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A Chronicle of Costs

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CONTENTS

Chapter 1 The Beginnings: 1978 through 1983 1
- Workshops on Future Accelerators: 1978 and 1979 1
- The Snowmass Summer Study: 1982 1
- The Cornell Workshop: 1983 1
- Other Activities: 1983 1

Chapter 2 The Reference Designs Study: 1984 3
- The Goal 3
- Assumptions and Specifications 3
- Results 4
- DOE Review 6

Chapter 3 Formation of the Central Design Group: FY85 7
- Magnet Selection 7
- CDG Task Force on SSC Commissioning and Operations 8

Chapter 4 The SSC Conceptual Design and Associated Efforts: 1986 10
- CDR Related Activities 10
- The Conceptual Design Report 11
  - Plan and Assumptions 11
  - Technical Components 12
  - Conventional Construction 12
  - Exclusions from the Estimate 13
  - Cost Results 13
  - Schedule 13
- DOE Review of the CDR 15
- Other Non-Construction Costs (within the TPC) 16
  - The CDG R&D Record 16
  - Further R&D Projections 16
  - Pre-Operations (Commissioning) Estimate 17
  - Equipment Projections 18
- Detector Costs 19
  - Prior Activities 19
  - The FY86 Effort 19
- Operations Costs 20
- Site Selection 21

Chapter 5 DOE Formal Funding Requests: 1987 to 1990 24
- FY88 24
- FY89 25
- FY90 25
- FY91 25

Chapter 6 The Site Specific Conceptual Design: 1990 27
- Introduction 27
- Preliminary Site-Specific Conceptual Design 27
- The Site-Specific Conceptual Design and Cost Estimate 30
- DOE Evaluation of the SCDR Costs 33
  - Cost Baseline 33
  - Schedule Baseline 35
  - Funding Profile 36
  - Conclusion 36

Chapter 7 Estimates for Detectors, Pre-ops, and Operations: 1990 to 1993 37
- SSC Detectors 37
- Pre-Operations and Operations Prior to FY2000 38
- Estimates of Operations Costs: FY2000 to FY2005 42

Chapter 8 Cost Reviews & Rebaselining Efforts: 1993 44

Chapter 9 Summary of SSC Cost Estimates 47
- Projected Costs 47
- Actual Costs: FY88 to FY93 50
- Termination Costs: FY94 and Beyond 52

Acknowledges 55

Selected References 56

CHAPTER 1 THE BEGINNINGS: 1978 THROUGH 1983

Workshops on Future Accelerators: 1978 and 1979

The general subject of proton-proton colliders in the 20 TeV energy range envisioned for the SSC was discussed by the world community of high energy physicists in the 1970 era following the completion of FNAL. Two workshops sponsored by the International Committee for Future Accelerators (ICFA), one in 1978 at Fermilab and one in 1979 at CERN, considered such accelerators among other potential candidates for frontier instruments in high energy physics. At these workshops, general techniques and schemes for reaching very high energy were discussed, while costs and engineering details were left for the future. In the intervening four years, magnet and colliding-beam technologies germane to proton-proton colliders made substantial advances. Inspired by these technical advances, and recognizing the enormous scientific opportunities of a multi-TeV proton-proton collider, U.S. leaders in the field of high energy physics suggested the exploitation of new technology and the start of construction of such a collider at the earliest possible date.

The Snowmass Summer Study: 1982

The efforts of the Snowmass participants in this study produced some of the first referenced data regarding the costs of pp and pp colliding beam facilities in the 20 TeV range. The purpose of the study was to assess the future of elementary particle physics and to consider the nature of future major facilities for particle physics in the United States. It was not the aim of the study to make detailed cost estimates or recommendations; however, the organizers hoped that the results would provide useful data for decision groups in the near future. Approximate estimates for "conventional" approaches for 20 TeV $\bar{p}p$ facilities ranged from $2.2 to $2.5B (FY82$) depending on the assumed maximum dipole field (10T or 5T). Similar estimates for pp (2 rings) facilities ranged from $2.9 to $3.2B. Other "low-cost" approaches projected costs for $\bar{p}p$ facilities in the $1.5B range.

The Cornell Workshop: 1983

Building on the Snowmass findings, a 20 TeV Hadron Collider Technical Workshop was convened in the spring of 1983 at Cornell University to consider further the technical issues. U.S. and European experts in accelerator science and accelerator construction technology met from March 28 through April 2, 1983. The workshop concluded that there were several viable approaches to building a 20 TeV collider facility with useful luminosity. There appeared to be no fundamental accelerator physics problems to prevent successful operation of such a collider, and the technology available in the near future was likely to yield overall costs of $70 to $110M/TeV of beam energy, including the cost of a new laboratory.

Given these findings, and the status of high energy physics (HEP) research, the workshop participants concluded that the time was ripe for the accelerator physics community to intensify engineering development of candidate magnet systems, leading to a sharply focused design and cost study that would narrow cost uncertainties and define more clearly the appropriate construction methodologies.

Other Activities: 1983

In February 1983, a HEPAP subpanel on new facilities was formed to consider and make recommendations relative to the scientific requirements and opportunities for a forefront U.S. high energy physics program in the next five to ten years. The subpanel's first and

unanimous recommendation was to begin immediately a project to design and construct a multi-TeV, high-luminosity proton-proton collider, which was designated the Superconducting Super Collider (SSC). To begin, they urged that an intensive R&D phase be carried out to establish a cost-optimized design for the facility. On July 11, 1983, HEPAP unanimously endorsed this plan with the highest priority.

Following an August 1983 request by Alvin W. Trivelpiece, Director of the Office of Energy Research, a subpanel of HEPAP was set up under the chairmanship of W.K.H. Panofsky to provide advice and recommendations on the content and implementation of a FY84 R&D effort. In several meetings held during the fall of 1983, the subpanel reviewed the various requests to carry out relevant R&D and recommended that several different approaches to SSC magnet design be pursued, including high-field magnets based on niobium-tin (Nb_3Sn) superconductor, medium-field magnets based on niobium-titanium (NbTi) superconductor, and low-field superferric magnets. It was also recommended that development of Nb_3Sn conductor, accelerator physics activities, and other critical technical R&D effort receive support.

In addition to extensive considerations by HEPAP and its subpanels, other activities provided significant input from the high energy physics and accelerator physics communities into nationwide consideration of the scope, design, and use of the SSC and of the R&D that would ultimately be required to generate the best design. These activities included:

- Ad hoc monthly meetings of the HEP user community at various universities and laboratories starting September 1983.
- The 1983 DPF Workshop on accelerator issues at the University of Michigan (December 12 to 17, 1983).
- The 1984 Workshop on cryogenics at BNL (January 17 to 19, 1984).

CHAPTER 2 THE REFERENCE DESIGNS STUDY: 1984

The Goal

In November 1983, a group of senior scientists from the nation's high energy physics program presented a petition to the directors of four U.S. high energy physics accelerator laboratories in which they proposed, in the interest of early initiation of SSC design work, a plan for the creation of SSC Reference Designs.

In December 1983 the directors of the U.S. high energy physics laboratories responded to the petition, and together with DOE, chartered the National SSC Reference Designs Study (RDS) to review in detail the technical and economic feasibility of various options for creating the SSC facility. The objective of the study was to help DOE, the high energy physics community, and the scientific community as a whole to decide how best to proceed with SSC R&D directed toward improving the cost effectiveness of applicable accelerator technology. Primary emphasis was on estimating the cost range within which SSC construction could confidently be expected to fall. The study was centered at the Lawrence Berkeley Laboratory from February through May 1984, involving some 150 scientists and engineers from national laboratories and universities. To initiate the SSC program, DOE redirected funds from the terminated Colliding Beam Accelerator (CBA) project to support the RDS and related R&D at various laboratories and universities.

In chartering the study, the laboratory directors suggested a set of primary design objectives to serve as a basis for the technical and cost analyses. The parameters were derived from previous meetings and workshops. The directors additionally suggested that a range of magnet options be considered: a 6.5 tesla cold-iron design; a 5 tesla iron-free design; and a 3 tesla iron-dominated design. The three options, referred to as (Designs A, B, & C respectively) corresponded to designs being studied by various research teams around the country. Together with the primary SSC design objectives, the conceptual magnet designs formed the basic technical input for the RDS.

Assumptions and Specifications

Apart from the specified collider parameters, other facilities examined in the RDS included an injector complex, and a campus-like arrangement of office and laboratory buildings to support the laboratory operations. In the model layout used for the study, space was provided for six possible interaction regions for independent physics experiments. It was assumed that four regions would be provided at beam turn-on, leaving the other two for future development. The injector complex included a 1 GeV linear accelerator, a 70 GeV conventional magnet synchrotron, and a 1 TeV superconducting synchrotron (comparable to the Fermilab Tevatron).

The RDS estimate considered Construction Costs only, which included design and construction of all technical systems, conventional plant systems, and associated laboratory facilities. The cost estimating model assumed that all primary technical components would be in an advanced state of development at the start of the construction phase. In particular, a magnet design was presumed to have been developed during the R&D phase such that a significant quantity of production prototype magnets would have been produced (using mass-production methods and tooling) and thoroughly tested under simulated accelerator operating conditions. It was assumed that all other technical components requiring substantial development would have been brought to the state of readiness required for engineering design.

For purposes of estimating the conventional construction costs, a "median site" was developed with a model facility layout. The median site was a composite of a variety of

geological, topographical, and meteorological zones to be found throughout the United States. The facility layout on the median site represented an extrapolation of Fermilab facilities. The facility was sized to accommodate a resident laboratory population of approximately 3000 scientists, engineers, and support staff.

The RDS cost estimate did not include certain preparatory costs that would be incurred prior to project approval. EXCLUDED from the cost estimate were site acquisition costs, power distribution beyond the site boundary, geotechnical investigations, preliminary studies for environmental impact and safety analysis reports, and preliminary engineering studies for planning and scheduling. In addition, the estimate DID NOT include costs for the R&D program for accelerator systems and components. The estimate EXCLUDED all costs for physics research, including a physics division staff, physics research equipment, particle detectors, and associated computing equipment. All costs relating to pre-operations and operations were also EXCLUDED.

Results

The overall results for Reference Design A (6.5 tesla cold iron collider magnet) are given in Table 2.1. The total estimate was $2,725M in FY84$. Table 2.2 provides the total costs for all three magnet designs (A, B, & C) together with a comparison of their major cost areas. Finally, Table 2.3 shows a cost profile projected for Design A based on a 6-year construction schedule. The design and cost details are found in the Report of the Reference Designs Study Group, DOE/ER-0213, May 8, 1984.

Table 2.1
Construction Project Cost Summary
SSC Reference Design A
(FY 1984 M$)

1.	SSC Laboratory			**2724.9**
1.1	Project Management and Administration		113.5	
	1.1.1 Construction Project Management	59.0		
	1.1.2 Laboratory Support Services	54.5		
1.2	Central Laboratory Facilities		127.0	
	1.21. Conventional Construction	86.0		
	1.2.2 Equipment	41.0		
1.3	Injector Facilities		186.8	
	1.3.1 Conventional Construction	39.6		
	1.3.2 Injector Systems	147.2		
1.4	Collider Facilities		1402.4	
	1.4.1 Conventional Construction	398.7		
	1.4.2 Collider Accelerator Systems	1003.7		
1.5	Experimental Facilities		87.4	
	1.5.1 Conventional Construction	87.4		
1.6	Systems Engineering and Design		255.5	
	1.6.1 Conventional Construction	97.9		
	1.6.1 Technical Components	157.6		
1.7	Contingency		552.3	
	1.7.1 Conventional Facilities	164.6		
	1.7.2 Technical Components	387.7		

Table 2.2
Estimated Costs, Including Contingencies, for
Reference Designs A, B and C
(FY 1984 M$)

	Design A (90 km)*	Design B (113 km)*	Design C (164 km)*	Common Systems
Conventional Facilities				
Central Lab Facilities				86.0
Injector Facilities				39.6
Experimental Facilities				87.4
Collider Facilities	398.7	496.1	733.5	
Technical Facilities				
Injector - Linac/LEB/HEB				147.2
Collider Magnets	783.0	955.3	357.5	
Collider Cryogenics	123.9	115.9	158.2	
Collider, Other				96.8
AE/CM + EDI	255.5	287.0	271.7	
Project Management and Equipment				154.5
Common Systems	611.5	611.5	611.5	611.5
Subtotal	2172.6	2465.8	2132.4	
Contingency	552.3	589.0	567.2	
Total	2724.9	3054.8	2699.6	

* Collider Circumference

Table 2.3
Preliminary Funding Profile
SSC Reference Design A
(BA in FY 1984 M$)

Fiscal Year	1	2	3	4	5	6	7	TEC
Technical Components	103	172	221	303	281	71	---	1151
Conventional Facilities	48	126	228	149	49	12	---	612
EDIA and Equipment	23	40	59	60	60	47	23	312
AE/CM	30	25	15	10	9	9	---	98
Contingency	34	73	148	148	112	32	5	552
Total	238	436	671	670	511	171	28	2725

DOE Review

From May 8 through May 11, 1984, a 45-member DOE Committee with consultant expertise reviewed the details of the RDS study in great depth. Excerpts from the committee report are given below.

The Committee believes that the RDS Report establishes the technical feasibility, economic credibility, and specific R&D needs of the SSC project. The general conclusion is that all three basic SSC designs considered by the RDS Group appear to be technically feasible and would meet the requirements of the future high energy physics research program to which the SSC would be dedicated.

Although we have identified possible errors and omissions, as well as areas where further extensive R&D work needs to be pursued, none of these findings affect the stated conclusion. These issues are expected to have relatively minor impact on construction cost and schedule.

Finally, we were impressed with the extent and the depth of the work accomplished by the RDS Group during its brief existence. Their results exceed in both quality and quantity that which is normally expected at this early pre-conceptual phase of a new accelerator facility. These accomplishments serve as a tribute to the skill and dedication the RDS Group members brought to their task.

