NATIONAL HIGH MAGNETIC FIELD LABORATORY

1996

Annual Progress Report to the National Science Foundation

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Cooperative Agreement
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Florida State University
University of Florida
Los Alamos National Laboratory

1996 ANNUAL PROGRESS REPORT

I. SUMMARY:

MISSION & STRATEGIC GOALS, ACHIEVEMENTS, AND CONCERNS & ISSUES

Mission and Strategic Goals

The mission of the National High Magnetic Field Laboratory (NHMFL) was established by the National Science Foundation in the 1989 solicitation leading to the award of the cooperative agreement to the Florida-Los Alamos consortium. The mission statement has been further refined by the NHMFL in consultation with the NSF, users, and advisory committees. The mission is structured around the following four charges:

(1) to the develop and maintain user facilities in response to all qualified users that open new frontiers for science and technology in high magnetic field related areas,

(2) to establish a magnet science and technology program in partnership with the private sector that enhances magnet and magnet materials technology and furthers U.S. competitiveness,

(3) to establish an in-house research program in partnership with external users that uses and enhances the facilities and promotes the development of new frontiers in science and engineering,

(4) to develop educational opportunities within the thrust areas of the laboratory that respond to national concerns for public awareness of science and engineering and that foster the involvement and participation of students in K-12, undergraduate, graduate programs, and post docs with specific attention given to under-represented groups.

The NHMFL is organized around three major divisions: Operations and Instrumentation Division, the Magnet Science and Technology Division, and the In-house Research Division. All are supported by the NHMFL Administrative and Facilities Program to provide a structure responsive to the mission.

In consultation with its advisory committees, the NHMFL has set specific goals and developed strategies to achieve its mission. As articulated in the five-year plan submitted to the NSF in the summer of 1995, the laboratory will provide continuous fields up to 50 tesla, a magnetic field region formerly accessible only by pulsed magnets. In cooperation with DoE, the laboratory will provide pulsed magnet fields to 100 tesla for several milliseconds, a dream of researchers for over a decade. In addition, the laboratory is committed to the development of magnetic resonance facilities at 900 MHz and beyond in response to new science and technology opportunities that can be effectively supported only in a unique center with the capacities of the NHMFL. Finally, the In-house Research Program has been established that will encourage collaborations with the external users. These proposals will support the development and utilization of advanced instrumentation and facility capability in response to new science and engineering and the needs of users.

Strategic goals have been established in support of the mission by the NHMFL, in consultation with the NSF and advisory committees. The major goals for the next several years are:

- the completion of the major projects initiated within the first five years:
  - the 45 tesla hybrid magnet,
  - the 900 MHz high resolution NMR magnet, and
  - the 60 T quasi-continuous pulsed magnet;
- to provide user access to
  - non-destructive pulsed magnetic fields at $B \geq 100$ tesla for 10-20 ms,
  - a highly homogeneous and stable resistive magnet system with $B \geq 25$ tesla, 52 mm warm bore, and inhomogeneity and instability ≤ 1 ppm,
  - ion cyclotron resonance (ICR) magnet systems capable of providing $B \geq 10$ tesla in a 200 mm warm bore and $B \approx 15$ tesla in a warm bore $\geq$ 110 mm,
  - magnetic resonance imaging system with $B \approx 12$ tesla and a warm bore of ≈ 400 mm,
  - a 20 tesla, 200 mm warm bore powered magnet,
  - a versatile new magnet system able to provide $\leq$ 27 tesla in 52 mm warm bore or 30 tesla in 32 mm with modulation and gradient coils
  - a capacitor driven pulsed magnet system with $B \geq 70$ tesla and bore ≥ 14 mm,
  - spectrometers at the cutting edge of electron magnetic resonance (EMR) instrumentation for continuous wave, transient, and pulse operation;
- to enhance the In-house Research Program at or near the 1995 requested funding, which utilizes and advances the facilities and is structured along the recommendations made by the NSF External Review Committee in September 1995;

- to develop and submit a proposal to the NSF and NIH that articulates the needs for a national magnetic resonance center and defines the scientific and technological impact of such a center;
- to expand the funding base for the magnet science and technology program through the development of cooperative programs with the private sector and other externally funded opportunities, e.g., GOALI, SBIR/STTR, etc.;
- to commission and make available to the user community the high B/T facility;
- to commission and make available the MRI facility housed within the UF Brain Institute;
- to develop and submit to NSF Education and Human Resource Directorate a proposal to provide academic year research participation opportunities for under-represented groups in science and engineering;
- to develop and submit to the Florida Department of Education a proposal for continued support of the STAR TREE program, a K-12 curriculum development program.

