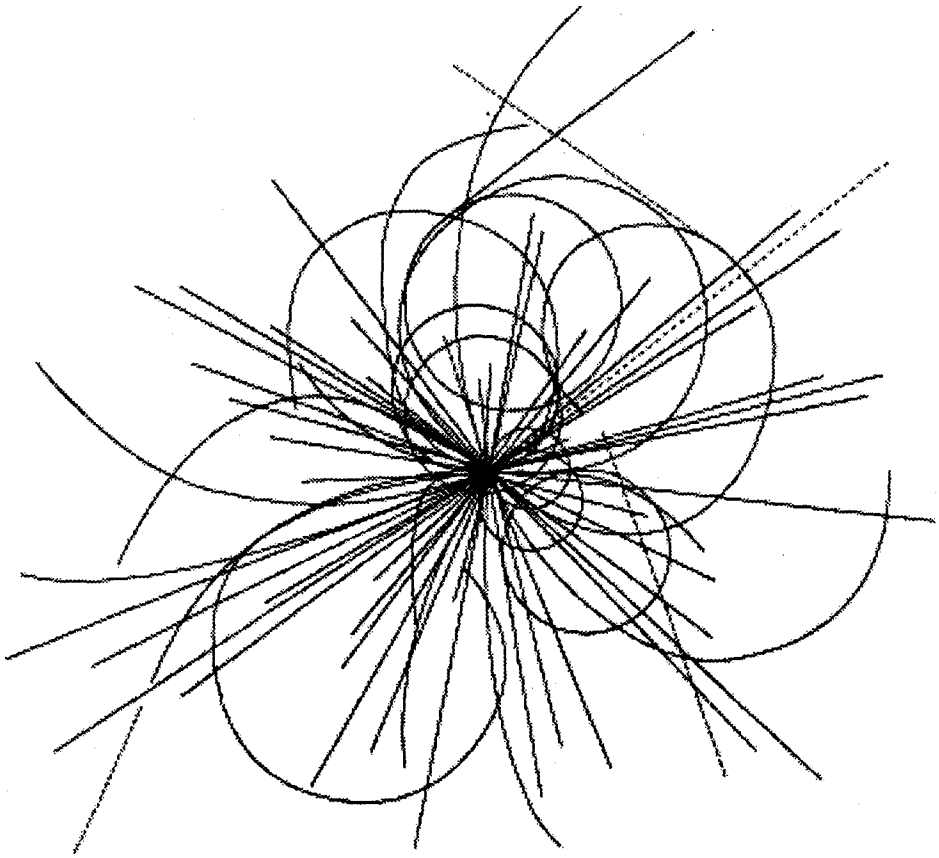
SSCL–SR–1216

SSCL–SR–1216
November 1992
Distribution Category: 400

SSC Laboratory Operations Program Plan FY2000 to FY2005



Superconducting Super Collider Laboratory

SSCL–SR–1216

SSC Laboratory
Operations Program Plan
FY2000 to FY2005

Prepared by

Tom Elioff
Directorate Project Planning Office

Superconducting Super Collider Laboratory*
2550 Beckleymeade Ave.
Dallas, TX 75237

November 1992

*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE–AC35–89ER40486.

Acknowledgements

The help and support of members of the DOE staff and their technical consultants in the review of the draft version of this report (September 14-16, 1992) are much appreciated. The review pointed out certain omissions and necessary clarifications as well as areas where staff projections could be improved. This document now reflects most of the changes suggested as a result of the review.

SSCL staff members who either made presentations to the review panel or provided information for this report include: Richard Briggs, Alex Chao, Roger Coombes, Gerry Dugan, Bob Daniels, Frank Paige, Fred Gilman, Philip Leibold, Vera Luth, George Mulholland, Phil Shelley, Michael Syphers, Tommy Thompson, Tim Toohig, Robert Van Ness, and Tom Whitaker.

The contributions of Karen Earley, Willy Poon, Robert Rooney, and Patsy Tucker toward the preparation of the printed report are also gratefully acknowledged.

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1
INTRODUCTION

SSCL PROGRAM GOALS

The Superconducting Super Collider Laboratory (SSCL) will be the world's premier high energy physics laboratory when its physics program begins at the turn of the century. If we are to optimize SSC's potential for physics discovery, ongoing research must continue to shape the details of the initial physics program plan. Nonetheless, it is important now to have a strategic plan for the SSC Laboratory's initial operating period. Such a plan is needed to guide the buildup of staff and the master plan for facilities at the Laboratory throughout the construction period. It is also an essential input into the long range-plan for the DOE's High Energy Physics Program. This report complements two other recent reports[3],[4] that deal with the near-term physics program and Laboratory operations by providing an endpoint to the scientific and technical staff buildup during the construction period.

Figure 1-1 shows the layout of the SSCL facilities and compares them with other existing accelerator facilities. The SSC represents a major step in both the accelerator and the detector technologies over existing high energy physics facilities. Indeed, every new major facility in high energy physics has traditionally pushed for performance levels that are at least an order of magnitude beyond the current state of the art, especially in the particle collision energy which sets the "resolving power" of the instrument's view into the subatomic world. This approach has paid off handsomely, with major new discoveries being the rule rather than the exception; and investments in these facilities have generally resulted in vital physics programs lasting several decades as improvements and upgrades are added. Past experience shows, on the other hand, that it requires some time for the machine and the experimental systems to achieve their full design potential. It is important to lay out a realistic, self-consistent plan for simultaneously bringing the accelerator and detector systems to their full design performance goals if the plan is to be useful as a guide to the resource needs of the SSCL in the early years of operations.

The top-level parameters that determine the content and pace of the physics program are the particle collision energy, the luminosity, and the availability relative to the scheduled experimental time. The particle energy is controlled primarily by the field strength of the superconducting magnets, and the margin available in this parameter should allow operation up to 20 TeV at the outset of the experimental program. Engineering developments and testing of all SSC components and systems strongly emphasize the beam availability goals in the early years of the physics program. Luminosity is controlled by the proton beam brightness (intensity and emittance), and prior experience shows that because of the many manipulations the beam is subjected to in a complex facility like the SSC, extensive diagnostic studies and operational experience will be required to achieve high beam brightness. The time scale for achieving the luminosity goals in the accelerator is likely to span several years. At the same time, the detector collaborations will need to concentrate in the initial experimental operations on high cross section events as part of the characterization of the detector systems. The early physics experiments will therefore be compatible with the lower luminosity available from the accelerator. In the following chapter, a "model" physics program for the first five years is outlined to illustrate in more detail a self-consistent evolution of the accelerator performance with the physics opportunities that are accessible.

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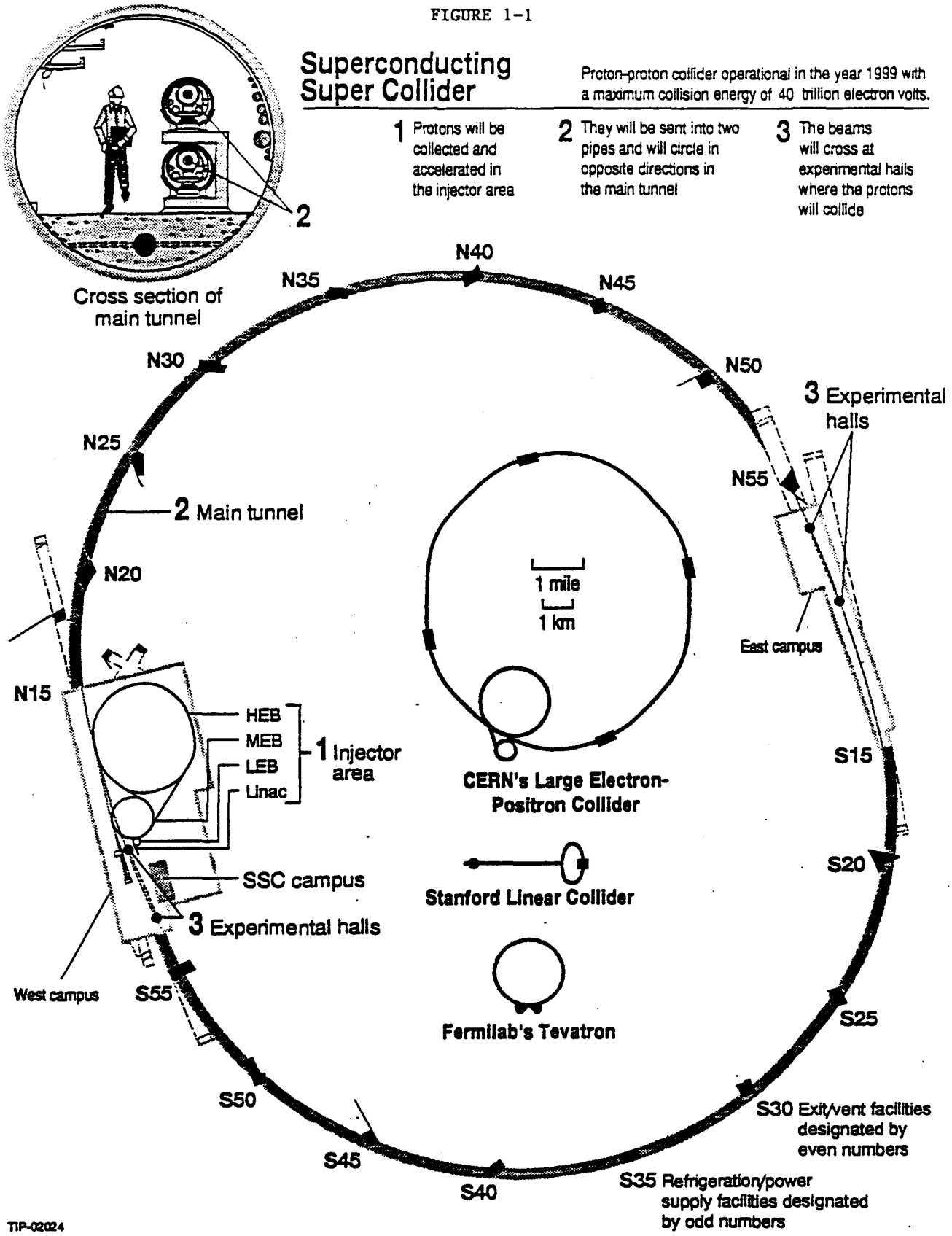
[3]SSCL Commissioning and Operations Report, SSCL-SR-1210, March 31, 1992

[4]Proposal from the Physics Research Division to DOE, April 1, 1992

FIGURE 1-1


Superconducting Super Collider
Proton-proton collider operational in the year 1999 with a maximum collision energy of 40 trillion electron volts.
1 Protons will be collected and accelerated in the injector area
2 They will be sent into two pipes and will circle in opposite directions in the main tunnel
3 The beams will cross at experimental halls where the protons will collide
2
Cross section of main tunnel
N40
N35
N45
N30
N50
3 Experimental halls
N25
N55
2 Main tunnel
N20
1 mile
1 km
East campus
N15
HEB
MEB
LEB
Linac
1 Injector area
CERN's Large Electron-Positron Collider
S15
S20
SSC campus
Stanford Linear Collider
3 Experimental halls
West campus
S55
Fermilab's Tevatron
S25
S50
S30 Exit/vent facilities designated by even numbers
S45
S40
S35 Refrigeration/power supply facilities designated by odd numbers
TIP-02024

PLANNING ASSUMPTIONS

The "model" plan presented here is based on a number of specific assumptions. It will be updated periodically as the Laboratory develops a better understanding of the performance capabilities of the machines and the detectors, and as more detailed analyses of the staffing and facilities required for the Laboratory become available.

Some specific assumptions follow below:

1. At the beginning of FY2000, the injector accelerators, collider, detectors, and experimental facilities will have successfully completed their commissioning phase in accordance with the current project schedule, and the plan outlined in reference 1 above. In Table 1-1, the dates for completion of commissioning of the various machines and facilities are summarized, and the period that the machine or facility will have been in operation at the beginning of FY2000 is indicated.

2. The Linac, LEB, and MEB will be operating reliably at the full intensity specified for the collider and for test beam operations, although the emittance goal in the collider-filling mode may not yet have been achieved. This is a reasonable assumption considering the extensive operational experience with these machines that will have been gained by the beginning of FY2000.

3. At the beginning of FY2000, the HEB will not yet have achieved its design performance or reliability, but this will not be a significant limitation in the collider performance for the three-year period during which the complex will be brought to full design luminosity.

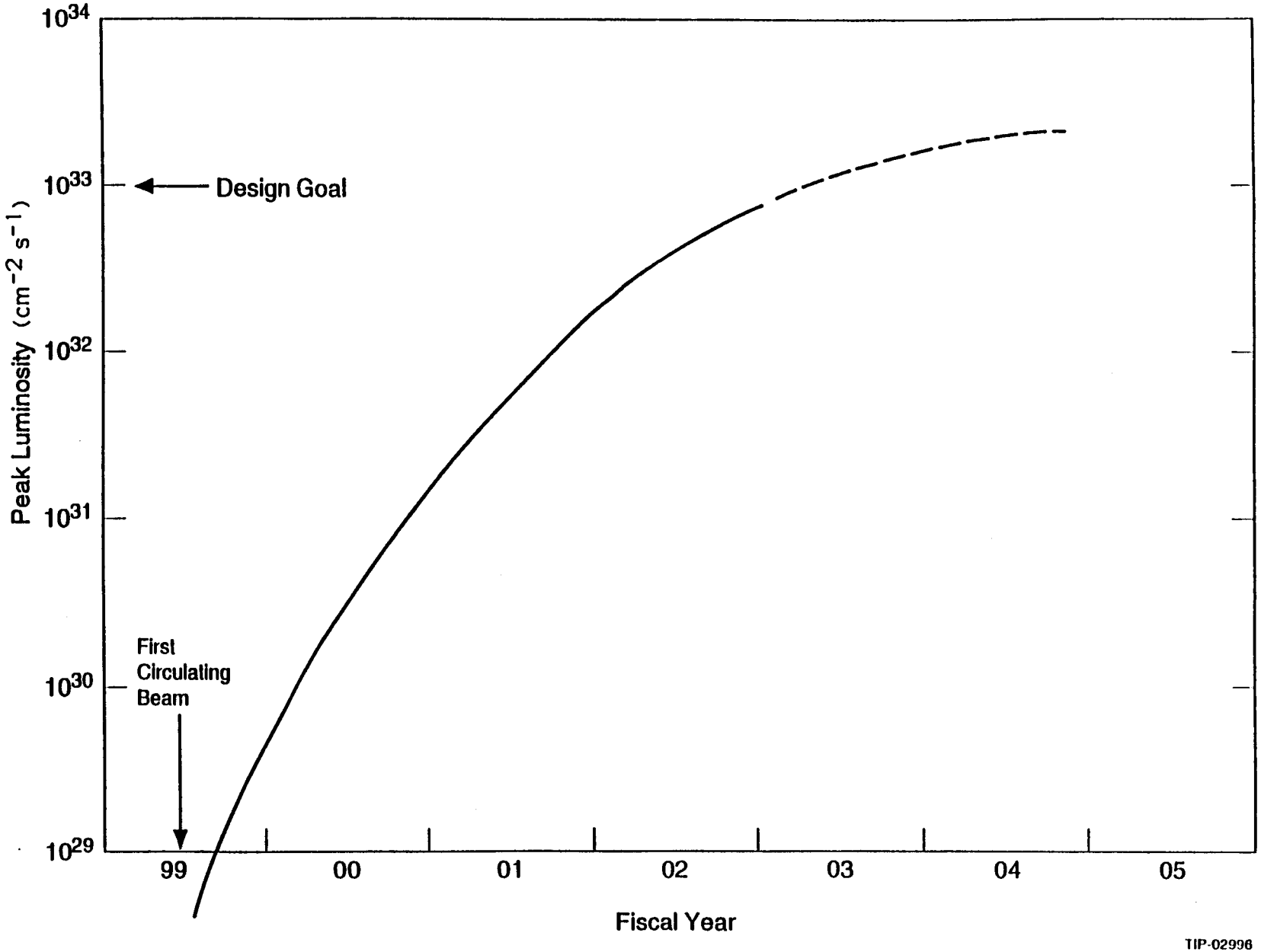
4. The collider will begin operation with reduced bunch intensity and/or larger emittance, and perhaps with a smaller total number of bunches than it will ultimately provide. The relatively conservative assumption is made that the resulting instantaneous luminosity will reach 1 percent of the design luminosity by the end of the first year. The beam energy will be capable of 20 TeV at the outset.

TABLE 1-1

	Completion of Commissioning	**Months in Operation through FY99**
Linac	4/95	54
LEB	4/96	42
MEB	1/97	33
HEB	2/99	8
Test Beams	1/97	33
Large Halls	1/96	45
Small Halls	1/97	33
Collider	10/99	0

Beyond FY2000 the luminosity will increase by approximately one order of magnitude per year reaching the design luminosity of 10^{33} cm^{-2} s^{-1} in the third year of operation. The projected performance (peak luminosity vs. time) is indicated in Figure 1-2. The luminosity curve together with the actual operations time in a given year yields the integrated luminosity for that period. The physics goals for increasing increments of integrated luminosity are described in Chapter 2.

Figure 1-2
Collider Projected Performance



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OVERALL REPORT PLAN

In the following chapters, we project the physics goals that will be addressed in the first years of operation and describe the overall operations of the Laboratory. The operations model is that of a single purpose High Energy Physics Laboratory. Figure 1-3 shows the basic functional components of the SSCL in this model. Note that this is not intended to be the exact organizational structure of the Laboratory. It is a model for functional completeness and cost estimating purposes.

In Chapter 3, the tasks associated with the Accelerator Division are described. The responsibilities include overall operations of the injectors and the collider. Overall electric power needs are also addressed in this chapter.

In Chapter 4, the Physics Division operations include the plan for in-house physics research, the support functions required for users, and overall detector operations. The Physics Division responsibilities include the operations functions for the experimental halls and associated facilities.

In Chapter 5, the overall Laboratory support areas are described. This includes the Director's office and the Directorate, the Administrative Services and Support Division, and the Laboratory Technical Services Division. The support for General Plant projects is included in the Technical Services Division responsibilities.

In Chapter 6, the costs and manpower details provided in the preceding chapters are summarized to project a total budget for overall SSCL operations in FY2000. In addition the potential increases for budgets extending to FY2005 are estimated. Finally, some of the possibilities for future Laboratory improvements are briefly described.

This report is based on currently available information and involves projections of these data for more than seven years into the future. The results will be updated within the next two years as new or additional information becomes available and as more detailed future plans are developed.

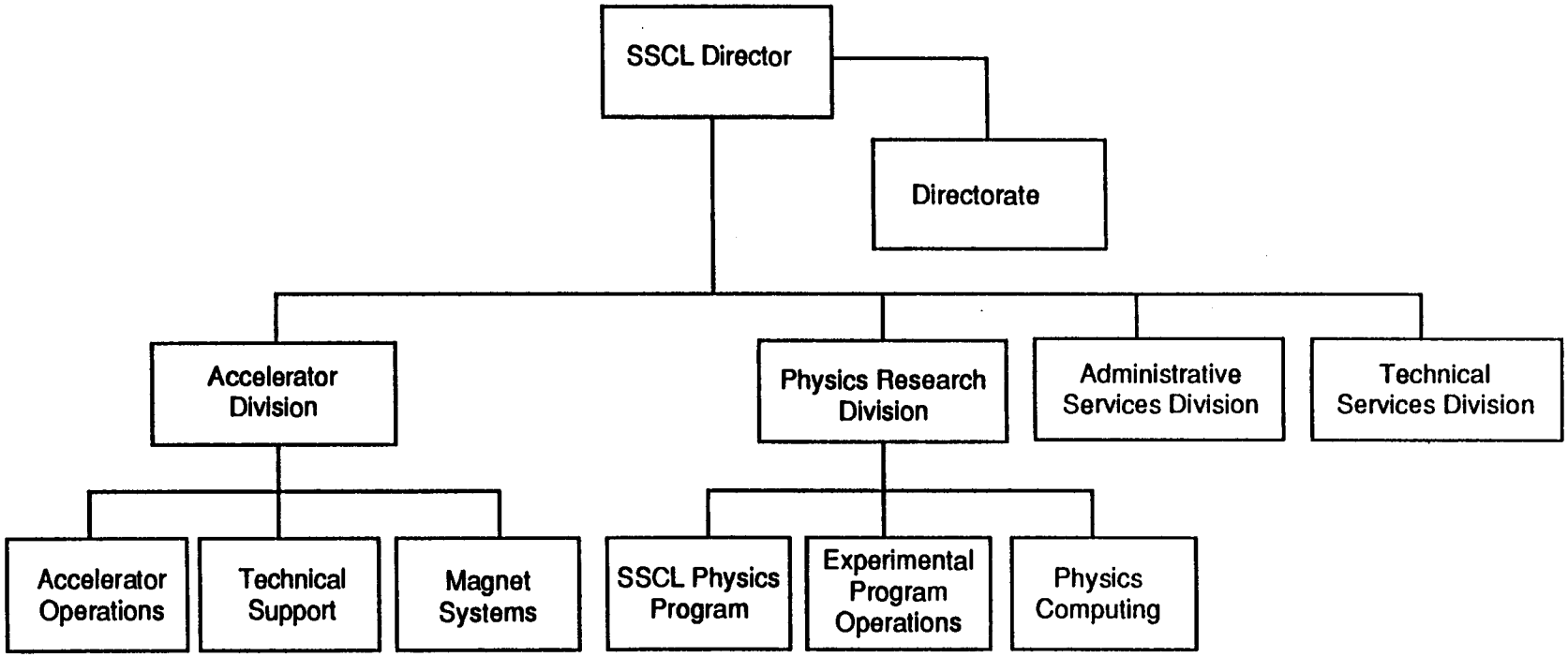

Figure 1-3
SSCL Functional Organization Model for Operations

2
GOALS AND PLANS FOR EXPERIMENTAL PHYSICS

INTRODUCTION

Our current understanding of particle physics is expressed by the so-called Standard Model of electro-weak interactions. It is the primary research goal of the SSC to explore what lies beyond the Standard Model, in particular to understand the origin of masses. In the simplest model, the masses of the W and Z bosons, as well as the masses of the charged fermions, originate from their interactions with a scalar field, the Higgs boson. While the couplings of the Higgs particles are determined by the masses of the fermions and gauge bosons, their masses cannot be predicted. As a result, their decay modes and thereby the methods of detection remain unknown. Supersymmetry theories can also explain the scale of electro-weak symmetry breaking and offer the possibility of unifying electro-weak and gravitational forces. The minimal supersymmetric theory predicts the existence of a supersymmetric partner for every particle. These new particles could have very large masses, and for that reason they can only be produced in high energy interactions. Their existence can be detected by the presence of large missing momentum and energy in the event.

GENERAL PROGRAM PLAN

The initial experimental physics research program at the SSC Laboratory will be carried out by two large detectors operating in the high luminosity interaction regions on the East Campus, and by smaller, more specialized experiments installed in the interaction regions on the West Campus. In the longer-term future, additional research activities will develop. Some of them will exploit extracted beams from the medium and high energy boosters, while others might use parasitically extracted or secondary beams from the Collider.

The evolution of the Collider research program will follow closely the evolution of the Collider luminosity in both peak and integrated performance. The two large detectors address physics at the TeV mass scale, and they have been designed to achieve their full physics potential for a peak luminosity of about 10^{33} cm^{-2} s^{-1}, although substantial capability will exist for higher luminosities. Some of the smaller, more specialized detectors can explore processes with larger cross sections and will be designed for peak luminosities of 10^{32} cm^{-2} s^{-1} or less. An important physics program is also open to experiments for luminosities significantly below the design value.

In the sections below, the experimental physics program is outlined for different ranges of collider luminosity based on parton cross sections[5] and estimates taken from the SDC Technical Design Report [6] and the GEM Letter of Intent.[7] The estimated efficiencies include detector acceptance, branching ratios, and selection criteria for signal and background suppression. The estimates do not take into account that certain elements of the detector may require to be staged due to schedule or budgetary constraints.

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[5]E. Eichten, I. Hinchlife, K. Lane, C. Quigg, Rev. Mod. Physics, 56, 579 (1984)

[6]SDC Collaboration, Technical Design Report (April, 1992)

[7]GEM Collaboration, Letter of Intent (1991)

In Figure 2-1 the cross sections for the production of jets, gauge bosons, heavy quarks, gluinos, and the Standard Model Higgs particle are given in units of the expected total interaction cross section at 40 TeV. While these processes are extremely rare compared to the total interaction rate, the number of events expected for an "operating year" of 10^7 seconds at the SSC design luminosity is sizable. The "physics reach" of the SSC research program will depend critically on the mass scale at which new phenomena manifest themselves, as well as on the performance of the Collider and the detectors. The reach is schematically summarized in Figure 2-2. Since the mass region of interest is unknown, the exploratory potential of the large SSC detectors could be realized even at the lower luminosities. An exception to this is the production and detection of Standard Model Higgs bosons. Luminosities in excess of a few times 10^{32} cm^{-2} s^{-1} are required to begin the search for the Standard Model Higgs.

PHYSICS PROJECTIONS VS. LUMINOSITY

Integrated Luminosity to 10^{37} cm^{-2}

The first year of operations will provide a "shakedown" period for the detectors and the associated physics analysis systems. This period will be particularly valuable for understanding trigger and data acquisition systems, as well as the calibration, alignment, and performance of detector subsystems. Also, machine background levels will need to be studied and the precise Collider luminosity must be established.

The study of known Standard Model processes in the new energy domain of the SSC will be a primary focus of activity. Studies of these processes are of interest to test the Standard Model at SSC energies and are also required to quantify backgrounds to new physics. Jet production, b quark production, and the production of single and multiple W and Z bosons will easily be studied in the first year of SSC operation. The exact details of the initial program at the SSC will depend also on the amount of data that have been collected and on the discoveries that have been made and the limits that have been obtained at the Fermilab Tevatron collider before the completion of the SSC.

Elastic and Total Cross Sections

A small and specialized experiment has been proposed to study elastic and diffractive scattering and to derive the total cross section. This experiment uses the Coulomb scattering amplitude for normalization and therefore requires measurements at angles of about 1μrad to the beams; consequently beams of small divergence or large β^* at the interaction region are required. If the luminosity for the standard β^*=0.5m equals $L=10^{30}cm^{-2}s^{-1}$, then for β^*=2000m one expects a luminosity of approximately 10^{26} cm^{-2} s^{-1} and a counting rate of 5Hz. Thus only a few days of operation with special beam conditions will result in significant measurements. Data at different energies will map the energy dependence of the elastic and total cross sections, requiring dedicated Collider operation.