CHAPTER 3 FORMATION OF THE CENTRAL DESIGN GROUP: FY85

To move expeditiously with the SSC program, DOE requested that URA undertake certain activities to assist in the management of the national effort for the R&D and Conceptual Design phases. The request, in a letter from James Leiss (DOE/OER) to H. Guyford Stever (URA) of March 1, 1984, identified the first two phases of the program. Phase O, for FY84, required the preparation of an R&D plan and a management plan which were needed by August 1984 for a secretarial decision on whether to proceed with Phase I. The Phase I plan, for FY85-86, included the development of a cost/performance optimized conceptual design and a firm cost estimate which were to be submitted by March 1, 1986 together with a site criteria document.

In June of 1984, URA formed the SSC Central Design Group (CDG) to carry out its responsibilities for directing and coordinating the national R&D work. By October 1, 1984, the CDG was headquartered at LBL, with Maury Tigner of Cornell University as Director. Technical staff members were drawn from high energy physics and accelerator and technical groups across the country, representing both universities and national laboratories. The work was focused first on the R&D leading to the Conceptual Design Report (CDR).

Magnet Selection

The principal activities for FY85 involved a diversified effort on magnet and cryostat R&D to provide the technical basis for selection of one of the superconducting magnet designs then under study as the basis of the SSC design. The conceptual design was to begin based on that selection. A detailed cost analysis was made for each magnet style. The technical aspects of field quality, R&D requirements, production and assembly methods, and reliability were studied in detail. Cost vs. aperture studies were also made for each magnet. Many technical reviews were conducted during the year in these areas.

While the three RDS magnet styles (described as Designs A, B, & C in Section 2.1) remained under consideration, two additional styles were added to the list, namely D and C*. Both RDS magnet styles A&B were so-called 2-in-1 designs, i.e. 2 magnet apertures within the same iron yoke and cryostat. While there are certain cost efficiencies in this design, there are also potential drawbacks, for example, increased complexity of magnet assembly and loss of flexibility in both commissioning and operations.

For these reasons the proponents of Design C (TAC) proposed Design C* as a 1-in-1 variant of Design C. Design A was primarily a BNL-LBL collaboration effort, and Design B was proposed by FNAL. In late 1984, all three institutions (LBL, FNAL, and BNL) joined forces to prepare Design D, which was a 1-in-1 design aimed at incorporating the best features of Designs A and B.

In April 1985, the CDG Magnet Technical Review Panel was asked to review the status of the 5 designs and determine whether technical information was available such that an appropriate choice could be made. After numerous meetings, the panel concluded that "a sufficient R&D base now exists for a style choice and that if the selection is made now it will narrow the scope of the R&D effort. This will conserve funds, make optimum use of the intellectual resources available in the community, and will result in expediting the technical feasibility for the SSC."

An SSC cost estimating task force was appointed by the CDG Director in May 1985. The charge to the task force was to perform a detailed review of costs for all five superconducting magnet design styles. The task force evaluated up-dated versions of

Designs A, B, & C as well as Designs C* and D. The basic magnet cost information was developed by participating laboratories and by industry.

The data were reviewed by the task force and its consultants to arrive at CDG estimates, which reflected corrections and/or additions to ensure appropriate normalization to the same design goals and to established cost estimating guidelines. The task force included the costs of magnet-dependent systems such as cryogenics, vacuum, power systems, r.f., and, in particular, the costs of the collider tunnel, roads, access, and utilities. The results are summarized in Table 3-1.

Table 3-1 Summary Costs for Magnet Dependent Systems
(FY84 M$)

Magnet Type	A	B	D	C	C*
Construction					
Magnet Systems	732	870	853	441	590
Related Tech Systems	224	223	236	281	301
Conventional Systems	410	444	410	762	762
Design/Systems Engineering	192	218	211	236	258
Contingency	350	416	390	463	509
Total	1909	2171	2100	2183	2420

A magnet selection advisory panel was appointed by the CDG director to consider all the available information on each design and to provide a recommendation in the form of an ordered list of the five magnet styles. In its final report (September 9, 1985) the panel noted that, of the two leading contenders (Designs D and C), it was unanimous in recommending D as the design basis for the collider dipole. The CDG director concurred with the recommendation thus establishing the dipole magnet design choice for the collider ring. The magnet choice was reinforced later by a special HEPAP subpanel chaired by Burt Richter in the summer of 1986.

Additional details relating to the magnet selection activities can be found in the following papers:

- The SSC Dipole: It's Conceptual Origin & Early Design History, SSCL-320, June 19, 1990.
- Cost Comparison of Magnet Dependent Systems, SSC-SR-1012, August 1985.
- SSC Aperture Estimates for Cost Comparisons, SSC-SR-1013, August 1985.

CDG Task Force on SSC Commissioning and Operations

In January 1985 a Task Force was organized to study the impact of magnet design on the commissioning and operation of the SSC. The results of the study were intended to be one of the sources of input for the above magnet type selection process. Within the Task Force, an Operating Cost Subgroup was charged with the task of estimating the yearly operating expenses of the SSC. This was done for the new laboratory as a whole, not just for the accelerator costs. The Task Force report (SSC-SR-1005) was completed in July 1985. The projection for annual operating costs totaled $224M (FY 85$). See Table 3-2. The effort did not include or estimate the level of annual funds needed under the categories of Capital Equipment, Accelerator Improvement Projects (AIP), and General Plant Projects (GPP), or the direct costs to support outside user groups.

Table 3.2
SSC Operations Cost Estimate
(FY 1985 Dollars)

Categories	Manpower (FTE)	Labor (M$)	Purchases (M$)	Power (M$)
Physics Research	400	16.0	3.1	
Injector Systems	300	12.4	14.8	9.0
Collider Cryogenics	85	3.5	3.6	14.1
Collider Other	320	13.2	15.0	
Magnet Power				0.8
RF Power				2.3
Misc. Power				0.9
Experimental Areas	300	11.0	6.0	11.7
Accelerator R&D	100	3.9	3.0	
Facilities R&D	150	5.8	4.5	
Computer Operations	125	5.0	2.5	
Central Shops	100	3.9	1.5	
Building Power				5.2
Subtotal	1880	74.7	54.0	44.0
G&A (40%)	750	29.9	21.6	
Total	2630	104.6	75.6	44.0

Total Cost = 224.2 M$

CHAPTER 4 THE SSC CONCEPTUAL DESIGN AND ASSOCIATED EFFORTS: 1986

CDR Related Activities

The SSC Conceptual Design Report (CDR) in 1986 drew on prior R&D efforts, including the work of many different 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 CDR. The scientific and academic institutions involved in the R&D or from which individuals were drawn are shown in Table 4-1. An additional 280 technical and managerial experts participated in the various CDG task forces, workshops, and panels that supplied key advice and technical information. Table 4-2 presents a partial list of these activities.

The CDR included a conceptual design for the SSC and a construction cost estimate, of $3010M (FY86$), with a schedule duration of 6-1/2 years leading to a completion date of mid-FY94. Because 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 cost estimate. In separate reports the CDG documented estimates of the operating costs for R&D, pre-operations, operations, and a range of costs for the initial complement of detectors and computers. Thus the estimate developed in the CDR and related documents (see the discussion of other non-construction costs and detector work below) represents the first TEC for the SSC.

Table 4-1
Institutional Participation in the SSC R&D
and Conceptual Design Report

Brookhaven National Laboratory	University of Michigan
Fermi National Accelerator Laboratory	Ohio State University
Lawrence Berkeley Laboratory	Rice University
Los Alamos National Laboratory	Stanford University
Stanford Linear Accelerator Center	Texas A&M University
Texas Accelerator Center	University of Utah
University of California, Berkeley	Washington University
University of California, Los Angeles	University of Wisconsin
Cornell University	CERN, European Lab. for Particle Physics (Europe)
University of Houston	Deutsches Elektronen-Synchrotron DESY (Germany)
University of Maryland	National Lab. for High Energy Physics, KEK (Japan).

Table 4-2
SSC Central Design Group Panels,
Task Forces, and Workshops
(Period of Activity)

Photo Description Task Force (8/84-12/84)

Magnet System Test Site Task Force (9/84-10/84)

Technical Magnet Review Panel (10/84-12/84, 7/85)

Magnet Fiscal and Management Review Panel (10/84-11/84)

Aperture Workshop and Task Force (11/84-8/85)

SSC Impedance Workshop (12/84-10/85)

Tunneling Technology Review Panel (12//84)

Task Force on Commissioning and Operation of the SSC (1/85-7/85)

DOE Workshop on Fine Filament NbTi Strand (1/85-)

Siting Parameters Document Review Panel (2/85-3/85)

Business Affairs and Management Advisory Panel (3/85-12/85)

Task Force on Quench Protection and Power Supply Operations (4/85-7/85)

Task Force on Low Temperature Operation (4/85-6/85)

Clustered Interaction Region Study Group (4/85-9/85)

Task Force on Detector R&D for the SSC (5/85)

Realistic Lattice Workshop (5/85-10/85)

Cost Estimating Task Force (7/85-8/85)

Magnet Selection Advisory Panel (6/85-9/85)

Magnet Length Workshop (10/85)

Workshop on Environmental Radiation Consideration (10/85)

Workshop on Cryogenic Design (10/85)

Magnet Systems Integration Meetings (10/85-10/88)

Magnet Program Advisory Panel (10/85-10/88)

Underground Technology Advisory Panel (11/85-10/88)

Injector Workshop (11/85)

The Conceptual Design Report

Plan and Assumptions

The overall responsibility for the cost estimate rested with the CDG. The accelerator systems design was directed by technical teams of the CDG, assisted by experts from the industries and institutions listed in Table 4-1. Costs for conventional facilities construction

were estimated with the assistance of the architectural - engineering joint venture RTK (Raymond Kaiser Engineers, Tudor Engineering, Keller & Gannon-Knight).

The general plan for the CDR cost estimate was to include all construction costs incurred after project approval to bring a 20 TeV colliding beam proton accelerator to a state of operation readiness and to create a laboratory environment suitable for conducting high-energy physics experiments. To accomplish this goal and to ensure completeness and uniform procedures in cost estimating, the following guidelines and assumptions were used:

- All primary technical components are developed previously to a state of engineering design readiness.
- The facility is constructed at a representative site within the United States.
- Materials costs and labor rates are national average rates.
- Cost estimates are in FY86 dollars.
- Overall management of construction contracts will be the responsibility of the SSC laboratory administration.
- Engineering Design (EDI) for technical components will be performed by the laboratory staff.
- Design and construction management for conventional systems will be performed by selected AE/CM firms.
- The final installation and testing of technical components and systems will be carried out by the SSC laboratory. The production of the collider ring superconducting magnets will be carried out in an industrial environment. Primary responsibility for technical risk and quality assurance will be borne by the laboratory.

Technical Components

The technical components were estimated based on the premise that all primary technical systems would be in an advanced state of development at the start of the construction phase. In particular, the collider ring magnet design was presumed to have been developed to the point where industrial technology transfer had begun, and industrial tooling and production studies, as well as model magnet assemblies, had been carried out in industry. In addition, it was assumed that during the R&D Phase, a number of full-scale magnets would have been fabricated and thoroughly tested for magnetic and operational performance, both individually and as assembled into a lattice half-cell module. This would ensure adequate knowledge of the performance, reliability, costs, and achievable production schedule.

Conventional Construction

Conventional construction costs were estimated based on example sites developed with RTK. The examples were based on an analysis of physiographic provinces within the United States. In the Reference Design Study, the conventional facilities were designed in the context of a "median site." That site represented a composite model, developed from characteristics associated with some of the potential sites that were known in 1984. For the CDR, three example sites were developed to provide a more realistic basis for design,

schedule, and cost studies. A variety of tunnel enclosure construction methods, appropriate to the three model sites, were considered in detail. The cost estimating methods were developed in sufficient detail to allow evaluation of the impact on cost of selected technical and geological variations. Furthermore, the associated geotechnical models, the tunneling methods, and the cost estimating procedures would also be useful to DOE during future evaluation of proposed sites.

Exclusions from the Estimate

The CDR estimate did not include certain preparatory costs that might be incurred prior to project approval to ensure an orderly and efficient project start-up. EXCLUDED from the cost estimate were site acquisition costs, primary power distribution to the site substations, geotechnical investigations, preliminary studies for environmental impact and safety analysis reports, and preliminary engineering studies for planning and scheduling. Furthermore, the estimate DID NOT include costs for the R&D program for accelerator systems and components, or costs for physics research equipment, particle detectors, and their associated equipment. In addition, SSC laboratory manpower and research costs for an SSC physics division WERE EXCLUDED from the estimate on the recommendation of DOE.

Cost Results

The CDR estimate totaling $3010M (FY86$) is provided in Table 4-3 in terms of the major WBS categories. The estimate included an overall contingency factor of 21.3 percent ($530M) which was derived from a detailed contingency analysis. The CDR result, with considerably more cost detail and a single magnet design (i.e., selected magnet Style D) for the collider, confirmed the cost projections of the 1984 Reference Design Study.

Schedule

As an aid to planning and as part of the exploration of technical feasibility, a construction schedule was developed consistent with achievable construction rates for both technical and conventional systems. The estimates for the conventional facilities were obtained by detailed consideration of possible site conditions and allowance of adequate time for design, preparation, and efficient contracting. The rates of production used for the principal technical components were derived from manufacturing plans made by industrial firms. It was assumed that project authorization would precede site selection by some 6 to 12 months so that site determination would be the principal critical path milestone. Central determinants of the schedule thereafter were collider ring underground construction and collider ring dipole magnet production. The collider ring construction sequence followed a closely coupled phased approach. As each tunnel section became available for occupancy, the installation and testing of technical components followed in a stepwise fashion such that acceptance testing of each section could begin as soon as installation was complete. This approach was possible because of the modular nature of the accelerator design. Analysis showed that the other components of the complete facility could be completed in a time significantly shorter than for the collider ring itself, thus keeping them safely off the critical path. The conclusion was that a 6 1/2 year construction duration was technically feasible.

