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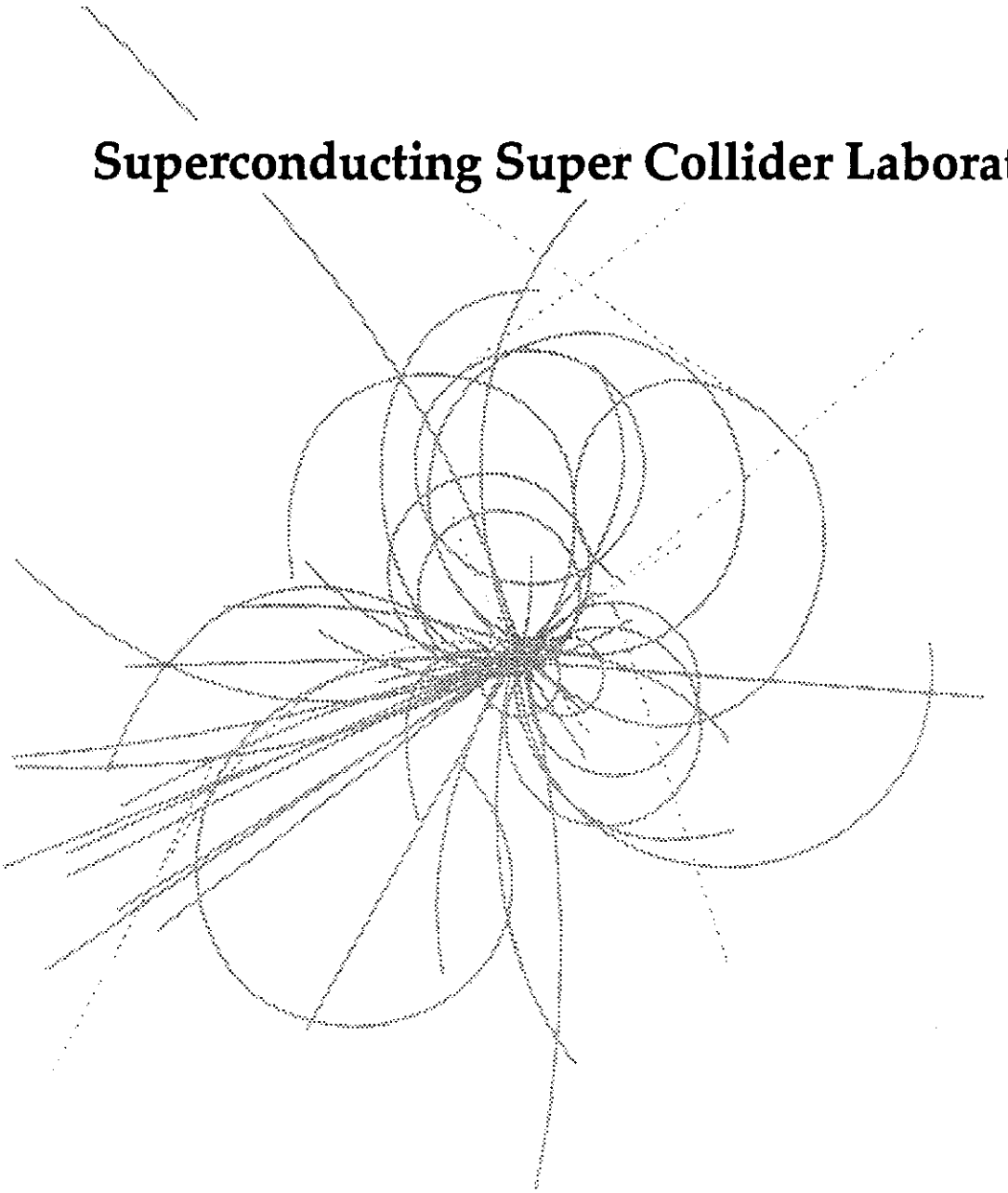
SSC-1

Superconducting Super Collider Laboratory



SSC Monthly Report

T. Elioff

October 1984

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Superconducting Super Collider
Universities Research Association
c/o Lawrence Berkeley Laboratory, University of California
One Cyclotron Road, Mail Stop 90-4040
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(415) 486-4772 – FTS 451-4772

January 3, 1985

MEMORANDUM

TO: Bremenkamp, Chao, Elioff, Hoedemaker, Jackson
Limon, Matyas, Sanford, Tigner, Wojcicki, Yourd

FROM: T. Elioff

SUBJECT: Monthly Report

Attached is a copy of the first SSC Monthly Report for the period Oct. and Nov. 1984. Please let us know your criticism with regard to form and content.

Your input and contribution for the next report covering the month of December is due by Jan. 11.

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Universities Research Association
c/o Lawrence Berkeley Laboratory, University of California
One Cyclotron Road, Mail Stop 90-4040
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December 21, 1984

Mr. Fred Mattmueller
DOE/Chicago Operations Office
9800 S. Cass Ave.
Argonne, IL 60439

Dear Fred,

The first FY85 report for the SSC project is enclosed. This report covers activities for October and November 1984.

We understand that the first SSC quarterly review is now planned for Jan. 29. We will contact you next week regarding the schedule and agenda.

Our group sends best wishes for the holidays, and, in particular, we wish you the very best in your endeavors beyond Jan. 3.

Regards,

Tom Elliott

for Maury Tigner

MT/ac
1107S
encl:
cc: R. Fricken (DOE)
J. Matheson (URA)
B. McDaniel (Cornell)
W.A. Wallenmeyer (DOE)

SSC MONTHLY REPORT

OCTOBER & NOVEMBER 1984

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SSC MONTHLY REPORT

OCTOBER AND NOVEMBER, 1984

A. PROJECT SUMMARY

This is the first integrated report of the Superconducting Super Collider (SSC) Project Phase I effort. A Central Design Group (CDG) has been established to lead this Research and Development Program with on-going activities at four national laboratories.

The CDG organization began operations in October with headquarters at the Lawrence Berkeley Laboratory. The current organizational chart is shown in Fig. A-1. Apart from the development of the CDG organization, efforts have included the establishment of task forces and review panels to explore technical features and research goals of the SSC program. These include:

- A magnet aperture workshop was held at LBL on Nov. 5-9, 1984. Forty accelerator physicists from throughout the U.S. and Europe attended the workshop.