The 1996-2001 NSF funding estimate required that certain activities and projects included within the 1995 NHMFL renewal proposal be either curtailed or eliminated. The projects and/or areas that have been terminated include:

- the development of a 45/50 tesla (≈ 1 ppm inhomogeneity)hybrid insert;
- the upgrade of the 60 tesla quasi-continuous pulsed magnet system to 70 tesla; and
- the 1.5 GHz solid state magnetic resonance (0.1 ppm spatial and temporal homogeneity) duplex magnet.

The projects and programs that have been delayed or deferred, i.e., full funding is not available during 1996-2001, include:

- K-12 educational and industrial outreach programs;
- procurement of new and expanded general user instrumentation;
- magnetic resonance users program;
- maintenance of major equipment;
- the continued development of high strength, high conductivity conductors;
- 1.1 GHz high resolution NMR magnet system;
- the 30 tesla, 32 mm split resistive magnet;
- the 40 tesla, 32 mm resistive magnet; and
- the 60 tesla hybrid study program.

The NHMFL welcomes input and advice from the NSF External Review Committee on the priorities identified above, along with input from the Users and External Advisory Committees to assist the laboratory in reassessing its priorities during the next year.

Achievements During the Last Year

The NHMFL has continued its aggressive efforts to develop facilities in response to the user community. There have been many significant achievements during the last year, which are summarized below.

- The commissioning of the 33 tesla, 32 mm bore resistive magnet set the current world record for resistive magnets and opened the NHMFL to fields that formerly were the exclusive domain of hybrid magnets.
- The NHMFL has established the In-house Research Program, incorporating the suggestions made by the September 1995 NSF External Review Committee, and the proposal solicitation has been issued.
- The world's highest field Ion Cyclotron Resonance Mass Spectrometer, a 9.4 tesla, 210 mm warm bore magnet, has been commissioned and made available to users.
- The NHMFL has demonstrated increased mass resolution, mass limit, number of ions and ion lifetime in Ion Cyclotron Resonance Mass Spectroscopy at 20 tesla in resistive magnet.
- The NHMFL has established the world's highest field, high resolution electron magnetic resonance spectrometer, 15/17 tesla.
- Funding by the Keck Foundation will result in a high resolution powered magnet system with B ≥ 25 tesla and a warm bore of 52 mm for magnetic resonance experiments.
- The NHMFL will be a beta test site for a 400 MHz high resolution NMR system with a high temperature superconducting probe, which was the product of a cooperative program between Varian, Inc. and Conductus.
- The NHMFL has demonstrated field stabilization using NMR field lock technology giving temporal field stabilization ≤ 1 ppm.
- The State of Florida provided $1,500,000 to develop and build a 15/17 tesla ICR magnet.
- Users are responding to increased demand by making more effective use of their magnet time.

They are getting more data at higher fields in less time.

- The NHMFL participated and provided support to a team of international scientists who reached 1000 tesla in a series of flux compression experiments, the Dirac Series, at the Los Alamos facility.
- The UF Brain Institute, in cooperation with the NHMFL, has secured $5,000,000 in supplemental funding to support the development and fabrication of the 12 tesla, 40 cm bore magnetic resonance imaging magnet.
- New staff at the NHMFL-Pulsed Field Facility have been hired, addressing previous concerns with regard to adequate user support.
- All the additional power supplies for the NHMFL-Pulsed Field Facility to support the 100 tesla program have been ordered.
- The 100 tesla cooperative program between NSF and DoE was formally established, and a management plan has been developed and signed.
- A cooperative development contract with IGC was negotiated and signed that provides a $1,000,000 contribution by IGC to the 900 MHz NMR magnet project.
- The NHMFL has continued to develop partnerships with the private sector that address economic development and technology transfer; the signing of a cooperative research and development contract with EURUS, Inc., exemplifies this.
- The NHMFL support base has been broadened, as recommended by the NSF External Review Committee in September 1995, to include outside contracts with Toshiba for a powered magnet for the National Institute for Materials Research, Tsukuba, Japan and other contracts with DoE, NASA, Westinghouse and the Navy.
- A full-time head of the NHMFL K-12 educational program has been hired along with support staff; a State-funded middle school science teachers summer program, STAR TREE, was initiated.
- A very successful summer research participation program for under-represented groups attracted sixty applications from around the United States; twenty offers were made by the NHMFL and eighteen were accepted.

Concerns and Issues

There are several issues of particular concern to the NHMFL about which we would appreciate receiving guidance from the NSF External Review Committee. In addition to the information contained in this progress report, supplemental information will be provided as part of the presentations during the review.