Based on the above schedule analysis, the resulting annual funding profile is shown in Table 4-4. The associated laboratory manpower profile is given in Table 4-5. The CDG, at this time, projected construction completion in FY94 based on a construction start in FY88.

Fig. 4-1

Table 4-3
CDR Project Cost
Summary

WBS		FY 86 M$	
1.	Superconducting Super Collider		3,010.3
.1	Technical Components		1,424.2
.1.1	Injector Systems	189.3	
.1.2	Collider Ring Systems	1,234.9	
.2	Conventional Facilities		576.3
.2.1	Site and Infrastructure	85.4	
.2.2	Campus Area	42.9	
.2.3	Injector Facilities	39.8	
.2.4	Collider Facilities	346.8	
.2.5	Experimental Facilities	61.4	
.3	Systems Engineering and Design		287.6
.3.1	EDI	195.4	
.3.2	AE/CM Services	92.2	
.4	Management and Support		192.3
.4.1	Project Management	114.8	
.4.2	Support Equipment	52.6	
.4.3	Support Facilities	24.9	
.5	Contingency		529.9

Table 4-4
Projected Annual
Funding Distribution
(FY86 M$)

FY	Obligations (M$)	Cost (M$)
88	130	75
89	635	296
90	660	628
91	645	791
92	475	675
93	415	493
84	50.3	51.3
Total	3010.3	3,010.3

Table 4-5
SSC Project -- Total Manpower*
(Man Years)

	Fiscal Year						
Category	88	89	90	91	92	93	94
Management and Support	130	281	457	510	390	216	82
EDI (Technical)	379	417	487	499	468	417	200
Construction	48	322	638	1447	1653	1412	135
Total	557	1020	1582	2456	2511	2045	417

* Does not include AE/CM and Conventional Systems Construction Manpower.

DOE Review of the CDR

From April 28 to May 3, 1986, a DOE Review Committee (DRC) evaluated the technical feasibility, estimated cost, and proposed construction schedule for the SSC as documented in the Conceptual Design Report. Excerpts from the report of the DRC are provided below.

The DRC concludes that the design set forth in the CDR is technically feasible and properly scoped to meet the requirements of the U.S. high energy physics program in the period from the mid-1990s to well into the next century. The design of the SSC is based to a large extent on previous experience with storage rings and synchrotrons (particularly the Tevatron, which uses superconducting magnets). While, in many aspects, the SSC requires extension of this experience, there is no question that a facility with the SSC specifications is feasible.

The DRC finds that the CDR cost estimate is credible and consistent with the scope of the project. Choice of an unfavorable site would have major impact on the cost of this facility. Although the DRC recommended a number of changes, the net impact of these on cost (2 percent) is quite small compared to the 20 percent contingency allowed.

The proposed 6 1/2 year construction project schedule appears feasible for the assumed funding profile and for the reasonable assumptions made concerning the characteristics of the site. Careful consideration must be given to optimizing pre-construction activities and to the schedule of activities during the first year of the construction project.

Finally, the DRC was impressed with the extent, quality, and depth of the work accomplished by the CDG and laboratory and industrial participants. The accomplishment serves as a tribute to the skill and dedication of this team.

Other Non-Construction Costs (within the TPC)

The first cost-estimates for R&D in support of SSC Construction, pre-operations, and equipment (relative to both R&D and pre-operations) were developed by the CDG in FY86. The details were presented in Report SSC-N-175 (May 5, 1986). The results are summarized below. The funding record for the CDG and its related national program is also provided for completeness.

The CDG R&D Record

With the formal establishment of the CDG, annual budget requests (FTP/As) were submitted to DOE for the accomplishment of the Conceptual Design and the pre-construction R&D activities described in the next section. On average, the CDG received about 40 percent of the requested budgets as summarized below:

The CDG Directed R&D
Funding Record (M$)

	FY85	FY86	FY87	FY88
CDG Request (FTP/A)	45	73	54	56
Approved Allocation	20	20	20	33

Further R&D Projections

The R&D area covers planned calculations and development activities including technical component models and prototypes, and experiments with systems and components to ensure technological readiness for detailed design and fabrication. The report noted above (SSC-N-175) provided details of specific R&D requirements for the Linac, LEB, MEB, HEB, and the Collider. For example, the plan included accelerator structure tests for the Linac, LEB vacuum chamber and r.f. system tests, development of fast pulsed magnets for injection and extraction systems, and the development of superconducting magnets and cryosystems for both the HEB and the Collider. R&D efforts were also projected for beam instrumentation and controls.

The overall R&D program goals are shown in Table 4-6. In estimating costs of R&D, it was assumed that existing manpower and physical resources of industry and the laboratories participating in the R&D program would be made available. Costs were based on

experience in the then current R&D program, as well as experience with developing similar equipment at other accelerators. The largest costs are those for the superconducting magnet systems. The projected costs for the major systems R&D are given in Table 4-7.

Table 4-6
SSC R&D Program Goals

October 1986	-	Begin "String" Test of Dipoles (~ 1/2 sector)
January 1987	-	Initiate Dipole Life Tests
September 1987	-	First Industry Produced Dipole
October 1987	-	Begin Integrated Systems Tests
April 1988	-	Complete Specifications for Refrigerator System
July 1988	-	Initiate Industry Tooling Fabrication for Collider Magnets
July 1988	-	Model Tests of Linac Accelerator Structures
September 1988	-	Complete Development Model of Collider Arc Quadrupole
October 1988	-	Complete Development Model of Collider Spool
November 1988	-	Complete Development Models of HEB Magnets
December 1988	-	Complete Prototype Models of LEB Magnets & Vacuum Chambers
January 1989	-	Complete Model of LEB RF Cavity
January 1989	-	Begin Site Demonstration Tunnels
June 1989	-	Installation and Test of Refrigerator Package
July 1989	-	Complete Models for LEB and MEB Kicker and Septa Magnets
July 1989	-	Initiate Industry Prototype Fabrication of Collider Magnets
September 1989	-	Complete Production Prototypes of HEB Magnets
April 1990	-	Report on Collider Systems Integration Tests

Table 4-7
R&D Costs for SSC Major systems
(FY86 M$)

	FY88	FY89	FY90	FY91	FY92	FY93	FY94
Linac	2.5	1.5	.5	--	--	--	--
LEB	.5	.5	.5	--	--	--	--
MEB	.5	.5	.5	.5	.3	.3	--
HEB	3.5	3.0	2.5	1.5	0.7	0.7	0.5
Collider	48.0	26.5	20.0	8.0	4.0	4.0	3.5
Tunnel Technology	1.0	8.0	5.0	--	--	--	--
Total	56.0	40.0	30.0	10.0	5.0	5.0	4.0

Pre-Operations (Commissioning) Estimate

The pre-operations budget category is composed largely of the commissioning activities for a given accelerator. It is assumed that after construction completion (including appropriate acceptance tests) of an accelerator, the commissioning phase will begin. This phase is devoted to achieving an understanding of the operational characteristics of all systems and components, as well as the methods and procedures required to achieve full beam capability and maximum operational efficiency. The expected start of the pre-operations phase for each injection accelerator was as follows:

Linac	FY91	(4th Q)
LEB	FY92	(3rd Q)
MEB	FY93	(2nd Q)
HEB	FY93	(4th Q)

Major parts of the Collider were projected to become operational sequentially in a manner similar to that of the train of injection accelerators. The acceptance test completion of each sector of the Collider would initiate its pre-operational test phase. The test schedule for the eight arc sectors and the east and west cluster regions would occur in a sequential manner starting in mid-FY92 with completion in FY94.

Preparations for operations of the Linac and LEB would begin early in FY91. The initial program would involve training the operations staff (crews) to understand the machine components and to diagnose and facilitate various required operating conditions. The process would occur in sequence for the operations group of each accelerator. By the beginning of FY94, it was projected that all the injection accelerators would be operational with full staffing of the operations crews.

In a like manner, crews would be trained and put in charge of the Collider sectors as they became pre-operational. By means of this phased turn-on and training procedure, the required trained staff would be ready for full operation of the Collider. The projected pre-operational costs are summarized in Table 4-8, including operations costs of staff and associated support groups together with power and utility costs.

Equipment Projections

The equipment requirements for FY88 through FY91 were closely coupled with the R&D program described above. During subsequent years, FY91-94, the equipment needs are more related directly to the pre-operations phase of SSC systems. The equipment items are required, for example, in the set-up of test facilities in direct support of the magnet R&D program. The categories of equipment include power supplies, vacuum system equipment, magnetic measurement equipment, and electrical and electronics equipment. The equipment would be used in the extensive tests of a wide variety of individual magnets types, as well as for tests of systems of magnets that closely correspond to actual SSC conditions.

In addition to the facility equipment for the magnet tests, the cryogenics R&D program required the purchase of a 3 MW refrigerator system in FY88. The system would be used to test refrigerator components and operation cycles that were projected for the Collider and the HEB. A major fraction of the FY88 equipment budget projection was planned for the refrigerator purchase.

For the period of FY91 through FY94, most of the equipment budget was required in support of the operational systems. The projection was based on experience with previous accelerator systems. The items would include free standing test equipment for analyzing system faults and beam performance and would include power supplies, vacuum leak analyzers, electronic logic analyzers, and fast pulse measuring devices that would improve the operations efficiency and/or beam reliability. The overall plan for the construction period is summarized in Table 4-8.

Table 4-8
SSC Auxiliary Costs
(FY86) M$)

	FY88	FY89	FY90	FY91	FY92	FY93	FY94	Totals
Accelerator R&D	56	40	30	10	5	5	4	150
Accelerator Equipment	9	6	5	3	3	4	10	40
Pre-Operations	-	-	-	5	22	43	29	99
Total Cost	65	46	35	18	30	52	43	289

Detector Costs

Prior Activities

A rough estimate of costs of three different 4π detectors, performed as part of the 1984 DPF Snowmass workshop, yielded a cost range per detector (before contingency) of $164M to $210M in FY84$. The Snowmass cost estimates did not include an allowance for EDIA, and they were based on a much lower number of electronics channels relative to later projections in FY86.

The 1985 HEPAP summer study estimated an annual expenditure for SSC detectors of $130M during SSC construction. A 4-to-5 year fabrication period (and, hence, spending period at that level) was anticipated, yielding a total cost for detectors of $520-650M. A first estimate of the associated computer costs was made in 1985 at the Fermilab workshop on triggers, data acquisition, and computing. This group made a preliminary cost estimate of $45M for off-line computing equipment.

The FY86 Effort

Near the beginning of FY86, three advisory panels of experts were appointed by the CDG to consider SSC detector requirements and to generate required cost estimates. The results of this effort are detailed in SSC Report SSC-SR-1023 (June 86) entitled "Cost Estimate of Initial SSC Experiment Equipment." The three panels were chartered as follows:

- The Detector Cost Model Advisory Panel (DCMAP) was charged with developing a reasonable model of what the initial detector complement might look like. This panel, chaired by George Trilling of the University of California at Berkeley, provided a report that was then used as input for the work of the other panels.

- The Detector Cost Evaluation Panel (DCEP), chaired by Roy Schwitters of Harvard University, was asked to estimate the costs for that complement of detectors. In its work the panel used the cost data base obtained from large detectors then under construction (CDF, DO, L3, SLD) and made estimates regarding future cost trends for electronics and data acquisition equipment.

- The Off-Line Computer Advisory Panel (OCAP), chaired by Stewart Loken of Lawrence Berkeley Laboratory, was charged with estimating the cost of the off-line computer facility. The data output of the detector complement generated by DCMAP was used to provide an estimate of the computing load.

The initial detector complement model suggested by the first panel (DCMAP) is summarized below. The DCEP panel evaluated the model detectors and estimated that the total costs (in FY86M$) should lie in the range of $558M to $755M <u>without</u> contingency.

• A new 4π all purpose magnetic detector	-	$290M - $334M
• A Spectrometer for high energy muons	-	$159M - $174M
• An upgraded existing 4π detector	-	$ 90M - $125M
plus a precision forward spectrometer	-	- $102M
• Specialized detectors (total cross-section, etc.)	-	$ 20M - $ 20M
Totals	-	$558M - $755M

The DCEP panel recommended that the upper limit for the major detectors be increased by 15% to account for "elasticity in the initial scope of the detectors. The above cost range becomes $558M - $865M. In addition the panel suggested an overall contingency of

$175M (~25%) which resulted in a total estimated cost of $733M - $1040M (with contingency).

The OCAP group considered two types of computing. The first area of interactive computing included program development, physics analysis, engineering calculations, and library management. The central processors were projected as powerful mainframe computers. To accommodate engineering and database applications, these computers were likely to have vector hardware and specialized database processors. The second type of computing is the reduction of raw data from the SSC detectors, and the Monte Carlo simulation needed to design the detectors and to calculate detector acceptance. This computing would be done on a large array of small processors, each of then fully analyzing a single event. The panel estimated that the initial computing needs at the SSC would require $65.6M for hardware and $5.0M for software, for a total of $70.6M.

The above panels concluded in their reports that a first-rate experimental program at the SSC could be generated within the cost estimates given. The above DCEP estimate of the total cost (without contingency) of the initial complement of detectors ranged from $558M to $865M. To this figure one should add the OCAP estimate for off-line computing equipment costs of $71M. The result is a cost range of $629M to $936M (in FY86$ without contingency). Software development and detector R&D costs were not included. For this initial stage of planning formal contingency was excluded because of the belief that it could be absorbed by adjustments in the total scope of the experimental program. Finally the report noted that to obtain the U.S. cost, one should subtract anticipated foreign contributions. The range of costs thus represented both potential variation in the scope of the detectors, uncertainties in cost projections, and unknown foreign contributions. In the first formal request for funding (see Chapter 5), DOE used a value of $664M (FY86$) .

Operations Costs

An operations cost analysis was provided in Report SSC-N-191 (September 1986). The estimate was based on a detailed manpower estimate that was derived from a model organization structure for operations. The report also provided a revised estimate for pre-operations based on this model.