- The Task Force on the SSC Magnet System Test Site was established. This group met four times during this reporting period and completed its final report (SSC-SR-1001).

- A photo desorption task force is reviewing an experimental program to address this phenomenon at SSC energies.

- A Magnet Technical Review Panel has reviewed the magnet R&D efforts at BNL, FNAL, LBL, and TAC.

- A Management and Fiscal Review Panel has reviewed the programs at BNL, FNAL, LBL, and TAC.

- A panel has been set up to review the potential of new methods and techniques for underground tunneling.

- The SSC Program Plan and the SSC Management Plan have been completed and are being reviewed.

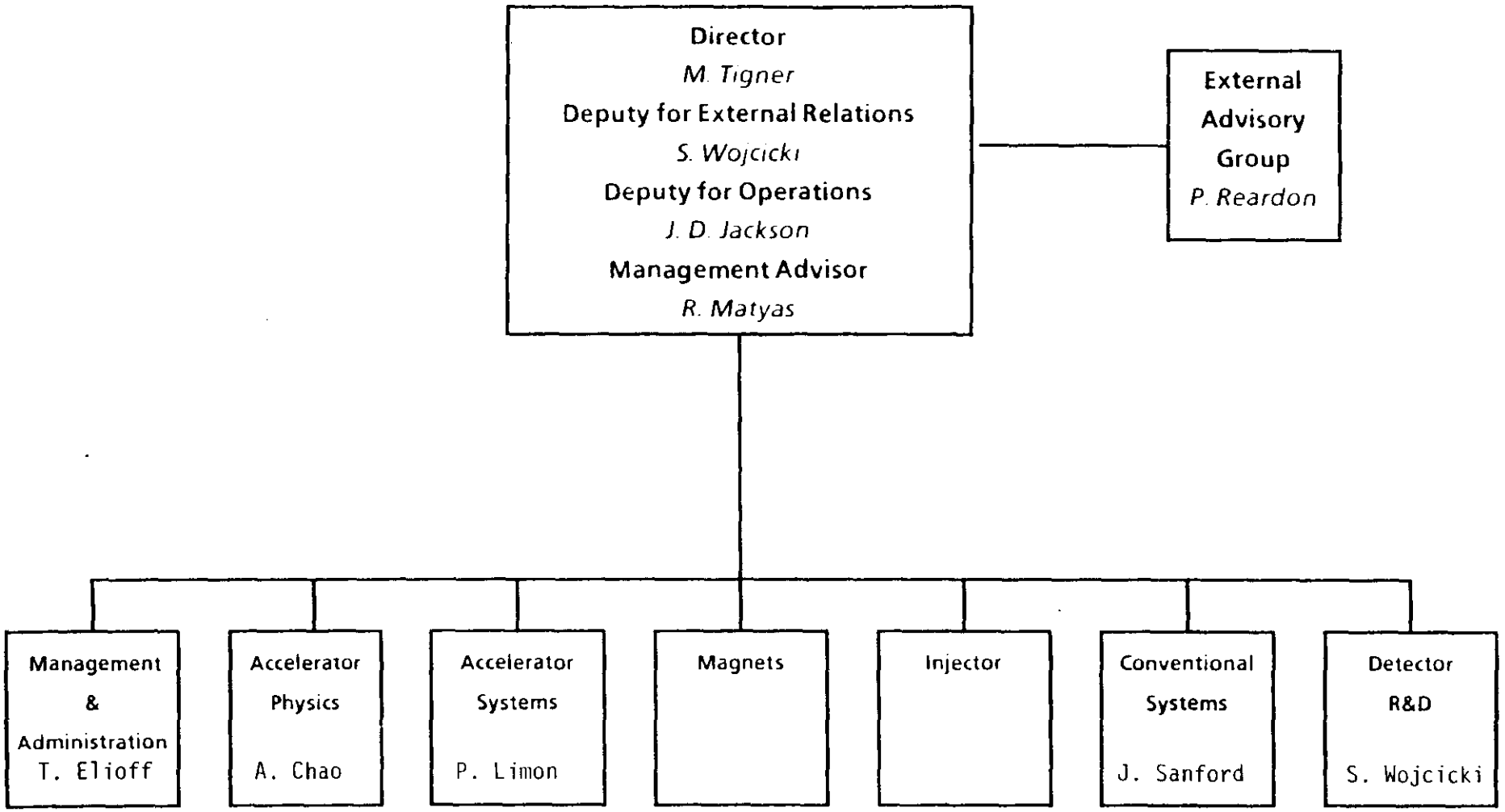
Director
M. Tigner
Deputy for External Relations
S. Wojcicki
Deputy for Operations
J. D. Jackson
Management Advisor
R. Matyas
External Advisory Group
P. Reardon
Management & Administration
T. Elioff
Accelerator Physics
A. Chao
Accelerator Systems
P. Limon
Magnets
Injector
Conventional Systems
J. Sanford
Detector R&D
S. Wojcicki

Figure A-1

The Superconducting Magnet Development Programs are continuing at BNL, FNAL, LBL, and TAC. The magnet design concepts and associated R&D have continued to evolve following the basic ideas set forth in the Reference Designs Study.

The BNL efforts have been directed at building and testing longer (4.6 meter) model magnets. Three magnets with 3.2 cm aperture and wound with CBA cable have been built and tested. BNL is currently designing and building tooling for the 4.0 cm aperture, collared coil design. The MAGCOOL facility is being reworked to accept the longer magnets designed for the SSC.

The FNAL activity during October and November centered on two long test models that are now nearly complete. One is the Magnetic Model (6 meters long), which will be ready for test in January. The magnet will have instrumentation that will record the mechanical behavior of the coil and shield system during a quench as well as during cool down. The second model, the Heat Leak Model, is presently being assembled. This model will be used to measure the thermal performance of a 12 meter SSC cryostat with dummy coil. Other work continues on one meter test coils to develop fabrication techniques. Particular emphasis is on dry (no epoxy) coil winding. New approaches to suspension systems are also being studied.