- The electrical costs to operate the powered magnets at the NHMFL-Tallahassee have grown at a faster rate than originally anticipated. This is a reflection of continued growth in user demand for the facility, higher field requiring higher power, and the fact that users are spending more time near the upper field limits, for low resolution NMR, for example. The issue is how to best deal with this increased demand.
- The September 1995 NSF External Review Committee encouraged the laboratory to develop a more formal proposal review procedure, which involved outside reviewers. This recommendation led to the requirement by NSF to establish a new committee, the Review Committee, to review proposals and make recommendations to the Director of the NHMFL with regard to the allocation of time. The laboratory has contacted other DoE- and NSF-operated facilities, and there appears to be quite a variation in how user proposals are reviewed. At the site review, the laboratory will present a few options for structuring this Review Committee and will seek the NSF committee's advice.
- With the reduction in NSF funding from the five-year requested level of $110,998,000 to the anticipated funding level of $87,500,000, a reduction in scope of the program was required. The NHMFL has developed a prioritized list of projects and programs that (1) funds the In-house Research Program at the five-year requested level as recommended by the NSF External Review Committee last year, (2) augments the user support staffing at the NHMFL-Pulsed Field Facility to better meet the needs of users, (3) minimally funds the users program eliminating any significant support for new user instrumentation, (4) commits funds to complete major projects initiated in the first five years, (5) removes nearly all facilities personnel and administrative staff formerly covered by the NSF contract, and (6) allocates the balance of funding to the maintenance of existing magnet systems with a reduced number of new projects (see list of goals and budget information). The laboratory would like the committee's input on the balance to programs and our prioritized list of projects.

The Progress Report

The following Progress Report is organized in the format used for the continuation proposal submitted to the NSF last year. The laboratory has included an additional section that provides a brief overview of the present status of the magnetic resonance program within the NHMFL and our plans for the future. The section outlining the Magnet Science and Technology Program includes separate project reports on each magnet project and significant development program. The format of these individualized reports has been structured to provide the NSF External Review Committee with a brief introduction to the magnet system, a list of accomplishments and milestones for the future, along with a separate budget summary for each project that includes expenditures to date and cost to completion. This format is used for monthly reviews within the laboratory and will be used in all future progress reports to NSF. The NHMFL hopes this consistency and format in reporting will be helpful to the NSF External Review Committees and to NSF in tracking progress on these projects.

The NHMFL would like to express its appreciation to the members of the NSF External Review Committee for their time and commitment to the NHMFL and NSF in reviewing our programs and for providing advice on how the laboratory can better serve the user community and the nation.

II. USERS PROGRAMS

The various user programs of the NHMFL continued to expand during 1996. New magnets and instrumentation were added and new users appeared. The DC Field Facility experienced a near doubling of the amount of electricity used per month from October 1995 through July 1996 with no sign of leveling off. This is cause for rejoicing in the increased efficiency of use of the capital equipment and in the never-before-possible experiments that require high, constant fields. It is prompting serious discussions, however, about ways to reduce the costs while continuing to increase "tesla hours." Listed below are a few highlights of the new support offered users during 1996, followed by some program-by-program details and access to facilities guidelines.

- In February 1996, the General Purpose DC Field Facility in Tallahassee installed a 33 T, 32 mm bore magnet. It was used the same day to examine the Fermi surface of a low-dimensional organic conductor.
- The 24.5 T, 32 mm bore, higher homogeneity magnet continued to be used for NMR studies of high T_C superconductors, quantum wells, and other condensed matter systems. This is the highest field NMR facility available, and it has attracted fifteen outside users in addition to the in-house research activity. This magnet also was used to better understand and eliminate the sources of field fluctuations with the aim of producing a magnet system for all kinds of magnetic resonance research at the 1 ppm level of inhomogeneity and instability.
- Multiple units of high demand instrumentation were purchased or built for users of the DC and Pulsed Field Facilities, thereby increasing the number of samples that could be studied per magnet hour. NHMFL staff responded to user requests for new sample holders to support interesting new techniques. Experience with operating major equipment led to improvements that increased reliability, user friendliness, and/or performance.
- The number of pulsed magnet stations that can accommodate concurrent experiments has been increased to four, and the amount of equipment available has also increased.
- The newest pulsed magnet produces 40 T in 24 mm over a long pulse length of 500 ms.
- The Ultra-High B/T Facility in Gainesville put its dilution refrigerator into operation and built and installed many small parts that will allow immediate use of the facility as soon as the high field magnet is delivered.

Each of the groups that make up the Center for Interdisciplinary Magnetic Resonance continued the development and use of magnet-based instruments originally brought on-line in 1995.

- Sixteen research groups have used the EMR facility since it was first made available in November 1995.
- Wide-line NMR in a resistive magnet was improved by development of a new low temperature cryostat insert and sample probe. Sources of field instability were studied and corrected.
- A new 400 MHz, 89 mm bore, high sensitivity spectrometer was delivered and will be available to users by 1/1/97. Varian and Conductus have designated the NHMFL a beta test site for a new, jointly developed, two-channel spectrometer that uses a detector made of high T_C superconducting material.
- The new 3 tesla 80 cm bore whole-body system for MRI and MRS that was installed last fall has already given exquisite head images and angiograms of unrivaled resolution during its testing and development phase. It will be available to researchers in September 1996.
- The world's highest-field, highest performance FT-ICR mass spectrometer (9.4 tesla superconductive) was completed.