The analysis for pre-operations gave the manpower build-up by fiscal year by functional department within each projected major division of the Laboratory. The Divisions included the Directorate, Accelerator Operations, Conventional Systems, Technical Support, and Administration. No costs were allowed for a Physics Division, Physics Department, or Detector Support in this analysis. The results are given in Table 4-9. The total pre-ops costs for FY91-94 were $112.6M(FY86$). This is slightly higher than the estimate of $99M arrived at earlier (see Table 4-8). The pre-operations time period was FY91 through mid-FY94.

Table 4-9
Revised Pre-Operations Cost Summary
(FY86 M$)

	FY91	FY92	FY93	FY94*
Manpower	4.0	14.8	25.5	13.6
M+S**	2.0	7.4	12.7	6.8
Power	-	3.4	11.0	11.4
Total	6.0	25.6	49.2	31.8

* First half of FY94
** Materials and services @ 50% of manpower costs

Full operation of the SSC was projected to begin in mid-FY94 at the end of construction. Manpower requirements were developed for the various technical operations and laboratory support functions. The manpower estimates, associated materials and support, and utility services are the major cost elements in the operations area. Projections were also provided for the categories of equipment, accelerator improvements, general plant project improvements, and general plant equipment.

The staffing model projected a rapid staff increase in the first three years of operation. It was also envisioned that the operational efficiencies of the injectors and the Collider would be continually improving during this period. It was assumed that a steady-state condition with routine and efficient operations would be achieved by FY99. The projected costs are given in Table 4-10.

Table 4-10
Costs for SSC Operations
(FY86 M$)

	FY94*	FY95	FY96	FY97	FY98	FY99
Staff	26.3	60.2	70.3	78.9	84.4	87.9
M&S**	13.1	30.1	35.1	39.4	42.2	43.9
Power	11.6	32.0	38.0	41.0	43.0	44.0
Total	51.0	122.3	143.4	159.3	169.6	175.8

* Last half of FY94
** Materials and services @ 50% of manpower costs

One can compare the above projections with those of the previous SSC Task Force on Operations and Commissioning. (See Chapter 3.) Both efforts projected operations costs for a period after construction in which reasonable operational efficiency has been achieved with "steady state" conditions. The Task Force scaled costs from FNAL experience, while the above estimate was based on a detailed manpower analysis. Although this model differs in detail from that of the Task Force, the total manpower projections and associated costs were in reasonable agreement. The primary difference lies in the higher percentage of M&S (materials & services) or "purchases" that were projected in the Task Force report.

Finally, projections for the categories of equipment related to Accelerator Systems, Accelerator Improvements, and General Purpose Plant were provided. The projections were estimated from experience primarily at SLAC and FNAL.

The overall results for all funding categories is summarized in Table 4-11. The analysis predicted an annual cost of approximately $233M (FY86$) with "steady state" operations conditions in FY99. The manpower associated with the funding is given in Table 4-12. A total of approximately 2500 FTEs was projected for FY99 exclusive of visiting scientists.

Site Selection

The cost projections in the sections above provided the basic values used in the Gross Life Cycle Cost Analysis of Proposed SSC Sites (October 1987) and the Gross Life Cycle Cost Analysis of the Best Qualified List of Sites (November 1988). In addition to the work described, the CDG also provided the siting parameters document (SSC-SR-2040, February 10, 1997), which provided a comprehensive description of the technical factors required by the SSC Laboratory and its accelerator facilities and their relationship to the physical setting, environment, geology, utilities, and other regional conditions and resources. The analyses were used by DOE in the site selection process. The cost estimates were also used by DOE in preparing of the FY88 budget request described in the following chapter.

Table 4-11
SSC Construction
and
Operations Projection Summary
(FY86 M$)

	Construction Phase							Operations Phase					
Fiscal Year	88	89	90	91	92	93	94	94	95	96	97	98	99
Construction (Costs)	75	297	628	791	675	493	51	-	-	-	-	-	-
R&D (Const. Related)	56	40	30	10	5	5	4	-	-	-	-	-	-
Pre-Operations	-	-	-	6	26	49	32	-	-	-	-	-	-
Operations	-	-	-	-	-	-	-	51	122	143	159	169	176
Accelerator Equip.	9	6	5	3	3	4	-	10	10	12	15	20	25
Accelerator Improv.	-	-	-	-	-	-	-	-	1	3	5	8	10
GPP/GPE	-	-	-	-	-	-	-	-	1	4	4	6	7
Detectors Systems	10	40	100	140	140	98	30	-	-	-	-	-	
Detector Syst. Support	-	-	-	-	-	-	-	-	5	10	15	15	15
Data Analysis System	-	2	8	15	20	15	11	-	-	-	-	-	-
Totals	150	385	771	965	869	664	128	61	139	172	198	218	233

Table 4-12
SSC Manpower Projections (FTE)

Fiscal Year	88	89	90	91	92	93	94	95	96	97	98	99
Management/Support	130	281	457	511	390	216	82	-	-	-	-	-
Tech-EDI	379	417	487	499	468	417	200	-	-	-	-	-
Tech-Construction	48	322	638	1447	1653	1412	135	-	-	-	-	-
Conventional-EDI	50	190	190	190	190	80	-	-	-	-	-	-
Conventional Const.	-	350	740	740	740	200	-	-	-	-	-	-
Subtotal	607	1560	2512	3387	3441	2325	417					
Research & Development	674	464	312	133	66	56	47	-	-	-	-	-
Pre-operations	-	-	-	96	380	661	353	-	-	-	-	-
Operations							681	1559	1821	2049	2179	2264
Accelerator Equipment	30	30	25	15	15	20	50	50	60	75	100	125
Accelerator Equipment	-	-	-	-	-	-	-	10	30	50	80	100
Visiting Scientists	30	50	100	200	300	350	400	450	500	500	500	500
Totals	1341	2104	2949	3833	4202	3412	1948	2069	2410	2674	2859	2989

FY88

The formation of the first budget request for SSC construction project funds was in progress early in 1987. In preparing the request for the FY88 period, DOE decided to base its initial request to Congress on the CDG construction cost estimate of $3010M (FY86$) which equates to $3210M (FY88$). An allowance was adopted for detectors and computers of $664M (FY86$) which equates to $719M (FY88$). Although at the low end of the range of the CDG estimate, the Department deemed this allowance adequate for a viable initial complement of four detectors of varying sizes. The DOE used an allowance of $446M (FY88$) for research and development and pre-operations. This was a substantial increase above the CDG estimate of about $300M and reflected a revised examination of the costs by the Central Design Group and the Department. These considerations led to a total project cost estimate of $4375M (FY88$). The schedule was extended by 1 year from that envisioned by the CDG to present a less aggressive funding profile. With escalation added, the first total project cost estimate submitted to Congress totaled $5320M (AY$s). No construction cost increase was estimated because of the extended schedule.

Table 5-1 provides a comparison of the 1986 CDG estimates (as presented in Chapter 4) with those of the first formal request. The DOE values are taken from the construction project data sheets prepared in FY87.

Table 5-1
CDG and DOE Funding Estimates (M$)

	1986 CDG		1987 DOE	
Projects Costs (TPC)	(FY86$)	(FY88$)	(FY88$)	(AY$)
Construction	3010		3210	4010
R&D	150		236 [1]	251
Accelerator Equipment	40		40	42
Pre-Operations	113		170 [1]	202
Detectors	629		719 [2]	815
Totals	3942		4375	5320 [3]
Annual Operations[4] Cost				
Operations	176	188	190	
AIP	10	11	11	
GPP/GPE	7	7.5	7	
Accelerator Equipment	25	27	29	
Detector Equipment	15	16	32	
Totals	233	250	270	

1. Approximately 50% increase from CDG values.
2. This is $664M in FY86$ representing a $33M increase from the CDG
3. Based on a 7.5 year construction schedule
4. Projections for FY99.

The FY88 budget request was forwarded to Congress after President Reagan made the decision to go forward with the SSC (the "Throw Deep" decision). While this request called for $10M in construction for FY88, no construction funding was appropriated. In FY87 and FY88, the CDG conducted research and development at a pace of about $20M and $33M, respectively, a significantly lower funding level than the $55M that had been requested. (See the CDG R&D Record in Chapter 4.)

FY89

The FY89 budget request to Congress reflected the same total project cost estimate as that of FY88 and included a request for initial federal SSC construction funding at a level of $283M, the same level previously indicated in the FY88 request as the planned funding level for FY89. The total project cost estimate and the completion data remained the same as in the FY88 request because the $10M of construction funds that had been requested in FY88 would have permitted only minimal construction activities. Hence, failure to receive these requested funds caused no appreciable delay or increase in cost. A significant increase in R&D funds (from $33M to $98M) was requested for FY89; however, no construction funds were appropriated.

FY90

The lack of construction funds in FY89 resulted in a schedule delay, making it impossible to hold to the mid-FY96 completion date. This delay, along with a stretchout in the funding profile, resulted in an increase in the cost estimate of $574M, which was reflected in the FY90 request of $5894M (AY$). The request included $160M for initial construction funds for the SSC. The estimated completion date was extended to mid-FY98. Although a reduced level of construction funding ($127M) was appropriated as indicated in Table 5-2, it provided for the START OF SSC CONSTRUCTION.

FY91

The FY91 budget request to Congress reflected the same total project cost and completion date as that in the FY90 request, pending completion of the updated, site-specific conceptual design and cost estimate by the SSCL. At the time the FY91 budget was submitted to Congress, DOE had approved conceptual design changes proposed by the SSCL, but did it not yet have the results of its reviews of the preliminary cost estimate. DOE 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 $5894M (as-spent), with a possible increase of as much as $1000M to $2000M.

Table 5-2
SSC Cost Estimates and Federal Budget Requests
Based on the 1986 SSC Conceptual Design

Year	Total SSC Budget (as-spent $M) Requested	Total SSC Budget (as-spent $M) Appropriated	Construction Funds (as-spent $M) Requested	Construction Funds (as-spent $M) Appropriated	TPC (as-spend $M)	Estimated Construction Completion Date
FY 1988	35	33[2]	10	0	5320	mid-FY 1996
FY 1989	363	98	283	0	5,320	mid-FY 1996
FY 1990	250	218[3]	160	127[4]	5894[5]	mid-FY 1998[5]
FY 1991	318[3]	243[3 6]	169	94[6]	5984[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.

CHAPTER 6 THE SITE SPECIFIC CONCEPTUAL DESIGN: 1990

Introduction

In 1988, concurrently with extensive site selection efforts, DOE sought the services of a contractor to manage the design, construction, and research program at the SSC Laboratory. It was announced in January 1989 that URA, in conjunction with its partners EG&G Intertech and Sverdrup Corporation, had been selected. URA announced that they had chosen Roy F. Schwitters of Harvard University as the director of the SSCL. The first members of the new Laboratory began work in the Dallas area in March of 1989.

With the selection of the near-Dallas site and the assembling of the design team, one of the first efforts was directed toward a revised conceptual design. Scientific and technical personnel studied the design and research objectives of the SSC, using the 1986 CDR as a starting point for their examinations. Over the intervening years many new considerations had developed, which are discussed in the Site Specific Conceptual Design Report of July 1990.

The overall physics objectives of the SSC remained as they were in the 1986 CDR. However, certain system parameters were modified and optimized to meet these goals. The revised design reflected: 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.

The revised design was somewhat more conservative than that proposed in the 1986 CDR, with 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 can be summarized as follows:

- An increase in energy for the injector accelerators from 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;
- A change of the magnetic focusing strength in the Collider ring, requiring an increase its circumference 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 4cm to 5cm;
- 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;
- Improved definition of the test and calibration beam capability needed to meet the requirements of the detector program.

Preliminary Site-Specific Conceptual Design

Changes to the 1986 conceptual design for the SSC were proposed in December 1989, in the form of a preliminary draft Site-Specific Conceptual Design Report. Although the changes addressed the detailed design of certain systems, there were no changes in performance and design objectives of the SSC. The SSCL, in proposing the design changes, noted that in the period since the 1986 CDR, 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 CDR.

In light of the impending increase in estimated cost, DOE requested a review by the High Energy Physics Advisory Panel (HEPAP) 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 HEPAP formed a blue ribbon subpanel on SSC Physics, which recommended strongly that the SSC energy be maintained at 20 TeV and concluded that implementing the design changes proposed by the SSCL 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 SSCL logic for making the recommended technical design changes.

The subpanel report was unanimously accepted by HEPAP, which in its letter of transmittal to DOE further stated that: "Timely completion of the Superconducting Super Collider (SSC) remains the highest priority of the national High Energy Physics program." After carefully reviewing HEPAP's advice, DOE Secretary Watkins reaffirmed that the SSC was properly scoped at a 20 TeV beam energy and that the design changes proposed were appropriate.

Concurrently with this process of reaffirming the basic parameters of the SSC, DOE 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 $7235M (AY$) based on a site-specific design, with construction completion projected at the end of FY98. This is indicated as the 20 TeV Recommended Design in Table 6-1. The cost was based on the assumption that certain project elements in the areas of cryogenics and utilities could be decapitalized (i.e., that the facilities would be built by industry and their capital costs would be amortized within the billing charges for the services provided). If these elements were included, the total preliminary project cost estimate would be $7830M as shown in the second column of Table 6-1.

The exercise at this time also showed the impact on cost of reducing the Collider energy as indicated in the last two of columns of Table 6-1. The preliminary review concluded that the cost estimate was in the range of $7 to $8B (AY$).