LBL is concentrating on short (one meter) test models, superconductor development, and cryostat design. LBL is also pursuing plans/studies on cryostat calculations, design and fabrication. During October and November, the fourth LBL 40 mm bore, 1 m long SSC model dipole was tested. This model

has nearly the same winding cross section and cable as Reference Design A, and produced a 6.5 T central field. The performance of correction coils, operated in a persistent mode as well as a driven mode, was measured. Acceptable 30 strand cable was produced in the LBL facility and production parameters were established. Tooling fabrication and other preparations began for construction of about 8 collared-coil magnet models.

The TAC program has completed two 3-foot models of the superferric design. These models were built to test mechanical and conductor characteristics. Successful tests have been conducted at the BNL test facility. The tooling has been completed for a 25-foot model and research efforts continue toward assembly and test of this unit.

Details of the above magnet programs are presented in Section B of this report.

At the time of the Reference Designs Study, a WBS was established which tracked the SSC preliminary cost estimate in a logical manner. The structure of this previous WBS has proven to be unwieldy for this R&D stage of the Project. Therefore a new WBS has been created which more closely parallels the organization and the Phase I R&D effort. This structure will also be used for the reporting format. The new WBS is shown in Table I.

TABLE I

WBS Structure (SSC Phase I)

1.0 Central Design Group
- 1.1 Directorate
- 1.2 Program Management
  - 1.2.1 Program Planning and Technical Coordination
  - 1.2.2 Administrative Support
- 1.3 Accelerator Research and Development
  - 1.3.1 General
  - 1.3.2 Theory and Computation
  - 1.3.3 Accelerator Systems
  - 1.3.4 Superconducting Magnets
  - 1.3.5 Injection Systems
- 1.4 Conventional Systems
  - 1.4.1 Planning and Coordination
  - 1.4.2 Site Parameters
  - 1.4.3 Conceptual Design
  - 1.4.4 Tunnel Concepts
- 1.5 Detector Development

2.0 Brookhaven National Laboratory
- 2.1 General
- 2.2 Magnet Models
- 2.3 Tooling
- 2.4 Superconductor Development
- 2.5 Magnet Measurements
- 2.6 Power Supplies and Quench Protection
- 2.7 Cryogenic System

3.0 Fermi National Accelerator Laboratory
- 3.1 General
- 3.2 Magnet Models
- 3.3 Cryostat Development
- 3.4 Superconductor Development
- 3.5 Facility Development
- 3.6 Accelerator Physics and System Study

4.0 Lawrence Berkeley Laboratory
- 4.1 Accelerator Theory and Design
- 4.2 Superconducting Magnet Development
- 4.2.1 General
- 4.2.2 Model Magnets
- 4.2.3 Superconductor and Cable Development
- 4.2.4 Theorectical Analysis
- 4.2.5 Instrumentation and Measurement

5.0 Texas Accelerator Center
- 5.1 General
- 5.2 Short Magnet Model
- 5.3 Long Magnet Models
- 5.4 Tooling Development
- 5.5 Theoretical/Analysis
- 5.6 Facility Development

B. PROJECT REPORT

1.0 Central Design Group.

This WBS category covers the work of the CDG including the Directorate, Program Management, Accelerator Research and Development, and Conventional Systems. Apart from the Task Force and Review Panel work reported in the Project Summary, a major effort of the CDG has been expended in organizational and personnel recruiting matters. The Conventional Systems Division Head has met with DOE officials and is preparing an A/E selection (for Phase I) protocol as well as a Site Selection work plan. The Accelerator Physics Division Head organized and conducted an Aperture Workshop at LBL on November 5 through 9. The Accelerator Systems and Management and Administration Division Heads have been actively involved with the Magnet Review Panels.

1.1 and 1.2 Directorate and Program Management. In addition to organizational and personnel recruiting, these offices have been involved in preparation of Task agreements on SSC R&D between the CDG and the magnet groups, establishing and supervising Task Forces to review various aspects of the SSC R&D program, and preparation of reports, including revised Program and Management Plans.

1.3 Accelerator Research and Development. Work in this area has concentrated on the SSC superconducting magnet system. The Accelerator Physics Division Head organized a week long Aperture Workshop (November 5-9). A summary report, SSC-TR-2001, has been

prepared. The Aperture Workshop was organized into 7 working groups, each led by a coordinator. In addition to technical discussions, a major outcome of the workshop is that each group identified areas that need work in order to arrive at a preliminary aperture evaluation for the various magnet design styles by March 1985. Each of the 7 working subgroups specifically proposed an action plan for the next 4 months. An Aperture Task Force was subsequently formed. The workshop coordinators assumed the role of coordinators for the Task Force.

The workshop concluded that aperture-related issues are important ones that must be resolved early during the SSC R&D phase. Magnet specifications and lattice design cannot be finalized until the aperture is optimized. In light of the schedule for SSC R&D, the next few months are critical ones for selecting the appropriate aperture and putting the tools (computational and experimental) in place that will be essential for the development of an optimal, cost-effective SSC design.

Other accelerator physics issues are being pursued. Although considered lower priorities compared with the dynamic aperture issue, some effort has been devoted to their studies. These studies included intrabeam scattering calculations, and coherent beam-beam calculations. In addition, a plan is being developed to review and study various beam intensity related questions.

The Accelerator System Division Head has been involved in organizational and recruiting matters as well as organizing an Operation Task Force which will provide vital input to the Magnet Style Selection process.

The SSC Technical Magnet Review Panel looked in depth at the superconducting magnet programs and their final report is in preparation. They have developed a structure for the Magnet Type selection process including Selection factors and a key activity schedule. After examining the three magnet programs it was the considered judgement of the Panel that any of the three styles of magnets, if chosen, could be developed into a "successful" magnet, i.e. a magnet that would operate in a stable fashion at a specified field. This does not imply that all magnets will lead to a successful SSC. It then becomes apparent that the style selection depends upon:

1) Total SSC construction cost including tunnel, service structures, cryogenic systems, etc. The magnet style affects many of these ancillary systems.
2) Aperture size and field quality as fixed by the Aperture Task Force.
3) Operational aspects that will be studied by the Operations Task Force.

A Management and Fiscal Review Panel for the SSC Magnet Program looked at the various efforts in parallel with the Technical Review Panel. This Panel was charged with recommending a uniform monthly accounting and technical reporting scheme, preparing a report on FY84 SSC Magnet R&D expeditures, and a report on proposed FY85 budgets for the performers. The result of this Panel's efforts is being incorporated into the CDG/Laboratory agreements.