General Purpose DC Field Facilities—Tallahassee

General Purpose DC Magnets Available in Tallahassee in September 1996

Field (T), Bore (mm)	First Use	No. in Use	Supported Research
Superconducting			
20, 52	3/93	2	Magneto-Optics, ultra-violet through far infrared; Magnetization; Specific heat; Transport; Temperatures from 20 mK to 300 K; Pressure from ambient to 13 GPa.
15, 45	7/95	1	
Resistive			
20, 50	3/94	2	Same as superconducting except the available temperature range is from 0.5 K to 600 K, and the possible experiments include low resolution magnetic resonance.
30, 32	3/95	2	
33, 32	2/96	1	
24.5, 32[1]	7/95	1	
14, 150	7/95	1	Split coil magnet with 30 X 70 radial access. Stress testing of materials, especially superconducting cable

[1] Increased homogeneity (10 ppm over 2 mm DSV) magnet for magnetic resonance experiments.

Instruments for Users of the Continuous Field General Purpose Magnets

Considerable effort went into improving the array of available instruments and experimental techniques based on our increasing experience meeting users' needs. Multiple copies of popular instruments increase the amount of data that can be taken per magnet hour. This makes more efficient use of researchers' time and NHMFL resources.

The two 20 T superconducting magnets were moved to their own low-noise hall away from the resistive magnets and their power supply. The move included the following improvements:

- Significantly lower vibration levels, reduced ambient acoustic noise, and cleaner electrical power.
- All user instrumentation, lab benches, etc. are located on a mezzanine at the same level as the top of magnet cryostats. No more climbing ladders or working on scaffolding.
- A low friction rotator was designed and built for the dilution refrigerator. It uses highly polished sapphire bearings and causes no detectable heating even when quickly rotated through large angles at 20 mK.

Magneto Optics

Recent improvements in the visible optics facilities include the ability to do UV photoluminescence measurements of GaN Gap Exciton spectra. A new sample holder makes possible Voigt geometry measurements (k vector perpendicular to B). Optical experiments were done at extreme pressures in a diamond anvil cell. Photoluminescence excitation is now possible. A Xe lamp is available for UV excitation. A stepper motor control for the Ti:Sapphire laser allows remote computer control of its wavelength.

Magnetization

A vibrating sample magnetometer was purchased and put into operation for samples that are too large or have moments that are too large for the cantilever force magnetometer. It will cover temperatures from 0.5 K to 400 K and has a resolution of about 10^{-4} emu.

NMR Spectrometers for High Field, Low to Medium Resolution Experiments

- A 15 T at 4.2 K, 17 T at 2.2 K, superconducting magnet, 1 ppm homogeneity, has been purchased for condensed matter NMR research, and as a staging magnet for NMR experiments in the medium homogeneity resistive magnet.

- A newly purchased Tecmag dual frequency spectrometer with R. F. leveling, dedicated to NMR in the resistive magnets, covers the frequency range 10-300 MHz. The dual frequency feature allows interleaving data from a standard and the nucleus being studied, greatly enhancing the accuracy of Knight shift data, or interleaving two different nuclei in the sample under study, effectively doubling the data acquisition rate.
- ^{7}Li NMR and ^{139}La NQR in lanthanum cuprates showed new hopping behavior.
- High-Field ^{17}O NMR studies of fluxoid lattice of $YBa_2Cu_3O_7$ at more than twice the field of previous work.

High Pressure Research

- A new plastic diamond anvil cell and a plastic sapphire ball cell will make it possible to do transport and optical measurements to high pressures in pulsed magnetic fields without eddy current heating of the sample.
- A new single axis He-3 rotator is large enough to accommodate our two smaller diamond anvil cells. Retractable optical fibers allow the pressure to be measured at the temperature of interest.
- Brush Wellman, in a loose collaboration with NHMFL and Meigan Aronson of U. Mich., has developed a magnetically clean BeCu:Co alloy that Stan Tozer has used to make small diamond anvil cells for magnetization work using a SQUID magnetometer. This cell has been successfully used to measure the magnetization of ferrite colloids at 67 kbar.

DC Facility User Statistics: The user activity is summarized below for the one-year period August 1, 1995, through July 31, 1996. A magnet day equals seven hours in a resistive magnet or up to twenty-four hours in a superconducting magnet. A user is anyone likely to be listed as a co-author.