Beauty Physics

Collider experiments studying the physics of beauty production and decay are also expected to benefit from very high production cross sections at SSC Collider energies and they can be operated at lower luminosity. The difficulties of such experiments lie in the efficient selection of a sufficiently clean sample of beauty events. The difficulties put stringent demands on the detector design, primarily the trigger and precision tracking system. The study of CP violation requires in addition excellent vertex resolution. For small angle experiments the requirements for rate capability and radiation hardness are extremely demanding and will require beam tests and background studies prior to data taking.

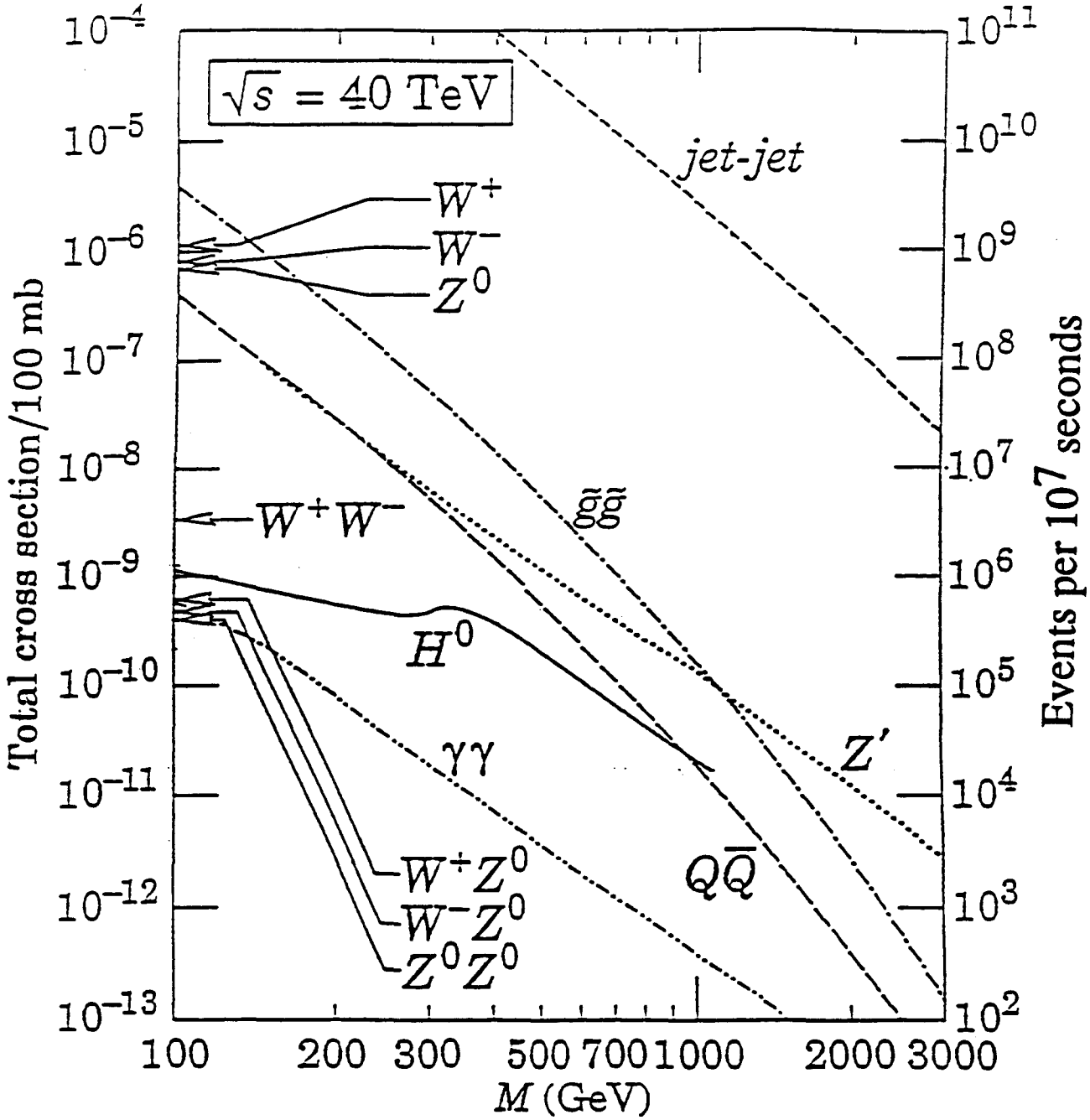


Figure 2-1
Production Cross Sections at 40 TeV

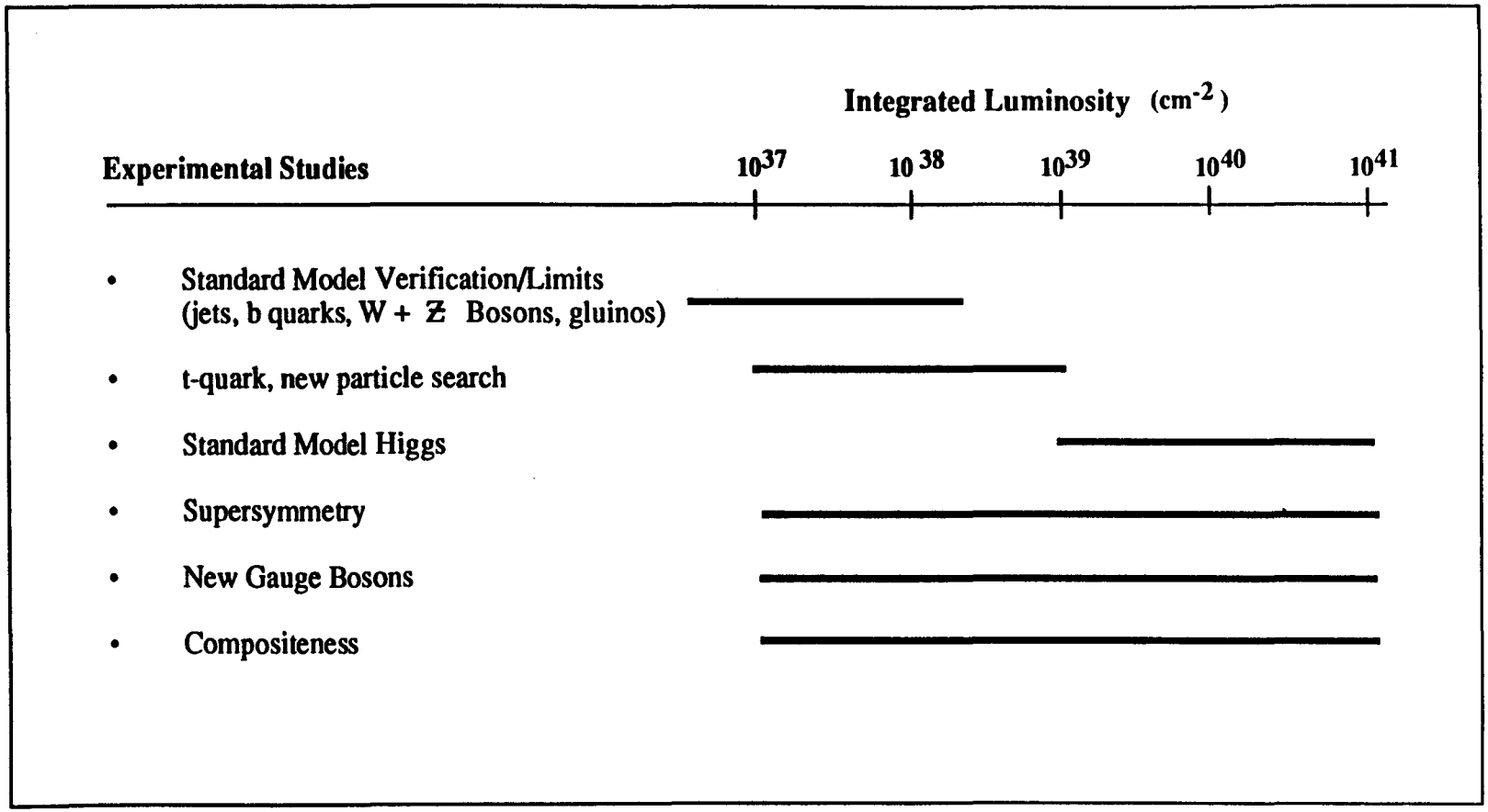


Fig 2-2

Areas of Experimental Study as a Function of Integrated Luminosity

W and Z Bosons

An integrated luminosity of 10^{37} cm^{-2} (for example, an average of $L=10^{30}$ cm^{-2} s^{-1} over 10^7 seconds) would result in 10^4 $Z \rightarrow \ell^{\pm} \ell^{\mp}$ and 10^5 $W \rightarrow \ell^{\pm} \nu$ events. Such a sample could allow a precision measurement of the W mass and a study of W production. It would also be extremely useful for the calibration of the tracking and calorimeter subsystems using the lepton pair decay of the Z and W. Based on the standard coupling, considered in reference 3 for a heavy Z boson, one would have produced 100 Z' and about 6 ee and $\mu\mu$ pairs for a mass of 1.5 TeV. With a more realistic assumption for the Z' coupling the rate would be smaller by a factor of five or so . (See reference 4 above.) The existence of a heavy W' would be detected by the very large missing energy in the events.

Heavy Quarks

If the top quark is discovered at the Tevatron, the initial SSC program would include studies of decays of the top quark. If the top quark is not discovered, finding the top quark will be one of the highest priorities of the initial operation. For a mass of m_t=140 GeV, one expects a cross section of 10 nb and 10^5 produced $t\bar{t}$ events resulting in about 1000 e μ events and 10,000 ℓ+jet events. The exact number will depend on the selection cuts. The existence of heavy quarks could be studied up to masses of 700 GeV, which represents the perturbative unitarity limit for the $t\bar{t}H$ coupling (a similar limit has been obtained from lattice calculations). From a sample of 100 produced $t\bar{t}H$ events with m_t=700 GeV, one would expect to observe 40 ℓ+jet events and a few eμ events which would probably be adequate for discovery.

Gluinos

The basic signature for supersymmetric particles is an imbalance in the transverse energy in a given event. For an integrated luminosity of $10^{37}cm^{-2}$, a 500 GeV gluino with standard model coupling would result in a few hundred events with a missing transverse energy of more than 200 GeV. To observe such events, complete calorimeter coverage down to small angles is required.

Jets

The kinematic limit for high transverse momentum jets will be extended well beyond 2 TeV, more than twice the range accessible at the Tevatron collider.

Integrated Luminosity of 10^{38} cm^{-2}

Studies and tests of Standard Model processes will continue as before, but with increased precision. In addition, the operation at lower luminosity will have provided an understanding of detector performance and backgrounds that will be important in extracting signals for new physics.

Heavy Quarks

If our current understanding of the constraints on the t quark mass is correct, the t quark will have been discovered before or during the initial operation of the SSC. Thus the focus of t-quark studies will shift to more detailed studies of t-quark decay rates and properties and their comparison with predictions of the Standard Model.

Particle Searches

A factor of ten improvement in luminosity will substantially expand the discovery limits for supersymmetry, new gauge bosons, and compositeness. The searches for heavy bosons and compositeness will be extended to masses of 3.5 TeV and 3.2 TeV, respectively. Scaling the gluino production cross section on the basis of the results in reference 3, one can expect to extend the search to masses of 0.8 TeV or higher, depending on the cut on the transverse energy imbalance in the event. Since gluinos are Majorana fermions, one would expect events with like-sign lepton pairs. To establish a signal and obtain a mass estimate, one needs to observe of the order of 100 events. This means that one can search up to gluino masses of 0.8 TeV for this signature, given an integrated luminosity of $10^{39}cm^{-2}$. If evidence for supersymmetry, new gauge bosons, or compositeness is observed, the focus of attention would obviously shift to detailed studies of these new phenomena.

Integrated Luminosity of 10^{39} to 10^{40} cm^{-2}

It is expected that it will take several years to reach Collider design performance both at peak times and on average. During this period the performance of the detectors will be studied in detail, and the data handling and data analysis tools will be developed to full capacity. Various detector components for which the construction and installation had to be delayed due to budgetary and schedule constraints will have been installed and become fully operational.

If discoveries of new particles or processes have not already been made, the primary focus of the research program will become electroweak symmetry breaking.

Higgs

Predictions for the production and decay rates of Standard Model Higgs bosons are already relatively well known and will improve in precision after the first years of operation of the SSC. At a luminosity of approximately 10^{32} cm^{-2} s^{-1}, the Standard Higgs boson begins to be detectable for the mass range of a few hundred GeV. Detection at lower and higher masses will require operation for at least one year at the SSC design luminosity of 10^{33} cm^{-2} s^{-1}. Full exploration of the mass range allowed for the Standard Model Higgs will require multiple-year operation at 10^{33} cm^{-2} s^{-1}. The detection and study of non-Standard Model Higgs particles will in general be more difficult and require the highest luminosity possible.

The capability of the two large detectors to detect and study the Higgs particle(s) will differ, and will depend on the specific decay modes, which in turn depend on the mass of the Higgs.

<u>$H \rightarrow \gamma\gamma$:</u> In the GEM detector, the significance of the signal in the mass range of 120 to 150 GeV will range from 7σ to 9σ at 10^{40} cm^{-2}, depending on the resolution of the electro-magnetic calorimeter and the level of background. For a mass of 80 GeV, the significance is expected to be no more than 3σ. The background can be reduced by selecting events consistent with the associated production of top quarks, i.e., $t\bar{t}H$, but only a handful of signal events will be left in a total sample corresponding to one year at design luminosity, i.e., 10^{40} cm^{-2}.

<u>$H \rightarrow ZZ^*$:</u> At design luminosity and for masses of m_H= 140, 150, 160, and 170 GeV, the expected number of events per year in this decay is only 60, 140, 60, and 36, respectively, just enough to discover a very narrow signal peak, provided the background is as low as can be expected.

H --> Z Z: This decay mode leads to a 4 lepton final state, and one expects for $m_H = 200$ GeV or 400 GeV, 200 or 140 detected events forming a fairly narrow mass peak above a rather small background. The numbers quoted are for 10^{40} cm^{-2}, indicating that a signal may be observable at somewhat lower luminosity, but any further study would require the full design luminosity.

Heavy Quarks

Studies of the t quark are likely to continue, but the emphasis will increasingly shift to searches for very rare processes or decays and to quantifying the backgrounds arising from the t quark and other Standard Model events.

Particle Searches

In addition, searches will extend to higher masses: for gluinos (1.4 TeV), new gauge bosons (5 TeV), and compositeness (4.2 TeV). The operation of the detector and analysis of data will have reached a mature stage, which will greatly improve the efficiency of the searches.

Integrated Luminosity above 10^{40} cm^{-2}

Operation at design luminosity and above will occur after a number of years of operation. The large SSC detectors have substantial capability to operate at luminosities above 10^{33} cm^{-2} s^{-1}.. Nevertheless, it is likely that physics discoveries as well as advances in technology will indicate the need for improvements and upgrades to the detectors after a few years of operation at 10^{33} cm^{-2} s^{-1}. The exact nature of these upgrades cannot be specified now but they are likely to include both additions and improvements (e.g., trigger and data acquisition) that can be made without significantly affecting operation of the Collider. Upgrades requiring replacement of detector elements that will prevent operation of the Collider may also be encountered. Hence, the detector upgrades must be carefully coordinated with the operation of the Collider.

The physics reach of the large SSC detectors will continue to expand at the higher luminosities. The allowable mass region for the Standard Model Higgs can be explored up to about 1 TeV in a few years of operation, but exploration to higher masses will require higher luminosity. In addition, compositeness and new gauge boson searches can be done at the highest luminosities anticipated from the Collider, up to a few times 10^{34} cm^{-2} s^{-1}.

3
ACCELERATOR DIVISION

INTRODUCTION

This chapter describes the accelerator operations plan in the first years beyond completion of construction . This involves a description of the functions of the organization and its responsibilities together with the associated manpower and costs. The manpower estimates are derived from the projected tasks required in the operations, maintenance, and improvements of the injector systems, the collider, the test beam facility, and the Magnet Test and Development facility. An organizational model is presented in the following section. The associated functions, tasks and responsibilities are described in the sections below on the Accelerator Operations, Technical Support, and Magnet Systems Departments.

At the beginning of FY2000, the injector accelerators and the collider will have successfully completed their commissioning phase in accordance with the current project schedule. The Linac, LEB, and MEB will be operating reliably at intensities specified for test beam and collider operations, although the emittance goal for the collider-filling mode may not yet have been achieved. The HEB will not yet have achieved full design performance, but this will not be a limitation in the collider performance in its first years of operation. The projected operating modes of the collider are described below assuming these conditions.

The post-commissioning operations effort will be devoted to continued improvement of operating software and hardware, optimization of machine performance and reliability, maintenance, and enhancing the skills of the operations and support staff. The Linac, LEB, and MEB will also support the operation of experimental test beams.

Apart from the specific operational tasks of controlling the injected beams and providing the collider beam conditions required by the experiments, there will be continued studies by accelerator physicists to understand beam behavior in arriving at optimum operating conditions, and to develop new operations modes as required. Examples of accelerator Research & Development that will assist in the accomplishment of the design luminosity and prescribed operating modes are described in the section below on Operations. New developments and designs for component improvement and/or replacement will be undertaken by the engineering staff. Finally the technician staff will implement technical changes and repairs as well as develop appropriate instrumentation for diagnostics. Repair or replacement of electrical and mechanical components and instruments is a continuous job that is necessary to maintain the accelerators in optimum operating condition.

The operations program is described in the section below on Projected Operating Modes. It is estimated that the peak luminosity will be near 10^{30} cm^{-2} s^{-1} at the beginning of FY2000. The design goal of 10^{33} cm^{-2} s^{-1} should be achieved approximately three years later (see Figure 1-2). The associated operating modes projected for this period are described. Finally, the overall costs for the accelerator operations staff, materials and supplies, power, etc., are provided in the concluding section below.

ORGANIZATION MODEL

The Accelerator Division will be fully organized and staffed with three Departments at the beginning of FY2000 (see Figure 3-1). The organization will begin to form with the commissioning of the Linac. As each accelerator is commissioned, a number of the persons involved with the construction of that accelerator will be transferred into the Accelerator Operations Department. The bulk of these transfers will become part of the Operations Group; however, some of the professionals will be assigned to the Accelerator Research and Development Group to support accelerator improvement projects after completion of construction.

Before FY2000, the existing Accelerator Systems Division and Magnet Systems Division will provide technical support for the new Accelerator Division as well as for construction activities. In FY2000 the support level required by the Accelerator Division will be lower than that required for construction, and this will allow the appropriate personnel from the construction divisions to form the core of the Operations Group.

The Accelerator Operations Department (AOD) will be responsible for operations, maintenance, and improvement plans for all SSCL accelerators and primary external beams. In addition, they will cooperate with similar activities in the interaction regions. This Department will have representatives on both the Operations Program and Operations Schedule Committees (see below) and will be charged with implementing the short-term operations plans generated by the Operations Schedule Committee. This Department will also issue weekly reports summarizing the planned program and the performance of the accelerators, including operating time, failures, and experimental beam time and quality.

The AOD will also be responsible for planning, scheduling, and tracking progress of all accelerator-related activities during shutdowns and maintenance periods. They will participate in the testing and re-commissioning of all new or modified installations with the goal of starting each operating period with healthy accelerators. The AOD Operations group will supply an operating crew for each shift of accelerator operations. It will be the responsibility of the Accelerator Chief of Operations (COO) to implement the operating plan as specified by the Operations Schedule Committee for his or her assigned shift.

The Accelerator Research and Development staff will be primarily accelerator physicists who plan and implement accelerator improvements. This staff will also plan, propose, and perform the majority of accelerator experiments required for optimizing performance. The research and development efforts will be supported by the Technical Support Department and the Magnet Systems Department.

The Accelerator Technical Support Department will provide operational support for all injector and collider technical components except magnets. In addition, this department will provide engineering research and development support to the accelerator R&D group for all new and modified accelerator systems.

The Magnet Systems Department will be responsible for operational support of the resistive and superconducting magnets in the injectors and the Collider. In addition, this department will pursue R&D in resistive and superconducting magnet technology (including a vigorous test program using the MTL) and in related technologies in support of accelerator performance improvements.

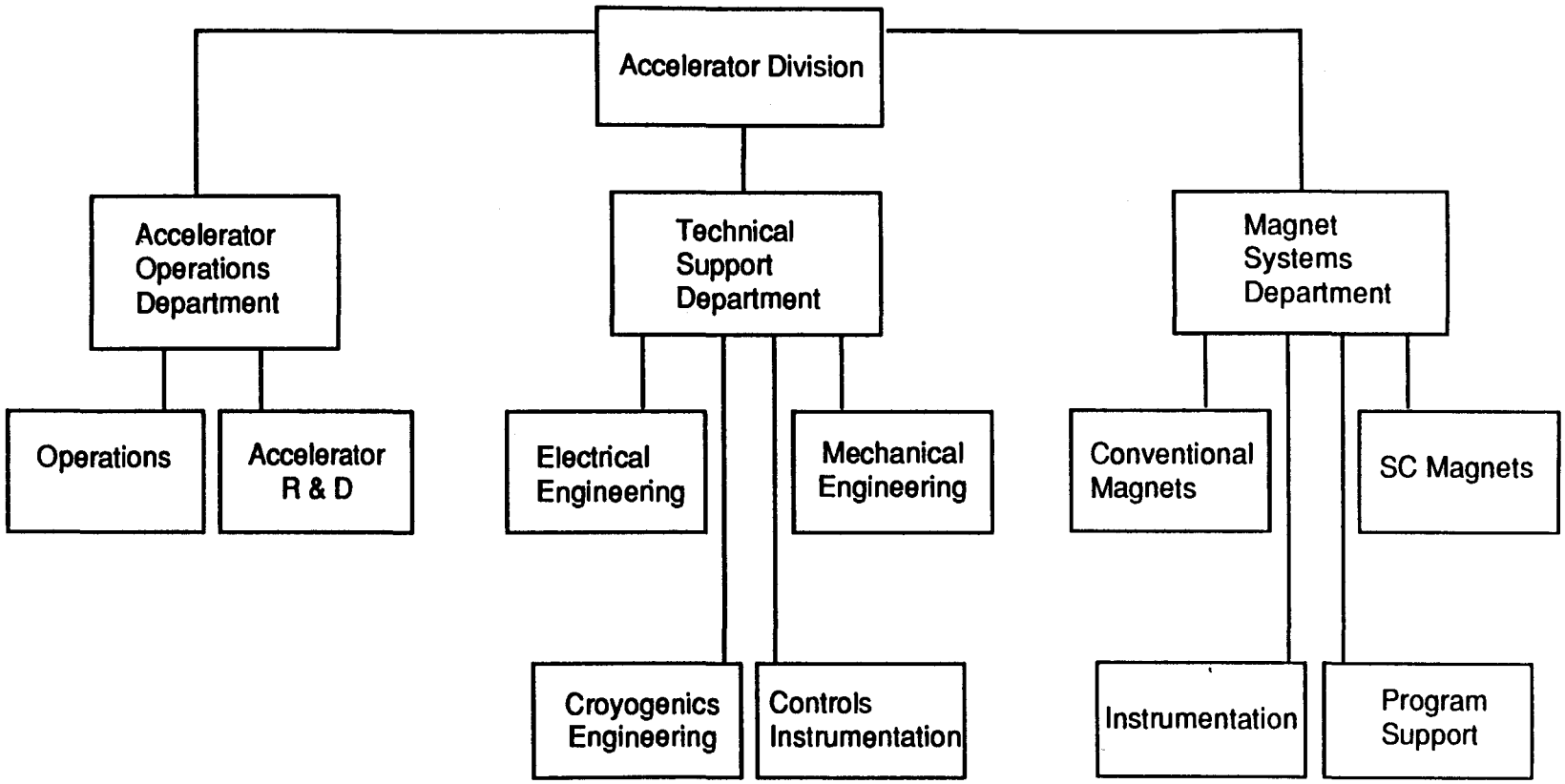


Figure 3-1
Accelerator Division Organization

ACCELERATOR OPERATIONS DEPARTMENT

Responsibilities

The Accelerator Operations Department (AOD) is split into two distinct technical efforts. The Operations Group will be concerned with the round-the-clock operations of all the accelerators and the test beams. The Accelerator Research and Development Group will be responsible for in-depth analysis of accelerator performance, the execution of experiments to improve performance, and the planning and implementation of accelerator improvements and upgrades.

The AOD will be responsible for developing and implementing accelerator schedules, coordinating all accelerator-related activities during shutdowns, tuning up the accelerators during turn-on, and operating and maintaining the accelerators. The Department will provide operations personnel 24 hours a day, 7 days each week. The specific duties of the Department include the following:

During Accelerator Operations:

- Perform search and secure operation as specified by operational procedures.
- Tune up the accelerators and test beams to support the specified operational plan.
- Maintain all operational systems as required.
- Maintain good communications with machine users.
- Monitor accelerator performance and respond to user requests.
- Address machine failures and problems by performing first-level repair. Call in Engineering support as required.
- Repair/modify off-line equipment as time permits.
- Support Accelerator Research and Development Experiments.
- Maintain an operational log and provide performance reports.

During Scheduled Shutdowns:

- Continue to maintain required operational systems such as the cryo system.
- Staff the Control Room, the central point for all accelerator activities. Control accelerator access as required.
- Track progress on the shutdown activity schedule.
- Operate accelerators not in the shutdown mode, as scheduled.
- Provide support for the installation of new systems and the modification of existing systems.
- Participate in the testing and commissioning of new or modified systems.
- Perform tests and measurements as required during shutdowns.
- Train and certify operations staff in new operating procedures.
- Maintain an operations log.

Operations Planning

Two committees will be responsible for implementing the decisions of the SSCL Director and the Laboratory Program Advisory Committee (PAC) with regard to the Operations Program. These committees will specify the long-term and the short-term operation schedules.

An Operations Program Committee will be responsible for planning the long-term (six to twelve months) schedule of the accelerators. It will decide the gross time division between HEP, accelerator research time, and maintenance. It will consider the state of the accelerators and experiments and the effects of planned accelerator improvements in the planning process. The committee will include representatives from the Physics Division, Accelerator Division, and Experimental Research groups. It will be organized six months before commissioning of test beams begins.

An Operations Schedule Committee will be responsible for preparing near-term operating schedules to satisfy the long-term Operations Program Committee plan. This committee will prepare and distribute a weekly operating plan specifying the activities of each accelerator. It will also review for approval all proposals for accelerator development experiments, and will schedule the experiments. Members of this committee will include Accelerator Operations, Physics Research, Technical Support, and Experimental Program Department personnel. The committee will be organized in time to support the initial Linac operations.

During program and operations planning, top priority will always be given to optimizing both the short- and long-term support of the HEP program. The membership of the two Planning Committees will be prepared to evaluate trade-offs in arriving at the most productive plan. The flow of operational plans is shown in Figure 3-2.