The basic conclusions of the Task Force on Magnet System Test Site is that the complete System Test Facility (STF) should provide two test vehicles:

1) a "Short String Facility" on which "wear-out" tests can be run; and

2) a "Long String Facility" where extensive testing and development activities involving the principal modular lengths of magnets and related systems can be conducted.

The Long String Facility configuration could be straight (or slightly curved, if necessary, to conform to an existing housing). The length of the Short String Facility should be one half-cell. The length of the Long String Facility should be approximately 1% of the circumference of the Main Ring. The comparisons made by the Task Force indicate that the total costs and manpower requirements for siting the STF at BNL and FNAL are roughly equal.

The STF will be a major component of the national SSC program, involving scientists from many different institutions. It is expected that the SSC Central Design Group will play a major role in this activity by providing technical, management, and budgetary input and direction.

1.4 Conventional Systems. The first technical task consisted of preparing a plan and timeline for the work associated with the site and conventional facilities activities that the CDG faces in the next two years:

- A Site Parameters Document
- An SSC Conceptual Design and Report
- Providing support to the DOE in Site Evaluations

To accomplish these tasks a plan was prepared with a series of steps to be taken in the months ahead. With respect to the Site Parameters Document, a full description of the SSC facility must be prepared. This will build upon the technical and conventional facilities that were described in the Reference Designs Report prepared in May, 1984. The new document will consist of the following elements:

1) A technical description of the SSC

2) Tables of SSC parameters

3) Information needed about proposed sites

4) Limits or magnitude of site criteria

In order to produce this material, professional help is being assembled at the SSC Center. In addition, a solicitation for assistance from an architectural/engineering firm is being formulated. A notice to be placed in the Commerce Business Daily has been written, and it is expected that a firm will be under contract by March. In the meantime, A/E help is being sought through existing contracts with the DOE.

2.0 Brookhaven National Laboratory (BNL) Program

The BNL program is closely coordinated with LBL. Efforts have been directed at building and testing (4.6 meter) model magnets. Three magnets with 3.2 cm aperture and wound with CBA cable have been built and tested. BNL is currently designing and building tooling for the 4.0 cm aperture, collared coil design. The MAGCOOL facility is being reworked to accept the longer magnets designed for the SSC.

2.1 General. Calculations were made on the peak field effects at the end of the Reference Design A dipole coils. There appears to be no significant effect on magnet performance if the iron laminations end within the conical section of the flared end. End multipoles were also calculated for a full length magnet and the quadrupole and sextupole moments were less than 4.0×10^{-4} of the central field. The program for calculating the end fields is being upgraded to include variable iron spacing in order to be able to optimize the end design. Good agreement was found between the calculated and measured value of the quadrupole and sextupole harmonics produced by the ends of the 3.2 cm x 4.5 cm demonstration dipole.

Preliminary calculations were performed on an alternative 1-in-1 dipole design to the BNL/LBL 2-in-1 design. This design incorporated the C5 coil configuration and stainless steel collars (the same 40 mm I.D. coil and collar of 15 mm radial thickness as used in the 2-in-1 design). The iron cross section is circular with an inner diameter

of 4.37 inches, outer diameter of 10.5 inches (compared to 14 inches for the 2-in-1), and has four coolant holes, two at each pole. The assumed conductor is nominally identical to that specified for the 2-in-1 design, yielding a load line of 10.145 G/amp at 6400 A(approximately 6.49 T), a sextupole term, b_2, at 6.5 T of 1.4 x 10^{-4} cm^{-2}, and average saturation induction in the iron return leg on the mid-plane of 2.08 T.

2.2 Model Magnets. SBN-003, a 3.2 cm x 4.5 meter magnet, was built and tested. Work continues on development of coil winding procedures for pre-reacted niobium tin cable. A problem of a large temperature difference between the mandrel and the coil form block in the coil curing press was encountered. The proposed solution is to put an additional steam heating channel in the top of fixture and reduce the rate of initial heating.

Collar design for the 4.0 cm magnets is completed, material has been ordered, and the die is out for bid. Lamination design has been completed and a contract for center and end yoke laminations has been awarded.

The necessary modifications of the yoke press for collaring coils were investigated. Stress analysis was performed on magnet end collars. Procurement was initiated of copper coil wedges. A model or mock-up of the magnet end assembly was completed to delineate thermal, mechanical and electrical considerations.

2.3 Tooling and Facilities. All drawing for parts of the four coil winding mandrel and for the coil curing press were released to Central Shops. Most of the drawings for the outer coil winding mandrel and the inner and outer form blocks were also released, as were all the drawings for the iron lamination stacking fixtures, winding mandrel supports, and cable restrainers.

Kapton-Teflon taped bore tubes were successfully thermally cycled for tests of integrity of bond and size variation. Tooling design for bore tube wrapping, curing and inspection, as well as for trim coil-bore tube assembly made substantial progress in this period. Computer generated samples of flat multiwire trim coil patterns were supplied by vendor for evaluation. A trim coil curing oven was ordered. Four trim coil and bore tube assembly surface plates were received; three of these were in the process of being installed in the CBA tunnel where a shop is being set up.

Work progressed on the magnet suspension system, mostly with surplus CBA components. Work also continued on the 10 kA lead package, as well as on the actual gas cooled leads themselves. Various components for the "mole" field measuring probe system were ordered, released to the shops in the form of prints, or tested. These include electronics for shaft speed feedback control, mole support system, drive mechanism, and housing.

2.4 Superconductor. The contract for a four-billet amount (1800 lbs.) of high homogeneity wire was finalized on November 19, with billet materials being prepared. This purchase is being closely coordinated with LBL and represents, with 900 lbs. now being processed, the amount of superconductor required for the dipole magnets planned for FY 1985. (4 ea. 4.5 m and one 16.6 m). Delivery of approximately 750 lbs. of strand for development of cabling techniques and practice winding for 4 cm aperture coils, drawn by Oxford Superconductors (with partially processed CBA material), was completed on November 20. This wire will be used for cabling R&D at LBL and cable manufacturing development at NEEWCO.