Number of PIs	72		
Number of Experiments	89		
Number of Users	245		
Number of Students	61		
Number of Post Docs	13		
Number of magnet-days:	Resistive	Super-conductor	
NHMFL, UF, FSU, FAMU, LANL	336	163	48%
U.S. university	166	205	36%
U.S. govt. lab.	18	22	4%
Industry	29	0	3%
Overseas	69	21	9%
Maintenance	40	152	
Idle	7	155	
Total: 1383	**665**	**718**	**100%**

Pulsed Field Facility—Los Alamos

General Purpose Magnets Available in Los Alamos in September 1996

Field (T), Bore (mm)	First Use	Pulse, Rise/Duration (ms)	Supported Research
Pulsed			
50-55, 24	12/92	6/30	Magneto-Optics, ultra-violet through far infrared; Magnetization; Mechanical Properties; Thermal expansion; Specific heat; Transport; Temperatures from 25 mK to 550 K; Pressure from ambient to 3 GPa; NMR in highest fields—low resolution
60-65, 14	3/93	7/35	
45/24[1]	2/95	9/60	
40/24	3/96	10/500	
Superconducting			
20, 52	12/92		Same as pulsed fields
9, 32	11/95		Magneto-Optics, ultraviolet to near infrared
Flux Compression			100 T - 1,000 T available through LANL programs

[1]*Higher homogeneity*

User Environment

The Pulsed Field Facility operates its user program according to the NSF-FSU Cooperative Agreement and in a manner tailored to the specific characteristics of pulsed field experiments. In particular, the heightened safety requirements attending pulsed field experiments, arising from the intrinsic high voltage and the non-negligible probability of magnet failure, dictate that experiments be reviewed for safe operation within the magnet and that users be assigned an NHMFL contact who guides and assists them in following local laboratory procedures, setting up the experiment, pulsing the magnet, and acquiring data. Even for experiments with the 20 T superconducting magnet, the NHMFL contact is needed to assure the safe operation of the magnet and the associated instrumentation and equipment. Accepted experiments can usually be scheduled within four to six weeks, or even sooner if an opening appears due to cancellation.

Magnet Update

There are four classes of magnets at the Pulsed Field Facility.

- A 20 T superconducting magnet for staging, set-up, calibration, and independent experiments. Among the associated instruments are a dilution refrigerator, a vibrating sample magnetometer, a magnetostriction probe, a high temperature Hall probe, and a variable temperature insert.
- The number of pulsed magnet stations that can accommodate concurrent experiments has been increased to four. A wide range of supporting equipment is available, including a dilution refrigerator, He-3 cryostats, and an optical spectroscopy lab. The addition of mobile pumping stations and additional cryostats has increased the efficiency of operations.
- The standard capacitor-driven 50 T and 60 T pulsed magnets are now offered at higher fields—up to 55 T and 65 T respectively—for those users willing to risk somewhat shorter magnet life.
- A newly acquired magnet produces 40 T in 24 mm over a long pulse length of 500 ms.
- A 60 T quasi-continuous magnet, the first of its kind in the US, is now undergoing final assembly and will produce a constant 60 T for 100 ms in a 34 mm cold bore, as well as a variety of other pulse shapes. Its description and schedule are given elsewhere in this report.

- Flux compression experiments up to 1,000 T are possible at Los Alamos in cooperation with other Laboratory programs. The most recent series (code-named 'Dirac') began in April and concluded in July 1996. NHMFL is the liaison between outside users and the explosive flux compression capabilities at Los Alamos. In effect, NHMFL, through Los Alamos, becomes perhaps the only magnet lab in the world offering general user access to this technique for producing ultra high fields

Staff

By September 1996, the user support staff at Los Alamos will consist of Director of Pulsed Field Facility, Operations Manager, Low Temperature Scientist, Postdoctoral—transport, Postdoctoral—magnetization, Postdoctoral—optics, Mechanical technicians (2), and Secretary. Near term openings exist for an optics scientist and an additional technician specializing in cryogenics.

Pulsed Field Facility User Statistics

The user activity is summarized below for the one-year period August 1, 1995, through July 31, 1996. These include only experiments with NHMFL magnets, not flux compression experiments. Magnet stations are assigned to users in units of days.

Number of PIs	58	
Number of Experiments	110	
Number of Users	84	
Number of Students	15	
Number of Post Docs	11	
Total number of magnet-days used	477	(20 T: 309)
Number of magnet-days used for testing	19	
Number of principal investigator-days	694	(20 T: 456)
University PI-days, including UF, FSU & FAMU	273	39%
Govt. lab. PI-days, including LANL	164	24%
NHMFL PI-days (incl. testing)	152	22%
Overseas (Czech, Japan, Neth., Korea, Brazil)	100	14%
Industry PI-days	5	1%
Total	**694**	**100**

Ultra-High B/T Facility—Gainesville

A special annex facility for studies of materials at ultra-high values of the ratio of magnetic field to temperature (B/T) is being developed as a collaborative effort between the NHMFL and the Microkelvin Laboratory at the University of Florida. Fields up to 20 T and temperatures down to 500 μK provide a B/T ratio of 4 x 10^4 T/K, the highest available anywhere. Users will be able to study new phenomena that require the establishment of high spin polarization or high magnetization.

