the SSC will be completed within the baseline funding and schedule estimates.

MANAGEMENT FRAMEWORK

The SSC project is being managed by the Department with a structured process for review, control, and decision making. The process is formalized under the Department's Project Management System, DOE Order 4700. This formalized project management system has been strengthened considerably under the guidance of Secretary Watkins to ensure that high-level Department officials are strongly involved at critical decision points. A series of Secretary of Energy Notices (SENs) and related guidance and Department Orders are being employed throughout the Department to control the execution of major projects and to manage them to meet project baselines. It is this system for project management that provides the framework for successful management of the SSC.

SSC PROGRAM AND PROJECT MANAGEMENT

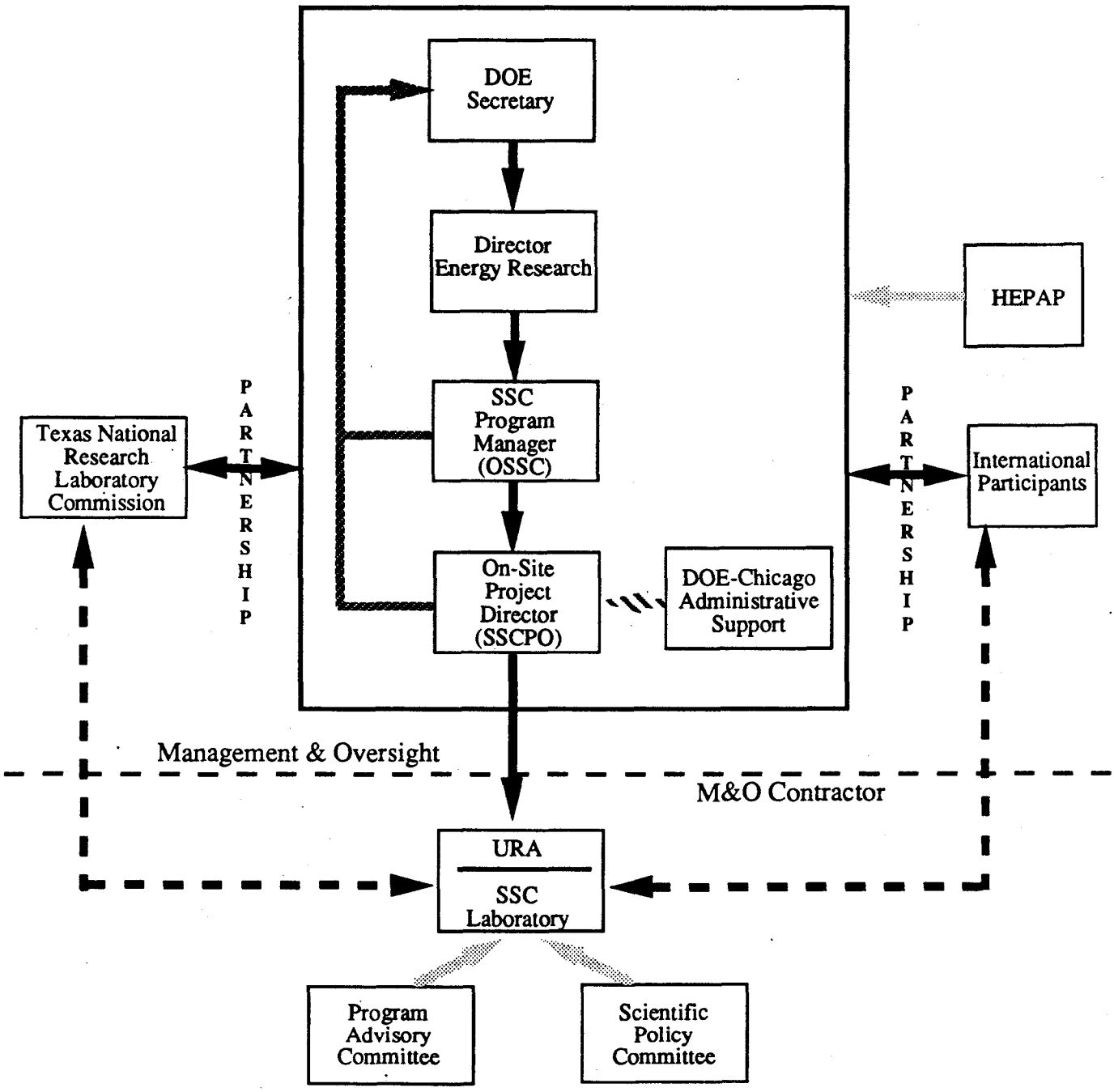
Incorporating the SSC into the management framework discussed above presents unique challenges not only because of the complexity of the project but also because of the involvement of several National laboratories, of potential international participants, and of the State of Texas which is committed to provide the land and major financial contributions to the project. Execution of the SSC project, therefore, involves coordination of project activities among many entities, including: Universities Research