BNL and LBL have received proposals for the development of high current density material with fine filaments (10 microns or less). These proposals are being evaluated. The three methods that were proposed make use of single extrusion, double extrusion and cable-of-cables. A decision on which proposals to accept should be made in early December.

2.5 Test and Measurements. During October, a 3.2 cm aperture x 4.5 meter long dipole made with new high-homogeneity NbTi cable (SBN-003) was successfully tested. The maximum central field achieved by this magnet was 7.8 T. Also during this month, two 1 meter dipoles made by the Texas Accelerator Center were tested. In addition, the new 10kA power leads were tested.

In November, both the first and second TAC magnets were tested for a second time, with corrected shimming in the two magnets. At the end of November, the third BNL 3.2 cm 2-in-1 dipole (SBA-OD3) was successfully retested. The magnet had been reassembled with instrumentation (heaters and voltage taps) for collecting data on quench propagation.

Initial testing in a magnetic field of a model version of the "mole" field measuring probe system was carried out to identify potential problems (e.g. mechanical resonances) and to incorporate possible modifications in the final design.

SBN-003 was the third in a series of 3.2 cm aperture demonstration dipoles to be tested. The first two were made with standard CBA cable. All three magnets reached their short sample limit with minimal training at 4.5 K. Because the high homogeneity conductor has a higher short sample current than the standard conductor, the 6.5 T central field @ 4.5 K obtained in SBN-003 was higher than that reached by the two previous magnets (6.0 T, 5.8 T). When tested in sub-cooled liquid helium, all three magnets exhibited some amount of training at 2.5 K. SBN-003 reached 7.8 T without having clearly reached the short sample limit, as compared to the short sample performance of the two previous magnets (7.2 T, 7.1 T). The extra training required by the third magnet may indicate that the prestress was not adequate for these field levels.

The field quality data from the test of SBN-003 was satisfactory in both bores of the magnet. The data from all six bores that were measured to date (three 2-in-1 magnets) indicate that the magnet-to-magnet field reproducibility is at the same level as the CBA and Tevatron magnets, i.e. a few parts in 10,000 (evaluated at 2/3 of the inner radius in each case), despite the factor of four reduction in coil diameter from CBA to these 3.2 cm coils. Field quality measurements also include detailed studies of magnetization effects at low fields. The high homogensity cable, which has 20 micron filaments, shows a much larger sextupole than the 9 micron filament standard cable. Calculations are being made to verify that the difference should be as large as expected.

2.6 Power Supplies, Quench Protection, Electrical Systems.

Texas Accelerator Center Model Magnet:

Provided electrical connection, mounting to dewar top plate and necessary tests to certify electrical integrity.

BNL SSC Magnets:

Provided electrical installation requirements and testing for dipole SBN-003.

Power Supplies:

The 5 kA power supply used with the vertical dewar was fitted with firing circuit modifications and tested. A new higher current series pass dipole assembly has been constructed. New computer controls for the 15kA power supply in the R&D Section have been fabricated and tested.

Dipole Coil Winder Controls:

After careful investigation, it was determined that the system necessitated redesign to provide noise isolation. All work was completed and preliminary tests indicated that the system is now immune to electrical noise.

2.7 Cryogenic System. The Cryogenic Division maintained and operated the helium refrigerators used in the Magnet Testing program in Building 902 and the Short Sample Testing Program in Building 960.

A two-stage oil-injected screw compressor is being installed to supply helium gas to the refrigerator used in the Short Sample Testing Program. The reciprocating compressors which this system replaces are about 20 years old. It is expected that as the new compressor becomes operational, it will provide higher reliability and require much less maintenance than the old ones.

An engineering study of the use of BNL facilities as the SSC String Test Facility was completed in October. This study, which describes the space, equipment and personnel that could be made available at BNL, was an appendix to the report prepared by a committee appointed to define the requirements for and choices available to the SSC management. A cost estimate was developed as part of the study.

In response to a request from the SSC Magnet Selection Criteria Committee, a paper giving the details of the calculations for the System-Wide Cooldown of Reference Design Magnet Type A was prepared and presented to that committee on November 12, 1984. The calculations presented in this paper show that the estimated cooldown times given for Magnet A in the RDS are conservative. The estimated total cooldown time can be reduced from 15 to 12.5 days.

3.0 Fermi National Accelerator Laboratory.

3.2 Magnet Models. The FNAL program currently involves a 1-in-1, no iron design magnet. The Tevatron dipole data base has been re-examined to look for persistent fields at low currents, hysteresis in the skew quadrupole moment, and to understand the longitudinal variation of multiple moments. In addition, a Tevatron dipole was measured with the rotating Morgan coil to test this device for SSC magnetic measurements.

Activity during October and November centered on two long test models that are now nearly complete. One is the Magnetic Model (6 meters, Tevatron coil, SSC coil collars and cryostat) which will be ready for test in January. The magnet will have instrumentation that will record the mechanical behavior of the coil and shield system during a quench as well as during cooldown. The second model, the Heat Leak Model, is presently being assembled. This model will be used to measure the thermal performance for 12 meter SSC cryostat with dummy coil.

Other work continues on one meter test coils to understand fabrication techniques. Particular emphasis is on dry (no epoxy) coil winding. The second 5 cm dry wound coil is nearly complete. New approaches to suspension systems are also being studied.

3.3 Cryostat Development. The design of the magnetic effect model was completed. Procedures were developed for the multilayer insulation system and for the overall assembly of the model.

Measurements of the vacuum vessel (as fabricated) straightness and circularity were made after forming, machining, and welding. The data provides a basis for future considerations of vacuum vessel quality.

The Tevatron coil has been successfully collared with SSC style collars. The single phase helium skin has been welded over the collared coil. The fixturing for alignment and welding of skin worked quite well. Besides the single phase, other components prepared were shields, superinsulation, and vacuum vessels. Assembly of the complete magnet was initiated.

Test procedures were developed and work was initiated on the test facility. Details of the instrumentation, data acquisition and analysis were established. Work was undertaken to prepare the facility and conduct shakedown test runs.