Table 6-1
SSC Project Cost Estimates
(Actual Year M$)

	FY 90 Congressional Submission	20 TeV "SCDR" (w/5 cm aperture)	20 TeV Recommended Design	17 TeV	~15 TeV
Injector	450	843	778	733	654
Collider	3147	4538	4150	3730	3320
Experimental Systems	1004	1226	1145	1145	970
Conventional Facs. (NEC)	233	106	93	93	90
Management & Support	308	365	317	290	260
R&D and Pre-Ops	732	732	732	660	580
Preliminary Design (PY$)	20	20	20	20	20
Total Project Costs	5894	7830	7235	6671	5874

The Site-Specific Conceptual Design and Cost Estimate

As a result of the January 1990 review, the Department charged the SSCL to refine the proposed design changes and to critically re-examine the cost estimate and schedule that had been submitted in December 1989. The SSCL completed documentation of the Site-Specific Conceptual Design Report (SCDR), total project cost, schedule, and funding profile in June 1990. The estimate reflected an increase in the total project cost to $7837M (AY$) and project completion by the end of FY98. The SCDR, which, along with documentation presented to DOE and its review teams in June 1990, formed the basis for the SSCL cost and schedule baseline.

The SCDR cost estimate is summarized in Table 6-2. The results are presented in FY90$ and in actual year dollars (AY$). The basis of the AY$ estimate was a 9-year construction schedule. This is longer than the 8 1/2-year schedule assumed in the DOE budget request for FY90. (See Table 5-2.) Table 6-3 provides a summary level comparison of the SCDR costs with those of earlier estimates by the CDG.

Some major technical features of the design changes are summarized below. In addition, it should be noted that the SCDR costs reflect higher labor rates than the national average rates assumed for the technical staff in the CDR. In addition the SCDR calls for a 9-year construction period compared to 6.5 years for the CDR. These factors resulted in an overall increase for staff costs in most areas.

The major part of the SCDR cost increase (+$1,042M) was in the area of Technical Systems. Of this amount, $718M was in the cost increase for superconducting magnets. This resulted from the revised lattice which called for additional dipoles, as well as two different lengths. The aperture increase from 4.0cm to 5cm resulted in a 33 percent increase in the unit costs of dipoles and quadrupoles. The significant cost increase for HEB magnets resulted from the doubling of the HEB energy. The overall costs are compared in Table 6-4.

The accelerator systems accounted for a $324M increase. For the Collider there were increased costs for power supplies and power distribution systems because of external warm leads to corrector magnets. Increased refrigeration required for the larger magnets plus an increased safety margin accounted for the major fraction of the increase. Costs changes for the LEB resulted from a nearly 50 percent energy increase. Cost increases for the MEB and HEB resulted from a 100 percent energy increase. The estimate for global systems resulted from additional estimates involving control systems, software, safety, and communications that were believed to be needed in addition to the individual accelerator systems estimated in the CDR. The results for each accelerator are given in Table 6-4.

The conventional systems cost increase (+$276M) was a result of the doubling of the length or circumference of the enclosures for the Linac, LEB, MEB, and the HEB together with a nearly 3-mile increase in the Collider circumference. In addition, the tunnel diameter for both the HEB and the Collider was increased from 10 feet to 12 feet. Finally the average depth of the Collider was nearly twice that assumed in the CDR model, resulting in increased costs for the many shafts around the Collider ring. In the area of experimental systems, the overall underground enclosure for major detectors increased by a factor of 2.5 in volume as a result of the evolution of detector designs.

The increase in SCDR costs for project management (Table 6-3) resulted from an increase in labor rates, the extended schedule, and additional considerations for systems engineering requirements.

In the WBS 4 area, the SCDR pre-operations projection returned to the value of the original CDG estimate (see Table 5.1) based on detailed manpower projections. The Research & Development estimate increased owing to the technical changes noted above, particularly for the new design requirements for superconducting magnets. The increases for Laboratory Technical Services were because of additional considerations of the requirements for Engineering & Design Services, Materials & Logistics, Computer Services, and communications. In the Laboratory Directorate area, other offices such as External Affairs, Legal, Planning, and International Coordination were estimated for the SCDR and not envisioned in the CDR. For Experimental Facilities Support, the SCDR included costs for Physics Division staff and User Support. These were traditionally excluded from the CDR. The SCDR estimate for contractor fees included estimates for teaming partners as well as URA. An overall comparison is provided in Table 6-6.

Table 6-7 provides a breakdown of the Experimental Systems costs in terms of development, detectors, and experimental computers. The bottom line of $752M (FY90$) did not change over the DOE request for FY88 (see Table 5-1).

Finally, Table 6-8 provides the first SSCL estimate for operations costs outside of the TPC. The subsequent modifications and changes in the areas listed are discussed in Chapter 7.

Table 6-2
SCDR Cost Estimate

Construction	FY90 M$	AY M$
1.0 Technical Systems	2,986.4	3,648.5
2.0 Conventional Systems	1,051.5	1,284.6
3.0 Project Management	48.7	59.4
Contingency	753.0	920.1
Construction Subtotal (TEC)	4,839.5	5,912.6
Other Programs Costs		
4.0 R&D, Pre-Ops, Admin./Tech Support	975.9	1,082.0
5.0 Experimental Systems	752.1	842.0
Other Subtotal	1,727.8	1,924.0
Total Project Cost (TPC)	6,567.5	7,836.6

Table 6-3
Cost Comparison Summary
(FY90 M$)

	SCDR	CDG
1.0 Technical Systems	2986	1944
2.0 Conventional Construction	1052	776
3.0 Project Management	49	26
4.0 Pre-op, R&D, Admin. & Tech Support	976	772 *
5.0 Experimental Systems	752	752 *
Total Direct Costs	5815	4270
Contingency	753	621
Total Project Cost (TPC)	6568	4891

*These estimates were Central Design Group estimates as modified by the DOE. See Table 5-1.

Table 6-4
Technical Systems Cost Comparison
(FY90 M$)

	SCDR	CDR
1.0 Technical Systems	2986	1944
1.1 Accelerator Systems	1082	758
1.1.1 Management	30.2	10.9
1.1.2 Linac	37.0	35.8
1.1.3 LEB	42.3	22.6
1.1.4 MEB	112.5	47.1
1.1.5 HEB	155.4	93.2
1.1.6 Collider	636.0	535.8
1.1.7 Test Beam	11.2	12.5
1.1.8 Global System	57.4	--
1.2 Superconducting Magnet Systems	1904	1186
1.2.1 Management	26.9	5.3
1.2.2 HEB Magnets	171.0	48.7
1.2.3 Collider Magnets	1667.6	1132.4
1.2.4 Development & Test Labs	38.6	--

Table 6-5
Conventional Systems
Cost Comparison
(FY90 M$)

	SCDR	CDR
2.0 Conventional Systems	1052	776
1.1 Accelerators	636	456
2.1.1 Management	37.7	10.0
2.1.2 Linac	2.9	2.0
2.1.3 LEB	5.1	1.5
2.1.4 MEB	34.7	12.6
2.1.5 HEB	74.0	23.7
2.1.6 Collider	464.2	400.0
2.1.7 Test Beam	17.1	6.0
1.2 Experimental Systems	126	71
2.2.1 WN	29.7	34.9
2.2.2 WS	38.9	
2.2.3 EN	21.3	35.9
2.2.4 ES	28.4	
2.2.5 Support Facility	8.0	--
2.3 Site and Infrastructure	111	98
2.4 Campus	55	49
2.5 Design/CM	124	102

Table 6-6
Pre-Operations, R&D, Administration
and Technical Support Costs
(FY90 M$)

		SCDR	CDR
4.1	Pre-Operations	130.7	233.1 *
4.2	Research and Development	396.1	264.8 *
4.3	Laboratory Administrative Services	83.6	104.5
4.4	Laboratory Technical Services	242.0	115.7
4.5	Laboratory Directorate	25.4	17.3
4.6	Experimental Facilities Support	63.9	24.5
4.7	Prime Contract Fee	34.0	11.6
	Total	975.7	771.5

* These estimates were Central Design Group Estimates as later modified. See Table 5-1.

Table 6-7
SCDR
5.0 Experimental Systems Costs

		FY90 M$	AYM$
5.1	Development	40.0	44.8
5.2	Detectors	637.7	713.9
5.3	Experimental System Computers	74,.4	83.3
	Total 5.0	752.1	842.0

Table 6-8
SCDR
6.0 Operations Projections
(Total Costs FY90 through FY99)

		FY90 M$	AYM$
6.1	Physics Research	102,.4	123.9
6.2	Laboratory Overhead	137.3	167.5
6.3	Laboratory Operations	164,.9	202.2
	6.3.1 Accelerator Operations	132.0	161.0
	6.3.2 Magnet Operations	7.1	8.6
	6.3.3 Physics Operations	25.9	32.6
	Total 6.0	404.6	493.5

DOE Evaluation of the SCDR Costs

Cost Baseline

To ensure a thorough evaluation of the design, cost, and schedule, DOE organized three reviews that included the customary program office (the Office of Energy Research) review

and the Department's Independent Cost Estimating staff review. To ensure that the SSCL estimate would receive a completely independent and critical review and that the Department's review process would also be examined, a third special review by HEPAP was requested.

All three review groups received in-depth presentations from the SSC Laboratory and had the opportunity to interact with Laboratory staff during the week of June 25 to 30, 1990. They held additional meetings to gather data, formulate findings, and develop recommendations. The results of the reviews were presented in the DOE report on the SSC Cost and schedule Baseline, DOE/ER-0468P, January 1991. The base SCDR costs developed by the SSCL together with the review recommendations formed the cost and schedule baseline for the SSC project. The revisions from the SCDR and the final cost estimate results are provided in Table 6-9.

Table 6-9
Baseline Cost Comparison
(M$)

Construction Project	SCDR	Baseline	Δ
1.0 Technical Systems	2986	3168	+182
2.0 Conventional Systems	1052	1073	+21
3.0 Project Management Support, & Indirects	49	248	+199
Subtotal (FY90$)	4087	4489	+402
Escalation	906	1019	+113
Subtotal (AY$)	4993	5508	+515
Contingency (AY$)	920	843	-77
Construction Total (TEC)	5913	6351	+438
Other Related Costs			
4.0 R&D, Pre-Ops, & Support	976	875	-101
5.0 Experimental Systems	752	760	+8
Subtotal (FY90$)	1728	1635	-93
Escalation	196	263	+67
Other Costs Total (AY$)	1924	1898	-26
Total Project Costs (TPC)	7837	8249	+412

The costs for technical systems (WBS 1.0) were increased by $25M to include costs for higher estimated vendor wage rates, freight for conventional magnets, and septum magnets. Also included was a $21M increase to the total estimated cost of accelerator system product development. For superconducting magnets, the costs were increased by $84M to provide for higher materials handling costs and by $52M for magnet system product development costs.

For Conventional Systems (WBS 2.0), costs were increased to include the accelerator systems string test facility, the prototype installation facility, and additions to various surface buildings.

The increase in WBS 3.0 reflects indirect costs that were previously carried in WBS 4.0. The overall increase in the escalation reflects an increase for the add-ons to the base, a decrease for revised DOE construction project escalation rates, and an increase for schedule

and funding profile adjustments. While the start of construction in FY90 remains the same, the baseline schedule is 10 years compared to the SCDR schedule of 9 years. Project completion was estimated to the end of FY99. The contingency decrease reflects the total of an increase to achieve a 20 percent allowance on the base construction costs and a decrease resulting from the removal of contingency from foreign in-kind contributions.

The change in WBS 4.0 is a result of including FY88 and FY89 R&D costs, which provides an increase of $123M. This is off-set by a reduction of $271M allocated to the total estimated cost to reflect indirect costs and accelerator and magnet system product development costs. These factors together with schedule and funding profile adjustments result in a decrease of $101M.

The change in escalation for other related costs reflects a decrease of $31M for support and indirect functions transferred to WBS 3.0 and an increase resulting from the use of the latest OMB escalation rates for operating and equipment funds. There is a further increase as a result of schedule and funding profile adjustments.

The net effect of the above changes results in a total cost of $8,249M (AY$) relative to the SCDR value of $7,837M (AY$) for a net increase of $412M.

Schedule Baseline

The baseline schedule established by the DOE review incorporates a schedule extension of 1 year (completion by the end of FY99) to reduce schedule and cost risks and to provide a more prudent and achievable ramp-up in the funding profile beginning in FY92. DOE stated that this schedule was still aggressive, but more cost effective with a balance between risk and total project cost.

An inclusive set of project milestones was established to provide goals for project activities and to provide a basis for measuring progress against the baseline. Most construction activities were scheduled to begin with detailed design in FY91. Design and construction of the injectors proceed sequentially starting with the Linac and moving through the injector chain to the High Energy Booster. Superconducting magnet and collider technical systems development proceed in parallel. The magnet development and prototype testing culminate in the magnet "string test" planned for late FY92.

Following successful completion of the string test milestone, magnets would subsequently be installed in 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 was scheduled to begin in the fourth quarter of FY92.

Commissioning of technical systems would begin in FY95 for the linear accelerator; followed by the Low Energy Booster in FY96, the Medium Energy Booster, which is the source of protons for the test beams in FY96; and the High Energy Booster in FY98. In a parallel fashion, the collider sectors would be commissioned beginning in FY95 and extending into mid-FY99, leading to turn-on of the SSC by the end of FY99. Magnet delivery schedules, tunnel completion, and magnet installation were being coordinated and integrated into a detailed logistics plan.

The experimental detectors would be designed and fabricated in parallel with the construction of the experimental halls and interaction regions with final installation and check-out prior to turn-on of the Collider by the end of FY99.

Funding Profile

Table 6-10 shows the DOE baseline funding profile for the total project cost. The table reflects estimates of both federal and non-federal contributions to the SSC. The estimates of non-federal contributions were 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 was committed to provide $1000M plus the land for the SSC.

Table 6-10
SSC Baseline Funding Profile
(AY M$)

	Total	Federal	Other
FY 1988	33	33	-
FY 1989	98	98	-
FY 1990	191	191	-
FY 1991	409	260	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

Conclusion

The above reviews resulted in a cost baseline for the SSC project of $8249M (AY$) and a baseline schedule calling for completion by the end of FY99. The cost and schedule baseline was expected to provide a high energy physics laboratory capability that would meet the science objectives of the SSC and result in a facility that could be commissioned readily and operate with high reliability.