Association (URA), the Department's management and operating contractor for the SSC; the SSC Laboratory, established by URA to design, build, and operate the SSC; and the Texas National Research Laboratory Commission (TNRLC), established by the State of Texas to oversee Texas participation in the SSC (Figure A-1). These interactions take on additional complexity with the inclusion of potential foreign partners and their contributions to the construction and operation of the SSC. In addition, there are a number of groups outside the Department that provide advice to both the Department and the SSC Laboratory.

The SSC Laboratory has the responsibility to design, build, and operate the SSC. The Laboratory will: develop the technical design for the systems and components of the SSC; oversee and integrate the activities of the major subcontractors for the technical systems; and install, commission, and ultimately operate the collider facilities. The team of Parsons Brinckerhoff/Morrison Knudsen, in association with CRSS Inc., is the architect-engineer/construction manager and will be responsible for design and construction of the tunnel and other conventional facilities. General Dynamics and Westinghouse have been selected for development of the superconducting magnets. Industrial contractors will be selected for production of other technical components for the SSC. In addition to building the SSC, the program requires the development of a new high energy physics laboratory at a greenfield site.

To effectively manage this undertaking, the Department has developed a special structure for the program and project management for SSC as indicated in Figure A-1. The Department's Program Manager is located in the Office of Energy Research (ER) with reporting responsibilities to the Deputy Secretary as the Acquisition Executive. The Department's On-Site Project Director reports directly to the headquarters' Program Manager and independently reports to the Secretary on status and progress for project activities. Appropriate levels of procurement and configuration management authorities have been delegated to the On-Site Project Director to ensure timely and effective management to meet the project baseline. The On-Site Project Director has the primary responsibility for the successful

Superconducting Super Collider Management and Coordination



Policy & Program Direction

Advisory

Coordination

Reporting

Administrative Support

Figure A-1

Baseline Fig.A-1
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accomplishment of the SSC under the approved baseline. This direct line management structure has been established early in the SSC project to ensure that appropriate management attention can be brought to bear on project issues when needed and in a manner that provides for effective decision making.

Primary Missions and Functions for the SSC Program and Project Offices are summarized as follows:

The SSC Program Office (Headquarters):

- Provides policy direction, management, and financial oversight.
- Develops program strategies and takes the lead in Department interactions within the Administration and with Congress, industry, etc.
- Formulates long-range plans and budget requests.
- Establishes policy for interactions with the SSC Laboratory and the Texas National Research Laboratory Commission.
- Establishes research policies for SSC and coordinates with the Department's high energy physics program and the High Energy Physics Advisory Panel (HEPAP).
- Develops and implements strategies for international participation in the SSC.
- Develops policies and programs for SSC in science education.
- Chairs, as designated by the Director, Office of Energy Research, headquarters' Change Control Board (CCB) which approves any top-level baseline changes.
- Coordinates with other agencies throughout the Administration on SSC policy matters and program issues.