Operations Implementation

At the beginning of FY2000, a well-trained and certified operating crew will be available to support Operations. The training and certification will take place during the Pre-Operations period for the various accelerators. A training program continuing throughout the life of the Laboratory will be conducted to assure that operator skills match the requirements for the position. Recertification will be required at specified intervals to assure that the level of excellence is being maintained.

A Chief of Operations (COO) will be in charge of each shift. The COO will have the responsibility and authority to assure that the accelerators are operated in a safe manner to support the planned program. The Cryo Systems Crew Chief, Control Room Crew Chief, Maintenance Crew Chief, and the Safety Crew Chief will report directly to the Chief of Operations. The operating crew structure is shown in Figure 3-3.

A Duty Officer will support the COO by taking responsibility for non-accelerator related items. The processing of visitors, operation of facilities such as the office buildings, site security checks, and emergency preparations are typical of the Duty Officer's responsibilities.

During the first year, accelerator operations group personnel will be stationed in four different areas during machine operations. The largest crew will be in the Control Room at the West Campus. This crew will be divided into the Control Room Crew and a Maintenance Crew. They will be able to provide quick maintenance support to the Injector Accelerators, as well as the west portion of the Collider. A second crew will be at the East Campus to handle maintenance activities on the east side. The remaining two crews will be located at maintenance stations in a north and south arc service area and will service the north and south portions of the Collider. This distribution should allow a crew to get to any problem area within a minimum time for a fault in a service building or for a fault in the tunnel closure. The site distribution of the Operations Group Personnel for day shift operations is shown in Table 3-1.

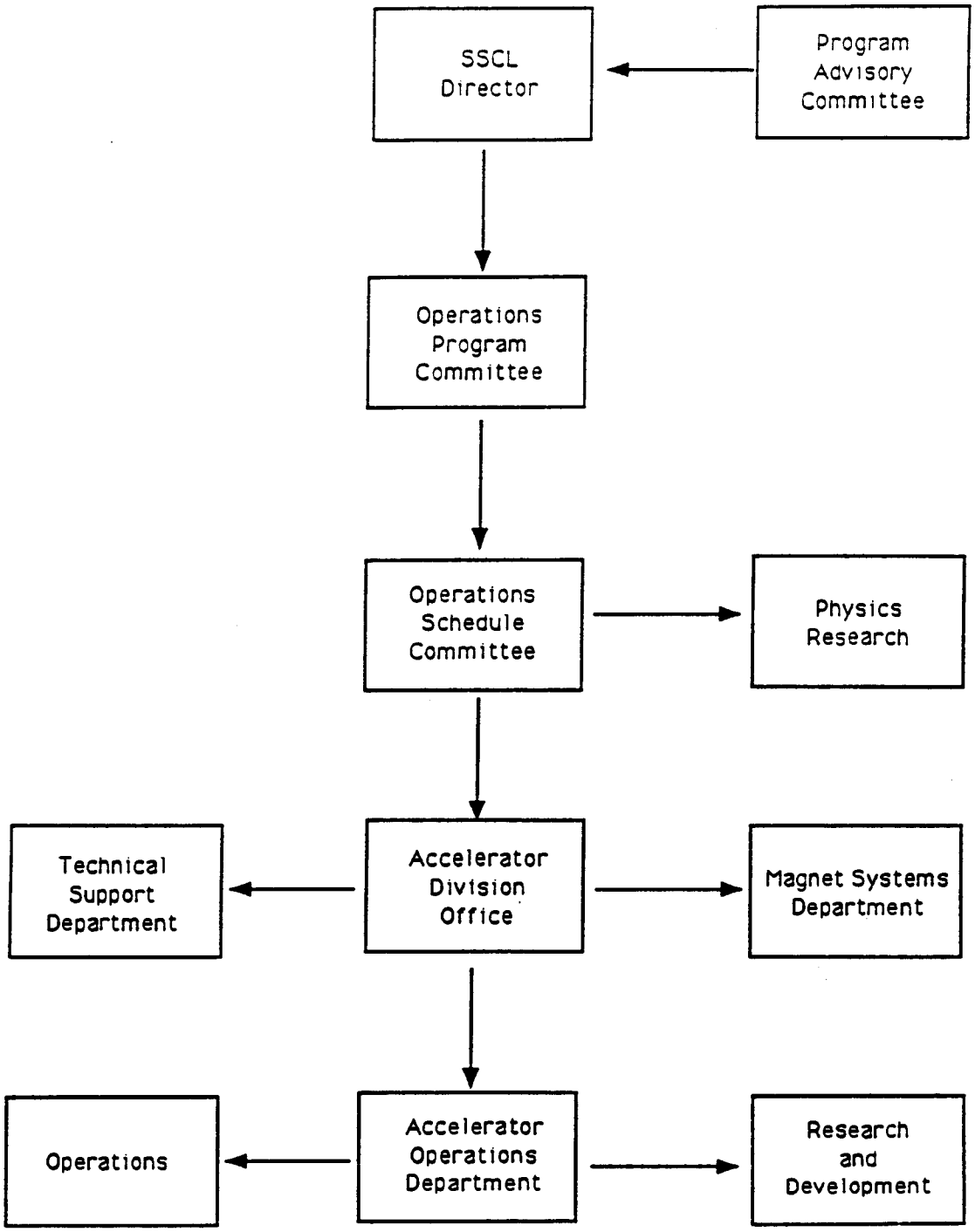


Figure 3-2
Flow of Operational Plans

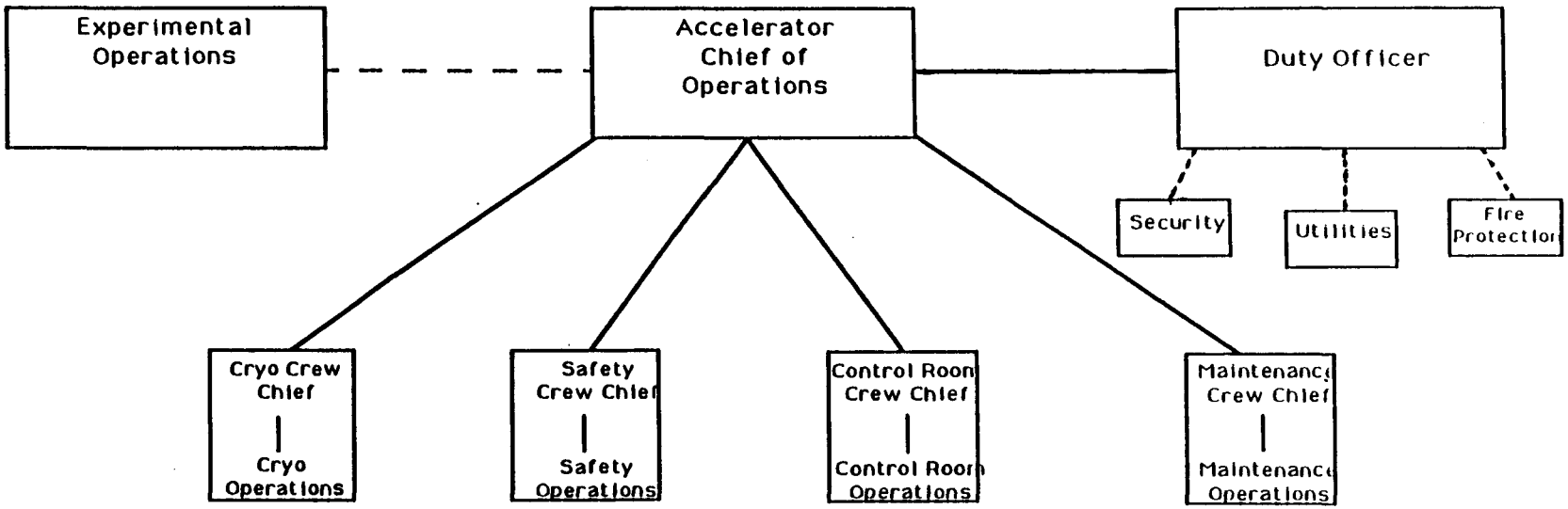


Figure 3-3
Structure of an Operations Crew

Table 3-1
Operations Group Site Location*

	FTE's				
	West	East	North	South	Total
Department Office	6				6
Operations Grp. Ofc.	8				8
Accelerator Operations	10 (10)				10 (30)
Accelerator Maint.	6 (6)	3 (3)	3 (3)	3 (3)	15 (45)
Cryo Maintenance	23 (6)	11 (4)	4 (4)	4 (4)	42 (54)
Safety	2 (2)	1 (1)	1 (1)	1 (1)	5 (15)
Survey/Alignment	16	—	—	—	16
	71 (24)	15 (8)	8 (8)	8 (8)	102 (144)

*Plan for day-shift operations. Numbers in parentheses are for swing, owl, and week-end shifts.

Details of the responsibilities of the accelerator operations are presented in Table 3-2. Three operators are projected for the resistive accelerators, three for the Collider, and one each for the HEB and Test Beams. In addition, Table 3-2 provides a breakdown of the manpower required by location for maintenance and for safety. The manpower disciplines required for the survey and alignment group are also given.

The plan for cryogenics maintenance is also provided in Table 3-2. Twenty-four FTEs are projected for general support of cryogenics operations during day-shift operations. This staff will analyze and test operational modes, handle special problems, and provide for repair and maintenance operations. In addition they will supplement the four crews (of 18 FTEs each) that are on shift operation at four locations (West, East, North, and South) around the ring. The cryogenics staffing plan will be reviewed after the first year's operation of the Collider and HEB and necessary adjustments will be made according to the provided experience.

In addition to the operations of the injection accelerators and the Collider, the operations group will operate and maintain the test beam facilities up to the primary target station. The test beam program is scheduled to begin operations upon completion of the MEB, and a continuing program is projected beyond FY2000. The facility will be used to test new detector concepts and components and provide for the necessary systems calibration.

There will be an aggressive approach to training and certifying all Control Room/Maintenance personnel so that they can perform first-level maintenance on all systems, and so that they can be interchanged in their assignments. The goal will be to train "accelerator operators" so that they can provide support in corrective and preventive maintenance, in addition to operating the facility.

Table 3-2

Operations Group Manpower by Assignment

Function	Subsystem	1 Shift	4 Shifts
Operations	Chief of Operations	1	4
	Duty Officer	1	4
	Resistive Accelerators	3	12
	Test Beams	1	4
	HEB	1	4
	Collider	3	12
	Total	10	40
Maintenance	Crew Chief	1	4
	Injectors, N15, West IR	5	20
	N25, N35, N45	3	12
	S35, S45, S55	3	12
	N55, East IR, S15, S25	3	12
	Total	15	60
Cryogenics	Crew Chief	2	2
	Sector Engineers	4	4
	System Engineers	4	16
	Sector Techs	9	24
	System Techs	13	40
	Maintenance & Repair	5	5
	Service & Parts	2	2
	Clerical	3	3
	Total	42	96
Safety	Crew Chief	1	4
	Injectors, N15, West IR	1	4
	N25, N35, N45	1	4
	S35, S45, S55	1	4
	N55, East IR, S15, S25	1	4
	Total	5	20
Survey/Align	Section Leader	1	1
	Clerical	1	1
	Design	1	1
	Physicist	1	1
	Collider Engineers	2	2
	Injector Engineers	1	1
	Collider Techs	5	5
	Injector Techs	4	4
	Total	16	16
Group Office	Group Leader	1	1
	Admin	1	1
	Clerical	3	3
	Design	1	1
	Phys, Eng	2	2
	Total	8	8
Total Group (FTE's)		96	240

The bulk of the accelerator operators will be electronic technicians, because experience has shown they can also handle the more routine mechanical problems. A certified safety technician will also be part of each crew.

Remote control consoles with total monitoring capabilities and assignable control functions will be available in each maintenance area for use by the operating crews. The appropriate spare parts and current documentation will also be available to support Maintenance Operations.

A staff of certified personnel trained in safety will be assigned to all shifts. It will be their responsibility to be the first to enter all machine enclosures after operations so that they can identify and tag radiation areas. They will also monitor repair operations, as well as inspect and sign off on new installations and modifications. They will review for approval the weekly operating plan and prepare a weekly report on operational activities.

Accelerator Research and Development

In FY2000, the boosters should be running smoothly and the Collider will have just been commissioned. The nominal design specifications such as the luminosity goal of 10^{33} cm^{-2} s^{-1} will not yet have been reached, and it will take accelerator R&D efforts to reach them during FY2000-2002. The exact nature of these efforts will be determined only at that time; however, a few likely scenarios can be discussed as below.

At the beginning of FY2000, it is possible that the space charge effect in the LEB will be more limiting than envisioned. If this is the case R&D will be needed to reach the design goals of 1×10^{10} protons per bunch and rms emittance of 0.6 π mm-mrad at the exit of the LEB. Possible improvement methods would include a second harmonic rf cavity and/or a higher dispersion function to enlarge the beam size. R&D will be needed to determine the most effective and economic compensation method.

Throughout the first years of operation, R&D will be needed to deal with the various real-time accelerator operation problems. For example, special corrections may be needed for orbit control, coupling, and for chromatic and beta function and dispersion function corrections. Time-dependent chromatic and optical effects may require more elaborate schemes. Innovation and fast turn around will be the keys to dealing with these problems as they arise in actual operations.

Nonlinear effects in the HEB or the Collider may require attention if they limit the dynamic aperture more than expected. These effects tend to be subtle and their correction will require careful study. Some of these problems may require implementing additional multipole corrections where spaces have been reserved for this purpose in the baseline design.

Beam intensity may be limited because of single- or multi-bunch collective instabilities in the chain of accelerators. R&D efforts will be needed to advance beyond these limits when they are identified. Single-bunch instabilities may be dealt with by adjusting the longitudinal density and/or identifying and replacing the components with excess broadband impedance. Multi-bunch instabilities can be dealt with by more effective feedback systems and/or damping the higher order rf cavity modes.

The beam-beam effect may turn out to be a limiting factor, particularly the long-range beam-beam interaction. If this turns out to be a problem, a larger crossing angle could relieve it at the cost of reduced dynamic aperture for the colliding beams. Optimization of these considerations will become an important R&D issue.

By dealing with these and perhaps other issues, it is expected that the SSC performance will improve steadily toward the design goals. By FY2003, it is expected that the nominal goals, including a 10^{33} cm^{-2} s^{-1} luminosity, will have been reached. Beyond that point, it may be possible to improve the performance further with the current design, which is optimized for 20 TeV and 10^{33} cm^{-2} s^{-1} luminosity. Examples of such improvements would include operating the SSC at a lower temperature with increased refrigeration capacity to increase the beam energy, coalescing the bunches in the MEB to achieve higher luminosity with a smaller number of bunches, increasing the beam intensity by overcoming the collective and the beam-beam effects, and improving the refrigeration capacity. More examples of improvements that involve substantial upgrades are discussed in Chapter 6.

It is also important that the SSCL carry out longer-term high energy accelerator R&D. Such efforts will play an important role in the future of high energy physics. Possible items would include R&D on nonlinear dynamics, collective effects, beam-beam effects, and polarized beams.

The total manpower needed in these R&D activities on the SSCL accelerator complex includes 40 accelerator physicists and 22 engineers and technicians with support from the other Accelerator Division Departments. An analysis of the projected responsibilities of this group by accelerator and by accelerator component system is provided in Table 3-3.

ACCELERATOR TECHNICAL SUPPORT DEPARTMENT

The Accelerator Technical Support Department provides on-going engineering and related research and development to support the overall accelerator operations and associated research and development efforts. Four technical groups are projected for this Department: mechanical, electrical, cryogenics, and controls.

The Mechanical Engineering Group will undertake the design of new or modified mechanical systems and components for the injection accelerators and the Collider. The design will include vacuum system components, mechanical supports, alignment systems, and overall structural components. The group will be responsible for the fabrication, installation, and tests to assure that the components perform according to design expectations. The group members will instruct or train the operations crew with regard to the operating characteristics, performance, technical limitations, and safety features of new components.

The Electrical Engineering Group will focus on the design and development of electrical and RF system components for the Collider and the injectors. For new or special magnets, associated power supplies will be designed including fast pulsed kicker magnets and corrector magnets. The group will seek , in general, to optimize the performance of all the power and power distribution systems for the injectors and the collider.

The Cryo-systems Group will provide design and development support for the overall cryogenic components and refrigeration plants. In particular this group will be responsible for the training of the cryogenics crews, who will be responsible for the operations and maintenance of the helium refrigerator plants located around the Collider ring circumference. While the daily direction of cryo-operating crews will be provided by the Accelerator Chief of Operations, the overall technical direction will be maintained by the Cryo-systems Group. The group will be on-call to address special or unexpected problems as they arise. For example, certain members will be needed during magnet replacement. In addition, long-term improvements or modifications to the cryo-plants and associated systems will be addressed.

Table 3-3

Accelerator Physics Group Manpower by Assignment

Machine	Subsystem	Physicist	Engineer	Technician	Total
Linac	Ion Source/RFQ	1	1	1	3
	DTL	1			1
	CCL	1	1	2	4
	Linac-LEB Beamline	1			1
	Total	4	2	3	9
LEB	Injection	1			1
	Optics/Beam Dynamics	3			3
	RF	2	1	2	5
	Total	6	1	2	9
MEB	Beam-trans./Injection	1			1
	Optics/Beam Dynamics	2	1	1	4
	Extraction	1			1
	Extracted Beam	1	1	1	3
	RF	1			1
	Total	6	2	2	10
HEB	Beam-trans. /Injection	2			2
	Optics/Beam Dynamics	3	1	1	5
	Abort	1			1
	Extraction	1			1
	RF	1			1
	Total	8	1	1	10
Collider	Beam-trans. /Injection	2	1	1	4
	Optics/Beam Dynamics	5	1	1	7
	RF	1			1
	Abort	2			2
	East IR/Utility	3	1	1	5
	West IR	2			2
	Vacuum	1	1	1	3
	Total	16	4	4	24
	Tech Systems Total	40	10	12	62
Group Office	Management				5
	Admin				1
	Clerical				4
	Design				2
	Total				12
Total Group (FTE's)					74

The Controls Engineering Group will be responsible for maintenance and development of the overall computer control systems, instrumentation and safety interlocks for accelerator systems and components. Personnel will provide for the repair, maintenance, test, and calibration of the many units of equipment, which will be used in the injection accelerator, the Collider, and the various associated beam transfer lines. The group will be on-call to address emergency replacement or repairs. It is expected that the effort will also address long-term improvements and/or modifications to instrumentation to facilitate and improve Collider operations.

In addition to meeting the immediate design and maintenance needs of the accelerator operations, the above groups will work closely with the Accelerator R&D group to design equipment or facilities for the Research and Development Program. There will be ongoing technical research efforts to improve the overall performance and efficiency of numerous technical systems. In this regard the engineering groups will play a major role in the Accelerator Improvement Projects (AIP) and in the design and implementation of new components and equipment for the Accelerator Systems. This department will also be responsible for providing information and training to operations and maintenance personnel regarding the use of new systems and associated equipment.

Table 3-4 provides an analysis of projected assignments of Technical Support Department personnel by accelerator and by accelerator technical systems.

MAGNET SYSTEMS DEPARTMENT

Included among the facilities already in existence at the SSCL site are the Magnet Development Laboratory (MDL) and the Magnet Test Laboratory (MTL). These facilities have been designed as research and development facilities for superconducting magnets, for materials used in these magnets, and for related technologies. When the superconducting magnets needed for initial operation of the SSC Collider and HEB have been designed, built, and tested, the MDL and MTL facilities will be available for operations support and for magnet maintenance and repair. The facilities will also provide the Accelerator Division, the SSCL, and the physics community with state-of-the-art facilities for ongoing research and development in magnet technology and in superconductivity.

Currently the operations program is projected to start in FY97 with Magnet Systems Department staff support estimated at 150 FTEs by FY2000.

Responsibilities

The scope of the Magnet Systems Department effort will include all aspects of magnet design, development, fabrication, repair, and testing, with each of these activities supported by a strong quality assurance program.The design effort will employ computer codes for the calculation of magnetic field properties and mechanical and thermal characteristics and operating conditions. Finite element methods will be used, and fully integrated three dimensional computational models will be further developed to increase their accuracy and useful range. A continuing program of software development and validation through measurements on model and developmental magnets will be an essential part of the program. This will require continued improvments in measurment capability including the development of creative new approaches. R&D will continue in some areas of magnet technology in order to support anticipated demands for magnets with improved performance characteristics.

Table 3-4

Technical Support Department Manpower by Assignment

Machine	Subsystem	Physicist	Engineer	Technician	Total
Linac	Power Supplies		2	3	5
	RF Systems		3	5	8
	Vacuum Systems		1	1	2
	Mechanical Systems		2	2	4
	Instrumentation		1	2	3
	Safety Systems		1	1	2
	Total	0	10	14	24
LEB	Power Supplies		1	3	4
	RF Systems		3	3	6
	Vacuum Systems		1	1	2
	Mechanical Systems		2	2	4
	Instrumentation		1	2	3
	Safety Systems		1	1	2
	Total	0	9	12	21
MEB	Power Supplies		2	4	6
	RF Systems		2	3	5
	Vacuum Systems		1	2	3
	Mechanical Systems		2	3	5
	Instrumentation	1	2	2	5
	Safety Systems		1	2	3
	Total	1	10	16	27
Test Beams	Power Supplies		1	3	4
	RF Systems				0
	Vacuum Systems		1	1	2
	Mechanical Systems		1	1	2
	Instrumentation		1	2	3
	Safety Systems		1	1	2
	Total	0	5	8	13
HEB	Power Supplies		2	5	7
	RF Systems		3	3	6
	Vacuum Systems		2	4	6
	Cryogenics	2	4	5	11
	Mechanical Systems		5	6	11
	Instrumentation	1	2	5	8
	Safety Systems		1	2	3
	Total	3	19	30	52
Collider	Power Supplies		8	14	22
	RF Systems		3	6	9
	Vacuum Systems		7	12	19
	Cryogenics	2	8	10	20
	Mechanical Systems		11	10	21
	Instrumentation	1	4	7	12
	Safety Systems		1	5	6
	Total	3	42	64	109
Global Systems	Computer Controls	8	30	30	68
	Total	8	30	30	68
	Tech Systems Total	15	125	174	314
General Support	Designers				32
	Crafts				8
	Laborers				4
	Total	0	0	0	44
Dept Offices	Management				13
	Admin				6
	Clerical				15
	Total	0	0	0	34
Dept. Total (FTE's)					392

Fundamental R&D will continue in selected areas such as improved NbTi superconductor and on methods of manufacturing wire and cable. It is believed that there are still potential gains to be made in this area. In addition to the further evolution of NbTi alloys, other low temperature superconducting alloys, such as niobium-tin that have the potential for even greater current carrying capacity, will be studied. Continued improvement in the current carrying capability of superconducting strand is anticipated as a result of these activities, and improvements in the mechanical design features of magnets using this strand will be required to take advantage of the improved technology.

Further investigation of the parameters affecting A.C. losses in superconducting cables will lead to improvements in the capability of the cable to support rapidly changing transport currents and magnetic fields that will be of value to the SSCL program and to other commercial applications of superconductivity.

Magnet Systems Department Tasks

The department organization is indicated in Figure 3-4. Four groups are projected: Resistive Magnets, Superconducting Magnets, Instrumentation, and a Plans and Programs group. The department office will be supported by a small QA and ES&H organization. Total staff is estimated to be 150 FTEs. The responsibilities of the department outlined in the previous section will be conducted by the groups in the following ways.

- Resistive Magnets

This group will be responsible for the engineering analysis, design, fabrication, testing set up, and repair of all conventional magnets required for the project. This includes the LEB, MEB, transfer lines and test beams, and any magnets needed for the Linac. The group will be supported by the plans and program group in establishing budgets and monitoring costs and schedules and by the QA & ES&H groups in their areas of responsibility. The Systems Engineering section will provide support in establishing specifications and organizing design reviews. The actual measurement of the magnetic field of magnets requiring test will be conducted by the Instrumentation group. The Resistive Magnet group will provide support to the Division during the change-out and repair of resistive magnets.

Continued development of resistive magnets for future use in the low and medium energy boosters, test beam areas, and extraction/injection areas in the Collider will be needed. This effort will allow flexibility in response to changing research needs and will stimulate improvements in resistive magnets and related technologies. Such improvements will lead to increased reliability and enhanced future performance of the Collider.

- Superconducting Magnets

This group will perform a role similar to that of the resistive magnet group, and the comments reflecting the activities of the resistive magnet group also generally apply here. However, due to the much greater complexity of superconducting magnets, other sections have been added. Also research and development on superconducting magnets will be crucial for optimization of the operation of the HEB and the Collider, particularly in the injection and extraction regions, but also in the insertion regions of the Collider where the beams will be brought into collision. It is also anticipated that there will be requirements for special purpose superconducting magnets for future use, possibly relating to the implementation of physics experiments. Success in this area will be essential to the efficient operation of the Laboratory in conducting high energy physics experimentation. Research and development will be conducted to improve all aspects of magnet design and construction including magnetic performance, reliability, supportability, and constructability. Operation of superconducting magnets in different thermal regimes, such as supercritical helium, could provide benefits under some circumstances and will require extensive testing before reliable operation becomes commonplace.