Accomplishments in the last year include:

- The magnet dewar and dilution refrigerator were tested, and the design temperature of less than 10 mK was achieved.
- The PrNi5 demagnetization stage was built and installed on the dilution refrigerator along with the necessary superconducting heat switch.
- The helium-3 melting pressure thermometer and the Pt nuclear resonance thermometer were built and installed ready for use.
- A cold finger extension from the demagnetization stage into the high field region was built.

The target date for opening this facility is January 1997. Delays have occurred because Cryomagnetics has been unable to deliver the 18/20 T magnet system. This magnet is the first with such a high field that Cryomagnetics has attempted and is an example of NHMFL work with U. S. industry to enhance its capabilities.

Center for Interdisciplinary Magnetic Resonance (CIMAR)

The magnetic resonance program spans all three institutions of the NHMFL. The primary facilities for nuclear magnetic resonance (NMR), electron magnetic resonance (EMR, including electron paramagnetic resonance and electron cyclotron resonance), and ion cyclotron resonance (ICR) are housed in Tallahassee. The primary site for magnetic resonance imaging and *in vivo* spectroscopy (MRIS) is at the University of Florida. However, there are NMR spectrometers at UF and MRI instruments in Tallahassee.

1. NMR Program

NMR systems have been that were put into operation in 1995 continue to be improved and used for research. Continued efforts have been made to attract highly-qualified staff. Research and development has concentrated on a wide range of areas.

- A new cryostat and new transfer line have been supplied by the manufacturer of the 850 MHz, 20 T, 31 mm bore magnet. It made 18 T at 4.2 K and 19.5 T at 2.7 K, so is expected to meet all of the design specifications by mid September 1996.
- The NHMFL has been designated a beta test site for a new kind of NMR detector that has been developed jointly by Varian and Conductus. They have loaned to the lab a complete 400 MHz, 89 mm bore, two channel spectrometer and magnet. The detector is made with high T_c material and has about five times the sensitivity of prior detectors.

Twenty-five research groups used the Tallahassee NMR facilities last year—18 local, 1 other university, 1 government, 4 overseas, 1 industry. Only 5% of the available time was needed for maintenance, calibration, etc.; 79% went to local users and 16% to external users.

2. NMR Imaging and In Vivo Spectroscopy

The major events in MRI/Spectroscopy in the past year were the acquisition of the 3 tesla whole body magnet at the UF Brain Institute/VA Hospital and the funding of the 12 T, 400 mm warm bore MRI magnet system. Final testing of the 3 T system is being done now, so it should be available for research use by September 1996. Rare or unique features of this system will produce images with spatial resolution of ≤250 microns/pixel and provide for 10 image/second acquisition rates, compared to the 1 to 3 image/second available on most other whole body systems. The use of high fields combined with high speeds should provide better head and spinal cord image quality. The 12 T, 400 mm system was funded by the Department of Defense through the UF Brain Institute. It will be designed and built by an NHMFL—private sector partnership.

3. Electron Magnetic Resonance Spectroscopy

High resolution EMR (0.01 mT) began in July 1995 with the installation of a 15/17 T, 52 mm superconducting magnet specially designed for EMR experiments up to 450 GHz, including EPR X-band measurements to 9 GHz. Research by in-house and visiting users has proceeded along with development of instruments. The scientific projects are drawn from physics (high T_c superconductors); chemistry (molecular magnetism); and biology (photosynthesis and proteins) Sixteen research groups have used the facility since November 1995. Six were local, six from other universities in the US, and four from overseas. The spectrometer is available 16 hours per day, six days per week, all year. About 65% of the available time was used by internal users, and 35% by external.

4. Fourier Transform Ion Cyclotron Resonance Mass Spectroscopy

During 1996, the FSU ICR group's main activity was the design, construction, and assembly of new instruments. As new techniques and experiments are developed on the NHMFL instruments, those methods will be implemented on external–user instruments in the NSF National High–Field FT–ICR Mass Spectrometry Facility.