It was noted that the increases in estimated total project cost were not the result of cost overruns or underestimates. Rather, they were the result of normal changes in cost that occur as the scope of a large project is better understood and defined. In this case, there were also adjustments in schedule to present a less aggressive funding profile and to reflect delays in appropriations for beginning construction.

The baseline cost included a contingency allowance of $843M (AY$), which was expected to provide an adequate contingency envelope for effective execution of the project. The contingency allowance was projected to 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 FY99 provided schedule flexibility and a more prudent ramp-up of funding. The schedule flexibility would allow more time to firm-up designs before entering into construction and magnet production, thereby reducing schedule delays and technical risks.

CHAPTER 7 ESTIMATES FOR DETECTORS, PRE-OPS, AND OPERATIONS: 1990 TO 1993

SSC Detectors

A general plan and associated cost estimate for the initial complement of SSC detectors was provided in 1986 (see Chapter 4). This work served also to provide information with regard to detector costs for the budget requests summarized in Chapter 5.

During the period from 1986 to 1989, the high energy physics community continued to develop and refine ideas for SSC experiments at many workshops and meetings. Much of this activity has been summarized in the proceedings of the 1987 Berkeley workshop on experiments, detectors and experimental areas for the Super Collider and the 1988 Snowmass meeting on High Energy Physics in the 1990s. The concepts presented in these workshops and others required a re-evaluation of detector design concepts.

In order to obtain new estimates of detector costs in FY90, a task force on SSC Detector Cost Estimates was convened. This task force was charged with updating the costs of the detectors given in the 1986 report and with defining new detector examples and related costs, reflecting progress made in detector conceptual designs since 1986. In this effort, the unit costs for various detector components were based on the actual expenditures for recent, large collider experiments such as CDF, Do, L3, SLD and ZEUS.

The revaluation of detector unit costs was followed by their application to the conceptual detector designs considered in 1986. Relative to the 1986 estimates, detector costs were found to be typically 50% higher. A large fraction of this increase arises from the indication of higher unit costs for electronics.

The task force also considered a number of more recent detector concepts. These included several versions of a large solenoidal detector with different coil geometries and detector technologies, a large detector that emphasizes precision muon measurements, a non-magnetic detector, and a specialized detector aimed at b-quark and other intermediate energy physics. The resulting model for a minimal initial complement of detectors and their associated costs is given below.

	FY 89M$
Two, new 4π detectors	610 - 990
A medium-sized new or upgraded detector	140 - 285
Small experiments	20 - 20
Total	770 - 1295

As a result of the above studies, it was recognized that major SSC detectors would be considerably larger and more complex than those envisioned in early studies during the 1980s. This translated into a need to move more rapidly with the design and construction of major detectors such that they could be completed and ready to take data at beam turn-on of the Collider. Early in FY90, the Physics Division developed a plan calling for Expressions of Interest for experiments and associated detectors that would be appropriate for the SSC.

As indicated in Table 6-3, $752M (FY90$) formed the baseline for detector related systems with $40M for generic detector R&D, $75M for related computer systems, and $637M for specific detectors. A revised general plan was formulated by the Physics Division that called for two large general purpose detectors and possibly two small specific purpose detectors. The associated funding plan is indicated in Table 7-1. Apart from the $637M SSCL total, the other numbers were approximate.

Table 7-1
Detector Cost Plan
(FY90M$)

	SSCL Cost	Foreign Contribution	Total Cost
Large Detector No. 1	281	225	500
Large Detector No. 2	281	225	500
Small Detectors	75	50	125
Total	637	500	1125

The large detectors were expected to cover a wide range of new physics opportunities opened by multi-TeV energies. The smaller detectors would provide coverage of phenomena at low transverse momentum as well as for B-physics experiments. The costs indicated for the detectors included engineering design, all fabrication and assembly, project management, and any required detector-specific R&D.

The overall plan called for Expressions of Interest by research groups in May 1990. Extensive international collaborations were expected. By the end of FY90, 22 Expressions of Interest were submitted by 2288 scientists from 373 institutions. This phase was followed in November 1990 by a call for more detailed letters of intent specifically for large detectors. Three collaborations (SDC, L*, and EMPACT/Texas) received funding in early FY91 to enable them to proceed toward development of the details of their proposals.

In January 1991, the SDC received additional support toward the development of a formal proposal. An SDC cost review panel was established by the SSCL in March 1991 for the purpose of reviewing the SDC cost estimates. The SDC produced a detailed Technical Design Report in April 1992. This was reviewed extensively by the SSCL Program Advisory Committee (PAC) in May and June of 1992. The final revised Technical Design Report of October 1992 provided a detailed cost estimate of $589M (FY92$) for the SDC detector.

The PAC did not approve the L* or EMPACT/Texas proposals; however, the Laboratory invited the formation of another collaboration proposal for a large detector, which resulted in the submission of a Letter of Intent for the GEM detector in November 1991. A preliminary design report was provided in June 1992 and was reviewed by the PAC. The final design and Technical Design Report for GEM was submitted in April 1993. The detailed cost estimate summed to $499M (FY90$).

Pre-Operations and Operations Prior to FY2000

As noted in Chapter 13 of the SSC Technical Documentation Summary Report, the DOE site office reviewed pre-operations and operations costs in 1991 and did not accept the methods and assumptions used to estimate the costs presented with the SCDR in June 1990. A commissioning plan was requested for each accelerator based upon specific ground-rules discussed in Chapter 13.

An operations and commissioning report (SSCL-SR-1210) was provided on April 1, 1992. The purpose of the report was to present a plan for the sequential commissioning and operation of individual accelerators and other technical facilities of the SSC. A central objective of this plan was to describe the activities at the SSCL that are not included as part of the construction project TPC, even though they occur during the overall project construction time frame. Examples of such activities include the operation of general

Laboratory facilities and services not specifically related to construction, the operating costs for the individual accelerators in the injector chain once these facilities have been commissioned, and the costs of SSCL physics research groups. The Operations and Commissioning Report provided detailed costs for the operations of each of the following SSC Laboratory facilities and research areas:

- Injection Accelerators;
- Test Beams;
- Experimental Facilities;
- Magnet Research Laboratory; and
- Physics Research.

General features of the model used for this report were presented in Section 1.13.3. Detailed specifics of manpower, schedules, operations shifts, Laboratory overhead, etc., can also be found in the report . The results for pre-operations are presented in Table 7-2. The total cost was $128.4M (FY91$). This is to be compared with the FY90 baseline cost of $130.7M (FY90$).

Table 7-2
Pre-Operations Cost Projection
(FY91M$)

System	FY94	FY95	FY96	FY97	FY98	FY99	Total
Linac	2.1	2.3	2.0	0.7	0.4	2.2	9.7
LEB	-	2.2	3.2	0.7	0.5	2.4	9.0
MEB	-	0.2	5.3	1.9	0.8	3.8	12.0
HEB	-	-	-	0.1	7.8	8.0	15.9
Test Beams	-	0.1	3.7	1.4	-	-	5.2
Collider	-	-	6.9	9.7	17.5	36.1	70.2
Exp. Facilities	-	3.3	2.6	0.4	-	-	6.4
Total	2.1	8.1	23.7	14.9	27.0	52.5	128.4

After the commissioning of a given accelerator, the plan assumed that the accelerator would become operational except during those periods when it was used to commission a subsequent higher energy accelerator in the injector chain or to commission the Collider. For example, the Linac, LEB, and the MEB were projected to be needed extensively for test beams in the FY97 through FY99 period. These costs would be charged to operations; however, when utilized to commission the HEB and the collider in FY98 and FY99, the costs would be charged to Pre-Operations.

The projected operations costs during this period of FY95 to FY99 are summarized in Table 7-3. The integrated total from FY91 through FY99 is $494M (FY91$). This can be compared to the June 1990 estimate of $405M (FY90$) which was not accepted by DOE, mainly because of the non-uniform allocation of overhead charges. The results are plotted by fiscal year in Fig. 7-1.

Figure 7-1

SSCL OPERATIONS

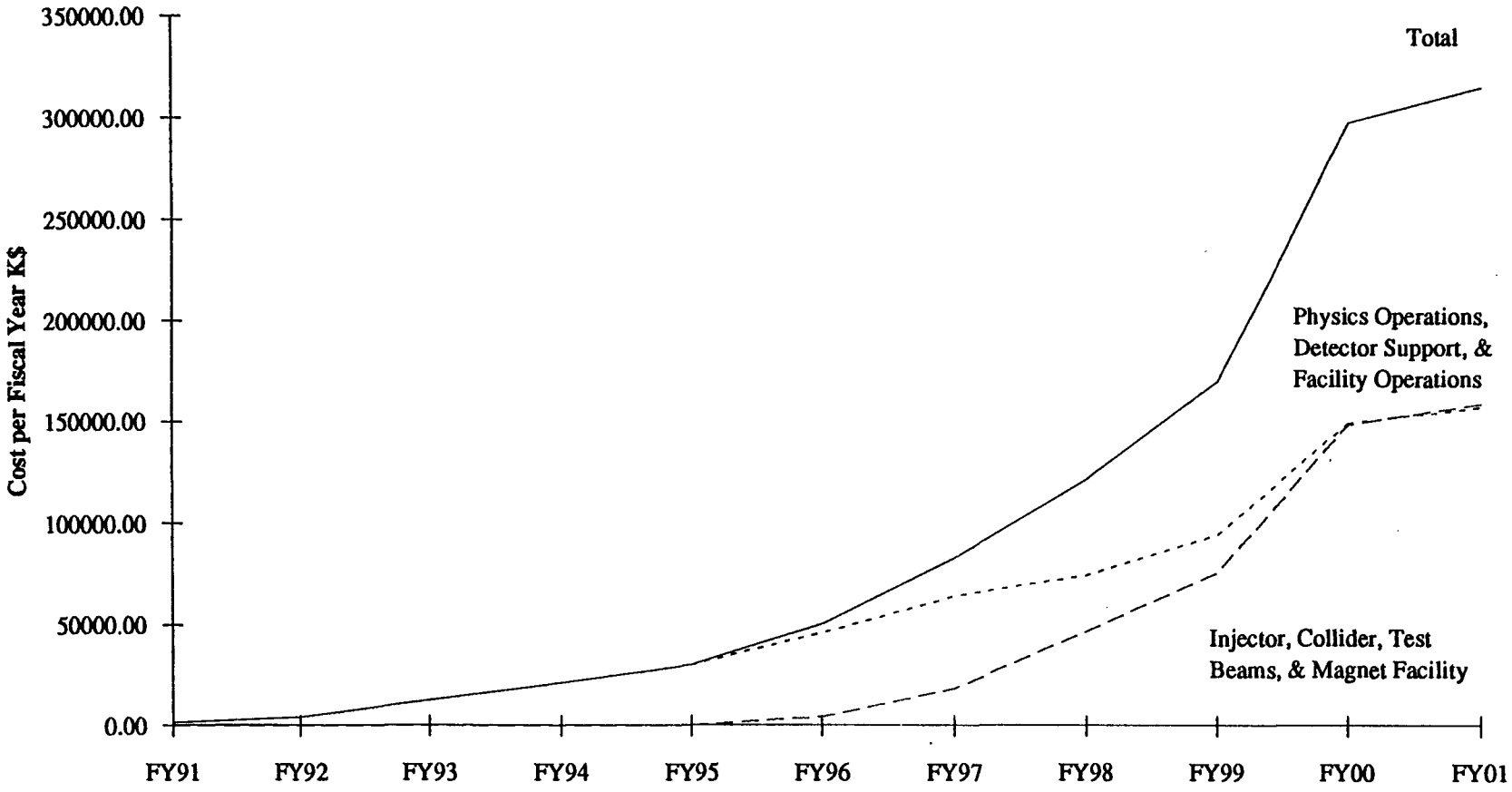


Table 7-3
Operations Cost Projections
(FY91$)

	FY94	FY95	FY96	FY97	FY98	FY99	Sum[1]	FY2000
Linac	-	3.5	5.2	7.4	7.7	5.0	28.8	8.5
LEB	-	-	2.6	7.9	8.3	5.3	24.2	9.2
MEB	-	-	-	8.9	13.2	8.5	30.6	14.5
HEB	-	-	-	-	-	7.4	7.4	24.2
Test Beam	-	-	-	6.7	10.8	10.8	28.3	10.8
Collider	-	-	-	-	-	-		54.9
Exp. Facilities	-	-	12.0	26.2	32.8	49.2	120.3	79.1
Magnet Research	-	-	-	3.5	5.5	15.8	24.9	24.9
Physics Research	(49.7)[2]	27.4	31.9	36.4	40.4	43.3	229.0	43.0
Detector Support	-	-	-	-	-	-	-	21.5
GPP	-	-	-	-	-	-	-	10.0
Total							493.6	300.6

[1]Sum of costs from FY94 through FY99.
[2]Sum of costs from FY91 through FY94

The physics research estimate and request for the years FY91 through FY94 summed to $49.7M as shown in Table 7-3. The specific values of the requests by Fiscal Year during this period are indicated in Table 7-4. It is of interest to compare the actual allocations in the first 3 years.

Table 7-4
Physics Research
Planned Budget vs. Actual
(M$)

	FY91	FY92	FY93	FY94	Total
Physics Research Request	3.2	9.4	15.7	21.4	49.7
DOE Allocation	1.9	3.0	2.5		

An extrapolation of the methods of this report to the year FY2000 provided an estimate for the first full operations years following construction. The results are shown in the last column of Table 7-3. The total Laboratory cost is estimated at $301M (FY91$) consisting of $216M in operations, $55M in equipment, $20M for AIP, and $10M for GPP.

Estimates of Operations Costs: FY2000 to FY2005

In response to a DOE request of July 16, 1991, a draft report on operations in FY2000 and beyond was provided in September 1992. The report was extensively reviewed by a DOE Task Force in October 1992. A final report (SSCL-SR-1216) was submitted in November 1992 based on a number of assumptions, which are described in more detail in the SSCL Technical Documentation Summary Report.