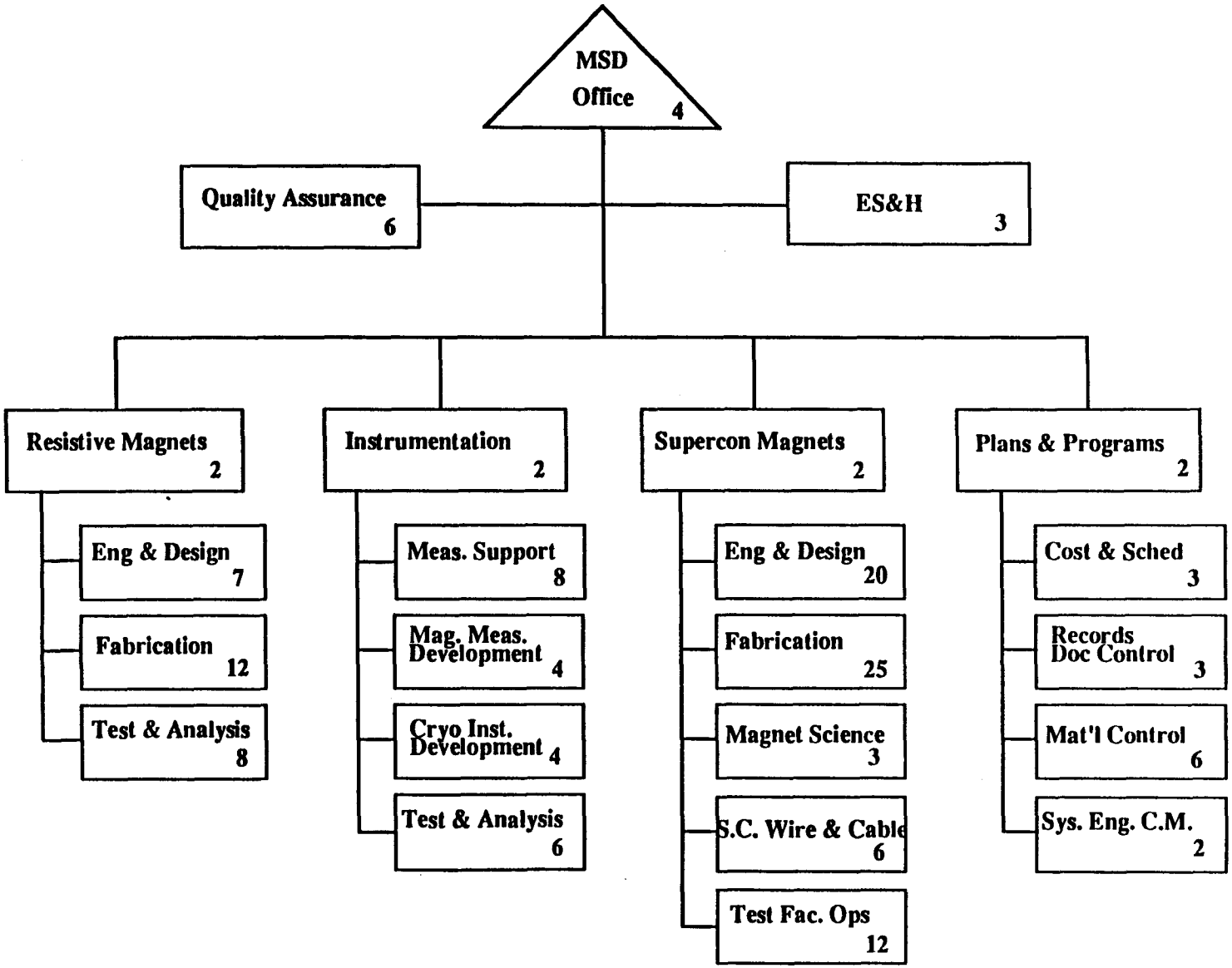


Fig 3-4
Magnet Systems Department
Year 2000

Total Staff
150

- Instrumentation

The Instrumentation group provides specialized services to the rest of the organization. All magnetic measuring equipment will belong to this group as well as specialized equipment for conducting other measurements. The group will provide the service of conducting all measurements on magnets both warm and cold and making the test data available (for example to the magnet science section). They will also be responsible for the development of new techniques and equipment for magnetic and cryogenic measurements. New instruments and techniques for detecting the onset of quench conditions, or even of conditions preceding the onset of a quench, will be investigated. Developments in this technology could lead to new ways to minimize magnet quenching and possibly to new techniques for protecting the coils of a magnet from damage in the event of unanticipated quenches. Improved protection systems could lead to the possibility of safe magnet operation under what are currently perceived as adverse operating conditions.

- Plans and Program

The Plans and Program group will be staffed by personnel specializing in program control. They will establish and monitor budgets and schedules and interface with the procurement office. The group will also be responsible for records and document control and material control as well as systems engineering activities, such as configuration management, configuration status accounting, specifications generation, and control and ICD activities.

Materials and Supplies

The cost of materials and supplies for the magnet systems department can be divided into four categories as described below.

- General Support

Experience at other laboratories has indicated that in similar environments there is need for general support at a level of approximately 40 percent of the labor costs. We follow this guideline here.

General Support (40 percent of labor cost)	$3.3M

- Replacement Magnets

Reliability studies indicate a need for replacing the equivalent of 6 superconducting dipole magnets per year. Since during the early operation of the machine there will be an insufficient number of spare magnets of all varieties to ensure that a suitable replacement magnet will always be available, it is assumed that the magnet spares inventory will be built up during the early years of operation. Thus it is projected that parts for eight dipole equivalent replacement magnets will be needed each year. Although some magnets may require only minor repair, experience has shown that when more extensive repairs are needed, most components of a superconducting magnet cannot be re-used economically.

Parts for eight dipole equivalents per year	$2.6M

- Accelerator Magnet Development

The Magnet Systems department will be required to support improvements to the machine complex by providing magnets to meet new performance characteristics. These magnets may require higher field strengths or gradients, larger apertures, or special configurations to provide, for example, an improved interface to a detector. The construction of these magnets will require the design and fabrication of new tooling, modifications to test stands, and the development of new measuring equipment. Because improvements are expected during the early operation phases of the machine, it is assumed that in FY2000 four new prototype magnets will be required at a cost of $850K each.

New magnet fabrication	$3.4M

- Advanced R&D Effort

It is difficult at this time to predict how the R&D effort will be used to provide most benefit to the program. However, it can be assumed that at least one magnet per year will be built to investigate or demonstrate new design features or operating characteristics. In addition, materials will be required for component development, instrumentation research and development, materials characterization, and similar needs.

Parts for one R&D dipole	$ 0.3M
Material for component development	$ 0.3M

The total M&S cost for all of the above four categories is $9.9M.

ACCELERATOR DIVISION MANPOWER

The tasks and responsibilities of the three departments of the Accelerator Division were described in the three preceding sections. Table 3-5 provides details of the manpower estimated for the various groups of each department according to the required disciplines. The personnel (FTEs) for the first shift (day shift) are indicated as well as the additional staff required for four shift operations in certain areas. A total of 879 FTEs is estimated for the Division operations. The associated costs are shown at the bottom of Table 3-5. Note that additional staff (67 FTEs) are required for the Equipment and AIP categories. This brings the total staff of the Accelerator Division to 946 FTEs as indicated in Table 6-1 in Chapter 6.

Figure 3-5 provides an approximate comparison of the projected SSC Laboratory manpower in the Accelerator Operations and Technical Support Departments in FY2000 with manpower currently associated with similar functions at FNAL. In the Fermilab manpower tally, the maintenance personnel in the systems and support departments have been added to the operations group. "Accelerator Physics" represents the FNAL systems departments.

Table 3-5

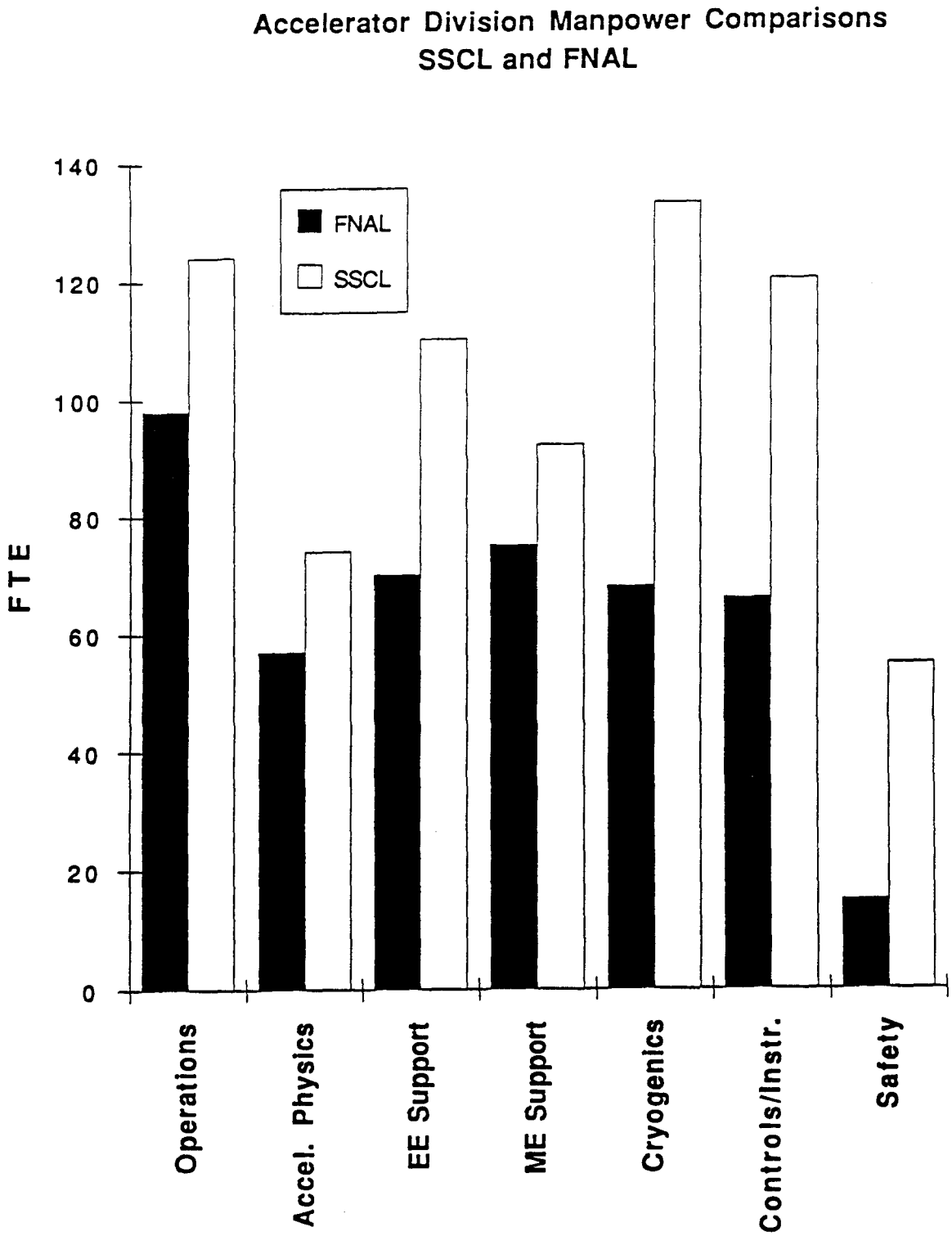
Accelerator FY2000 Operations Manpower
(Costs in FY91 K$)
FTE's One Shift

Functions	Manage E3	Admin (E1+E2)/2	Clerical N2	Physics E2	Engr E2	Design E1	Acc Op E1	Techs E1	Craft N3	Labor N2	Total	Four Shift Operations Total
Accelerator Div Office	2.0	1.0	2.0	2.0	0.0						7.0	7.0
ES & H			1.0	3.0	1.0			5.0			10.0	10.0
Total	2.0	1.0	3.0	5.0	1.0	0.0	0.0	5.0	0.0	0.0	17.0	17.0
Accel Operations	2.0	1.0	1.0	1.0	1.0						6.0	6.0
Operations Group	1.0	1.0	3.0	1.0	1.0	1.0					8.0	8.0
Control Room				1.0	1.0		8.0				10.0	40.0
Cryogenics			3.0		10.0			29.0			42.0	86.0
Accel Maintenance								15.0			15.0	60.0
Safety				1.0				4.0			5.0	20.0
Survey & Aligment	1.0		1.0	1.0	3.0	1.0		9.0			16.0	16.0
R & D Office	2.0	1.0	1.0								4.0	4.0
R & D Staff	3.0		3.0	40.0	10.0	2.0		12.0			70.0	70.0
Total	9.0	3.0	12.0	45.0	26.0	4.0	8.0	69.0	0.0	0.0	176.0	320.0
Accel Tech Support	2.0	2.0	2.0		2.0						8.0	8.0
Electrical Eng	1.0	1.0	1.0		1.0						4.0	4.0
Power Supplies	1.0		1.0		18.0	4.0		33.0	4.0	2.0	63.0	63.0
RF Systems	1.0		1.0		13.0	3.0		25.0			43.0	43.0
Mechanical Eng	1.0	1.0	1.0		1.0						4.0	4.0
Vacuum Systems	1.0		1.0		12.0	3.0		18.0	2.0	1.0	38.0	38.0
Mechanical Systems	1.0		1.0		18.0	5.0		22.0	2.0	1.0	50.0	50.0
Cryo Eng	1.0	1.0	1.0								3.0	3.0
Staff				4.0	12.0	3.0		15.0			34.0	34.0
Controls Eng	1.0	1.0	1.0		1.0						4.0	4.0
Computer Controls / Comm	1.0		3.0	8.0	30.0	10.0		30.0			82.0	82.0
Instrumentation	1.0		1.0	3.0	10.0	2.0		17.0			34.0	34.0
Safety Systems	1.0		1.0		7.0	2.0		14.0			25.0	25.0
Total	13.0	6.0	15.0	15.0	125.0	32.0	0.0	174.0	8.0	4.0	392.0	392.0
Accel Magnet Systems	2.0	2.0	2.0		4.0			3.0			13.0	13.0
Conventional Magnets	1.0		1.0	1.0	5.0	4.0		17.0			29.0	29.0
Cryo Magnets	1.0		1.0	4.0	11.0	13.0		38.0			88.0	88.0
Instrumentation	1.0		1.0	9.0	4.0			9.0			24.0	24.0
Program Support	1.0	6.0	1.0		2.0			8.0			16.0	16.0
Total	6.0	8.0	6.0	14.0	26.0	17.0	0.0	73.0	0.0	0.0	150.0	150.0
FTE ACCEL TOTAL	30.0	18.0	36.0	79.0	178.0	53.0	8.0	321.0	8.0	4.0	735.0	879.0
ACCEL RATES ($/hour)	38.7	22.8	14.0	27.0	27.0	18.8	18.8	18.8	17.4	14.0		
ACCEL COSTS PER YEAR (K$)	98.6	57.9	35.6	68.6	68.6	47.2	47.2	47.2	44.4	35.8		
TOT FTE'S COST PER YR (K$)	2957.5	1043.0	1282.9	5423.3	12219.6	2503.9	377.9	15164.9	355.1	142.5	41470.7	46723.2

Four Shift Operations

FTE ACCEL TOTAL	30.0	18.0	36.0	85.0	193.0	53.0	32.0	420.0	8.0	4.0	879.0	
ACCEL RATES ($/hour)	38.7	22.8	14.0	27.0	27.0	18.8	18.8	18.6	17.4	14.0		
ACCEL COSTS PER YEAR (K$)	98.6	57.9	35.6	68.6	68.6	47.2	47.2	47.2	44.4	35.6		
TOT FTE'S COST PER YR (K$)	2957.5	1043.0	1282.9	5835.2	13249.3	2503.9	1511.8	19841.9	355.1	142.5	48723.2	

Figure 3-5


Accelerator Division Manpower Comparisons
SSCL and FNAL
FNAL
SSCL
FTE
140
120
100
80
60
40
20
0
Operations
Accel. Physics
EE Support
ME Support
Cryogenics
Controls/Instr.
Safety

CAPITAL EQUIPMENT AND ACCELERATOR IMPROVEMENT PROJECTS

Capital Equipment

Equipment funds are used for purchased or fabricated equipment to support the accelerator systems and the experimental physics program.

For the accelerator systems in the SSC injector chain and the Collider, the equipment category covers a wide range of items in support of the Laboratory operations. Some examples are listed below:

- Power supplies of all types
- Computers and peripheral equipment
- CAD workstations
- Measurement instruments
- Vacuum pumps
- Test Equipment
- Oscilloscopes
- rf/signal generators
- Spectrum analyzers
- Gauss meters
- Recorders
- Survey and alignment instruments
- Electrical shop equipment
- Special handling and rigging devices
- Mechanical pumps
- Leak Detectors
- Gas detectors
- Oil Analysis systems
- Special magnets
- Test Stands
- Mass spectrometers
- Optical comparators
- Cabling machines
- Tensile test equipment
- Hardness test equipment
- Creep test equipment
- Vibration test equipment
- Welding machines
- Portable generators
- Compressors
- Water pumps
- Hoists, cranes
- Other special vehicles
- Vehicles for magnet transport and replacement
- Communications equipment

Accelerator Improvement Projects

Accelerator Improvement Projects provide for essential modifications and upgrades of the accelerators and associated experimental facilities on an annual basis. The improvements are geared to maintain the scientific effectiveness, operating reliability, and, hence, cost effectiveness of the accelerator systems and the experimental halls that support the operations of the major detectors at the SSCL.

Examples of possibilities for the future include the following:

- Improved beam transfer lines between accelerators
- New beam lines for the fixed target area
- Modified target stations for the fixed target experiments
- I.R. Hall modifications
- Improved power supply systems
- Improved RF systems
- Modified correction magnet systems
- Control system modifications
- Improved instrumentation and Controls
- Beam damping systems
- Improved beam scraper systems
- Linac upgrade
- I.R. region modifications (new magnets and beam tubes)
- Improved surveillance and communications systems

Other examples might involve implementation of some of the potential future improvements described in the closing section of Chapter 6.

PROJECTED OPERATING MODES

The SSC Control System will be capable of supporting independent non-beam operation of each accelerator and/or beam operation for one through five accelerators. For beam operation of a specific accelerator, each preceding accelerator must also be operational. A possible scenario illustrating the operational flexibility available from the Control System follows:

> During collider maintenance, certain collider systems could be exercised for performance measurements.
>
> The HEB could be closed and secured with pulsing of the ring magnets in an asynchronous mode for performance measurements.
>
> The MEB could be under controlled access for corrective maintenance.
>
> The Linac and LEB could have beam operation to the LEB dump for tune up measurements.

The flexibility of the Control System will allow an unlimited number of operating modes. The parameter "settings" for a number of modes will be stored in the Control System, making it relatively easy to switch between modes, thus optimizing the availability of all facilities.

Because there are an unlimited number of operating mode possibilities, we describe below a model operations cycle that might be typical for operations during a 24-hour period. This in turn provides a mechanism for determining a reasonable estimate for power costs.
With the costs thus established for a typical 24-hour period, the description below of a model for annual operations provides an estimate of the overall experimental potential during the first years of Collider operations.

Model Operation Cycle

Operations for experimental physics will have the highest priority. During these operations the superconducting magnet accelerators (HEB and Collider) will operate to inject and accelerate proton beams to 20 TeV. The beams will interact at the experimental halls where detectors for experiments are located.

During the time that experiments are being conducted in the Collider, the resistive magnet accelerators will be used to conduct "test beam" experiments allowing no reduction in load. The HEB will be non-operational, that is, not cycling, and set to injection energy.

The high energy beams, after acceleration in the Collider, will be maintained for approximately 20 hours. During this time, independent operations can occur in the injector accelerators.

A basic 24-hour operation for the Collider, including experimental hall and test beam operation, will consist of 2 hours of injection and acceleration to 20 TeV, 20 hours of operation, and 2 hours ramp down, data gathering, and preparation for the next operational cycle. Five different modes of operation are included within the 24-hour cycle period. The modes are defined below.

Mode 1 - Collider Injection
During mode 1 operations, all injector machines are operating, or cycling, at full power. That is, the LINAC, LEB, MEB, and HEB are cycling while the Collider ring is at the injection energy level. A beam is prepared for introduction to the Collider ring from continuous cycling of the LINAC, continuous cycling of the LEB, 96 MEB cycles/hour to fill the HEB, and 8 HEB cycles/hour to fill the Collider. Mode 1, injection, lasts for about 1 hour.

Mode 2 - Collider Ramping
During mode 2, the Collider accelerates the beam introduced from the HEB. The LINAC, LEB, MEB, and HEB fall to injection level energies. Collider acceleration of the beam lasts for about 1/2 hour. This is followed by tune-up and set-up of stable conditions for colliding beam operations. It is estimated that approximately one hour will be required for this operations mode.

Mode 3 - Collider Storage Without Test Beam Operations
For Mode 3 operations, the injector machines remain at the same level as in Mode 2. The Collider maintains a holding energy level while operating for the approved experiments. Operations in this mode last until test beam operations begin: about 12 hours.

Mode 4 - Collider Storage With Test Beam Operations
For Mode 4 operations, the MEB is cycled at 200 cycles per hour to provide for test beam operations, thereby increasing overall power requirements. The other machines remain at their Mode 3 energy levels: the LINAC and LEB cycling, the HEB at injection energy, and the Collider holding. Mode 4 operations last 8 hours.

Mode 5 - Studies and Preparations for Next Cycle
During Mode 5 operations, MEB continues cycling at 200 cycles per hour, HEB cycling resumes its 8 cycle/hour rate, and the Collider cycles, ramping 28 minutes up and 28 minutes down. The time allocated for this operation is 2 hours.

The above modes are summarized in Table 3-6, and the average energy usage associated with each mode is plotted in Figure 3-6.

In addition to the above operational modes, we define the time period for major maintenance. During this period it is assumed that all major technical systems are shut down. This excludes cryo systems, control systems, etc., and building power that would normally be required in this type of operation. Examples of major maintenance include collider magnet replacement, detector modifications, and replacement or modification of major technical systems in the injector system or the Collider. Note that routine weekly maintenance is not included in this category.

Estimates of the power use in each of the five operating modes and the maintenance mode have been made. The results are summarized in Table 3-7 for each injection accelerator and the Collider. The requirements for the entire Laboratory are given including the campus area, the N-15 area, and the experimental facilities.

The information in Table 3-7 is based upon current available design data. One must recognize that many accelerator technical systems are in various design stages. The detector systems are in a very preliminary design stage. While large changes are not expected, the power use summary of Table 3-7 will require an up-date as the design of each major technical system is completed.

Model for Annual Operations

In the first year of full-scale operations of all accelerator systems, it is assumed that there will be a number of failures of various technical components (collider magnets, for example) and hence a significant amount of unscheduled down-time for repairs, replacement, and modifications. The same scenario will apply to the large detector systems. Long periods of scheduled down-time (up to 3 months) are not planned, because this would further reduce the actual operations time for the year.

It is estimated that the overall operations efficiency (actual operations/scheduled operations) will be about 35 percent in the year 2000 and will improve to 70 percent in the year 2004. With this improvement, the scheduled down-time can be more systematically scheduled over longer time intervals. It can be hoped that this will be coincident with the potential needs of the detectors for major maintenance and improvements. The assumed allocation of annual time is illustrated in Figure 3-7 for FY2000.

Table 3-8 projects operations for the first 5 years. The model assumes a one-month continuous shut-down per year. On a weekly basis, 7 weeks operation with a one week shut-down is assumed. Finally the operations efficiency is assumed to increase from 35 percent in FY2000 to 70 percent in FY2004.

In estimating the power costs for the SSCL, we use the data from Table 3-7. For simplicity, the full operations costs for the 5 operating modes are assumed for the actual operations time and the scheduled periodic shut-downs which are of short duration. The costs for the maintenance loads are assumed for all other periods.

Table 3-6

MODEL FOR 24 HOUR OPERATION CYCLE
MAGNETIC FIELD STATUS FOR INJECTORS & COLLIDER

MODE	MACHINE						OPERATION
	LINAC	LEB	MEB	HEB	COLLIDER	T B	HOURS
MODE 1	CYCLING	CYCLING	CYCLING [1]	CYCLING [2]	INJECTION	INJECTION	1
MODE 2	INJECTION	INJECTION	INJECTION	INJECTION	RAMPING	INJECTION	1
MODE 3	INJECTION	INJECTION	INJECTION	INJECTION	STORE	INJECTION	1 2
MODE 4	CYCLING	CYCLING	CYCLING [3]	INJECTION	STORE	CYCLING	8
MODE 5	CYCLING	CYCLING	CYCLING [3]	CYCLING [2]	RAMPING	INJECTION	2
MAJOR MAINTENANCE	INJECTION LEVELS OR LESS, ACCORDING TO MAINTENANCE OPERATIONS						

NOTES

1 96 CYCLES PER HOUR

2 8 CYCLES PER HOUR

3 200 CYCLES PER HOUR

Figure 3-6

ELECTRICAL ENERGY USAGE- 24 HOUR OPERATING CYCLE

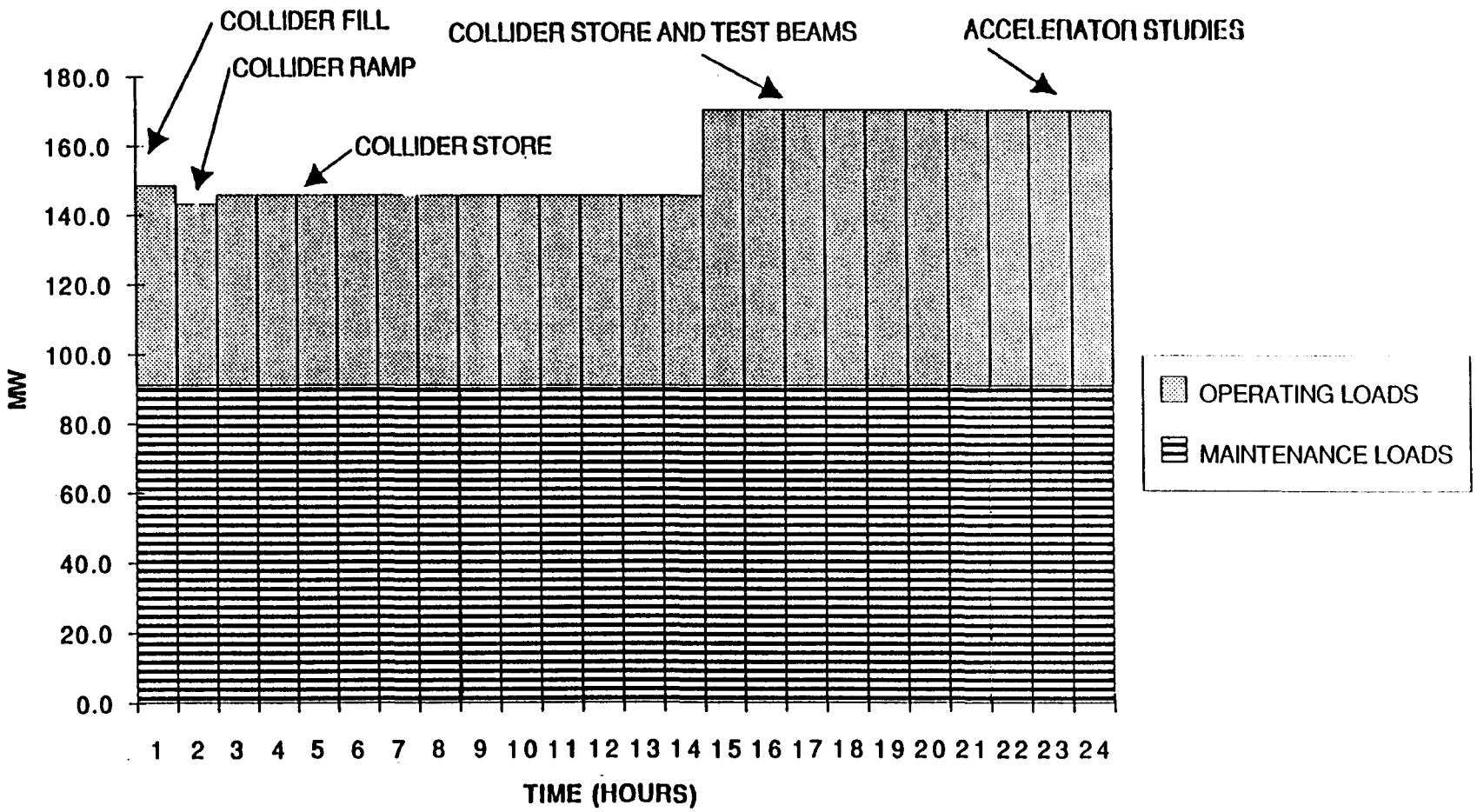


Table 3-7

POWER REQUIREMENT ANALYSIS FOR BILLING CONSIDERATIONS

	MODE 1	MODE 2	MODE 3	MODE 4	MODE 5	MAINT.
TOTALS	AVERAGE LOAD (MW) 148.7	AVERAGE LOAD (MW) 143.3	AVERAGE LOAD (MW) 145.9	AVERAGE LOAD (MW) 170.7	AVERAGE LOAD (MW) 170.5	AVERAGE LOAD (MW) 91.2
N15	7.5	7.5	7.5	7.5	7.5	7.5
CAMPUS	7.5	7.5	7.5	7.5	7.5	7.5
COLLIDER	62.8	78.5	81.1	81.1	78.5	48.1
E. EXP HALLS	20.5	20.5	20.5	20.5	20.5	11.5
INJ-HEB	15.7	12.5	12.5	12.5	15.7	7.3
INJ-LEB	6.3	1.7	1.7	6.3	6.3	0.7
INJ-LINAC	2.1	1.7	1.7	2.6	2.6	1.1
INJ-MEB	16.8	4.0	4.0	22.5	22.5	1.2
TEST BEAMS	2.8	2.8	2.8	3.7	2.8	1.7
W. EXP HALLS	6.6	6.6	6.6	6.6	6.6	4.7