- Design and construction of a 9.4 tesla FT-ICR mass spectrometer with home-built electrospray source and dual octupole ion guides were completed early in 1996. It represents the world's highest field (and highest performance) FT-ICR mass spectrometer, and is available to external users. It offers improvements in dynamic range (factor of 10) and mass resolving power at high mass (factor of 2) compared to the best prior instrument anywhere. Mass resolving power of 150,000 for a protein of 112,000 dalton molecular weight was achieved, and hundreds of combinatorial peptides can be detected simultaneously in a mixture.
- The ICR and NMR groups at NHMFL combined to produce the first mass spectrum of a ^{13}C, ^{15}N isotopically doubly-depleted protein. Just as ^{13}C, ^{15}N *enrichment* simplifies and improves S/N ratio for NMR spectra of proteins and nucleic acids, ^{13}C, ^{15}N *depletion* compresses the isotopic distribution and improves S/N for mass spectrometry.
- A 20 tesla resistive-magnet FT-ICR mass spectrometer with a home-built (MALDI) fiber-optic source was built. This small-bore system produced the world's highest-field (by a factor of more than 2) FT-ICR mass spectra, at a mass resolving power more than 10 times higher than the spatial homogeneity of the magnet itself. These results validate the projected performance for the Keck 25 T resistive magnet.
- $1,500,999 was granted by the State of Florida to develop a 15 T, 110 to 200 mm warm bore magnet

system. Proposals have been sought from companies wishing to join with the NHMFL in a partnership to design and build this system.

Forty-five researchers have used the facility in the past year. Thirty-four of these were local, seven from other U.S. universities, one from a U.S. government lab, one from U.S. industry, and two from overseas. About 75% of the effort on the two systems available to outside users has been directed at instrument building in the past year. The remaining 25% breaks down as follows: The 6.0 T FT-ICR instrument is available 10% internal and 90% external. The 9.4 T FT-ICR instrument is available 90% internal and 10% external.

Access to NHMFL Facilities

User access to NSF-funded NHMFL facilities is controlled by a two-step proposal and review process that is administered by the Director of Continuous Field User Programs and the Director of the Pulsed Field Facility. A brief initial proposal is reviewed by NHMFL staff and approved or denied by the Director of NHMFL. Then, every six months, a summary listing of all user programs is compiled and ranked in order of magnet use. Users who have consumed a significant portion of resources (about 1% to 2%) within the past year are then required to submit a more detailed proposal based on their present and future work in high fields. Users in this category are the largest users and collectively account for at least 80% of the annual total facility use. In addition, all users of the 45 T hybrid magnet will be required to submit such a proposal for peer review. Each accepted proposal is in force for three years. Each detailed proposal is reviewed by one member of the Users' Committee, one outside reviewer (not NHMFL or Users' Committee), and one member of the NHMFL In-House Research Program Committee. Each reviewer gives the proposal a score on a "0-to-10" scale. The total of the review score determines the priority and amount of magnet time given to the proposed experiments. The final decision for use of the High Field Facility rests with the Director of the NHMFL. Six three-year proposals have been through this process. Eleven principal investigators have been asked to submit proposals.

The detailed proposal process is waived for any research program that is supported by a grant from any other public or private agency that follows a rigorous peer-review process acceptable to the NHMFL and the NSF. This waiver assumes that the research proposed is fully described in the grant proposal or award and that funds were included to support the high magnetic field research activity. The two largest users of the resistive magnets are in this category; a new user has recently joined it.

Most of the NMR spectrometers, electron magnetic resonance facilities, FT-ICR mass spectrometer facilities, isotope geochemistry facilities, and the magnetic resonance imaging facilities are supported by grants other than the NHMFL Cooperative Agreement with the NSF. Access to them is governed by the terms of the grants or the principal investigators. The fraction of time available to general users equals the fraction of the facility cost paid by the NHMFL.

The new NSF-FSU Cooperative Agreement calls for the establishment of a proposal review committee to select reviewers for proposals, review progress reports, and advise the Director on the resources to be allocated to each proposal. The NSF has encouraged the laboratory to select for the review committee individuals who are not users and whose expertise covers the fields of study being pursued by users of the NHMFL. The structure of this committee and the review process will be presented to the NSF External Review Committee for their input during its September 1996 review.

III. MAGNET SCIENCE AND TECHNOLOGY PROGRAM

The Magnet Science and Technology (MS&T) Program is responding to the priorities established by the NHMFL in consultation with the Renewal Site Review Committee, the NSF, and the Users' Committee. The NHMFL renewal proposal set forth a number of magnet projects based on the proposed funding.