The design for the heat leak model was also completed. Revisions were made in the configuration to permit use as a test dewar for 12 m coils after the heat leak measurements are completed. Procedures were developed for the heat leak measurements. Procurements of all components was completed and fabrication was initiated. Emphasis was placed on the end vessels to permit an expedited measurement of their base heat leak.

Data from the initial engineering runs of the suspension heat leak dewar was analyzed. Modification were made to the dewar to provide improved accuracy in subsequent measurements. Calibration runs at 80°K and 4.5°K are planned to be followed by the heat leak measurement of a post having the configuration of the heat leak model. Coils suspension design work continued. Included in the design effort were pivoted and fixed posts, straight and folded posts, and ring and arch type supports. Development of a suspension design criteria to guide future development was initiated.

The definition of the radiation environment internal to the vacuum vessel was begun. Such information is essential for the design of the conductor insulation, multilayer insulation and suspension components, all of which can employ non-metallic materials with limited tolerance to radiation.

3.4 Superconductor Development. Studies continue on the current carrying properties of NbTi and NbTiTa superconductors. The initial small quantity (~ 150 lbs.) of cable made to SSC specification performs remarkably well. The two conductors are made with 25 and 23 strands of 0.030 diameter strand with 1.6 to 1 Cu/Sc ratio. They perform as follows:

25 strand (inner coil)	8911A @ 6T
	7046A @ 7T
23 strand (outer coil)	8061A @ 6T
	6050A @ 7T

The final outer cable would have less superconductor to reduce cost.

3.5 Facility Development. Work continues on improvements to the magnet test and measurement equipment, including new data acquisition hardware and software.

In connection with dry winding, a continuous cable measuring device is being designed which is intended to measure cable thickness to one or two tenths of a mil. These measurements will be used to control conductor placement in magnet fabrication.

4.0 Lawrence Berkeley Laboratory Program

4.1 Accelerator Theory & Design. The SSC-LBL theory group will be located with the SSC Central Design Group and the activities will be an integral part of the total CDG effort (See Section 1.3).

Work of the LBL - accelerator physics group covered the areas of lattice design, nonlinear dynamics (in particular numerical and analytical approaches to the problems posed by imperfections of the magnetic guide field), and collective effects. The common focus and guiding principle of most of these activities is to establish guidelines for magnet aperture and magnetic field quality. The group both aided in the organization of, and vigorously participated in, the SSC Aperture Workshop, held at LBL Nov. 5-9, 1984.

Lattice design is a prerequisite for almost all subsequent beam dynamics studies. The object of the lattice work was to create lattices that are simple enough to be easily and quickly generated and modified, but retain most of the important features. At present they consist of six superperiods, each of which is made up of regular arcs, dispersion suppressors, phase trombones and low beta insertions. In collaboration with workers at other institutions, six such "test lattices" were established for field levels of 6.5 T, 5.0 T and 3.0 T, and phase advances of 60° and 90° in the regular cells,

respectively. These lattices are stored in the SSC data base that has been established.

In the area of nonlinear dynamics, considerable effort went into work towards establishing tracking codes that meet the requirements of SSC related work. At present no code exists, of either the "kick code" or the Lie algebraic variety, that comes even close to meeting all the requirements. Versions of many of the relevant codes were transferred to both the Livermore Cray XMP and a local VAX. Substantial progress has been made in evaluating the internal structure of codes such as PATRICIA, PATRIS, and RACETRACK, in particular with regard to their treatment of "off energy" quantities where the important question of simplicity of the formulation arises. A strategy to implement an upgraded PATRICIA version has been formulated. In terms of analytical approaches, a first and second order formulation to calculate "distortion function" and random errors was developed. Progress was also made in the area of the algebraic methods where a generating function representation and a concatenation (i.e. "multiplication") algorithm for 5th order Lie transformations were developed.

In the area of collective effects work on beam-beam oscillations, review and critique of previous results (impedance estimates, thresholds), and renewed refinement of intrabeam scattering calculations were carried out. The problem of coherent

transverse oscillations driven by the (linearized) beam-beam force received some attention and was reformulated for the case of the SSC, where, apart from "hard" collisions at the nominal interaction points, a large number of "soft" collisions occur at many nearby locations of close encounter. Strictly this leads to the evaluation of eigenvalues of approximately 40,000 x 40,000 matrices; present work aims at approximations leading to greatly reduced dimensionality of the problem.

In the context of impedances and single beam instabilities, the primary effort has been in preparation for an "impedance task force" meeting which was to develop a detailed plan to address collective phenomena in the SSC. Central to this discussion has been the evaluation of the impedance estimates and coherent instability analysis of the Reference Designs Study. Questions concerning the high frequency impedance offered by various bellows geometries and the resistivity of cold copper in a magnetic field appear to be the most crucial since they have direct impact on aperture. In the longer term, analysis of coupled-bunch feedback systems and kicker impedances should receive considerable work.

In addition, a new intrabeam scattering code has been developed in collaboration with other LBL projects. This program allows for input of detailed lattice functions. Checks against both existing codes and experiments have been carried out, and the program is now available in a VAX version for SSC design studies.

4.2 LBL Superconducting Magnet Development.

4.2.1 General. This category includes all administrative activities, purchasing, planning, and travel expenses. There was extensive participation by LBL staff in CDG activities, particularly the Task Force on the Magnet System Test Site and the Technical Magnet Review Panel.

4.2.2 Magnet Models. Work has proceeded on three different 1 m long "one-in-one" dipole magnets--D12B2, D121C1, and D12C2. D12B2 has split iron yokes with the two coil layers clamped directly between the yokes. The magnet has a 40 mm bore and utilizes tilted cone type coil ends. Keystoned (1.2^0), NbTi cable is used in both the inner and outer coil layers - the inner coils were wound with 23 strand cable and the outer coils with 30 strand cable. Strain gauge type load cells are installed in the pole pieces to measure the pre-load on the coil both before and during operation. The split iron yoke is fastened with Al tie bolts. Coil ends were impregnated with epoxy to improve rigidity. The mechanical assembly of this magnet was completed in early October.

The design of D12C1 differs from that of D12B2 in two major ways. First, in this design, the coils are clamped in keyed

aluminum collars. The collars were machined from 1/8" thick 7075 Al alloy and have a radial thickness of 25 mm. Secondly, wedges have been incorporated into the design of the coil ends to provide a pre-load on the cable layers at this location during operation. Other parts of the design are similar to that of D12B2.