October 1992

Figure 3-7

Accelerator Annual Time Allocation: FY2000

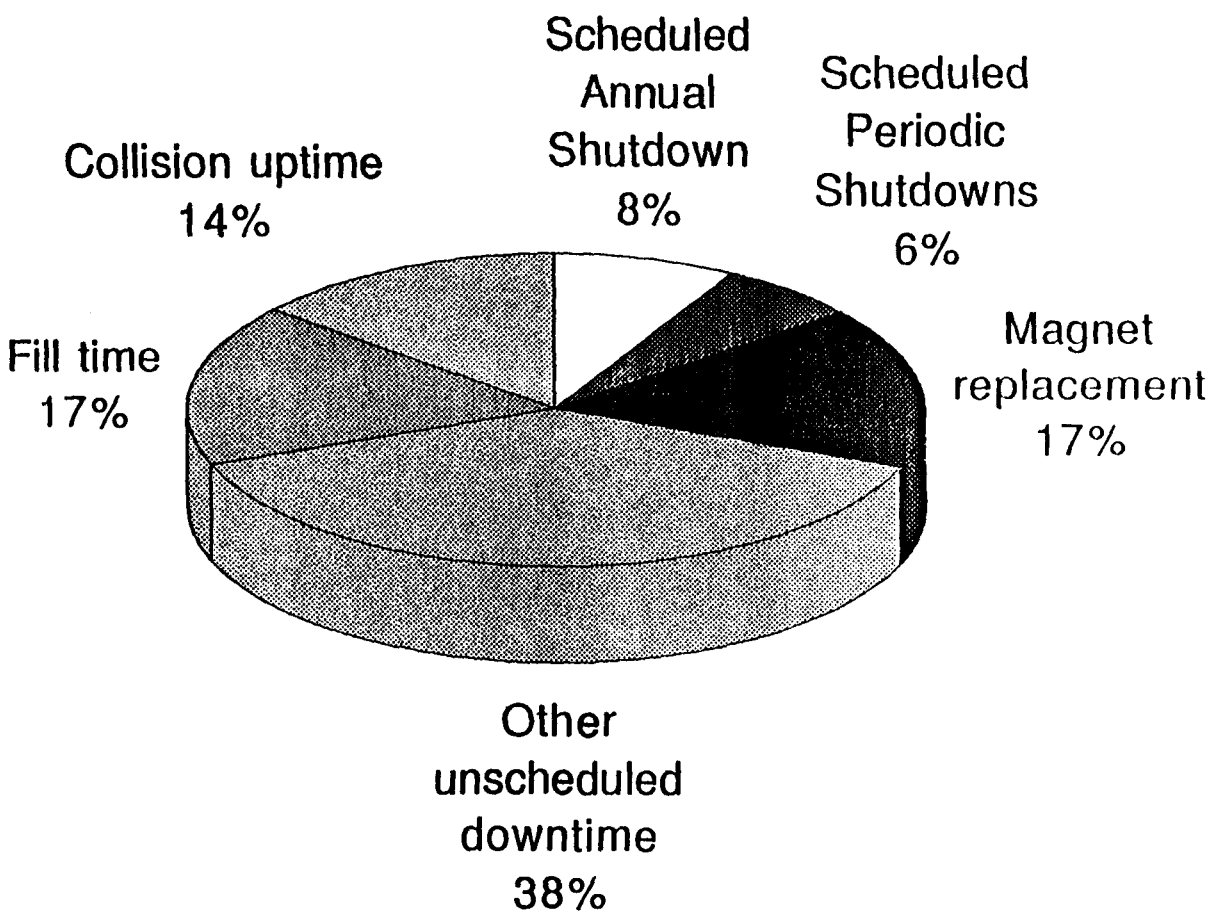


Table 3-8
Model for Collider Operations

Fiscal Year	Operating Efficiency (%)	Scheduled Operations (Hours)	Actual Operations (Hours)	Unscheduled Down-time (Hours)	Scheduled Down-time (Hours)
2000	35	7000	2450	4550	1760
2001	45	7000	3150	3850	1760
2002	55	7000	3850	3150	1760
2003	65	7000	4550	2450	1760
2004	70	7000	4900	2100	1760

ACCELERATOR OPERATIONS COSTS

Staff

Table 3-5 provides the detailed operations staff estimates for each of the three Departments of the Accelerator Division. The estimates indicated a total of 735 FTEs during the normal day-shift operations of the for Collider and an additional staff of 144 FTEs, who will carry out operations during the swing, owl, and week-end shifts of operation. The costs/FTE in each manpower discipline are given in Table 3-5. A total cost of $48.7M (FY91$) is indicated for FY2000.

The 144 FTEs of shift personnel are largely accelerator operators and technicians. If a shift differential pay scale of 11.7 percent is considered (based on FNAL experience), it would result in increased costs of $0.8M. This increase could be partially off-set by the transfer of some personnel from the Exempt to the Non-Exempt category. This detail does not appear warranted at this time. If the increased costs for shift personnel are added to the above costs from Table 3-5, the total personnel cost estimate becomes $49.5M.

The above staff total includes an increase of 31 FTEs above that of the August 28, 1992 draft report. Most of these personnel have been included in appropriate sections of the Technical Support Department, which now has a total of 125 engineers and 174 technicians. It is deemed inefficient to add a fifth operating shift to accommodate vacation and sick leave for the four shift operation crews. Instead the appropriate personnel of the Technical Support Department as well as the Magnet Systems Department can be called upon when needed to supplement the operations crews. At other times they will continue with their normal tasks.

Materials and Services

The Materials and Services (M&S) category covers the costs of materials, supplies, components, and certain services that are necessary to support the operations and enable the staff to maintain, service, and operate all accelerator systems. Table 3-9 provides an example of the general categories of M&S as well as an example of their relative percentages taken largely from FNAL experience.

Table 3-9
Materials and Services (M&S)

Component	%of Total M&S Cost
Materials & Supplies	34
Stores[1]	11
Shops & Facilities	12
Contract Services	18
T&M Contracts	9
Purchased Services	5
Travel and Education	6
Consultants	1
Miscellaneous	4
TOTAL	100%

1) Includes spares and special process spares

Within the various areas of M&S illustrated in Table 3-9, experience at other accelerators indicates that part of the M&S costs are manpower related with the remaining costs related to Technical Systems requirements. The fraction that is manpower related is typically 40 percent of the manpower costs.

At FNAL the fraction of M&S related to Technical Systems requirements is approximately 25 percent of the total M&S costs. We use this experience for the systems related M&S for the injectors. In this analysis we assume that the manpower for the injectors is 66 percent of the total manpower of the Operations and Technical Support Departments as estimated in the March 1992 Operations and Commissioning Report. There is no comparable experience for the Collider. As a best approximation we use the ratio of Collider technical systems costs (exclusive of Superconducting Magnets) to that of the injector systems. The result indicates that the collider systems related M&S should be 1.8 times that of the injector systems.

For the Magnet Systems Department (see the discussion above) a separate analysis also projects a 40 percent manpower related M&S. In addition the materials cost for magnet replacements, both superconducting and resistive magnets, is estimated. The overall systems related M&S, including tooling, is $6.6M.

The overall M&S estimate for the Accelerator Division is summarized in Table 3-10. The total of personnel and systems related M&S is $35.6M.

Table 3-10
Accelerator Division
Manpower and M&S Costs ($M)

Area	Operations Manpower Cost	Personnel Related M&S	Systems Related M&S
Division Office	1.0	0.3	
Operations Department	18.2	7.3	
Technical Support Department	22.0	8.8	
Magnet Support Department	8.3	3.3	
Injectors			3.3
Collider			6.0
Magnets			6.6
Total:	49.5	19.7	15.9

Power

A typical operations cycle was used in the section on Operating Modes above together with projected operating efficiencies to estimate the power use in the first years of SSCL operations. The power rate for FY91 is 0.047 $/KWH. The resulting costs for FY2000 through FY2005 are presented in Table 3-11. Note that these are for the entire SSC Laboratory, including the accelerators, experimental facilities, and all other Laboratory functions.

Table 3-11
SSCL Power Costs

FY	MWH	FY91 M$
2000	10.1×10^5	47.5
2001	10.5×10^5	49.5
2002	11.0×10^5	51.7
2003	11.4×10^5	53.8
2004	11.6×10^5	54.8

Cryogens

Recent quotations for liquid Nitrogen indicate an average cost of $0.23 per hundred cubic feet (or $57 per ton) for quantities of 400 tons/day in 20-ton trucks. This amounts to $8.4M per year. If there is a dedicated facility near the site, this estimate could be reduced by up to 40 percent.

Quotations for liquid Helium indicate a current cost of $8 per gallon (96 s ft^3). If we assume that the SSC will require 25 percent of the liquid Helium inventory per year, 15 x 10^6 s ft^3 are required for a cost of $1.3M. Thus a maximum annual cost of $9.7M is estimated for both Nitrogen and Helium.

Accelerator Improvement Projects and Capital Equipment

Examples of potential Accelerator Improvement Projects (AIP) and a list of equipment items that have been required in existing accelerators were presented in a section above. At this time, it is not possible to determine which improvements to the various accelerator systems will be needed. In current schedules, the year FY2000 will signal the end of commissioning of the Collider and the first year of operations. Significant improvements should not be required. On the other hand, some of the injection accelerators have been in operation for as much as three years. It is assumed that current levels of AIP and Equipment at FNAL might be required. These values together with a modest increment for the Collider lead to estimates of $10M for AIP and $3M for accelerator equipment in the year FY2000.

Cost Summary (FY2000)

A summary of costs presented in the above sections is tabulated in Table 3-12.

Table 3-12

FY2000 Accelerator Operations

Category	FY91M$
Manpower	49.5
M&S	35.6
Power*	47.5
Cryogens	9.7
AIP	10.0
Equipment	3.0
Total	155.3

*Total Laboratory Power

4
PHYSICS RESEARCH DIVISION

PHYSICS RESEARCH DIVISION OFFICE

The Physics Research Division consists of three departments: Physics Research Program, Experimental Program Operations, and Physics Computing. The division office is responsible for managing and coordinating the detector development effort for all approved experiments. The division management provides oversight of the approved detector program and will track associated tasks through design, fabrication, assembly, installation, commissioning, and operations. It will provide the necessary project interface to ensure that all experimental facility requirements are specified and met during operations. Responsibilities include specifying requirements for test beams and detector hall modifications and providing the oversight and direction for the specifications, procurement, installation, and operation of the major computing systems that will be used to analyze data from the experiments. The division office is responsible also for the planning of future detectors and experiments as well as plans for additional experimental facilities and improvements. Lastly an ES&H group is included within the division office to supervise and monitor all division activities with respect to Environmental Health and Safety.

An organization chart of the Physics Research Division activities is shown in Figure 4-1. The functions of each of the three departments of the Division are described below.

SSCL PHYSICS RESEARCH PROGRAM (IN-HOUSE)

Overview

The success of the SSC physics program requires the most crucial resource of all: talented, creative physicists. More than 700 U.S. physicists are involved currently in the major detector collaborations, part of a total of 1400 scientists worldwide. The total involvement of scientists, actual and projected, in the SSC experimental program is shown in Figure 4-2. The actual numbers for the total and the participating U.S. physicists are based on the collaborators in GEM and SDC. Beyond that, jumps in FY1993/FY1994 of 100 physicists (50 U.S., 50 non-U.S.) for each of two smaller experiments are assumed, together with a 2 percent yearly growth through the end of the decade. The total participation then approaches 1800 physicists at the beginning of the next century, roughly 1000 of them from the United States. Based on this scale of worldwide and U.S. participation in the SSC experimental program, it is planned that 195 experimental physicists (SSCL staff and paid visitors) will be at the SSCL by the start of Collider operations.

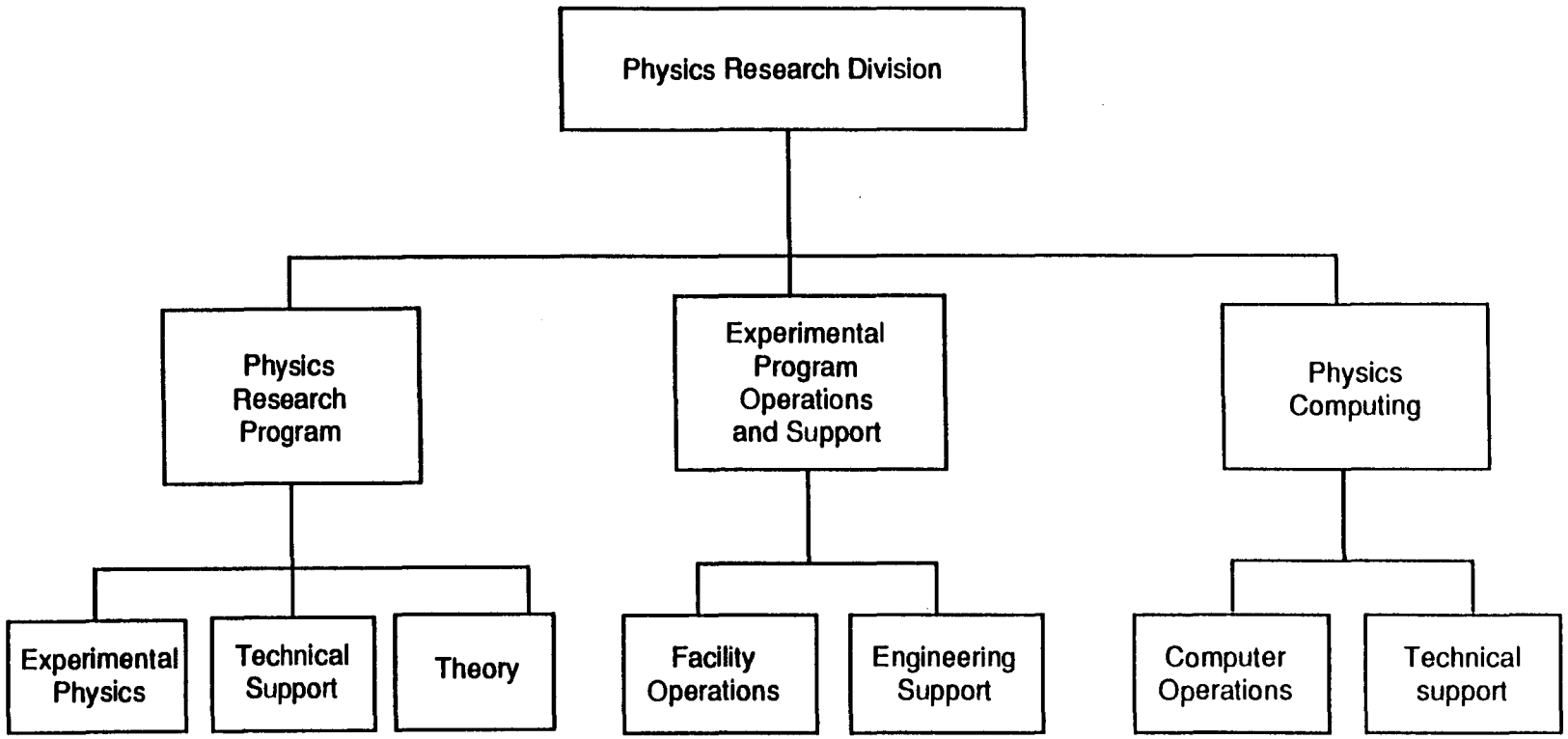


Figure 4-1
Physics Research Division Organization

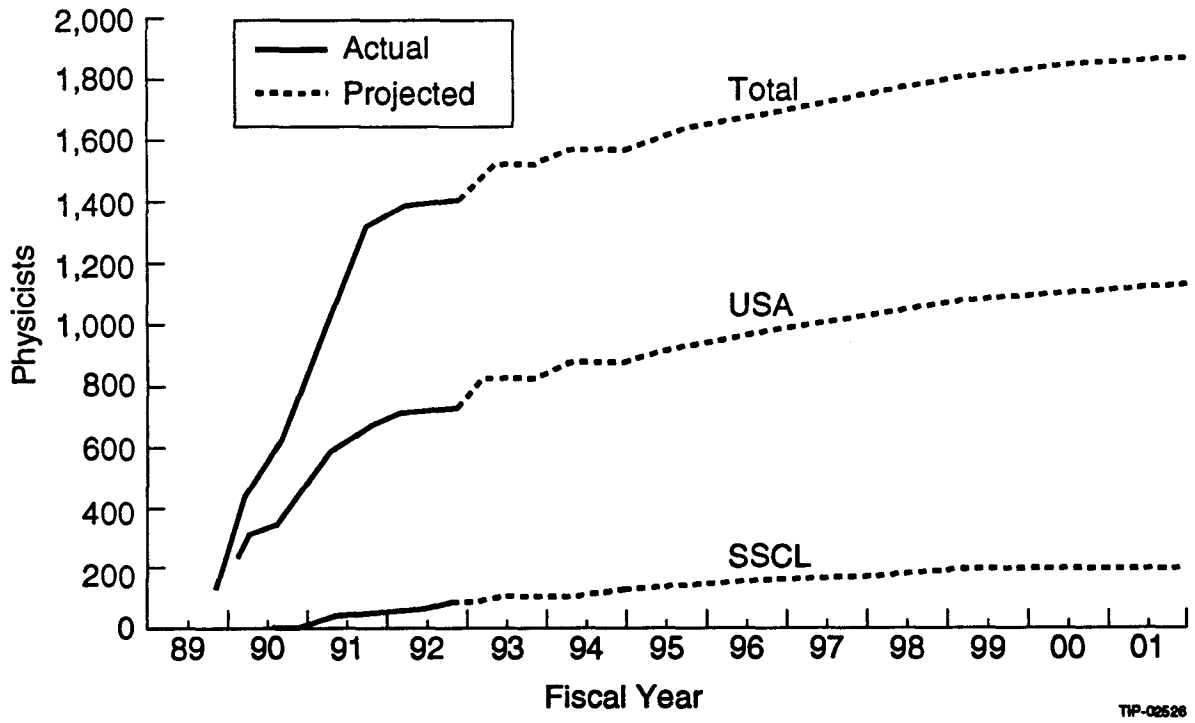


Figure 4-2 Physicist Involvement in the SSC Experimental Program

SSCL Research

Experimental Physics

Strong in-house groups of physicists are needed at the SSC Laboratory to successfully carry out the design, construction, and operations of the major detectors. The role of these groups is both to support the international collaborations and to make significant contributions to high energy physics as an integral part of the collaborations. SSCL physicists act as a spearhead for those in the collaborations, providing support for the collaborations, forming liaison with the other parts of the SSC project that involve technical facilities and the accelerator, and helping to shape the scientific program. The importance of the Laboratory physics program during the period 2000 - 2005 can be summarized as follows:

- Laboratory physicists are essential to all aspects of detector operations.
- Laboratory physicists are essential participants in the continuous tasks associated with design and integration of the upgrades to the experiments after initial turn-on.
- Laboratory physicists have a unique role in forming the liaison between the collaboration and the accelerator and the support departments of the SSC Laboratory. Specific items that require such liaison are IR magnets/optics, radiation/machine associated backgrounds, test beams, and computing/simulation.
- Laboratory physicists provide for coordination/commonality between detectors.

- Laboratory physicists have a special liaison role concerning lab resources, integration, installation, and commissioning of upgrades built elsewhere.

- Laboratory physicists are needed for their contributions to research in particle physics and detector technology.

While direct contributions to research are a prime objective, Laboratory physicists must spend a significant fraction of their time in planning, coordinating, and executing basic support tasks for the Laboratory and for the collaborations. At the start of collider operations, we project there will be 195 experimental physicists within the Physics Research Division. Given the size of the detector collaborations noted above, this number translates to in-house groups associated with each of the major detectors that will represent about 10 percent of the total collaboration. Others will be associated with the smaller experiments. These physicists fulfill both "service" and "research" roles within the Laboratory, as indicated in the points immediately above. In fact, it is natural that particular individuals will quite often perform both sorts of roles within their job description. We have chosen to identify almost all the experimental high energy physicists in the Laboratory in this one organizational unit, whether or not they devote 100 percent of their time to "research."

The above projection was arrived at primarily by comparison with previous history, but it is consistent with bottom-up estimates as well. The data in Figure 4-3 are gathered from the recent U.S. "large" collider detector collaborations CDF, DO, and SLD. They show a substantial component (16 percent - 25 percent) coming from the host laboratory starting at the earliest stages of the experiment. The sum of these three collaborations, totalling 700 scientists or approximately the size of one SSC major detector collaboration, involves 130 to 150 associated experimental physicists inside the Laboratory. European experience is much the same. The Zeus experiment at HERA, with 313 Ph.D. physicists, has 31 in-house physicists. ALEPH, at CERN, has about 50 CERN physicists within a total collaboration of 350 physicists. Based on a present total of more than 1400 collaborators and U.S. HEP community involvement already numbering more than 700 (which we expect to grow to around 1800 and 1000, respectively, by the time of collider operations), 195 experimental physicists at the Laboratory in FY 2000 is a minimal basis on which to plan.

These comparisons with current experiments in both the United States and Europe provide a top-down basis on which to calculate the size of the in-house groups of experimental physicists at the SSC Laboratory. A bottom-up analysis of tasks and the corresponding experimental physicists in the Physics Research Division at the end of FY1992, as well as bottom-up needs in FY1993 and FY1994 has recently been presented to the Division of High Energy Physics of the DOE. In this analysis, more than half the 195 experimental physicist FTEs needed in FY2000 are already accounted for by the middle 1990s.

Experimental Physics Technical Support

During the construction phase the physics staff will be increasing. Physicists will draw on project support staff for many of the project-related activities; however, there is need for a small, but critical, technical support staff, who are devoted to the research activities of the in-house physicists. This technical support staff plays the same role as the "captive" engineers and technicians found at all major high energy physics research groups at either laboratories or universities.

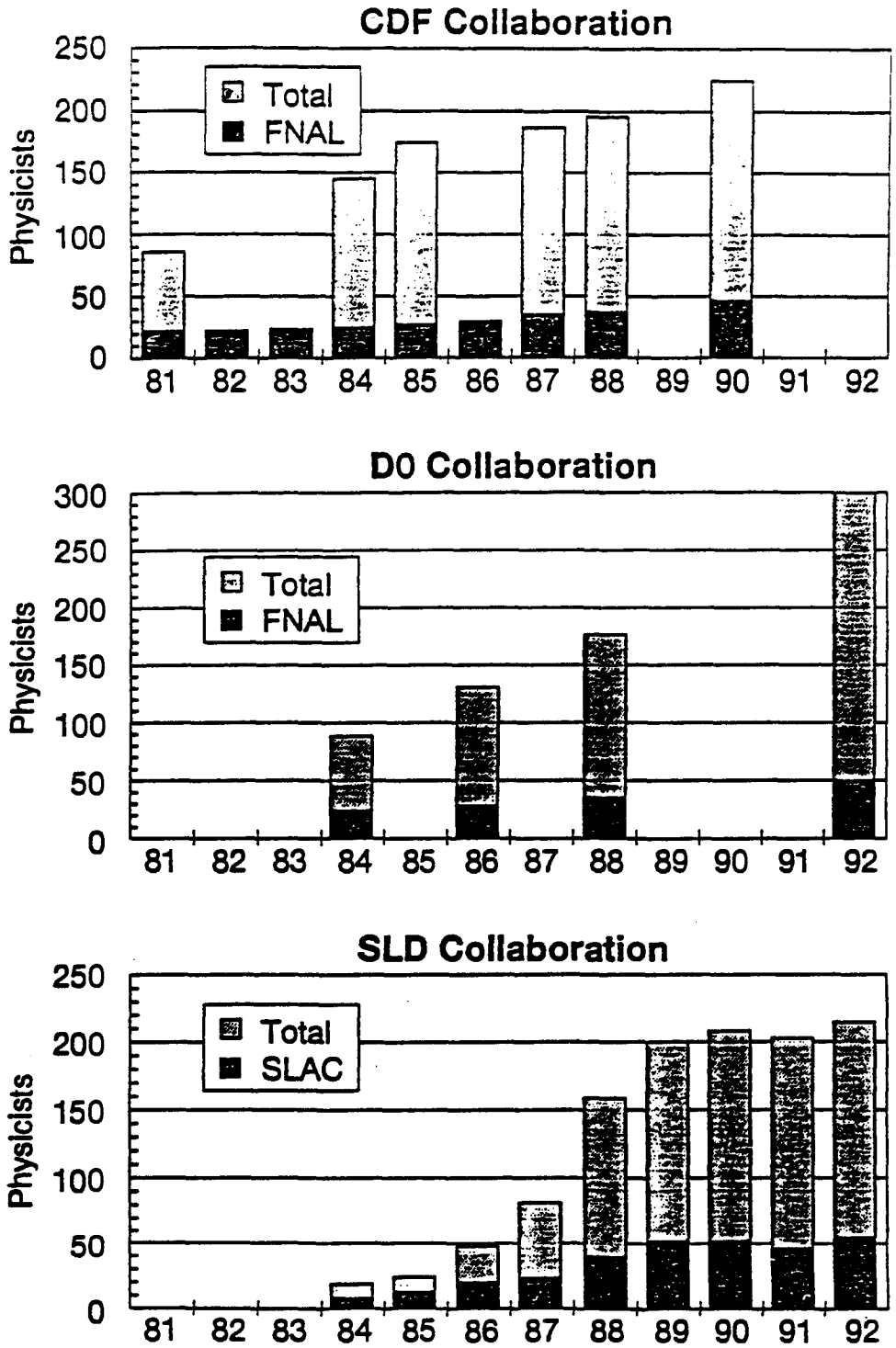


Figure 4-3
Large U.S. Detector Collaborations

Experimental Physics Support staff functions include R&D activities, test beam activities, and development of Laboratory research infrastructure and instrumentation. The level of this support is expected to reach 35 FTEs, supporting the 195 FTE experimental physicists at the time of SSC turn-on. The 35 FTEs represent support to programs at the end of the construction period. After the start of operations, additional support will be obtained as needed from staff within the Engineering and Support Department (see the Experimental Program discussion below).