The SSC Project Office (On-Site):

- Executes policy and management direction provided by the headquarters' Program Office.
- Takes actions necessary to ensure successful, on-time, on-budget completion of an SSC which meets technical performance goals and operates reliably, cost effectively, and safely.
- Provides leadership for resolution of day-to-day management issues at the project site.
- Assesses on-site progress and reports to the Program Manager and to the Secretary.
- Serves as head of the SSC contracting activity on-site.
- Chairs the on-site Change Control Board which approves any substantive baseline modifications.
- Develops detailed project plans and budget submissions.
- Serves as the primary Department point-of-contact for day-to-day interactions with the Texas National Research Laboratory Commission.
- Reviews and audits SSC Laboratory practices and procedures.

MANAGING SSC AS A MAJOR PROJECT IN DOE

The SSC project is designated as a Major Systems Acquisition (MSA) in the Department's project management structure, with Deputy Secretary Henson Moore designated as the Acquisition Executive responsible for establishing DOE policy, approving milestones and plans, and validating that key milestones established for the project have been met. Appropriate procurement authority for the SSC project has been delegated directly to the On-Site Project Office to provide for timely and effective project management and control.

ENERGY SYSTEM ACQUISITION ADVISORY BOARD

Decisions on the SSC will be made by the Department's Energy System Acquisition Advisory Board (ESAAB), chaired by the Acquisition Executive, Deputy Secretary Henson Moore. This Board is comprised of Assistant Secretary level managers from the Department and is designed to provide the Acquisition Executive advice and assistance at key decision points. These key decision points include: initial approval of mission need and inclusion of the project in the Department's budget requests; approval to begin final design; approval to commence construction; and approval to commence operations.

This Board meets at least once a year to be apprised of status even when a key decision is not scheduled. Each meeting involves the presentation of project progress and status, readiness to proceed to the next phase, problems and issues, and items for decision. The SSC will shortly request approval to enter into detailed design and to begin construction as the next key decision milestones.

COST BASELINE

The cost baseline is developed in terms of two categories of cost--total estimated cost (TEC) and the total project cost (TPC):

- The <u>total estimated cost</u> includes all costs associated with engineering, design, and construction for physical facilities and technical components. For the SSC project, the total estimated cost includes the magnets and technical equipment for the injector accelerators and the collider, surface utilities and buildings, the tunnel, and experimental halls. Cost estimates for project management by the SSC Laboratory, for contingency, and for escalation are also included.

- The <u>total project cost</u> includes the total estimated cost, but also captures all other costs properly associated with the project. For the SSC, these associated costs include the costs for research and development, commissioning and preoperations, and experimental systems (detectors and associated computers). Related laboratory management and administration costs and escalation associated with these activities are also included.

TECHNICAL BASELINE

The technical baseline for the SSC project is based on a set of performance requirements which lead to definition of systems, facilities, and technical component requirements. These requirements are developed for technical systems (including the injector accelerators, the collider, the detectors, and supporting systems and equipment), and for the conventional facilities (including the tunnels, surface facilities, and utilities). These requirements are described in detail in the Site-Specific Conceptual Design Report (SCDR). They are defined in the Project Management Plan (PMP) in increasing levels of detail for each of the organizations involved in the SSC which are responsible for them. The project will be designed, constructed, and commissioned in accordance with this technical baseline.

SCHEDULE BASELINE

The schedule baseline for the SSC project includes the Master Summary Schedule, accompanied by a limited number of high level milestones which must be met to ensure completion of the project as planned. Milestones are also provided for each critical program activity (magnets, tunnel, detectors, etc.) to ensure that interfaces with other activities are properly identified and met. Additional supporting milestones at lower levels are defined to permit tracking of progress on all major project elements. These milestones and the related control mechanisms are defined in the Project Management Plan.