The operations report summarized the physics goals for detector operations during the first five years. The Physics Division operations were described in terms of in-house physics

research, the support functions for users, and operations functions for the experimental halls and associated facilities. All the tasks associated with the Accelerator Division operations of the injectors and the Collider were discussed, and a detailed manpower analysis for each task was provided. Finally, the Laboratory support areas were described and manpower estimates provided. The support areas include the Directorate, the Administrative Services and Support Division, and the Laboratory Technical Services Division. The support for general plant projects (GPP) was included in the Technical Services Division responsibilities.

The draft report of this plan (August 28, 1992) indicated a total SSCL operations cost of $336M (FY91$) for FY2000. The consensus of the above DOE review was that "the total estimate ($336M) was in the right range, but may be possibly on the high side." As a result of the review discussions, several revisions were made including a reduction in the manpower support levels required for operations of the experimental areas and a revised estimate of the power costs. The modifications were incorporated in the final report resulting in a total operations cost of $317.2M (FY91$) for FY2000. This total included costs for all Laboratory manpower (2428 FTEs), materials and supplies, power and utilities, cryogens, equipment, accelerator improvements (AIP), and general plant projects (GPP). The results are summarized in Table 7-5 in terms of specific cost categories for each of five SSCL divisions that were projected for the full operations phase.

Table 7-5
SSCL Total Costs[1]
for FY2000 (FY91M$)

Laboratory Division	Operations Manpower	M&S	Power and Utilities	Cryogens	Equipment	AIP	GPP	Total
Accelerator Operations	49.5	35.6	47.5 [2]	9.7	3.0	10.0	-	155.3
Physics Research	39.5	20.5	-	-	40.3	-	-	100.3
Directorate	7.3	5.7	-	-	0.1	-	-	13.1
Administrative Service	7.5	1.7	-	-	0.3	-	-	9.5
Technical Service	23.0	8.7	1.6	-	0.7	-	5.0	39.0
Total	126.8	72.2	49.1	9.7	44.4	10.0	5.0	317.2

[1]Data from Special Report SSCL-SR-1216
[2]Total electrical power for the SSC Laboratory

CHAPTER 8 COST REVIEWS & REBASELINING EFFORTS: 1993

Four exercises during FY93 were aimed at re-evaluating the SSC project baseline. Unfortunately, NONE of the Laboratory efforts was successfully completed for this objective. The efforts included:

- SSC rebaselining exercise of May & June 1993
- DOE review for baseline validation in July 1993
- SSC value engineering exercise of October 1993
- Rebaselining plan of October and November 1993

In May 1993, the SSCL began an exercise to determine then-current cost projections for the project and to rebaseline in areas where appropriate. At the same time the exercise involved a determination of the cost impact of a revised funding schedule in which the annual funding was limited to $500M as proposed by the new administration in Washington. Although a great deal of information was assembled, the exercise was not completed because of the DOE baseline validation review and other reviews that were directed in July 1993.

There was no opportunity to thoroughly review, understand, and scrub the assembled data, which, at this preliminary stage, involved double-counts, redundancy, errors, misunderstandings of the requirements, and hidden contingencies. In some cases there were revised design parameters that were unapproved. In addition, in some areas, there was no clear distinction between rebaselining and the effects of a schedule extension. The imposed annual funding limit would have extended the project schedule from 2 to 4 years with considerable cost escalation. The exercise was abruptly terminated with oncoming DOE reviews in July 1993.

DOE conducted a baseline validation review of the SSC project from July 13 to July 31, 1993 at the request of the Director of the Office of Energy Research. A committee was assembled of knowledgeable, expert personnel from inside and outside DOE. The committee responded to three charges:

1. To validate the project progress and status as identified in the May 1993 Monthly Progress Report.

2. To project a cost estimate-at-completion based on current trends and projected changes.

3. To provide an assessment of the usefulness of the current business management systems based on information gathered from the review.

The committee determined that the project's progress was reasonably reported in the May 1993 Monthly Progress Report with project completion at approximately 20 percent, but that it was very difficult to track using the current project and business management systems. Progress was assessed through field visits, review of documentation of the actual percentage of work completed as compared to the planned percentage, comparison of progress with lower level schedules, and interviews with SSCL staff. In these interviews, much of the data (neither reviewed or approved by SSCL) from the incomplete rebaselining effort was available to the committee members.

The final report of the DOE Committee acknowledged that they did not assess possible changes in management approach, the impact of trade-off studies or scope changes, or potential changes to improve staff efficiencies. All the above were in process in the rebaselining effort and could have significant impact on costs. With these considerations, the DOE report identified a potential cost risk of ~$1.5B.

The DOE validation report emphasized that its purpose was not the establishment of a new baseline. While the review committee developed an estimate-at-completion in accordance with its charge, it was expected that normal project actions would mitigate some of the identified risks, particularly if management initiatives were undertaken to mitigate the increase. Finally, the committee recommended that the project be rebaselined and that a new, integrated, resource-loaded project schedule and bottoms-up estimate be completed. As part of the rebaselining, the management structure and approach should be modified with the goals of reducing project costs, placing an emphasis on cost containment, and identifying cost responsibility. As part of this, the SSCL staffing levels and mix should be critically examined. Substantial improvements to the project and business management systems should be implemented immediately to bring these systems up to the standards normally required for complex, multi-billion dollar construction projects.

In late September 1993, the SSCL established 20 value engineering teams to investigate and to minimize the cost risks that were indicated by the DOE review, as well as by the incomplete SSCL rebaselining effort of June 1993. The specific areas of responsibility for each team and the identified cost risk are shown in Table 8-1. The effort was undertaken in cooperation with DOE. An outside value engineering consultant was associated with each team. SSCL team members varied from 6 to 20 individuals including technical experts as well as members of the SSCL cost group. Each team also had a member from DOE.

In some areas the value engineering effort progressed rapidly with daily meetings that developed many ideas regarding containment or reduction of cost risks. In other areas work progressed toward understanding the costs and risks of the technical design, but there was not sufficient time to arrive at specific suggestions for minimizing the cost risks. The overall effort was stopped before completion at the end of October 1993 because of the congressional action that month terminating the SSC project. Although incomplete, the second column of Table 8-1 attempts to show the progress of the value engineering effort at the end. The potential cost risk decreases were indicated in preliminary reports by the teams. In some cases no report was available. The preliminary reports were not reviewed in detail; however, they indicate the progress that was under way to minimize the risks, and they show that methods were available to contain costs.

In concert with the value engineering effort, a plan was developed by SSCL in early October 1993 to accomplish the rebaselining. This was basically a resumption of the incomplete effort of June 1993, a recommendation of the DOE validation committee, and a direction by DOE to complete the effort by the end of calendar year 1993. The value engineering exercise above was considered a vital part of this effort. A leader for this work was named by the SSCL director, and a rebaselining executive committee was appointed to oversee the progress and help guide the work. A detailed schedule called for completion of the work with final reports to DOE by 12/24/93. The main efforts started ~ October 15 but were stopped soon after because of termination of the project.

Table 8-1
Value Engineering Exercise
(FY93 M$)

	Cost Risk	Value Eng. Risk Reduction[1]
Superconducting Dipoles	311.6	143.0
Installation (all)	188.8	151.0
Management	158.4	134.0
Civil Construction	158.3	NA[2]
Spools (Collider)	108.2	89.6
Controls (all)	101.1	60.0
Beam Transfer/Abort	45.4	NA[2]
Cryogenics	45.2	NA[2]
Special Superconducting Magnets (collider)	38.2	5.0
HEB Quadrupole/Spool	33.6	24.0
Superconducting Correctors	31.3	86.6
Superconducting Quadrupoles (Collider)	23.1	27.0
Acc. Design (incl. R&D)	18.8	5.0
RF (Collider)	17.9	~14.0
Instrumentation (all)	16.2	8.0
Linac	21.4	NA[2]
Accelerator Commissioning and Operations	11.1	26.5
Electrical Engineering	10.2	56.3
Utilities (all)	7.7	~22.0
RF (LEB)	8.1	NA[2]
Total	1354.0	852.0

[1]Based on preliminary data
[2] Not available. No information provided

CHAPTER 9 SUMMARY OF SSC COST ESTIMATES

Projected Costs

The first consideration of the design of a pp collider in the 20 TeV range began in workshops and summer studies during the period 1978 to 1983. Some very preliminary estimates indicated costs in the range of $2 to $3B. In early 1983, a HEPAP subpanel on new facilities was formed. The subpanel unanimously recommended a project (designated the SSC) to design and construct a multi-TeV, high luminosity collider. In August 1983, at the request of DOE, another HEPAP subpanel was set up to make recommendations for a 1984 R&D effort that would focus on SSC goals. This subpanel provided advice on the details of the R&D effort, particularly with regard to accelerator physics and superconducting magnet development needs.

In November 1983, a group of senior scientists from the nation's high energy physics community presented a petition to the directors of four U.S. high energy physics accelerator laboratories in which they proposed, in the interest of early initiation of SSC design work, a plan for the creation of SSC Reference Designs. In December 1983 the laboratory directors responded to the petition and, together with DOE, chartered the National SSC Reference Designs Study (RDS) to review in detail the technical and economic feasibility of various options for creating an SSC facility. The objective of the study was to help DOE, the high energy physics community, and the scientific community as a whole to decide how best to proceed with R&D directed toward improving the cost effectiveness of accelerator technology applicable to an SSC. Primary emphasis was on estimating the range of costs within which SSC construction could confidently be expected to fall.

The RDS was centered at LBL from February through May 1984 and involved more than 150 scientists and engineers from national laboratories and universities. Construction costs were estimated for a 20 TeV collider with consideration of three different superconducting magnet types for the main ring dipoles, namely, a 6.5 tesla cold-iron design, a 5 tesla iron-free design, and a 3 tesla iron-dominated design. The RDS arrived at total construction costs for the Collider and its injectors of $2.72B, $3.05B, and $2.70B (all in FY84$), respectively, for the above three magnet types. The RDS also concluded that the effort could be accomplished within a 6-year construction schedule. The results were then reviewed in detail by a special DOE committee.

As a result of the success of the RDS, URA in the fall of 1984 formed the SSC Central Design Group (CDG) to direct and coordinate the national R&D work. Headquartered at LBL with Maury Tigner as director, the CDG technical staff members were drawn from high energy physics and accelerator and technical groups across the country, representing both universities and national laboratories. The work of the many contributing institutions, firms, and individuals was focused first on R&D leading to a Conceptual Design Report (CDR).

The principal activities for FY85 involved a diversified effort on model magnet and cryostat R&D to provide the technical basis for selection of one of the superconducting magnet designs then under study. A detailed cost analysis was made for each magnet style. The technical aspects of field quality, R&D requirements, production and assembly methods, and reliability were studied in detail. Cost vs. aperture studies were also made for each magnet. Many technical reviews were conducted during the year in these areas. Upon the recommendation of a special magnet selection advisory panel, a 1-in-1, cold iron, 6.5 tesla design was selected as the choice for the collider magnets. This design was to be evaluated and costed in the CDR.

The CDR effort in 1986 drew on prior R&D efforts, including the work of many different groups assembled by the Central Design Group to address specific technical issues. The CDR included both a conceptual design for the SSC and a cost estimate -- for the construction portion of the project -- of $3010M (FY86$). A schedule duration of 6-1/2 years was estimated leading to a completion date of mid-FY94. Because no site had as yet been selected, conventional construction costs were examined for three "example" sites from around the country and averaged to arrive at a cost estimate. In separate reports the CDG documented estimates of the additional costs for R&D, pre-operations, operations, and a range of costs for the initial complement of detectors and computers. Thus the estimate developed in the CDR and related documents represents the first TEC estimate for the SSC (see Table 9-1 column one).

Formation of the first budget request for SSC construction project funds was in progress early in 1987. In preparing the request for the FY88 period, DOE decided to base its initial request to Congress on the CDG construction cost estimate of $3010M (FY86$) which equated to $3210M (FY88$). An allowance was adopted for detectors and computers of $664M (FY86$) which equated to $719M (FY88$). DOE used an allowance of $446M (FY88$) for research and development and pre-operations. These considerations led to a total project cost estimate of $4375M (FY88$). The schedule duration was extended by 1 year from that envisioned by the CDG to present a less aggressive funding profile. With escalation added, the first total cost estimate submitted to Congress totaled $5320M (AY$).

In 1988, concurrently with extensive site selection efforts, DOE sought the services of a contractor to manage the design, construction, and research program at the SSC Laboratory. It was announced in January 1989 that URA, in conjunction with its partners EG&G Intertech and Sverdrup Corporation, had been selected. URA named Roy F. Schwitters as the Director of the Laboratory. With the selection of the near-Dallas site and the assembling of the design team, one of the first efforts was directed toward a revised conceptual design. The overall physics objectives of the SSC remained as they were in the 1986 CDR. However, certain system parameters were modified and optimized to meet the goals. The revised design reflected: 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.

Somewhat more conservative than the design proposed in the 1986 CDR, the revised design focused on reducing the commissioning time for the Collider, ensuring highly reliable operation, and maintaining flexibility in experimental capability. The primary design changes can be summarized as follows:

- An increase in energy for the injector accelerators from 1 TeV to 2 TeV for the HEB, along with related increases in the energy of the MEB and LEB.
- A change of the magnetic focusing strength in the Collider ring, requiring an increase in the circumference of the Collider ring.
- An improvement in the field uniformity and design margin of the Collider superconducting dipole magnets, related to an increase of the coil inner diameter.
- Adaptation of the facility to the site, including the depth of the Collider tunnel.
- Incorporation of flexibility in the design to make possible later installation of beam bypasses.
- An increase in the size of the experimental halls in view of the latest understanding of the size, complexity, and technical sophistication of the detectors.

The SSCL completed documentation of the Site-Specific Conceptual Design Report (SCDR), total project cost, schedule, and funding profile in June 1990. The estimate reflected an increase in total project cost to $7837M (AY$) and a 9-year schedule that extended project completion to the end of 1998. The SCDR, along with documentation presented to DOE and its review teams in June 1990, formed the basis for the SSCL cost and schedule baseline (see Table 9-1 column three).