The instrumentation of this magnet will consist of strain gauge load cells located in the collars to measure the pre-load on the coils during assembly and operation. Four strain gauge type devices will also be installed on the yokes near the magnet center to measure the position and shape of a collar during assembly and operation. A series of voltage taps will also be installed on the coils and monitored during magnet operation.

A detailed design of D12C1 was finished during this reporting period. All the major procurement orders have been placed and some of the major fabrication elements, such as collars and yokes, were completed. Completion of the magnet assembly is scheduled for early February.

D12C2 is very similar in design to D12C1. One major difference is the collar construction. D12C2 will use stainless steel collars. They will be fabricated from 0.063" thick Nitronic 40 annealed sheet and will have a radial thickness of 15mm. The collar design is nearly identical to the BNL design. The coils for this magnet will

be cured in a fixture under heat and pressure and held to a precise geometry during this operation. Instrumentation will be the same as used on D12C1. As of the end of November, preliminary engineering design is complete and fabrication orders for yokes and collars are placed. The schedule for this magnet calls for the assembly to be completed by the end of March and testing to start at the beginning of April.

A significant effort was expended in collar analysis and fabrication methods. A series of mechanical load tests were performed on a 25 mm aluminum collar hard pack, and the results compared to a finite element analysis production. Various fabrication techniques were investigated for producing a relatively small number (1000-2000) of stainless steel collars. N.C. laser cutting, although not as precise as punching or the E.D.M. process, was selected due to delivery time and cost factors.

4.2.3 Superconductor. The results of a collaborative research program (involving LBL, U. of Wisconsin, Teledyne Wah Chang, and Intermagnetic General Corp.) have shown that a critical current value of 2400 A/mm^2 at 5 T is readily achievable in the LBL/BNL conductor. A specification using this value was prepared and samples requested from prospective vendors in order to assess their ability to achieve 2400 A/mm^2. Four vendors submitted samples and were asked to bid; three vendors responded, and Intermagnetics General Corp. was awarded the contract to produce 1800 lbs. of wire. This

material will be delivered by March 15, 1985. Part of this material will be used at BNL and part will be used in 1 m models at LBL. This completes the procurement of standard (20 filament size) conductor for the 4.5 m LBL/BNL model program for FY85. After the results of the fine filament R&D program are known, additional fine filament material may be procured for the model magnet program.

Small quantities of fine filament NbTi have been produced by Oxford Superconducting Technologies and Alsthom-Atlantique. Both companies used a Cu Ni sheath around NbTi filament in order to (1) prevent the formation of a hard, brittle intermetallic Ti_2Cu layer from forming during extrusion or other heat treatments, and (2) provide an interface which more nearly matches the mechanical properties of NbTi than does copper. The Oxford material has a filament size of 1.6 μ m and no value for J_c at 5 T has been reported. The Alsthom material has a range of filament sizes, from 1.3 to .08 μ m, with a J_c value reported only for the 1.3 μ m size (J_c = 1950 A/mm^2 at 5 T). These results show that fine filaments are feasible.

When potential problems are eliminated by proper processing and quality control, there is no metallurgical reason why a J_c value of greater than 2400 A/mm^2 cannot be achieved. In fact, the increased total reduction in area of the NbTi filaments may mean that it is possible to introduce more heat/cold work cycles and hence raise the value of J_c.

The LBL/BNL team is investigating a two-level cable with material from two sources. First, standard 500 filament material will be processed to a wire size of 0.009" diameter; this will produce filaments of about 7 μ m diameter. This wire will be used to fabricate a 7-strand cable which will then be used to replace the 0.0255" diameter monolithic strands in standard Rutherford cable. Next, material from the Superconductor R&D program will be drawn, with appropriate heat treatments, to a 0.009" diameter wire with 2 micron filaments. This material will also be evaluated in a two-level cable.

Although Rutherford cables have been used routinely for at least 10 years, there are a number of problems with cables made at present. These include (1) difficulty in achieving the required dimensional tolerances, especially with keystoned cables, (2) degradation of strand critical current during cabling, (3) limits on the number of strands which can be cabled successfully, and changes in cable dimensions which occur upon bending, due to internal corrugations. In order to improve upon conventional cables and develop new cables, a cabling machine has been designed and constructed which is versatile and allows precise control of important cabling parameters such as strand tension, strand twist, and cabling speed.

The cabling machine was commissioned and work began immediately to establish the parameters for the 30-strand outer layer cable. It

was demonstrated that this cable could be produced at a rate of 10 ft/min. (standard production line speed) and the appropriate parameters necessary to achieve the dimensions required for this cable were determined. This information has been transferred to the cabling vendor (New England Electric Wire) and they will produce about 400 lbs. of cable for LBL/BNL dipole models in December.

In addition the first 36 strand Rutherford cable has been produced. This cable was attempted in order to establish a practical limit on the number of strands in a single-level Rutherford cable, and to provide magnet designers with a new option to consider in designing a single layer dipole. Next quarter, investigation will continue on new cable options such as the internal flat cable and cables with an internal wedge to increase the keystone angle.

4.2.4 Theoretical Analysis. Improvements on POISSON - a two-dimensional, real-iron computer program - have continued. The program now correctly simulates conditions on outer boundary surfaces in air. That boundary, which can be either circular or elliptical, can be placed close to the magnet, resulting in a large decrease in memory usage and running time.

A method for predicting the magnetic-field aberrations resulting from random manufacturing errors has been developed. This includes errors that affect the positions of both the radial and azimuthal boundaries of the coils, and the individual conductors.

4.2.5 Instrumentation and Measurements. Dipole magnet D12B2, the fourth LBL one meter long model magnet, was tested in October, 1984. Short sample central fields of 6.55 tesla at 4.3K and 8.12 tesla at 1.7K were reached after significant training, (some evidence implicates the epoxied ends). The prestress in the winding was measured by strain gauges; 10,000 psi decreased to 9,500 psi during the week or two before the coil was cooled. At 4.2K, prestress was 8,500 psi. During the training sequence the pressure, at zero field, further decreased to 5,500 psi. Extensive magnetic field measurements were made to determine the built-in field errors and especially those field distortions caused by persistent currents induced in the superconducting filaments by prior field changes.