Theoretical Physics

An excellent theoretical physics group is an essential component of a high energy physics laboratory. Not only does such a group contribute directly to the research goals of the laboratory, but it plays a key role in establishing the intellectual atmosphere that exists at a great research institution.

The theory group not only contributes to research and acts as host to visiting theorists, but it will keep experimentalists at the Laboratory informed of the latest theoretical developments. This role is of great importance, for the program of the Laboratory is to explore the nature of fundamental interactions of matter at energies never before probed, and it is only through the interaction between theory and experiment that this program can be fully successful. The latest avenues suggested by theory can be used to tailor experiments or the analysis of experiments so as to explore new directions.

The theory group may also play a role in education, an area where the SSC Laboratory has important programmatic goals as well. Graduate students in experimental particle physics who are required to spend large amounts of time at a laboratory away from their parent institution often miss the opportunity to take any but the most basic graduate courses. Theorists can alleviate the situation by organizing short academic training courses at the appropriate level.

We project a group of 25 theoretical physicists at the start of collider operations in FY 2000, including permanent appointees, term appointees, and long-term paid visitors. Based on experience at other national laboratories, there might be approximately equal numbers in these three categories.

User Assistance

Current projections indicate that, on-average, there will be ~500 experimental users on site at the SSCL in FY2000. The users will require office space and office equipment and a variety of services, such as secretarial service, communications, desk computers, shop services, design services, assistance with reports and publications, and a variety of miscellaneous materials and supplies.

We estimate that about 15 FTEs, largely administrative and clerical personnel, will be needed to assist users with their technical activities. In addition $4K/year per user is estimated on average for the other services listed above.

(Note that the activities just described are not related to the user office in the Directorate, which deals with housing, travel, and other non-technical user needs.)

Strategy

To achieve the goals described in the previous sections, the overall strategy is to have a steady growth in staff over the 1990 decade and to make a smooth transition from the construction period to that of the fully operating Laboratory in FY2000. In doing so, we would phase out outside research as the SSC detectors start being assembled in 1996. In this same time-frame, experimental facilities and test beams become part of the operating Laboratory.

The envisioned ramp-up in experimental physicists is shown in Figure 4-4. The 195 experimental physicists projected for FY2000 are divided into 85 on SDC, 85 on GEM, and 25 on other, smaller experiments. This is based on a model that assumes parity between the major detectors and a number associated with smaller experiments that is roughly proportional to the Laboratory resources involved in each experiment. The major growth occurs before FY98 in the program of designing, building, and testing the detector systems.

Note that the simple model we have used already has been modified by the actual needs and plans of the SSC detector collaborations. GEM, whose center of operations from the beginning has been at the SSC Laboratory, currently has a somewhat larger group of physicists and long-term visitors than does SDC, and that situation will continue through the mid-1990s.

EXPERIMENTAL PROGRAM OPERATION AND SUPPORT

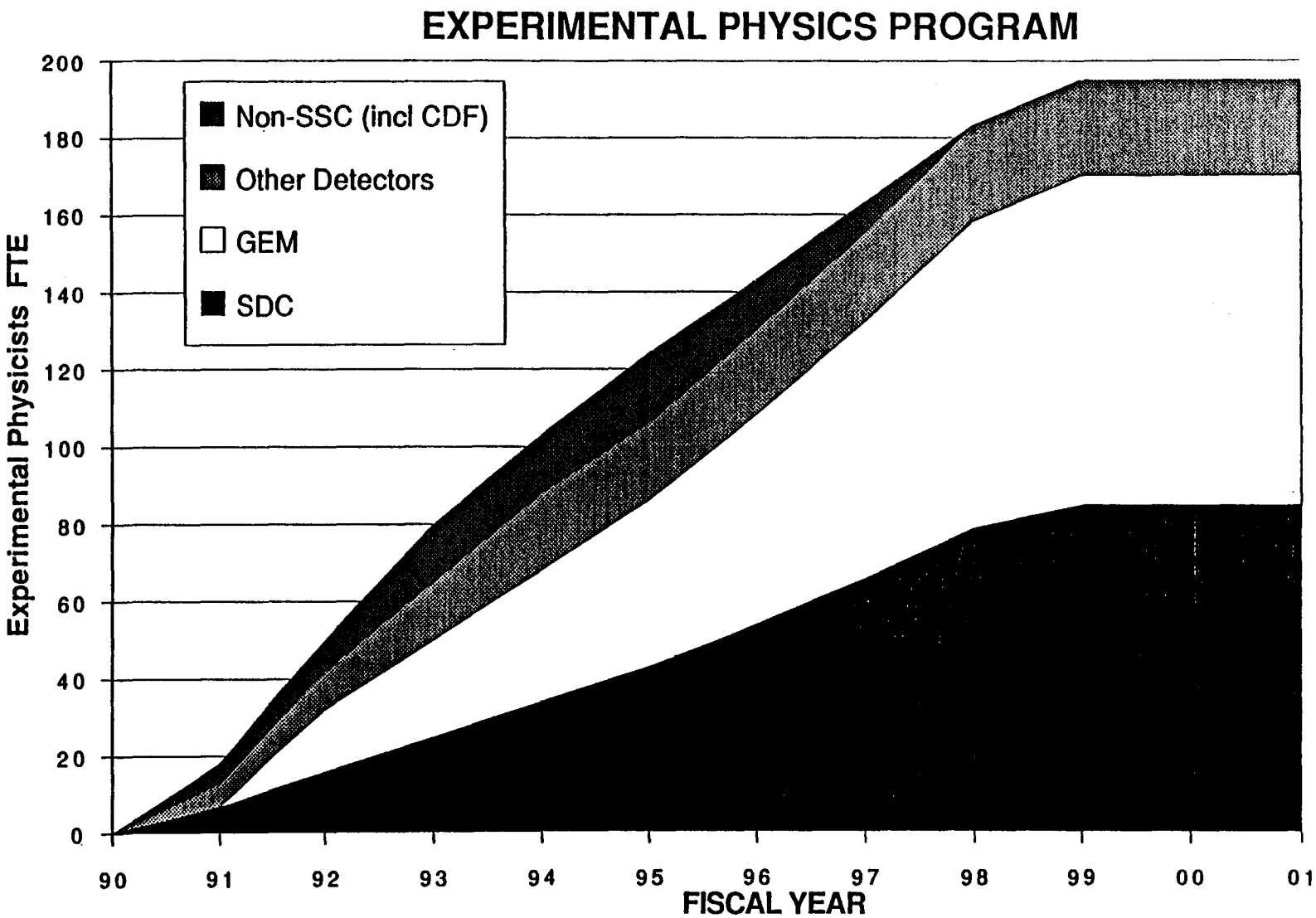
Experimental Facilities Operation

In this section we estimate the cost of the Experimental Facilities Operation Group, which will operate and manage the facilities supporting the SSCL detectors. The support will include the underground halls that enclose the detectors, the surface structures that support the assembly, test, and operations, and the associated power and utilities for these operations. Four experimental areas are planned at Interaction Regions 5 and 8 on the east side of the collider, and Regions 1 and 4 on the west side. Two large experimental halls (approximately 100m long x 30m wide x 40m high) will be located at Regions 5 and 8. These will provide the underground enclosures for the Solenoidal Detector and the GEM detector. The designs for these facilities are already under way.

An "intermediate" size detector is contemplated for IR1, and a relatively "small" experiment is forecast for IR4. No detailed proposals for detectors have been accepted for these regions. For purposes of estimating the experimental facilities staff that will be required, we assume that the IR1 and IR4 regions will require about 1/3 and 1/9 respectively of the manpower required by IR5 and IR8.

The large halls are scheduled for completion in FY96 and the smaller ones in FY97. These dates signal the availability of the halls for assembly of the detector systems. The transport of thousands of tons of detector components via crane from the surface facilities to the underground enclosure followed by assembly of components within the halls will be a complex and lengthy procedure.

Figure 4-4


EXPERIMENTAL PHYSICS PROGRAM
Non-SSC (incl CDF)
Other Detectors
GEM
SDC
Experimental Physicists FTE
200
180
160
140
120
100
80
60
40
20
0
90
91
92
93
94
95
96
97
98
99
00
01
FISCAL YEAR

The Experimental Facilities group will provide area supervision and technical support for the detector assembly process and the detector operations thereafter. It is projected that the group will rapidly build to a three-shift operation within one year of the beneficial occupancy of each experimental hall. At the end of this period the detector assembly program will become a 24-hour operation. During this time there will be considerable activity in the above-ground buildings with regard to detector component assembly and tests.

In the pre-operational period prior to acceptance of the experimental hall, the facilities department will be assembling and training staff. They will become knowledgeable with regard to the facilities (access, power, utilities, etc). The staff will also become familiar with the detector requirements for assembly, crane use, special handling of components, and overall schedules for component delivery, test, and final assembly. A major responsibility of the facilities group will be to establish and enforce safety rules and procedures.

After beneficial occupancy, the facilities group will supervise and approve procedures for detector assembly, particularly operations that require the handling of heavy components. General tasks include the operations and maintenance of buildings, power systems, cryogenics plants, and utilities. The operation of cranes, lifts, and elevators will also be the responsibility of this group.

The installation of the detectors will require special devices and facilities, trained operators, safety monitors, maintenance people, and management for their operation. Such devices will be needed as early as FY1996. By FY1998, the detectors will be well along in their construction. As each subsystem is installed, it will be operated to make certain that it functions according to specifications. The tests will require operational support facilities: detector gases, cryogenics, water, and power systems.

By FY97, the large magnets involved in the general purpose detectors will be undergoing current tests and field mapping. The tests will require operating support, including trained staff available on a three-shift-per-day basis. The magnets will require operations support for cryogenic refrigeration systems, power supplies, safety systems, and magnet control systems. Researchers involved in making field maps will also require data management and computing support.

The facilities staff will monitor and enforce safety rules and regulations. Monitoring will include the establishment of emergency procedures, the maintenance of access and egress, and the assurance that procedures are enforced for fire protection, the handling of hazardous materials, and environmental protection.

Other responsibilities include the supervision of space use in the IR halls and above-ground buildings, the maintenance of tools and equipment that may be required for detector component assembly and tests, and the maintenance of records, drawings, logs, and reports with regard to the detectors and operation of the overall facility. In addition, if improvements to the facilities or modifications in them are required to accomplish and/or expedite the assembly and operations of the detector, the facilities group will be responsible for evaluating and implementing such changes.

The staff needs associated with the Experimental Facilities Operation for each of the 4 experimental areas are given in Table 4-1. Apart from the department office, a 4-shift operation is required for each area. A total of 128 FTEs is projected for the activities described above in FY2000. While most of the staff will have been assembled in the detector construction phase, the activities noted above will continue beyond FY2000. In the operations phase, detector repairs, modifications, and improvements will be needed. The operations group will continue to have the responsibility for approving, supervising, and assisting in these areas as well as in the operations of all facilities. The responsibility includes control of all above ground buildings and facilities as well as the experimental halls. The above-ground buildings currently planned for IR8 are illustrated in Figure 4-5. As noted above, the enforcement of safety and emergency procedures will be the responsibility of the experimental facilities operation group.

Table 4-1
Experimental Facilities Operations*
Staff for Large Detector Area

Function	Physicist	Engineer	Tech	Craft	Clerical
Area Supervisor Office	1				1
Operations Coordinator	1 (1)				
Building Supervisors			2 (1)		
ES&H		1	1 (1)		
Power & Water Systems		1	2 (2)		
Cryo Plant & Gas Systems		1 (1)	2 (1)		
Shops & Tools				4 (1)	
Crane Operations & General Maintenance			4 (2)		
Totals:	2 (1)	3 (1)	11 (7)	4 (1)	1

*Plan for day-shift oeprations. Numbers in parentheses are for swing, owl, and week-end shifts.

The Materials and Services associated with the operations of one of the large detectors are estimated in Table 4-2. The exact details will vary with each detector.

The detectors used as the major research instruments at the SSCL are themselves capitalized equipment items that are expected to be valued in excess of $1B. Although these detectors will be coming into full operation in FY2000, design and fabrication will have started in FY93. A number of components will have been designed and fabricated long before the year 2000. As a result some improvements are expected to be under way at that time. For example, various upgrades to the data analysis and computing systems are expected as well as possible upgrades to the electronics and particle identification elements of the detectors.

While the specific needs of detectors for improvements and modifications will be the responsibility of each collaborative group, the projected improvements are budgeted under this operation. It is estimated that each of the large detectors will require ~$14M/year in the equipment category for maintenance and "routine" improvements. This amounts to $28M for the two large detectors and $5M for the two smaller experiments for a total of $33M.

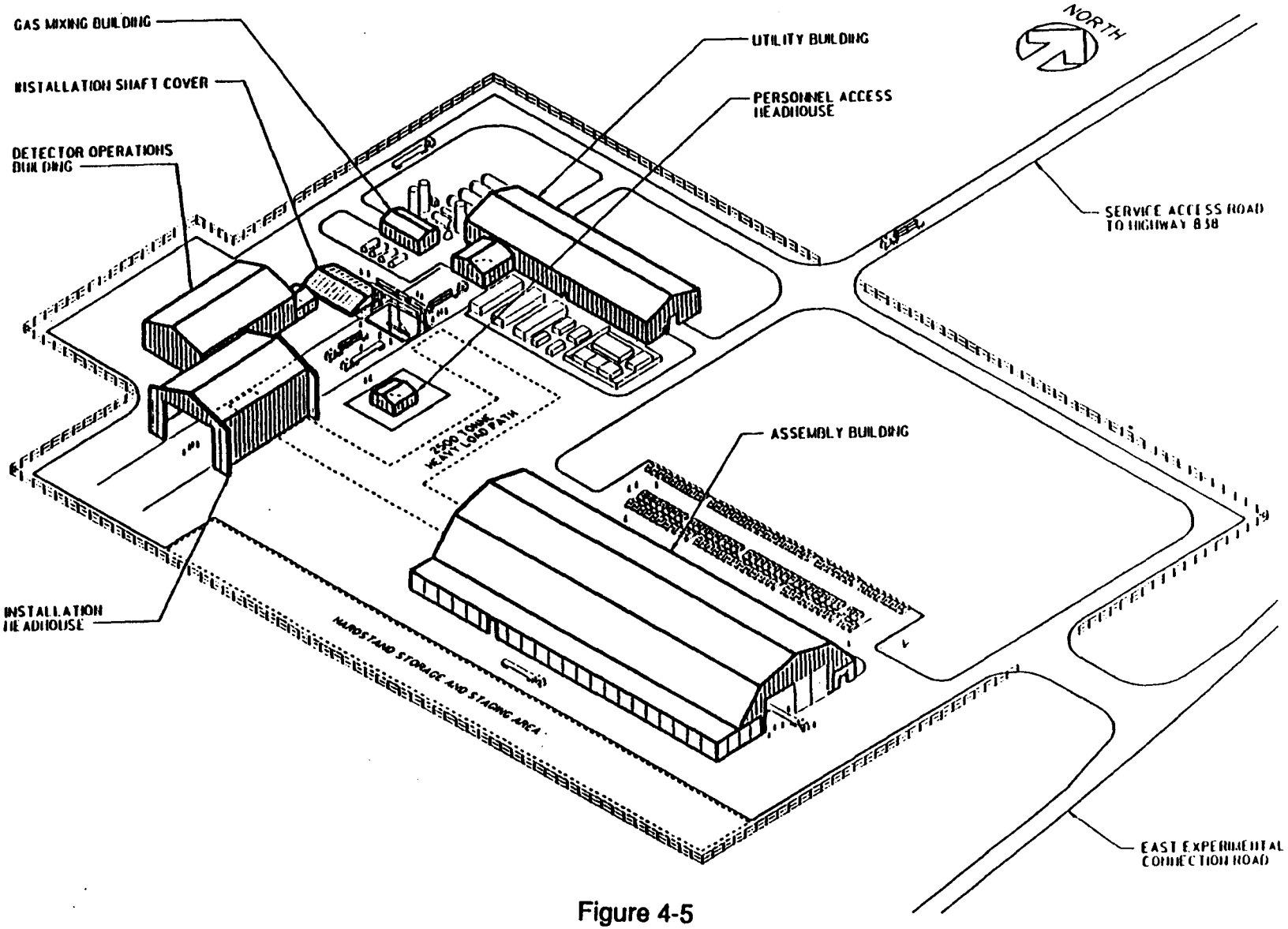


Figure 4-5

IR-8 SITE (SDC)

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Table 4-2
Experimental Facilities Operation
M&S Estimate for Large Detector Area

Items	Cost $M
• Special materials usage (includes Liquid Nitrogen, Liquid Helium, Liquid Argon, and gases)	0.6
• Support system maintenance (includes cryogenic, electrical and gas systems)	1.0
• General Materials & Supplies (in support of I.R. Hall and above ground facilities)	1.0
Total for one Large Detector area	2.6
Total for 4 Detector areas	6.6

Engineering Support

The Engineering Support group provides support of detector technical systems, in particular systems that are of general use among the detector research groups. This includes technical support to the Physics Research Department, administration for engineering resources, planning and development for experimental facilities, electrical and mechanical engineering support, electronics engineering and development, and test beam instrumentation and support. This department also provides assistance to detector groups in the areas of safety, quality assurance, and systems engineering.

At the start of operations, IR8 and IR5 will have, in addition to their respective experimental halls, extensive surface facilities which were used to stage and assemble the detectors. It is envisioned that some of these facilities will undergo transition to support future detector modification and upgrades, while others may be used to assemble and test smaller detectors scheduled for IR1 and IR4. In any case, the need for a coordinated planning effort for these facilities will be required to assure and maximize their effective use.

It is expected that this group will monitor the installation of the first detectors and their operations. Members will work closely with the Experimental Facilities Operations Group and members of the Detector Collaborations to understand the problems and needs of the experiments. Improvements and/or modifications to the experimental facilities will be analyzed, developed, and planned as needed.

The Engineering Support group is responsible for providing engineering resources to maintain and upgrade the underground and surface facilities at the Interaction Regions. The group acts on behalf of the detector collaborations in a coordinating capacity with the Facilities Engineering Department (Technical Services Division) to set goals for facility planning and operations. This group also works with the collaborations on planning detector subsystem assembly and detector maintenance procedures.

The Cryogenics staff, working closely with the detector collaborations, will provide engineering support for cryogenics upgrades and modifications, including the planning, design, procurement, and tests.

In a similar manner, the Electrical staff will be involved with operations and maintenance of technical systems such as the magnet power supply and bus, cryogenic electrical systems, power for HVAC systems in detectors, and 400-Hz power. The electronics engineering personnel will provide support to the detector groups for the development and maintenance of electronic components and systems.

The Mechanical personnel will have responsibilities for the design, operations, and maintenance of air systems interior to the detectors, water systems (LCW and MCHW), and various gas systems as required by specific detectors. They will also aid in the implementation of detector modifications, and will seek to optimize the use of assembly and installation facilities and rigging and lifting equipment for the major detectors to reduce the cost of the detector assembly and maintenance.

Other support for the detector collaborations will involve assistance with safety analysis and quality assurance programs for the experimental systems. The safety effort includes hazard identification and analysis for the detector. General support is also provided for systems integration. The Q/A staff, working closely with the collaborations, will develop appropriate quality assurance implementation plans and procedures associated with the experimental systems operations.

Test Beam Operations

Calibration beams were deemed necessary at the SSCL on the basis of collider experience at Fermilab and CERN. Current design calls for a 200 GeV proton beam to be extracted from the MEB through a switchyard to three targets in a target hall.

The operation of the primary extracted beam and the target stations is the responsibility of the Accelerator Operations Department. The operation of the secondary beam lines and the calibration/experimental hall is included here. A 5-day operation with 2 shifts/day is projected on the average with ~8 hours of beam time and 8 hours of preparation or change. A crew of 8 FTEs is estimated for each shift. The crew will operate the secondary beam lines and assist in the set-up and operation of tests and experiments. They will also maintain associated power, water, and gas systems for the facility.

PHYSICS COMPUTING

Many concepts and models for off-line computing are being studied to determine the most effective architecture for handling the projected detector data rates. Studies are currently under way to examine the possible integration of Level-3 triggering with off-line production systems. The use of distributed computing techniques and commercially available RISC technologies will determine the architecture for major off-line resources. Large data bases and data management systems will be needed to organize, store, and distribute data. Concepts of regional computer centers are also being evaluated. The primary resource for processing experimental data will reside at the SSCL while a capability is provided for physicists to access these data from the central data bases through a standard query interface.

In order to manage and support the above systems, the Physics Computing Department will be organized in two groups. One group will operate and maintain the computer systems and networks for off-line analysis. The second group will provide technical support to the detector collaborations by way of hardware and software development and maintenance that will be required in operations of the detectors.

Computer Operations

Experimental Systems Computer Operations will be primarily responsible for providing off-line analysis capabilities to all the major detector collaborations. The responsibility will require a close coordination of the off-line computing requirements with the overall computational planning of each experiment.

FY2000 computer operations will consist of those resources required to operate and maintain off-line computing systems, which provide capabilities needed by physicists for production, analysis, and simulation of physics data acquired from the two large detectors and smaller experiments. Included are systems for software design, coding, testing, integration, and maintenance. It is assumed that off-line computing systems, although supporting multiple experiments, will be located in a common facility and, where applicable, resources will be shared between experiments.

Because of the large amount of experimental data (approximately 2×10^{15} bytes of raw data each year of operation), it is estimated that approximately 10^6 SSCUPS (SSCUP is a measure developed by the SSCL roughly equivalent to the performance of a VAX 11/780) will be required for first-pass data reconstruction. This will result in a requirement for a data storage capacity at the off-line computing facility of 4×10^{15} bytes for each year of operation. This storage would be handled in automated systems capable of accessing up to 4×10^4 19mm helical scan tapes each with the capacity of 100 Gbyte/reel. Disk farms consisting of high speed disk arrays and distributed disk for analysis stations will have a capacity in excess of 2×10^{12} bytes. Local area networks (LANS) will provide the backbone for interconnecting data reconstruction ranches, data archival facilities, and user workstations. The LANS also provide a high capacity gateway to wide area networks (WANS) used for communication among collaborators and transfer of data files to a user base, which may be typically 400 simultaneous users from a community of 2000 worldwide.

Operation of these systems will require a 3-shift-7-day/week schedule. Support personnel will include: operators, systems administrators/managers, network support, documentation specialists, tape librarians, system maintenance technicians, applications support, and shift supervisors. These personnel will operate and maintain the distributed computing environment consisting of multi-processor workstation-like computers, which will make up the data reconstruction and analysis ranches and data archival facilities. Support will include maintaining disk farms, automated tape handling systems, data distribution facilities, libraries, coordination with on-line systems, and communications/network resources.

Computing Technical Support

The activities of this group thus far have been focused on developing resources to support work on physics simulations to guide detector design. R&D projects have already been initiated with existing collaborations to investigate database technologies and their applicability to the analysis and distribution of experimental data and high-speed tape technologies for data storage. Software engineering tools and methodologies for use in the development of major software applications for on-line and off-line systems are under review.

In the period before FY2000, the computing group will be involved in the development of methods for high speed data storage and retrieval as well as optimized methodologies for the analysis of many petabytes (10^{15} bytes) of data. The off-line architecture necessary for the collection and analysis of data will be implemented. The development of software as well as hardware systems requirements will define the basis structure and data relationships for the off-line analysis programs. Code structures, management, and engineering tools will be incorporated into the software development activities.

At the start of Collider operations, the technical support group will be heavily involved in the support of data production, analysis, and distribution systems for all SSCL detectors. In addition the group will provide input and design criteria for the continued development of the overall SSCL computing resources. Responsibilities will include user support, systems programming, physics applications, software development, off-line analysis, on-line support, and systems integration and development. Personnel will assist and support the detector groups with the acquisition and analysis of data as well as the development and up-grade of hardware and systems application software.

COST AND MANPOWER SUMMARY

The manpower estimates for the Physics Division office and the groups within each of the three departments are provided in Table 4-3. The associated costs for M&S and equipment are provided in Table 4-4.