To ensure a thorough evaluation of design, cost, and schedule, DOE organized three reviews: the customary DOE program office review, the Department's Independent Cost Estimating staff review, and a third special review by HEPAP. The base SCDR costs developed by the SSCL together with the review recommendations formed the cost and schedule baseline for the project. The revisions resulting from the reviews and the final cost estimates are provided in the fourth column of Table 9-1. While the baseline showed certain increases over the SCDR for Technical Systems, a significant part of the increase was due to an extension in schedule from 9 to 10 years and the inclusion of R&D costs from FY88 and FY89 as indicated in Table 9-1.

The values in Table 9-1, converted to FY93$, are plotted in Fig. 9-1.

In the area of projected operations costs, more detailed estimates were developed in 1992. An operations and commissioning report (SSCL-SR-1210) was completed in April 1992. The purpose of the report was to present a plan for the sequential commissioning and operation of individual accelerators and other technical facilities of the SSC. A central objective of the plan was to describe activities at the SSCL that are not included as part of the construction project TPC, even though they occur during the overall project construction time frame. Examples of such activities include the operation of general Laboratory facilities and services not specifically related to construction, the operating costs for the individual accelerators in the injector chain once they were commissioned, and the costs of SSCL physics research groups. The Operations and Commissioning Report provided detailed costs for the operations of each of the following SSC Laboratory facilities and research areas: injection accelerators, test beams, experimental facilities, magnet research laboratory, and physics research. The report projected total operations costs of $493.6M (FY91$) for the period FY91 through FY99.

In response to a DOE request in July 1992, a draft report on operations in FY2000 and beyond was provided in September 1992 and extensively reviewed by a DOE Task Force in October of that year. The report summarized the physics goals for detector operations during the first five years. The Physics Division operations were described in terms of in-house physics research, the support functions for users, and operations functions for the experimental halls and associated facilities. All the tasks associated with the Accelerator Division operations of the injectors and the Collider were discussed, and a detailed manpower analysis for each task was provided. Finally, the Laboratory support areas were described and estimates of manpower needs were made.

The final report estimated a total annual operations cost of $317.2M (FY91$) for the year 2000. The total included costs for all Laboratory manpower (2428 FTEs), materials and supplies, power and utilities, cryogens, equipment, accelerator improvements (AIP), and general plant projects (GPP) (see Table 9-1 column five).

Table 9-1 Summary of the Evolution of SSC Program Costs
(M$)

Project Costs (TPC	1986 CDG (86$)	FY88 DOE Request (88$)	1990 SCDR (90$)	Jan 1991 Baseline (90$)	Nov 1992 (91$)
Construction	3010	3210	5288	5487	
R&D	150	236	356	322	
Accel. Equip.	40	40	40		
Pre-Ops	113	170	131	131	
Detectors	629	719	752	760	
FY88 & 89 Costs	-	-	-	133	
Total	3942	4375	6567	6833[1]	
Construction Period	(6.5 years)	(7.5 years)	(9 years)	(10 years)	
Annual Operations					
Operations	176	190	-	-	258
AIP	10	11	-	-	10
GPP/GPE	7	7	-	-	5
Accel. Equip.	25	29	-	-	4
Physics Equip.[2]	15	32	-	-	40
Total	233	270	-	-	317

[1]This equates to 8,249M$ in AY$.
[2]Includes detectors and computers.

Actual Costs: FY88 to FY93

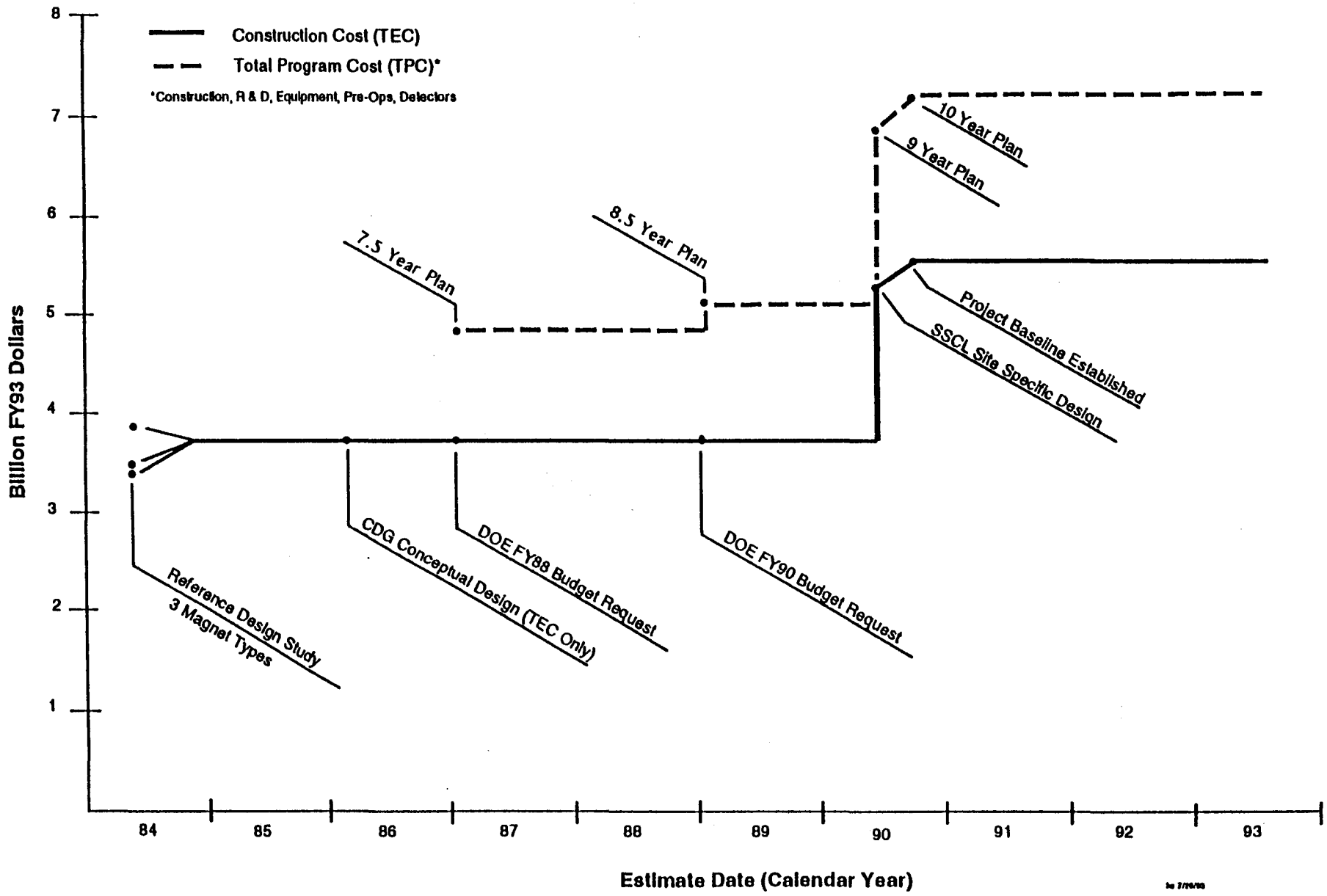
The annual allocations of funds to the SSC are summarized below. The budgets for FY88 and FY89 represent pre-construction R&D efforts, but they are included in the TPC as indicated in Table 9-1. The total amount ($1973M) represents the costs of the SSC project to its termination point (end of November 1993). Of this total, $1551M were provided by DOE and $422M were provided by the State of Texas and other sources.

Table 9-2
SSCL Funding Record

FY	Budget Allocation (M$)
88	33
89	100
90	210
91	385
92	605
93	640
Total	1,973

Figure 9-1.

SSC Cost Estimates In FY93$



Termination Costs: FY94 and Beyond

In mid-1992, questions were asked regarding the termination costs of the SSCL. A very preliminary estimate was developed by DOE in consultation with the SSCL. This value of $232M (FY92$) is shown in column 5 of Table 9-3. In a letter (December 15, 1992) from George Brown (Chairman of the House Committee on Science, Space, and Technology) to James Watkins (Secretary of Energy), estimates of the implications, impacts, and requirements for termination of the project were requested.

In the response letter (January 14, 1993) to Brown, Watkins provided a revised estimate of $278M (FY92$) which is shown in the fourth column of Table 9-3. In this response, Watkins noted that the major impact of termination of the SSC project would be that the nation would surrender leadership in high energy physics and lose an exciting opportunity to explore man's understanding of the most basic forces and components of nature. In addition, the following impacts would be felt: thousands of jobs would be lost; more than 100 universities would lose research grants across the country; America's finest high energy physicists and graduate students would be lost to superior facilities outside the country; American industry's ability to compete internationally in the superconducting technologies would be severely damaged; state governments and potential international partners would be discouraged from future participation on major projects; and many U. S. educational programs aimed at encouraging young students to study science would end.

Watkins stated further that perhaps the greatest cost, to the nation, of termination of this high visibility project would be the negative message we would send to the international science community and young Americans about the nation's commitment to science and technology. Approximately 25,000 students and teachers participated directly in SSC educational activities in 1992 alone.

In July of 1993, in response to requests from Senator Bennett Johnston and others, a revised estimate with more detailed considerations was developed by DOE and SSCL. A preliminary first-cut is shown in column 3 of Table 9-3. More detailed considerations with back-up explanations were provided on July 26, 1993 in a letter to Bennett Johnston from Roy Schwitters of the SSCL and Joe Cipriano of DOE. The information provided is shown in column 2 of Table 9-3 indicating direct costs of $546M (FY93$) plus a litigation potential of $550M (FY93$). Some modest modifications were made to the estimate in October 1993 resulting in the values shown in column 1 of Table 9-3.

Following the congressional action to terminate the SSC project, a November 19, 1993 letter from James Hall (the new DOE/SSC Project Director) to John Peoples (the new SSCL Project Director) requested the development of a detailed termination plan with costs and schedules in accordance with an outline developed by DOE. The SSC staff, in cooperation with DOE, began developing this plan on December 21, 1993. The various tasks were analyzed in some detail, and an appropriate work breakdown structure (WBS) was developed. The plan was completed and submitted to DOE on February 2, 1994. The associated direct costs for the efforts described in the plan over a 4-year period (FY94 through FY97) were estimated at $559M (AY$). With the addition of contingency and DOE site office costs, the total estimate was $644M (AY$).

During the period February 22 to March 11, 1994, a verification review of the plan was conducted by DOE which produced a revised direct cost estimate of $451M (AY$). The most significant change was in the area of site restoration work where the previous estimate was reduced by $96.2M. The estimate is shown by major WBS category and by fiscal year in Table 9-4. With the addition of contingency ($41M) and DOE program direction effort ($25M), the total costs become $517M (AY$).

Table 9-3
Estimated Costs of SSC Termination

	93M$			92M$	
	10/93[a]	7/26/93[b]	7/10/93[c]	1/93[d]	7/92[e]
1. DOE Staff Close-out					
• Relocation (50% of current staff)	2	2	2	–	–
• Site supervision staff (decreasing over 5 years)	27	27	27	–	–
2. SSCL Staff (URA and EG&G) Close-out					
• Close-out staff (decreasing over 15 months)	43	43	75	47	45
• Severance costs	86	61	95	60	50
3. Technical Systems					
• Close-out of Existing Subcontracts	78	78		–	–
• Decommissioning of Magnet Factories	18	18	150		
• Foreign Country Commitments	8	8		65	57
• Finalization of near completion work in progress	38	38			
4. Conventional Systems (Site, Structures, & Environment)					
• Mothballing of Facilities	20	20	40-150	–	–
• Site Restoration	127	127		–	–
5. Termination Liability	65	65	–	45	36
6. Facilities Maintenance and Disposition					
• Distribution of Technical Components and Equipment	16	16	–	–	–
• Maintenance of Facilities pending disposition	20	20			
• Security	13	13	32	40	23
• Storage of Data (long term)	10	10			
Sub Total	571	546	421-531	258	211
7. Litigation Potential			400-600	20	20
• SSCL Employees	100	100			
• Contractors	150	150			
• State of Texas	300	300			
• Texas local governments	60	–	–	–	–
Sub Total	610	550	400-600	20	20
TOTAL	1,181	1,096	821-1,131	278	232

(a) October '93 Revisions (SSCL & DOE).
(b) Letter of Schwitters & Cipriano to Bennett Johnson (7/26/93).
(c) Preliminary evaluation by DOE Site Office.
(d) Letter of Admiral Watkins to George Brown (1/14/93).
(e) Preliminary DOE Estimates with SSCL Data.

Table 9-4

TERMINATION COST ESTIMATE *
FIRST LEVEL WBS SUMMARY
(AY$ IN THOUSANDS) **

WBS	DESCRIPTION	FY94	FY95	FY96	FY97	TOTAL
1	ADMIN & SUPPORT	24,159	15,119	663	661	**40,602**
2	PERSONNEL DEMOB.	49,865	25,459	205	0	**75,529**
3	DOC. & TECH. CLOSE-OUT	31,787	2,855	0	0	**34,642**
4	CONTRACT CLOSE-OUT	139,915	55,166	0	0	**195,081**
5	ASSET PHASE-OUT ***	9,589	13,711	12,682	0	**35,982**
6	ES&H	7,251	5,832	0	0	**13,083**
7	ECONOMIC DEV. & FACIL. USE	3,989	1,828	0	0	**5,817**
8	FACIL MAINTENANCE & SECURITY	26,497	12,185	5,832	6,059	**50,573**
	TOTAL	293,052	132,155	19,382	6,720	**451,309**

NOTES:
* Does not include SSCL costs for OCT & NOV 1993, DOE program direction, contingency, or settlement with State of Texas.
** Actual Year Dollars (AY$) includes escalation.
*** Includes Site Restoration.

Revision A
AS OF 3/28/94

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