A superconducting sextupole correction coil that could either be externally powered or be used in the self powered, or shorted mode, was mounted on the bore tube. During the October test the sextupole error field within the bore tube could be reduced by about a factor of ten using this correction coil in either mode. The reduction was not greater because the angular alignment of the correction coil with respect to the sextupole from the dipole was off by some 2 to 3 degrees.

During November 1984, the magnetic measuring system was improved so that the correction coil could be aligned within the dipole at room temperature, when using a few amperes in the winding.

5.0 The Texas Accelerator Center (TAC)

TAC is developing a 2-in-1, cold iron (superferric) design magnet. Two 3-foot long models have been built and these were tested in the magnet test facility at BNL. These models were designed to test mechanical and conductor characteristics and have both been successful.

The first two magnets were taken apart and the asymmetric shims and slightly magnetic spacers replaced with appropriate parts. The magnets are quite consistent with each other except for a_1 deviation in a multipole at low field. Construction continues on the 25 foot magnet, however, difficulties with the center lamination die has slowed assembly of the magnet, now scheduled for completion by December 31, 1984. Specific components of the TAC program are summarized below.

5.1 General. Detailed plans for the FY85 program have been finalized in concert with negotiations with the CDG regarding planned FY85 budget allocations.

5.2 Analysis. Magnetic calculations are being performed with Poisson to find poleface shapes and coil positions to reduce the decapole. Calculations are also being done for the ends of the magnets.

5.3 Short Magnets. The current center laminations had too much of a burr. TAC is working with the die maker to improve the stampings. Enough good laminations are on hand to complete a 3 foot and a 25 foot magnet. The 25 foot model should be complete by the end of December.

5.4 Long Magnets. Negotiations are underway with General Dynamics of San Diego for a CPFF contract to assemble three 92 foot magnets.

5.5 Tooling. The tooling for the 25 foot magnet has been completed. Modifications will be made as the first magnet is assembled.

5.6 Facility Development. A large press, mill, and lathe arrived from ANL. They are in good shape and were put into operation. The Hewlett Packard microcomputer system and DVM's for the magnetic measurement system have arrived and are being commissioned.

C. PROGRAM COSTS.

The total program costs for October and November with associated manpower (FTE) is summarized below. The manpower levels are those as of November 30. Additional details for each program component are provided in Tables C-1 through C-5.

Table C-0
SSC Program Summary
October and November 1984

	Costs (K$)	Manpower (FTE)
CDG	242	18
BNL	1618	37
FNAL	1020	41
LBL	150	15
TAC	478	23
Total	3508	134

TABLE C-1
CENTRAL DESIGN GROUP*

Cost Report October and November 1984
(K$)

	Program Element	Labor	Material & Services	G & A	Month Total*	Year to Date	Projected Annual Budget
1.1	Directorate	40			40	40	450
1.2	Program Management	60	32	50	142	142	1500
1.3	Accelerator R&D	40		10	50	50	1750
1.4	Conventional Systems Develop.	7	—	3	10	10	1150
1.0	Total	147	32	63	242	242	4850

* A portion of the CDG costs for this period is estimated. Final actual costs will be presented in the next report when the procedure for receiving all personnel costs from all associated institutions is completed.

TABLE C-2
BROOKHAVEN NATIONAL LABORATORY

Cost Report October & November 1984
(K$)

	Program Element	Labor	Material & Services	G & A	Month Total*	Year to Date	Projected Annual Budget
2.1	General	56	152	42	250	250	860
2.2	Magnet Models	104	142	58	304	304	2,540
2.3	Tooling	116	329	81	526	526	810
2.4	Superconductor Development	43	53	33	129	129	670
2.5	Magnet Measurement & Develop	66	38	35	139	139	780
2.6	Power Supplies & Quench Protection	41	2	18	61	61	360
2.7	Crogenic Systems Development	107	56	46	209	209	980
2.0	Total BNL	533	772	313	1618	1618	7000

* Costs for October & November included for this period.

TABLE C-3

FERMI NATIONAL ACCELERATOR LABORATORY

Cost Report October & November 1984
(K$)

	Program Element	Labor	Material & Services	G & A	Month Total*	Year to Date	Projected Annual Budget
3.1	General	4.6	9.5	5.0	19.1	19.1	340
3.2	Magnet Models	151.	255.6	146.3	553	553	3350
3.3	Cryostat Devel.	112.5	161.0	98.5	372	372	890
3.4	Superconductor Development	16.1	0.9	6.1	23	23	400
3.5	Facility Devel.	38.8	7.5	16.7	63	63	340
3.6	Accelerator Physics						830
	Total	323.0	434.5	272.6	1030	1030	6150

* Costs for October and November included for this period.

TABLE C-4
LAWRENCE BERKELEY LABORATORY

Cost Report October & November 1984
(K$)

	Program Element	Labor	Material & Services	G & A	Month Total*	Year to Date	Projected Annual Budget
4.2.1	General	7	6	7	20	20	113
4.2.2	Short Magnet Models	31	10	20	62	62	394
4.2.3	Superconductor	7	6	6	18	18	411
4.2.4	Analysis	15	0	7	22	22	125
4.2.5	Instrumentation Measurements	15	5	9	29	29	156
4.2	Magnet Program Cost Totals	74	27	50	150	150	1200
	Additional Committments		109		109		
	Equipment	11	3	0	14	14	75
4.1	Accelerator Theory and Design	70		33	103	103	800
4.0	LBL Program Total:						
	Operations	144	27	83	253	253	2000
	Equipment	11	3	0	14	14	75

* Cost for October and November included in this period.

TABLE C-5
TEXAS ACCELERATOR CENTER

Cost Report October & November 1984
(K$)

	Program Element	Labor	Material & Services	G & A	Equipment	Month Total*	Year to Date	Projected Annual Budget
5.1	General		69	17		86	86	825
5.2	Short Magnet Models	114	170	34		318	318	1150
5.3	Long Magnet Models	40				40	40	1660
5.4	Tooling							630
5.5	Theoretical Analysis	6				6	6	130
5.6	Facility Development				28	28	28	605
5.0	Total	160	239	51	28	478	478	5000

* Costs for October and November included for this period.