PROJECT MANAGEMENT PLAN

An SSC Project Management Plan (PMP) is required to set forth the plans, organization, and management systems which will be utilized for the project. This management plan formally defines: project objectives, performance criteria, organizational responsibilities, a project work plan, a Work Breakdown Structure, a configuration management process, quality assurance procedures, a contingency management process, a system for cost/schedule measurement, and reporting mechanisms. Key milestones and levels of configuration and change control are identified for management review and decision making. Approval of the Project Management Plan for the SSC will be requested as part of the next ESAAB review.

CHANGE CONTROL

A baseline change control process is required for all DOE programs, and recent Orders and SENs have strengthened that process. The change control process for SSC will ensure that any changes in the baseline cost, schedule, and scope are defined, documented, and approved at the appropriate management level and that there is accountability and traceability throughout the process. Any changes that are requested will be reviewed by Change Control Boards at the contractor level, the project office level, the program level, and the ESAAB process as specified in the Project Management Plan. Appropriate levels of authority are provided to each Board. Time for making decisions will be limited, with a maximum of 10 days for even the highest level change requests. A configuration management and change control process for the SSC has already been implemented and will serve as the process with which the baseline presented in this report will be managed.

COST AND SCHEDULE CONTROL

Cost and schedule control will be effected through a cost and schedule control system (CS/CS) which tracks monthly progress against the approved baseline cost and schedule. The SSCL will be required to have its CS/CS

validated by the Department to ensure that the system is properly structured and that approved project data are properly incorporated. Monthly reports will be provided to assist both the contractor and DOE in determining current performance status, identifying deviations and trends, and forecasting future work situations.

ENVIRONMENTAL COMPLIANCE

Under the Administration of Secretary Watkins, compliance with the National Environmental Policy Act (NEPA) has been raised to the highest level of project consciousness. Secretary of Energy Notice 15 (SEN 15-90) has outlined mandatory procedures to ensure that appropriate processes are in place for preparing required Environmental Impact Statements, Environmental Assessments, Monitoring Plans, and Safety Analysis Reports.

APPENDIX 2

CONGRESSIONAL BUDGET OFFICE STUDY

In 1988, the Senate Budget Committee requested that the Congressional Budget Office (CBO) conduct a special study to analyze the potential risks and benefits of building the SSC. The report of this study, published in October 1988 (Reference 17), suggested that the estimated costs might rise by as little as 4 percent (well within the Department's own estimating accuracy) or as much as 46 percent. The latter figure was based on the Congressional Budget Office's historical analysis which the Department concluded to be badly flawed (Reference 18). The analysis suggested that the cost of any accelerator project, no matter how conservatively designed and costed, could increase by this percentage. The Congressional Budget Office estimate resulted from a comparison of estimated costs to as-built costs for a selection of four of seven large high energy physics accelerator projects completed since 1965, including two that, unlike the SSC, required pioneering new technology. The Congressional Budget Office sample excluded the two projects most similar to SSC: the initial construction of the Fermi National Accelerator Laboratory (Fermilab) and of the Stanford Linear Accelerator Center (SLAC), which in each case involved the establishment of a new laboratory on a greenfield site with an accelerator based on an extrapolation of existing technology. A Department analysis of all seven large, high energy physics accelerator construction projects showed the actual total completed construction cost to be only 1.2 percent above the sum of the initial cost estimates.

The Congressional Budget Office report also suggested three alternatives to building the SSC: joining with the European community in the construction of the Large Hadron Collider (LHC) at CERN, the European Laboratory for Particle Physics; building an advanced electron-positron linear collider; or deferring the decision while doing R&D on superconducting magnets or alternative particle accelerators. These alternatives had been carefully

considered by the Department in earlier deliberations on proceeding with the SSC and were concluded to be far inferior to constructing the SSC.