Table 4-3

Physics FY2000 Operations Manpower
(Costs in FY91 K$)
FTE's One Shift

Functions	Manage	Admin	Clerical	Physics	Engr	Design	Acc Op	Techs	Craft	Labor	Total	Four Shift Operations Total
	E3	(E1+E2)/2	N2	E2	E2	E1	E1	E1	N3	N2		
Physics Div Office	3.0	2.0	3.0	2.0							10.0	10.0
ES & H			1.0	2.0	1.0						4.0	4.0
Total	3.0	2.0	4.0	4.0	1.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0
Physics Research	2.0	1.0	2.0								5.0	5.0
Physics Research Staff	18.0			177.0							195.0	195.0
Technical Support					11.0	4.0		20.0			35.0	35.0
Theory	5.0			20.0							25.0	25.0
Adm/Clerical Support		3.0	14.0								17.0	17.0
User Support		2.0	12.0	1.0							15.0	15.0
Total	25.0	6.0	28.0	198.0	11.0	4.0	0.0	20.0	0.0	0.0	292.0	292.0
Exp Program Operations	2.0	2.0	2.0	1.0	1.0						8.0	8.0
Area #5			1.0	2.0	3.0			11.0	4.0		21.0	51.0
Area #8			1.0	2.0	3.0			11.0	4.0		21.0	51.0
Area #1			0.4	1.0	1.0			4.0	2.0		8.4	20.4
Area #4			0.1	0.3	0.5			1.0	0.5		2.4	6.0
Engineering Support	1.0	1.0	3.0		23.0	12.0		30.0			70.0	70.0
Test Beams (2 shifts)				1.0	1.0			5.0	1.0		8.0	16.0
Total	3.0	3.0	7.5	7.3	32.5	12.0	0.0	62.0	11.5	0.0	138.8	222.4
Physics Computing	2.0	1.0	2.0								5.0	5.0
Technical Support	1.0	1.0	2.0	6.0	18.0	4.0		28.0			60.0	60.0
Central Computing	1.0	1.0	3.0	3.0	5.0			15.0			28.0	58.0
Total	4.0	3.0	7.0	9.0	23.0	4.0	0.0	43.0	0.0	0.0	93.0	123.0
TOT FTE PHY RESEARCH	**35.0**	**14.0**	**46.5**	**218.3**	**67.5**	**20.0**	**0.0**	**125.0**	**11.5**	**0.0**	**537.8**	**651.4**
PHYSICS RATES ($/hour)	44.3	22.8	13.4	25.9	25.9	19.7	19.7	19.7	18.3	13.4		
PHYSICS COSTS PER YEAR (K$)	112.8	57.9	34.1	65.8	65.8	50.0	50.0	50.0	46.5	34.1		
TOT FTE'S COST PER YR (K$)	**3949.3**	**811.2**	**1584.9**	**14374.9**	**4444.8**	**1000.9**	**0.0**	**6255.3**	**534.2**	**0.0**	**32955.8**	**39050.9**

Four Shift Operations

TOT FTE PHY RESEARCH	**36.1**	**15.1**	**49.7**	**230.5**	**82.2**	**20.0**	**0.0**	**195.6**	**22.3**	**0.0**	**651.4**
PHYSICS RATES ($/hour)	44.3	22.8	13.4	25.9	25.9	19.7	19.7	19.7	19.3	13.4	
PHYSICS COSTS PER YEAR (K$)	112.8	57.9	34.1	65.8	65.8	50.0	50.0	50.0	46.5	34.1	
TOT FTE'S COST PER YR (K$)	**4070.2**	**873.3**	**1694.4**	**15179.2**	**5410.0**	**1000.9**	**0.0**	**9766.9**	**1035.9**	**0.0**	**39050.9**

Table 4-4
FY2000 Research Operations Cost Summary
(FY91$M)

Function	Manpower	M&S	Equipment	Total
Physics Division Office	0.9	0.4		1.3
Physics Research	19.1	8.7[1]	2.0	29.8
Experimental Facilities Operations				
Exp. Facility Operations	7.6[3]	6.6	33.0[2]	47.2
Engineering Support	3.8	1.5		5.3
Test Beams	0.9	0.5	0.3	1.7
Physics Computing	7.2[4]	2.8	5.0	15.0
Totals:	39.5	20.5	40.3	100.3

[1]Includes 2.0M$ for User Support. The remaining $6.7M is based on current SSCL experience.
[2]Primarily Detector Modifications and Maintenance.
[3]Includes $0.3M for shift differential compensation (not included in Table 4-3).
[4]Includes $0.2M for shift differential compensation (not included in Table 4-3).

5
SSCL OPERATIONS SUPPORT

Chapters 3 and 4 provided projections for the operation of the accelerators and the operation of the detectors and experimental facilities covering the overall technical operations at the SSCL. In this chapter we describe the remaining Laboratory functions that are required to support the technical operations and the Physics Research program. As illustrated in Figure 1-1, the remaining divisions include the Directorate, the Administrative Services and Support Division, and the Laboratory Technical Services Division. The primary tasks and responsibilities of these divisions are described below. Manpower estimates and associated overall costs are provided for the period of operations.

THE DIRECTOR'S OFFICE AND THE DIRECTORATE

The projected organization of the overall Laboratory functions in this area is illustrated in Figure 5-1 and briefly described below. The associated manpower and costs are summarized in Table 5-1.

The Director's Office

The central office for overall SSCL operations is the Director's office which includes the Director, Deputy Director, Associate Director, and immediate support staff. The SSCL Director is responsible for total Laboratory operations including the accelerators, the research program, and associated Laboratory infrastructure to meet the needs of the international High Energy Physics Program in the 21st century. The Director is also responsible for all Laboratory policies and procedures.

The Directorate

The Directorate includes a number of offices: Education; External Affairs; Environment, Safety and Health (ES&H) Oversight; Quality Assurance (Q/A) Oversite; International Coordination; Legal Counsel; Planning; Technology Transfer; Library; and Users (see Figure 5-1).

The Education Office is creating a national resource at the SSCL for science education. It maintains contact with educators and manages a number of programs such as summer internships at the Laboratory for high school and college students, work-study programs, and assistance with secondary school curriculum development. The "Adopt-a-Magnet" program, for example, provides modules for the teaching of science at all levels from kindergarten through twelfth grade, using the SSC superconducting magnets as a point of connection with the Laboratory. The staffing and costs presented here are only those supported by high energy physics. Additional support is expected from other sources.

External Affairs serves as the Laboratory's point of contact with the press and the general public. It disseminates information about the SSC through printed and electronic mail newsletters, special publications, posters, press conferences, exhibits, and workshops. A speakers bureau fills the many requests from private organizations for speakers about the SSC with the help of volunteer speakers from the Laboratory staff.

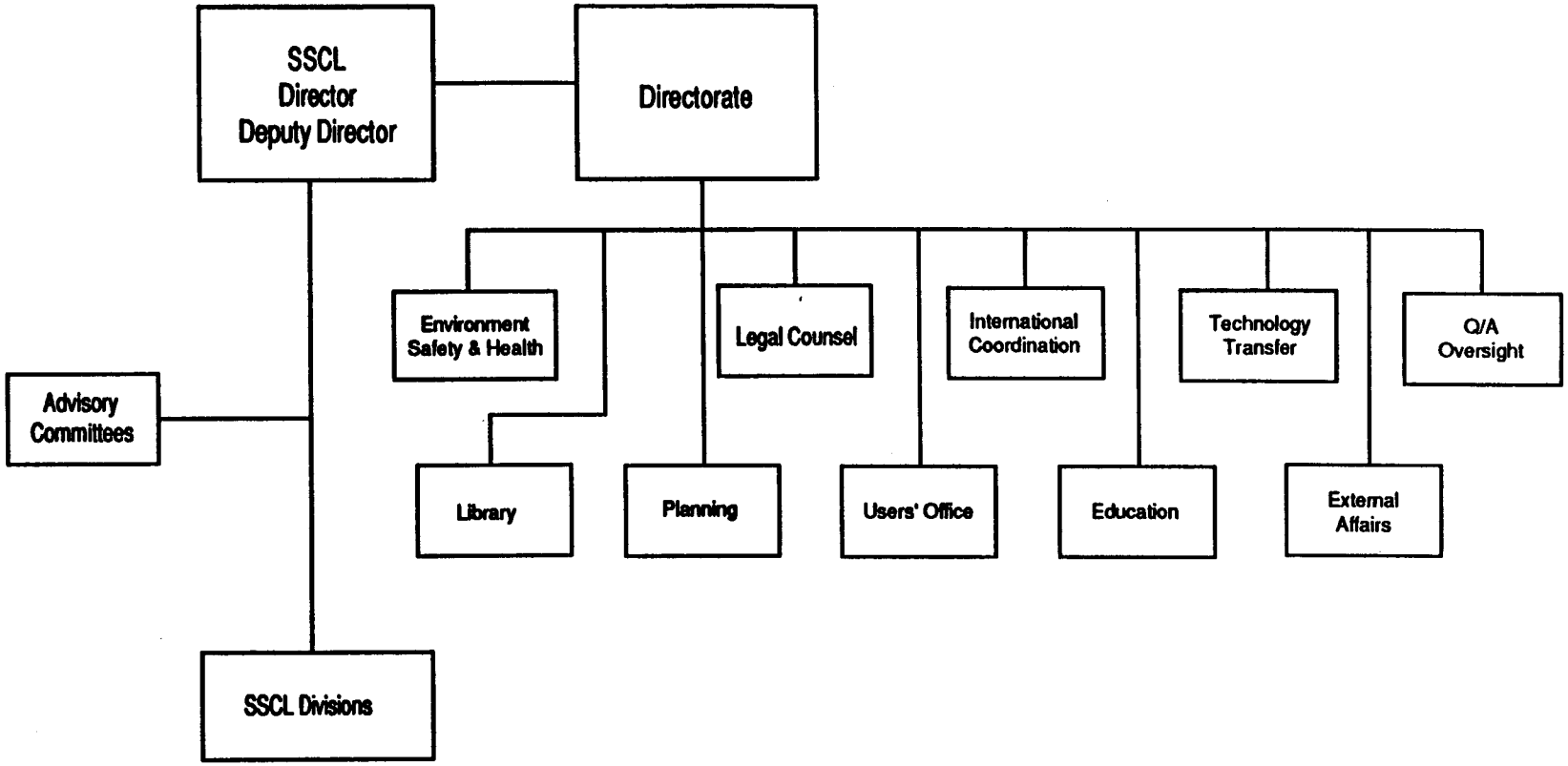

Figure 5-1
Director's Office and Directorate

Table 5-1
Directorate Staff and Associated Costs
FY2000

	FTE's						
Staff Categories	E_3	E_2	E_1	N_3	N_2	N_1	Total
Director's Office	3	4	2		3	1	
International Coordination		1			1		
Legal	1	6	1			2	
ES&H	5	15	8	10	15	5	
Planning	1		2			1	
User's Office		1			2	2	
External Affairs	1	1.5	2		2		
Education	1	1	2		1		
Technology Transfer	1				1		
Library		7	7	3	7	1	
Quality Assurance	1	1			1		
Total FTE	14	36.5	24	13	33	12	132.5
COSTS							
Annual Rates (FY91K$)	125.0	74.1	39.2	38.5	34.9	24.3	
Manpower Costs (M$)	1.75	2.70	0.94	0.50	1.15	0.29	7.3
M&S ($M)							2.5
Subcontracts (M$)							0.7
Contract Fee (M$)							1.5
Library Books/Subscriptions							1.0
Operations Total							13.0
Library Equipment							0.05

Environmental Safety and Health (ES&H) develops environment, safety, and health policies that can be implemented in a demonstrable manner, consistent with applicable DOE Orders. The office provides liaison with DOE on ES&H policy matters to keep the Laboratory informed of changes in regulations or DOE orders. This office monitors ES&H policy compliance at the Laboratory and investigates any significant ES&H occurrences or deficiencies and develops programs to improved safety practices.

The central ES&H office in the Directorate will supervise all Laboratory ES&H activities and coordinate ES&H functions that are part of the responsibility of each division. The central office will include a Medical Department, a Safety Department, and a Department of Environmental and Industrial Hygiene.

International Coordination coordinates the Laboratory's contacts with other countries that may participate in the construction, operation, or scientific research programs of the SSC. The office sets up and coordinates technical meetings at the institutional level to discuss possible areas of collaboration, and supports the Department of Energy in its negotiations at the governmental level.

Legal Counsel advises Laboratory management on legal issues affecting the Laboratory's construction and operation. Such issues may include contracts, personnel matters, equal opportunity and small business matters, patents, and the prosecution and defense of legal actions. This department also provides internal audit functions for the Laboratory and plays a major role in all matters relating to the Laboratory prime contract.

Planning provides a broad range of support to the director in many areas including the development of long-term plans for Laboratory operations and improvements, as well as the coordination of the annual FTP/A funding request. Other examples include overseeing the creation of a master plan for development of the Laboratory site and the development of long-range operations plans for the accelerators and the experimental facilities.

Technology Transfer assesses technology developed at the Laboratory and supports its transfer from SSCL to industry. The office maintains contact with industrial firms that may have an interest in such technology, sets up Cooperative Research and Development Agreements to develop technology in industry where appropriate, and seeks to identify inventions at the Laboratory that are suitable for patents.

The Users Office serves as a point of contact for all scientists who use or plan to use the SSC research facilities. It provides the users and the Laboratory with a wide range of information and assistance, for example, identification of users with authorized access to the site, organizational support for meetings, and logistic support for long-term visiting scientists.

Library Services, as part of a major educational institution, provides information resources and services in high energy physics and those fields relevant to the design, construction, and operation of the SSCL. These areas include accelerator physics, most areas of engineering, conventional construction, computing, and mathematics. The Library also provides substantial support for the experimental physics collaborations and attempts to meet the information needs of students and teachers involved in SSCL educational programs and the general public interested in HEP. The Library is also responsible for collecting and preserving the Laboratory's historically significant records, maintaining the DOE/FOIA Public Reading Room, and meeting the Laboratory's other research, technical, and administrative information needs.

THE ADMINISTRATIVE SERVICES AND SUPPORT DIVISION

Support activities for the overall Laboratory include financial planning, accounting, procurement and contract services, travel services, personnel services, minority affairs, and centralized records management. Each of these functions is briefly described below. The division structure is illustrated in Figure 5-2. The associated manpower and costs are summarized in Table 5-2.

Administrative Services Departments

The Division Office directs and oversees all the departments whose functions are indicated below. The office consists of the division director and his or her support staff.

The Accounting and Finance Department is headed by the Chief Financial Officer. Responsibilities include overall Laboratory budget and accounting, fiscal policy and procedural controls, preparation of fiscal year budgets, tracking and reporting, and control of expenditure of funds. The general accounting functions include general ledger and financial statements as well as property and stores accounting. This office is responsible for the development and implementation of financial policies and procedures that conform with generally accepted accounting principles as well as compliance with DOE regulations. Other tasks include preparation of laboratory financial reports and payment of payroll, invoices, and travel for laboratory personnel and guest scientists. The operation of computer systems required for budget and accounting activities is also included.

The Procurement and Contracts manager and staff are responsible for the solicitation, negotiation, award, and administration of subcontracts. Procurement includes small purchases, orders for off-the-shelf materials/equipment, and formal subcontracts for major systems. Also included are the operation and support of data systems necessary for management oversight, including record-keeping associated with small and disadvantaged business subcontracting.

The Travel Service manager and staff develop and administer travel policies, authorize travel through issuance of trip numbers, determine amount of travel advances, and coordinate travel arrangements (air, hotel, car) for SSCL personnel and visitors through a travel subcontractor.

The Personnel manager and staff are responsible for SSCL staffing and recruiting, administration of personnel policies, benefits, employee relations, employee development and training, educational aid, relocation, records, and compensation. The office ensures laboratory compliance with federal and state regulations, professional standards for personnel practices, and the prime contract with DOE.

The Minority Affairs director and staff are responsible for two areas: Small and Disadvantaged Business Utilization and Equal Employment Opportunities/Affirmative Action.

SADBU responsibilities include contract compliance monitoring, subcontracting ID and SADBU directory compilation.

EEO/AA responsibilities include contract compliance, government agency coordination, EEO awareness training, grievance hearings and investigations, and report preparation. Both areas share responsibility for community outreach efforts

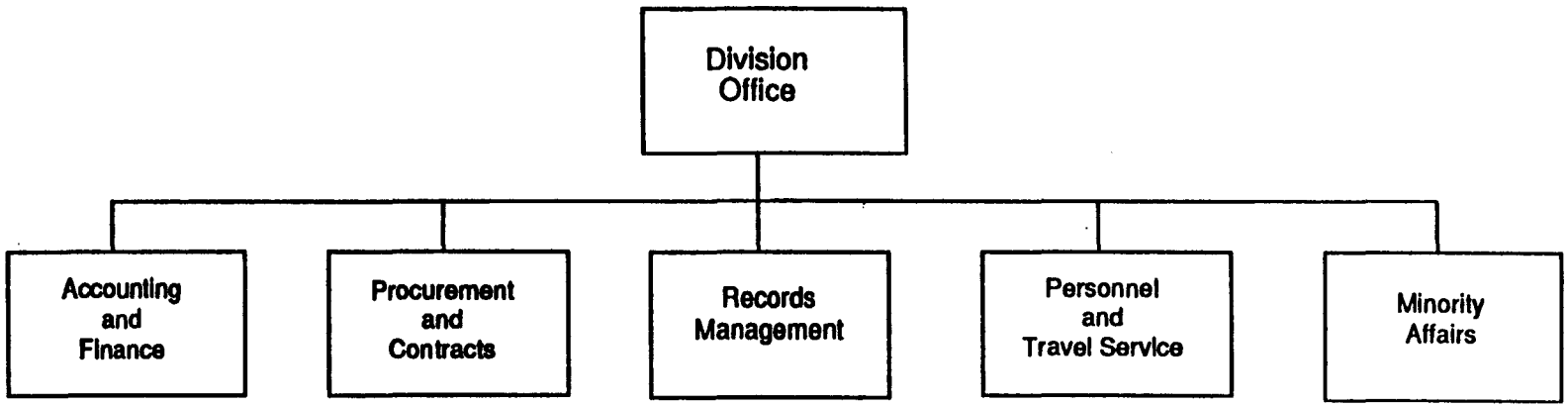

Figure 5-2
Administrative Services and Support Division

The Records Management department is responsible for planning, controlling, directing, organizing, training, promoting, and other managerial activities related to the creation, maintenance, use, and deposition of records to achieve (1) adequate and proper documentation of policies and transactions, and (2) effective and economical management of the Laboratory's recorded information. Essential elements include issuing up-to-date program directives and disposition schedules, properly training those responsible for implementation, and carefully evaluating the results to ensure adequacy, effectiveness and efficiency in the operation of file stations, central files, records retention center, vital records, equipment and supply standards, and related technologies.

Table 5-2
Administrative Services Staff and Associated Costs
FY2000

	FTE's		
	E	N	Total
Division Office	1	1	
Accounting/Finance	28	22	
Procurement/Contracts	30	14	
Human Resources & Travel	18	16	
Minority Affairs	4	1	
Records Management	7	2	
Total FTE's	88	56	144
COSTS			
Annual Rates (91K$)	67.2	28.8	
Manpower Cost (M$)	5.9	1.6	7.5
M&S (M$)			1.7
Total (FY91 M$)			9.2
Capital Equipment (M$)			0.3

THE LABORATORY TECHNICAL SERVICES DIVISION

The Laboratory Technical Services Division (LTS) was established to provide support services to the SSCL through the construction phase, with continuation of these in support of the operational Laboratory. As in other laboratories, these efforts are more efficiently provided through centralized management, although the services are in support of all technical and administrative areas of the Laboratory. Support includes plant facilities operation and maintenance, transportation and communication systems, and general shop facilities. These and other major categories of the LTS responsibilities are shown in Figure 5-3. A brief description of the function of each department is given below. Associated manpower and costs are summarized in Tables 5-3 and 5-4.

Some Laboratory support services (security, custodial, and cafeteria) are subcontracted. The personnel in these subcontracts are not included in the Laboratory staff. The costs are shown in Table 5-4.

The Division office provides overall management of the LTS Departments and their associated tasks and plans activities to effectively support the technical divisions. The office includes a Human Resources group, a Planning and Controls group, and an ES&H group. The Human Resources group implements and administers personnel policies and procedures. The Planning and Controls group provides base cost/schedule planning and control support to all LTS department managers; develops, operates and maintains C/S^2 compliant systems and procedures; and provides for management and administration of the LTS planning and control function. Lastly the ES&H group provides overall supervision and monitoring of ES&H activities for the division.

LTS Departments

Facilities Engineering and Maintenance is responsible for modifications, operations, and maintenance of completed facilities exclusive of accelerators and experimental halls. During the construction period, the Conventional Construction Division (CCD) has the responsibility for providing design specifications and overseeing the design and construction of SSCL buildings and facilities that are executed by the AE/CM. It is expected that experienced CCD personnel will become senior staff members of the Facilities Engineering and Maintenance group in the operations phase. Areas of responsibility include the following:

- Building maintenance consisting of structural systems (walls, roofs, floors), HVAC, electrical power and water up to technical user interface, and safety and fire protection systems (except for tunnels and controlled collider access points).
- Infrastructure maintenance consisting of utilities to within five feet of the building enclosure, water systems, waste treatment, ground surface (roads, bridges, sidewalks), landscaping, open grass lands, and watershed.

Design Support provides common Computer Aided Design (CAD) and drafting services in addition to support to CAD groups in other divisions. These services include application specialists, CAD data management, selection and training of CAD operators, maintaining the interfaces between specialized Laboratory CAD systems, and supporting common print/plotter groups. The Design Support Group works closely with the LTS Facilities Engineering Group and provides support to other Laboratory divisions. The Design Support Group also operates the Technical Document Control and Engineering Drawing Reproduction Center.

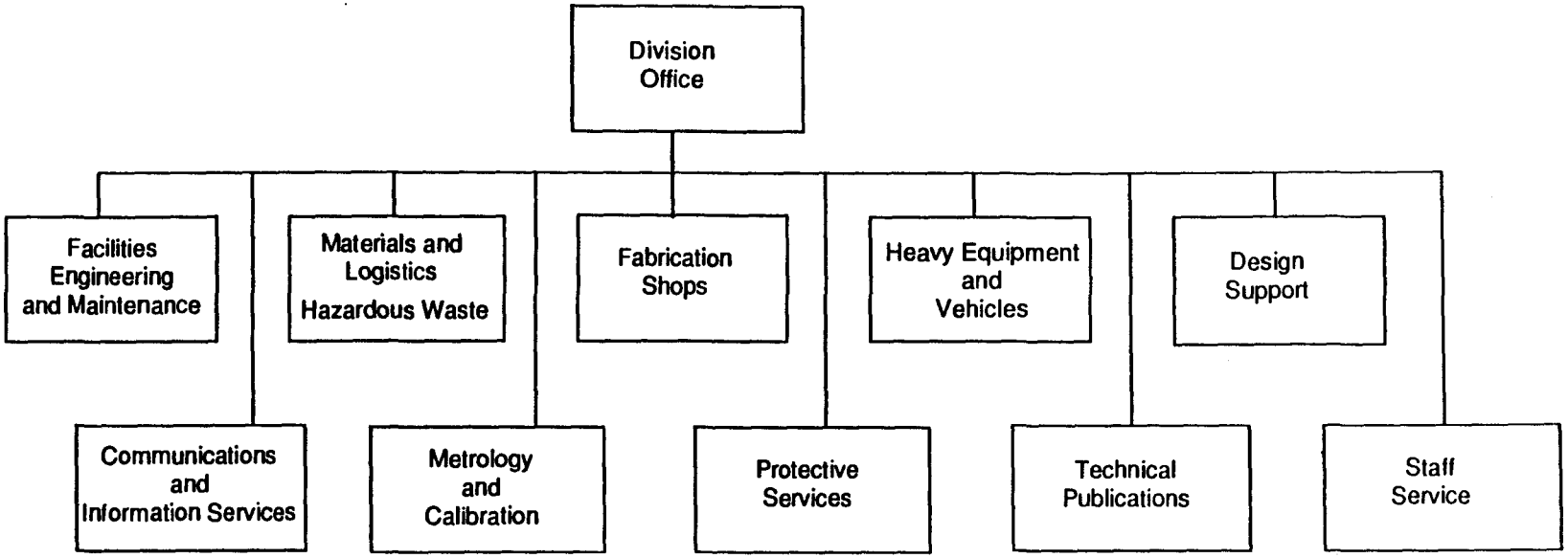

Figure 5-3
Laboratory Technical Services Division

Table 5-3
Technical Services Staff Costs
FY2000

	FTE's						
Staff Categories	E_3	E_2	E_1	N_3	N_2	N_1	Total
Management (Division Office)	6	4	6	2	8		26
Engineering Standards		2					2
Facilities Eng. & Maintenance.	2	11	22	10	49	21	115
Design Support	1	4	6	3	9	3	26
Material & Logistics		2	4	15	25	10	56
Hazardous Waste Removal		2	2			1	5
Fabrication Shops		8	12	35	35	5	95
Heavy Equipment & Vehicles		1	1	5	6		13
Information Services	1	10	14	8	8		41
Communications	1	7		8	8		24
Metrology & Calibration	1	2	2	8	6		19
Protective Services	1	2	4	11	21		39
Staff Services		2	6	27	9		44
Technical Publications	1	4	6	11	6	4	32
Total (FTEs)*	14	61	85	143	190	44	537
COSTS							
Annual Rate (FY91K$)	99.9	66.1	44.4	43.8	34.1	23.1	
Manpower Costs (M$)	1.40	4.03	3.77	6.26	6.48	1.01	22.95

*Does not include GPP personnel.

Material & Logistics is responsible for shipping and receiving of procured materials and equipment including internal distribution of such materials in support of SSCL operations. This function also provides warehousing support, inventory documentation and control of capital and sensitive equipment, stores procurement and distribution of expendable items, and traffic management of shipments to and from the SSCL.

Hazardous Waste Removal will move hazardous waste material from the place of use to designated areas for pickup by disposal personnel. All hazardous waste material will be moved and documented to meet federal, state, local, and Laboratory requirements.

Table 5-4
Technical Services Associated Costs

		K DOLLARS
UTILITIES		
Gas (natural)	$	106
Water/Sewer		1,500
Sub-total	$	1,606
CONTRACTS		
Facilities open service contracts & supplies (electrical, trash, HVAC, plumbing, pest, lawn, fire pumps, roadwork, sewer plant)	$	1,850
Janitorial contract		1,050
Security contract (80 FTE's)		1,400
Sub-total	$	4,300
M&S		
Fabrication Shops supplies		465
Design Support supplies		280
Communications supplies		410
Metrology/Calibration Repair Lab		225
General Services		836
Publications		2,200
Sub-total	$	4,416
EQUIPMENT		
Required for CAD systems, shops, computer services, communications systems, transportation		700
Sub-total	$	700

Fabrication Shops provide for operation and maintenance of the Laboratory general shop facilities and fabrication manufacturing capabilities, including providing, maintenance and calibration of equipment, training as required, and providing a safe environment for operation. The Laboratory's shop and fabrication facilities supported by this function include:

Mechanical Shops
- Central Machine Shop
- Division Support Shops as required
- Fabrication facilities used to manufacture or assemble Accelerator and Detector components

Special Purpose Shops
- Electronic
- Instrument
- Model
- Mechanical Repair
- Welding
- Mobile Shops

Heavy Equipment & Vehicles provides support for the acquisition, logistics management, safety, training and maintenance of material handling equipment. Such equipment includes:

- Fork lifts for warehouse, shops, and assembly areas
- Cranes (fixed and mobile) at shops and assembly areas
- Heavy vehicles
- Heavy equipment maintenance and repair

Information Services provides computer-related services to the Laboratory, including:

- ADPE acquisition and compliance support (hardware and software)
- Work station and PC installation, set up, maintenance and repair, training and network
- User services: planning, updates, modifications, software support and consulting
- License management
- Training: PC utilities, operation system, MIS
- MIS support (hardware and software), support operational MIS, MODS implementation
- Project management systems support (hardware and software)
- Database management for MIS and PMS
- Networks/communications software and protocols (Quickmail, Appletalk, Decnet, TCP/IP [ISM], etc.)

Communications provides services to support lab-wide telephone systems, including help desk services for telephones, networks, video, radio and computers; video teleconferencing systems/facilities operation and maintenance; radio and microwave systems, mobile radio and paging services; and CATV and satellite TV service. Other services include technical support for video and still photography documentation, audio/video duplication, video production, photography prints, audio/visual equipment, and coordination of live and taped programming on the in-house CATV system. Additionally, Visual Media provides support for SSCL training requirements.