The energy of the proposed LHC at CERN (at most only 40 percent of the SSC energy) was considered of questionable utility for some of the most important scientific studies to be undertaken with the SSC and one which would force operations at very high rates, where detector performance is questionable. This view was subsequently reconfirmed by a blue ribbon High Energy Physics Advisory Panel (HEPAP) subpanel convened by the Department in January 1990 (Reference 19). The proposed LHC design had additional technical risks beyond that of proceeding with the SSC in that it depended on the feasibility of 10-Tesla magnets requiring the containment of forces about twice as large as those in the SSC magnets; and a lower operating temperature for the magnets (one-half that of the SSC). In addition, with a total experimental capacity about one-quarter that of the SSC, it could at most support only a small fraction of the U.S. research needs. Furthermore, there was significant cost uncertainty of the LHC preliminary design, and the project had not been approved by CERN. (The LHC project is still pending formal approval by the member countries of CERN, and a detailed conceptual design is not yet completed.)

In the case of the linear collider, the Department had convened two separate technical reviews in 1985 (References 22 and 23). Both reviews indicated that demonstration of feasibility was a decade or more away. The JASON study group reported that ". . . the proposed technologies are so new, and the specifications which must be met to produce a multi-TeV particle physics machine are so stringent, that in our opinion 20 years are likely to pass before any of them are ready for an accelerator with more than SSC capability." While there has been substantial R&D progress since that time, including operation of the Stanford Linear Collider, this technology is still far from providing a practical design for a facility with the science capability of the SSC.

APPENDIX 3

REFERENCES

1. Proceedings of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, June 28-July 16, 1982, Snowmass, Colorado

2. Report of the 1983 HEPAP Subpanel on New Facilities for the U.S. High Energy Physics Program, July 1983 (DOE/ER-0169)

3. Hearing before the Subcommittee on Energy Development and Applications of the Committee on Science and Technology, U.S. House of Representatives, October 19, 1983

4. Report of the Reference Designs Study Group on the Superconducting Super Collider, May 1984 (DOE/ER-0213)

5. SSC Magnet Selection Advisory Panel Report to the Director of the Central Design Group, September 9, 1985

6. Conceptual Design of the Superconducting Super Collider by the SSC Central Design Group, March 1986 (SSC-SR-2020)

7. Cost Estimate of Initial SSC Experimental Equipment, June 1986 (SSC-SR-1023) and SSC Operations Projection, June 12, 1986 (SSC-N-191)

8. Report of the DOE Review Committee on the Conceptual Design of the Superconducting Super Collider, May 1986 (DOE/ER-0267)

9. Superconducting Super Collider, September 1987 (DOE/ER-0339) and April 1988 (DOE/ER-0363)

10. DOE FY 1988 Congressional Budget Request Construction Project Data Sheet on the Superconducting Super Collider, Project No.: 88-R-103

11. DOE FY 1989 Congressional Budget Request Construction Project Data Sheet on the Superconducting Super Collider, Project No.: 89-R-450

12. DOE FY 1990 Congressional Budget Submission Construction Project Data Sheet on the Superconducting Super Collider, Project No.: 90-R-106

13. DOE FY 1991 Congressional Budget Request Construction Project Data Sheet on the Superconducting Super Collider, Project No.: 90-R-106

14. Site-Specific Conceptual Design Executive Summary, July 1990 (SSCL-SR-1055) and Site-Specific Conceptual Design, July 1990 (SSCL-SR-1056)

15. Report of the 1990 HEPAP Subpanel on SSC Cost Estimate Oversight, July 1990 (DOE/ER-0464P)

16. Report of the DOE Office of Energy Research Review Committee on the Site-Specific Conceptual Design of the Superconducting Super Collider, September 1990 (DOE/ER-0463P)

17. Risks and Benefits of Building the Superconducting Super Collider, A Special Study by the Congressional Budget Office, October 1988

18. Department of Energy Response to the Congressional Budget Office Report on the Superconducting Super Collider; letters of November 9, 1988; February 10, 1989; March 10, 1989; and March 27, 1989

19. Report of the 1990 HEPAP Subpanel on SSC Physics, January 1990 (DOE/ER-0434)

20. Request for Proposal Number SSC-90-A-01701 for Collider Dipole Magnets, July 25, 1990

21. Summary of the Meeting and Recommendations of the Superconducting Super Collider Program Advisory Committee, Snowmass, Colorado, July 1990

22. JASON Study on the Role of Advanced Accelerator Technologies in the Future Design of High Energy Particle Physics Machines, October 24, 1985 (JSN-85-3000)

23. Report of the HEPAP Subpanel on Advanced Accelerator R&D and the SSC, December 1985 (DOE/ER-0255)

APPENDIX 4

GLOSSARY

Accelerator	A device that increases the speed, and thus the energy, of charged particles such as electrons and protons
A-E/CM	Architect-Engineering/Construction Management
APS	American Physical Society
ASST	Accelerator Systems String Test
BNL	Brookhaven National Laboratory on Long Island, New York
CBO	Congressional Budget Office
CDG	Central Design Group
CDR	Conceptual Design Report (1986)
CERN	The European Laboratory for Particle Physics near Geneva, Switzerland
Collider	An accelerator in which two opposed beams of particles collide head-on
CS/CS	Cost Schedule Control System
Department	U.S. Department of Energy
Detector	Any device that can detect the presence of a particle and measure one or more of its properties
DOE	Department of Energy
DPF	Division of Particles and Fields of the American Physical Society
EDIA	Engineering, Design, Inspection, and Administration
EIS	Environmental Impact Statement
Electron Volt	The energy given to an electron (or proton) falling through a potential drop of 1 volt
Energy Saver	Superconducting synchrotron with energy about 1 TeV, built at Fermilab near Chicago, Illinois; also known as the Tevatron

EOIs	Expressions of Interest
ER	DOE's Office of Energy Research
ERC	Energy Review Committee
ESAAB	Energy System Acquisition Advisory Board
Fermilab	Fermi National Accelerator Laboratory near Chicago, Illinois
fundamental forces	Forces between particles; four are known: the strong force binding nuclei, the electromagnetic force, the weak force controlling radioactivity (closely related to the electromagnetic force) and the gravitational force
FY	Fiscal Year
GeV	One billion electron volts (Giga-electron Volt)
HEB	High Energy Booster
HEPAP	High Energy Physics Advisory Panel
HERA	Hadron-Elektron-Ring-Anlage, an electron-proton collider under construction at the DESY laboratory near Harmburg, Germany
High energy physics	The study of the interactions and properties of energetic elementary particles of matter.
ICE	Independent Cost Estimating
Kelvin.	A measure of temperature starting from absolute zero (-273.15°C)
LBL	Lawrence Berkeley Laboratory at Berkeley, California
LEB	Low Energy Booster
Linac	Linear accelerator used to increase the energy of particles in a single pass using radio frequency fields
Luminosity	A term used to specify the rate of interactions in a collider
MEB	Medium Energy Booster
MSA	Major Systems Acquisition
NEPA	National Environmental Policy Act
OMB	Office of Management and Budget

OPO	On-Site Project Office
OSSC	DOE's Office of Superconducting Super Collider
PAC	Program Advisory Committee
PIF	Prototype Installation Facility
PMP	Project Management Plan
R&D	Research and Development
RDS	Reference Designs Study (1984)
rf	radio frequency
RFP	Request for Proposal
SCDR	Site-Specific Conceptual Design Report (1990)
SEN	Secretary of Energy Notice
SLAC	Stanford Linear Accelerator Center at Stanford University
SLC	Stanford Linear Collider
SSC	Superconducting Super Collider
SSCL	Superconducting Super Collider Laboratory
TEC	Total Estimated Cost
Tesla	A measure of magnetic field (1 Tesla is about 10,000 times the earth's magnetic field)
TeV	One trillion electron volts
Tevatron	The collider recently constructed at Fermilab, smashing together protons and antiprotons of energy 1 TeV
TNRLC	Texas National Research Laboratory Commission
TPC	Total Project Cost
URA	Universities Research Association
WBS	Work Breakdown Structure