The Metrology and Calibration Laboratory functions as an SSC standards laboratory which performs instrument calibrations and non-routine measurements while ensuring NIST traceability. Responsibilities include testing, repair and calibration of measurement equipment, maintaining a periodic instrument calibration recall program in accordance with DOE requirements, and serving as a point of contact for returning unacceptable equipment to vendors for replacement, recalibration, or repair.

Protective Services provides 24-hour security and fire protection lab-wide, including buildings, experimental areas, accelerator access points, and support facilities. Services include operation and maintenance of alarm systems, key control access devices, identification badges, and laboratory emergency service coordination, including:

- ODH confined space and underground rescue
- Hazard material spill response
- Safety
- Fire Department
- Emergency Operations Center
- Ambulance and first aid
- Security
- Hazard material tracking

Staff Services provides services supporting the functions of the SSC Laboratory and its employees that generally can be categorized into the following areas:

- Mail Room and Courier Services process both incoming and outgoing USPS, express mail services and accountability thereof, delivery of both inbound and outbound media as well as internal mail to the various buildings and sites. Additionally, shuttle service is provided between various SSCL buildings and sites. Courier Services provide delivery/pick-up of packages and documents requiring special handling.

- Secretarial Pool Services maintains and administers a group of professional, qualified SSC Lab employees to assist in periods of heavy workload, leaves of absences of regularly assigned secretarial personnel, illness, etc. Additionally, a staff of receptionists is provided to service SSCL entrances/lobbies, assuring appropriate coordination, control, and recording of visitors.

- Food Services administers the cafeteria operations that service the SSCL as well as any special guest dining arrangements and catering services.

- Moving and Furniture Services support the SSCL employees in the physical moving of personnel due to reorganization, changes in facilities, and reassignments. This includes furniture, computer equipment, and other work related materials. Additionally, free-standing furniture planning requirements, inventory, assignment, budgeting and accountability are administered by this group.

- Facility Support Services provides technical support and cost-efficient administration of all SSCL convenience copiers and fax machines. This includes lease, purchase, placement, operation, supplies, and maintenance.

Technical Publications provides lab-wide printing, editorial and graphics services. Its function includes publication support for technical papers and reports, forms design, large volume reproduction, binding, and laboratory photographic services.

General Plant Projects

General Plant Projects (GPP) provides for many types of alterations, additions, modifications, replacements, and non-major construction items that are required for general purposes at a major accelerator laboratory. The items are needed for the general maintenance and/or improvement of the overall Laboratory plant. GPP are intended as short-term projects whose timely accomplishment is essential for maintaining productivity, increasing operational cost effectiveness, and ensuring that the necessary Laboratory support services are available to the technical research effort. It is expected that the LTS Facilities Engineering and Maintenance Department will play a major role in the planning, design, and execution of GPP.

GPP is intended to be responsive to immediate needs of the Laboratory. Some projects are directly related to programmatic support. An example would be a power system up-grade. Other projects are more closely related to plant operation and safety. Specific fire protection improvements could be included in this category. In addition, the future climate will call for special concern for environmental protection at all DOE operating facilities.

While the examples below are somewhat typical of the improvements at existing high energy physics accelerator laboratories, it should be recognized that the SSC injectors are comparable in size to the overall FNAL accelerator facilities. The collider ring represents a significant step of more than an order of magnitude in size greater that the FNAL facilities. While general laboratory buildings will be comparable to FNAL facilities, the larger size of the collider ring will call for substantially larger costs for roads, utilities, cryo facilities, security, etc.

Some examples of potential GPP include the following:

- Road maintenance and up-grades. The substantial weights of magnets and detector components will require a substantial maintenance program.
- Electrical systems modifications and improvements.
- Water systems modifications and improvements.
- Projects aimed at improving environmental protection. Drainage measure and/or habitat restoration could be included.
- Safety and fire protection improvements.
- Cryo plant improvements or additions.
- Security improvements such as additional fences, surveillance systems, and guard stations might be needed.
- Modifications to shops and facilities that might be needed to meet the requirements of future detectors.
- Facilities to provide for laboratory growth. Building additions, office space, and special facilities may be required for the large and increasing number of scientists from institutions throughout the world.

The costs for GPP at FNAL have been in the neighborhood of $5M over the past few years. It is estimated that the SSCL will require this amount in the first year of operation because many of the Laboratory facilities will have been completed in prior years. In particular some of the injector facilities will have been in operation for four years prior to FY2000. The manpower associated with the GPP is estimated at 17 FTEs for FY2000. This manpower is in addition to the operations staff summarized in Table 5-3. The GPP needs may reach as much as $15M by FY2005. This is necessarily a rough estimate as precise requirements cannot be determined at this time.

6
SSCL OPERATIONS SUMMARY

FY2000

The organizational model for the SSC Laboratory was described in Chapter 1. Its purpose was to help ensure that all aspects of the Laboratory operations were considered. Chapter 2 presented a scenario for the physics program for the first years of operation corresponding to the expected increases in luminosity during this period. In Chapters 3 and 4, the staffing levels for the Accelerator and Physics Research divisions were developed in detail for FY2000. Finally, in Chapter 5, a detailed estimate of the manpower in the Laboratory support areas (i.e., the overhead functions) was provided. In the above analysis, the overall goal was to estimate the manpower and associated costs for a fully staffed Laboratory capable of operating and using the SSC facilities to the maximum extent possible. The results are summarized below together with a comparison with previous estimates over the past seven years.

The work here assumes that all construction has been completed and that the schedule for turn-on of the injection accelerators and the collider has been achieved (see Table 1-1).

Note that the manpower and costs projected below are only those for operations of the SSC Laboratory for Collider operations and the associated high energy physics experimental program. It is possible that the SSCL, because of its unique technical expertise and technical facilities, will become involved in other research. An example would be use of the Linac for a medical treatment facility. The plan provided in this report does not include work outside of the high energy program in other disciplines in which the Laboratory could become involved.

Manpower and Costs

The projected manpower for the SSCL in the first year after completion of all construction activities is summarized in Table 6-1. The details of the manpower analysis were presented in Chapters 3,4, and 5 for all areas of the Laboratory. The results indicate a total staff of 2344 FTEs required for operations in FY2000. The labor associated with Accelerator Equipment, AIP, and GPP is also projected and brings the total Laboratory staff to 2428 FTEs. In addition, approximately 500 visiting scientists who are collaborating on the experimental program are expected to be on site. With these numbers and the consideration of some part-time staff as well as contract labor, a total Laboratory population of approximately 3000 individuals is expected.

Table 6-2 provides a summary of the total SSCL costs projected for FY2000. The results are summarized in the major areas of manpower, M&S, utilities, equipment, accelerator improvements, and general plant projects. A total budget of $317M is estimated.

Possible Future Cost Changes

In some areas the potential exists for cost reductions in the projected annual budget for FY2000. In Table 4-4, the equipment budget for Experimental Facilities Operations is estimated at $33M. Of this amount, $28 M is earmarked for the two large detectors, and $5M is intended for the two smaller detectors. This budget provides for annual maintenance and relatively minor

Table 6-1
SSCL Manpower Summary* - FY2000

Laboratory Division	FTE	(FY91) M$
Accelerator	879	49.5
Physics Research	651	39.5
Directorate	133	7.3
Administrative Services	144	7.5
Technical Services	537	23.0
Operations Total	2344	126.8
Accelerator Equipment	13	**
AIP	54	**
GPP	17	**
Non Operations Total	84	
Laboratory Total	2428	

* Data from Tables 3-5, 3-10, 4-3, 4-4, 5-1, 5-2, 5-3
** Labor cost included in Associated Funds

improvements to the detector technical systems. It is anticipated that support from the non-U.S. members of the detector collaborations will continue after the initial contributions for the detector design and fabrication. Such contributions may reduce the overall amounts projected here. The details and possible arrangements for such support will not be available for some time.

In the accelerator area it was noted (Chapter 3) that the costs for cryogens assumed transportation from a distant source. The availability of a nearby liquid nitrogen plant would result in an annual cost savings of $3 M.

The estimate for SSCL power use in FY2000 is judged to be conservative. The Laboratory has focused on the determination of maximum power demand for various systems in order to specify required power station equipment. At this early stage of technical system designs, it is prudent to provide some degree of contingency in the specifications. A more detailed analysis of diversity factors and, in particular, further information regarding detector power use is expected to lower the projected power costs based on the assumed rate of 0.047$/kWh. There is also the possibility that this rate may change in the future as a result of pending negotiations by DOE and power company officials.

Table 6-2

SSCL Total Costs* for FY2000
(FY91 M$)

Laboratory Division	Operations Manpower	M&S	Power & Utilities	Cryogens	Equipment	AIP	GPP	Total
Accelerator Operations	49.5	35.6	**47.5	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 Services	7.5	1.7			0.3			9.5
Technical Services	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

* Data for Tables 3-12, 4-4, 5-1, 5-2, 5-3

** Total Electrical Power for the SSC Laboratory.

Comparison with Previous Estimates

The 1985 Operations and Commissioning Report

The 1985 Operations and Commissioning Task Force Report (SSC-SR-1005) provided the information summarized in Table 6-3. A major purpose of the 1985 report was to determine operational cost differences that would result from various collider magnet designs.

Table 6-3
Comparison with the 1985 Operations & Commissioning Report

	FTEs	
	1985 Report	**Current Estimate**
Injectors	300	
Collider	320	
Cryo Systems	85	
Accelerator R&D	100	
Sub-total	(805)	(879)
Experimental Areas	300	
Facility R&D	150	
Computer Operations	125	
Physics Research	400	
Sub-total	(975)	(651)
Central Shop	100	
G&A @ 40 percent	807	
	(907)	(814)
Total FTEs	2630	2344
MANPOWER COST ($85M)	104.6	
MANPOWER COST ($91M)	~130.0	126.8

The difference between the current estimate and the operations task force report is mainly in the experimental facilities and physics research areas. The 1985 report assumed that there would be 6 large experimental halls in service for 6 major detectors. This is more than projected in current plans which call for 2 major detectors and 2 smaller experiments.

There was no detailed estimate for the Laboratory support functions. If the central shop is added to the G&A estimate, it would amount to an effective overhead of ~53 percent which is considerably higher than current detailed estimates.

The 1988 Life Cycle Cost Analysis of the SSC Best Qualified Sites

The life cycle cost analysis of the best qualified sites (October 1988) used the costs indicated in Table 6-4. The primary data in terms of staffing and associated costs were taken from an analysis by the SSC Central Design Group. The costs were based on national average rates for labor, materials, power, etc., for the purpose of site comparisons with the national average.

The LCC staff estimate was 2274 FTEs which is comparable with the current estimate of 2344 FTEs. The current labor rates for the SSC are ~10 percent higher than those assumed for the LCC.

The Materials and Services (M&S) area differs considerably. The LCC analysis assumed a laboratory average of 50 percent of labor cost. The current more detailed estimate for each SSC Division indicates a greater need which is based on both manpower related requirements and on requirements related to the overall technical systems.

The Accelerator Equipment and AIP categories in the current estimate more accurately reflect FNAL experience for FY2000. Note that significant growth in these areas is expected by FY2005 as described in the next section.

Table 6-4
Comparison with the 1988 Life Cycle Cost (LCC) Analysis Data

	FY91M$	
	LCC Estimate	Current Estimate
Staff	109.3	126.8
M&S*	54.6	81.9
Power and Utilities	50.8	49.1
Accelerator Equipment	32.8	3.0
Detector Equipment	36.0	35.0
Other Equipment		6.4
AIP	12.4	10.0
GPP	9.0	5.0
Total	304.9	317.2

* Including Cryogens

Comparison with the March 1992 Operations and Commissioning Report

The SSCL March 1992 Operations and Commissioning report primarily addressed pre-operations and subsequent operations of the injector accelerators during the construction period. The analysis included also the operation of experimental halls and facilities. The report extrapolated the analysis to FY2000, which will be the first year of total operations after construction is completed. The current estimate is compared with the previous report in Table 6-5. A comparison of the manpower estimate is provided in Table 6-6.

Table 6-5
Cost Comparison with the March 92 Operations and Commissioning Report

	FY91M$	
	March 92 Report	Current Estimate
Staff	109.3	126.8
M&S	65.5	81.9
Power and Utilities	41.2	49.1
Accelerator Equipment	8.8	3.0
Detector Equipment	46.0	35.0
Other Equipment		6.4
AIP	19.8	10.0
GPP	10.0	5.0
Total	300.6	317.2

Table 6-6
Manpower Comparison with the March 92 Operations & Commissioning Report

	FTEs	
	March 92 Report	Current Estimate
Accelerator Operations	708	879
Research Operations	679	651
Overhead Functions	N/A	814
Total		2344

The increase in the staff estimate since the March '92 report resulted from more detailed considerations of the integrated accelerator operations. A more complete picture of the operations organization structure indicated the need for additional personnel in management, engineering and design, and technician support for the three departments of the Accelerator Division. In the Physics Division, additional staff were added for computer operations and user support; however, there was a significant reduction in experimental area operations support.

The increases in the Materials and Services (M&S) area resulted from separate estimates for each technical department as well as new specific estimates for the support divisions. Included also is a more conservative estimate for the cost of cryogens.

The lower costs shown in the current report for AIP, GPP, and Equipment reflect a plan that forecasts lower needs for the Collider which will have only completed commissioning at the start of FY2000. These requirements will grow in subsequent years as indicated in the discussion of FYs 2000 to 2005 below.

Changes from the August 28, 1992 Draft Report

The current report reflects a significant reduction in power costs primarily because of a more careful analysis of power use in non-operating periods. As indicated above further decreases are expected as more design details become available.

Technical manpower has been added to the Accelerator Technical Support Department. This reflects considerations of projected needs and will also provide staff for the Accelerator Operations Department to supplement the operations when needed for vacation and sick leave incurred by the crew for normal operations.

Premium pay has been included for personnel in swing, owl, and week-end operation shifts of the accelerators in the Accelerator Division as well as for computer operations and experimental facilities operations in the Physics Research Division.

Test beam activities have been reduced to a five day/week operation with two shifts: one shift for beam tests and one shift for experimental preparations and/or changes. The support crew for this operation has also been reduced.

A support group has been included for the special handling of hazardous wastes. This group is included within the Materials and Logistics Department of the Technical Services Division.

The staff and associated costs for the SSC Laboratory Library functions have been included in this report. A central Quality Assurance office has also been projected. These are now included in the offices of the Directorate.

The Physics Division has been reorganized to clarify the support function activities. The Experimental Facilities Operations staff has been reduced with the consideration that many of the functions required in the assembly and test of the detectors will have been completed. Specifically, the manpower has been reduced for the swing and owl-shift operations. This reflects a consideration that there is a reduction in tasks during these periods and that personnel can be on-call during periods of emergency. In addition, personnel from each of the four experimental areas can provide some degree of mutual assistance to take care of routine fluctuations in work loads.

The overall staff for ES&H activities has been increased by almost 60 FTEs. This is because of a better understanding of current ES&H requirements as well as recent projections by the newly formed ES&H group at the SSCL. This report reflects a total staff of 181 FTEs in various environmental, safety, and health areas of the different divisions. For convenience, the staff is summarized in Table 6-7. Note that final organizational details will be determined in the future and may differ from those projected in Table 6-7.

The computing functions of the Physics Research Division have been combined into a single department. In the overall Physics Division staff support of computing and computing services, there are modest increases. The overall physics computing staff has been increased by 20 FTEs. Also 10 FTEs have been added to the Accounting/Finance Department of the Administrative Services Division to operate and maintain the computers required for that division. The overall Laboratory computer related staff is summarized in Table 6-8. It should be noted that a Computer Division may be created in the future that would integrate computing activities apart from those specialized in the accelerator controls area.

Table 6-7
Summary of ES&H Personnel

Division	Function	FTE's	
Directorate:	Central Office	6	
	Safety Department	20	
	Medical Department	12	
	Industrial Hygiene Department	20	
			58
Accelerator:	Division Office:		
	Supervision	4	
	Radiation Physics	6	
	Operations Safety	20	
	Cryogenics Safety	8	
	Safety Systems	20	
			58
Physics Research:	Division Office:		
	Supervision	4	
	Exp. Facilities Operation	13	
	Test Beams	2	
	Detector Engineering	2	
			21
Technical Services	Division Office:		
	Supervision	4	
	Fire Protection	35	
	Hazardous Waste	5	
			44
	Total:		181

Table 6-8
Computer Services Summary

Division	Function	FTEs
Accelerator	Computer Controls	68
Physics Research	Computer Dept. Office	5
	Computing Technical Support	60
	Central Computing	58
Administrative Services	Accounting/Finance	10
Technical Services	Laboratory Information Services	41
Total:		242

FY2000 TO FY2005

The objective of the estimate for FY2000 was to establish staff and associated costs for a fully operational SSC Laboratory. As a result, only modest increases in certain departments are anticipated.

For the accelerator operations, a full staff capable of around-the-clock operations of all accelerator systems was estimated. This staff will have evolved from the first Linac operations in FY95. In the first years of collider operations, a large fraction of the staff will direct attention to problems, refinements, and corrections that will be needed to achieve design luminosity and full operational efficiency. As these tasks lessen, more of the members of the Accelerator Technical Support Department as well as the Accelerator Research and Development Group will turn their attention to future improvements, new designs, and new techniques. As a result no significant increase in staff is projected. The major changes in this category will be related to increased power cost as a result of improved operational efficiency and increases in the AIP and Equipment categories.

In the Magnet Systems Department, there will be continued support of operations. In addition, new developments in superconducting magnet technology are planned. The department personnel are highly experienced and will have the capability for undertaking new developments as described in Chapter 3.

For the physics research area, it is assumed that the Experimental Program Operations Department will have been adequately staffed in FY2000. A constant level to FY2005 assumes that there will be no new facilities that would require additional personnel.

The Physics Research Department is expected to have some modest growth as the detectors become operational and new ideas for experiments, data analysis, and detector improvements evolve. This growth will require some corresponding increase in the associated Technical Support area.

It is anticipated that foreign contributions, apart from those for the initial fabrication of the detectors, will continue for future modifications and operations of the various detectors. These contributions normally will be recognized in the agreements between the SSCL and the institutions of each detector collaboration. No increases are projected in the annual equipment budget for detectors.

In the Laboratory support area, the Administration Services Division and the Directorate are expected to remain near their FY2000 levels. A modest increase is projected for the Technical Services Division. This is expected primarily because of increased demands from the SSCL Physics Research Program and from increased user needs.

Lastly, the General Plant Projects area is expected to grow significantly as the need for maintenance and modification of facilities increases. At Collider turn-on, some of the injector facilities and other Laboratory buildings will be ~5 years old and will require appropriate maintenance. A starting value of $5M is estimated for FY2000 rising to a plateau of $15M in FY2005.

In total, the above plan may require a staff increase of ~200 FTEs by FY2005. An approximate estimate for the overall cost increases is provided in Table 6-9. The results would support prediction of a budget of ~$369M (FY91$) in FY2005.

Table 6-9
Potential Cost Increases
From FY2000 to FY2005

Area	(FY91 M$) Cost Increase
Manpower and M&S	18
Power & Utilities	9
AIP	10
Accelerator Equip.	5
GPP	10
Total	52

POTENTIAL IMPROVEMENT PROJECTS

Once the Collider is fully operational and the SSC has reached its design luminosity, the Laboratory will continue to strive toward higher luminosities and energies with increased reliability. The list of accelerator improvement projects is likely to be determined by R&D efforts such as those described in Chapter 3. Examples would include lower temperature operation of the Collider magnets in order to achieve higher energies; emittance reduction techniques, such as electron cooling at lower energies or bunched-beam stochastic cooling at higher energies to reduce the proton beam emittance; bunch coalescing to generate higher intensity bunches; and improvements to the interaction region magnetic elements to permit a smaller beam spot size at the interaction point.

Each of these items would involve modifications to the current accelerator systems. Lower temperature would require improvements to the cryogenic plants throughout the Collider. Beam cooling systems and bunch coalescing generally require new features to RF systems as well as special beam pick-ups and relay circuits. An attempt has been made to keep current accelerator designs flexible enough to take advantage of such future enhancements.

As for the interaction region magnets, the challenge would be to produce quadrupoles that could provide higher focussing strengths, yet have enough aperture to allow larger beams to pass through them off-axis. In addition, the magnets would have to be able to handle more power from the reactants of the beam-beam collisions that would occur as the luminosity increased. The current interaction region optical design has the potential of operating at a $\beta* = 0.25$ m, in contrast to the nominal value of 0.5 m. There will undoubtedly be a push to reduce this number even further.

The designs of the east and west complexes allow for the possibility of building beam bypasses around the initial interaction regions. If such a scheme were to be employed in the future, the number of interaction regions could be increased from four to eight. This would generate space for a third, and perhaps a fourth, large detector for high luminosity operation. It would also allow large experiments to switch in and out of the accelerator, which could improve operating efficiency in the HEP program.

Other improvement projects will involve the smaller colliding beams experiments. Since these will be easier to assemble and disassemble than the major detectors, changes to these areas are likely to occur more frequently. Making such changes would again be simplified with the implementation of a beam bypass.

An improvement program to provide for colliding polarized proton beams would also be possible. This would involve the installation of a polarized ion source, and the development of procedures to preserve the polarization of the beams from the ion source to the Collider. The use of devices such as Siberian snakes would be required in the higher energy machines (Medium Energy Booster, High Energy Booster, and the Collider) to avoid depolarization. The current design of the machine lattices has sufficient flexibility to allow for the insertion of such devices.

The potential also exists to provide the HEP community with higher energy extracted beams. At present, the Medium Energy Booster is planned to provide 200 GeV proton beams to the test beam area for detector research, development, and calibration. This area could be turned into a fixed target experimental facility in the future. With the construction of a new tunnel and the addition of the appropriate hardware, the High Energy Booster could provide 2 TeV proton beams to the same facility. In addition, a low-intensity 20 TeV beam could conceivably be extracted from the Collider at the east complex. An Expression of Interest already has been submitted to the Laboratory for such an experiment.

At the other end of the energy spectrum, use of the low energy accelerators for medical or material science applications may also be a possibility.

Many of the above mentioned experimental program projects would involve improvements and/or modifications to the accelerator systems. Beam optics requirements could differ from one experiment to another. Insertion of resonant extraction devices for fixed target beams from the HEB and RF system modifications as proposed in the 20 TeV fixed target proposal are two more examples.

Apart from possible future improvements to the accelerator facilities listed above, there is the possibility of major improvements or additions to the experimental areas. These could include new large and/or small detectors, new interaction regions, and associated experimental halls and above ground facilities.

APPENDIX

SSCL FY91 DIVISION LABOR RATES

LABOR CATEGORY	ADOD HRS	ADOD $	ADOD $/HR	ACCEL HRS	ACCEL $	ACCEL $/HR	PMO HRS	PMO $	PMO $/HR	CCD HRS	CCD $	CCD $/HR
E1	26,497.00	501,105.17	18.91	127,677.00	2,369,733.55	18.56	3,868.80	84,055.18	21.73	5,163.00	91,223.20	17.60
E2	48,810.50	1,415,188.55	28.99	213,228.20	5,751,224.60	26.97	31,359.50	879,776.49	28.05	21,951.50	662,221.31	30.17
E3	19,128.00	753,871.48	39.41	35,035.10	1,358,740.89	38.73	17,093.50	816,654.23	47.78	4,091.50	197,412.64	48.25
N1	2,801.00	24,475.58	8.41	22,737.10	199,281.82	8.76	5,587.50	49,687.57	8.89	2,541.80	20,705.79	8.15
N2	4,270.90	58,423.80	13.21	99,605.00	974,479.92	14.00	13,868.10	189,023.52	13.63	8,370.00	80,553.85	12.65
N3				27,507.80	479,852.14	17.44	0.00	0.00				
TOTAL	101,307.40	2,751,082.66	27.16	495,780.20	11,131,292.89	22.45	71,777.40	2,019,176.97	28.13	40,137.80	1,052,116.99	26.21

LABOR CATEGORY	PHYS IND(LIB) HRS	PHYS IND(LIB) $	PHYS IND(LIB) $/HR	ADMIN HRS	ADMIN $	ADMIN $/HR	COMPUTING HRS	COMPUTING $	COMPUTING $/HR	MAGNETS HRS	MAGNETS $	MAGNETS $/HR
E1	7,482.00	128,243.80	16.87	58,930.30	991,816.38	16.83	28,482.50	473,739.23	17.89	108,305.60	2,004,625.71	18.51
E2	2,250.50	58,348.01	25.04	94,082.00	2,485,040.63	26.41	27,311.50	699,992.73	25.63	201,222.10	5,432,598.34	27.00
E3				12,651.40	469,482.54	37.11				32,618.30	1,241,515.34	38.06
N1	2,857.50	24,719.08	8.65	61,019.80	604,855.88	9.91	5,271.40	54,829.60	10.36	35,371.80	356,689.77	10.08
N2	5,813.50	74,848.05	12.84	44,291.00	584,384.51	12.74	25,710.70	346,390.70	13.47	41,249.70	576,829.18	13.98
N3										6,351.30	114,956.07	18.10
TOTAL	18,403.50	281,957.72	15.32	270,974.50	5,115,559.72	18.88	84,776.10	1,574,752.26	18.58	425,118.80	9,727,214.41	22.88

LABOR CATEGORY	GEN MGR (IND) HRS	GEN MGR (IND) $	GEN MGR (IND) $/HR	PHYS HRS	PHYS $	PHYS $/HR	DIR HRS	DIR $	DIR $/HR	LTS HRS	LTS $	LTS $/HR
E1	2,458.50	44,328.41	18.03	31,046.80	610,520.87	19.66	15,011.10	231,002.69	15.39	48,875.40	852,892.37	17.45
E2	178.50	3,451.97	19.23	77,084.60	1,993,930.46	25.87	28,426.00	827,624.70	29.12	79,031.60	2,052,708.75	25.97
E3	1,857.50	88,869.70	47.84	13,750.20	609,545.16	44.33	13,557.50	748,950.10	55.24	8,464.00	332,478.43	39.28
N1	2,729.50	23,128.27	8.48	18,502.50	189,131.76	10.22	10,776.50	102,817.73	9.54	91,653.20	832,022.63	9.08
N2	291.50	4,091.40	14.04	12,112.90	162,184.55	13.39	12,026.30	164,851.46	13.71	94,253.50	1,261,664.88	13.39
N3				8,568.50	120,261.97	18.25				4,399.90	75,753.70	17.22
TOTAL	7,515.50	163,869.75	21.80	158,065.50	3,885,574.77	23.17	79,797.40	2,075,246.68	26.01	328,677.60	5,407,518.76	16.55