• Authorized Projects

45 T Hybrid Magnet Project, including resistive insert.

Completion—September 1997

900 MHz Wide Bore NMR Magnet

Completion—December 1998

Delta B Program—Advanced development program for the 1.1 GHz High Resolution NMR Magnet, Phase 2

Ongoing development

Resistive Magnet Program

20 T, 200 mm large bore resistive magnet, cooperation with Grenoble—May 1997

Resistive Magnet Maintenance—Ongoing

33 T Magnet I—Completed—Feb. 29, 1996

33 T Magnet II—Completion—July 1997

Hydraulic Test Stand, support of future resistive magnet development

Completion—October 1996

Pulsed Magnet Program

50-80 T Pulsed Magnets (for use with capacitor banks), support for User Facility—
Ongoing development

60 T Quasi-continuous Pulsed Magnet

Completion—October 1997

100 T Pulsed Magnet, cooperation with DOE

Completion—December 1998

• Deferred Projects

Split Coil Resistive Magnet (Start)

Deferred to later years

40 T, 32 mm Bore Resistive Magnet

Deferred to later years

60 T Hybrid (Study)

Deferred to later years

1.1 GHz High Resolution NMR Magnet

Deferred to later years

• Canceled Projects

45/50 T Hybrid Inserts—Medium Resolution (1 ppm)—Eliminated

70 T Quasi-continuous Magnet Upgrade—
Eliminated

1.5 GHz Solid State NMR—Eliminated

The status, schedule, and cost data for each of the above authorized programs is given in the individual project reports that follow. This format will be used in future external reviews so that progress on individual projects can be more readily tracked.

NHMFL Magnets Funded from Other Sources

In addition to the NSF-funded magnet programs, MS&T has obtained funding from other sources to support several projects. One project (the "Keck" magnet) will result in another resistive magnet being installed at NHMFL. Several other major superconducting magnet programs designed and built in cooperation with the private sector will similarly advance the NHMFL facilities.

25 T, 52 mm bore, 1 ppm Resistive Magnet ("Keck" Magnet)

To be used for magnetic resonance applications, funded by a grant from the Keck Foundation.

9.4 T/10.5 T FT-ICR/MS Magnet

Superconducting magnet to be built in cooperation with industry—funded by NSF ICR Center grant.

15/17 T FT-ICR/MS Magnet

Superconducting magnet to be built in cooperation with industry, funded by State of Florida as match to NSF ICR Center grant.

12 T, 40 cm bore MRI/S Magnet

Superconducting magnet to be built by industry in collaboration with MS&T, funded by DOD grant to the Brain Institute at University of Florida.

SMES Conductor Test Facility

4 T magnet with an inner diameter of 1.85 m and a cryostat capable of testing SMES conductors, joints, etc. This facility, funded by the U.S. Navy, is being built by Westinghouse and will be installed at the NHMFL. The facility will be available to users after completion of the Navy test program.

Work for Others

MS&T is establishing a reputation as an internationally recognized center for magnet science and technology. This is evidenced by the various magnet programs that have developed involving design and fabrication of magnet systems for use by other groups.

NASA Magnet

0.16 T, 184 mm bore magnet funded by NASA Huntsville.

NRIM Magnet

30 T, 32 mm bore resistive magnet funded by NRIM for installation at NRIM.

LANL Neutron Scattering

30 T, 2 Hz, split pair, pulsed magnet for LANSCE Facility at LANL. Initial design and materials studies funded by DOE through LANL.

Wisconsin Pegasus Solenoid

20 T, 60 mm, 1.5 m long pulsed magnet for Pegasus Tokamak Project, funded by DOE through University of Wisconsin.

Project status reports are provided for these programs that involve in-house design or fabrication activities.

PROJECT TITLE: 45 T HYBRID MAGNET PROJECT

REPORT DATE: July 31, 1996

Objective:

Produce a versatile, reliable, user-friendly magnet system providing at least 45 T in a 32 mm bore. Objectives are to be accomplished using:

- a superconducting outsert with clear bore of 616 mm and producing 14 T on axis during normal operation
- a resistive insert producing at least 31 T while immersed in the background field of the outsert
- technology that significantly advances the state of the art for large, high-field superconducting magnets.

The outsert magnet is being developed in cooperation with Intermagnetics General Corporation, New York.

Status:

The Hybrid Project includes five major components or systems: (1) superconducting outsert magnet, (2) resistive insert magnet, (3) cryogenic system, (4) outsert power/protection system, (5) system integration.

Superconducting Outsert Magnet

- Coil B winding is completed and coil was received at NHMFL on July 1, 1996.
- Heat treatment process and systems have been fully developed. Confirmation trials have been completed. Coil B to be heat treated early September 1996.
- Initial round of VPI trials for Nb_3Sn coils are completed. Problems with cracking in the "neat" region of the CTD-101 resin have been encountered. Changes in curing cycle and alternate resins are being evaluated.
- Joint/termination development is complete. A fully acceptable and repeatable joining process has been developed.
- Coil C conductor is in NHMFL possession. Everson Electric, in conjunction with NHMFL are developing the insulation and VPI procedures and testing them on a dummy pancake coil.
- Stacking and joining procedures for the Coil C pancakes are presently being developed.
- Coil A is being wound at IGC, with completion scheduled for November 1996.
- Outstanding Issues:

  The number of unblemished Coil C pancakes is just adequate. A decision will have to be made regarding which pancakes to keep as spares and where to place blemished pancakes if used.

  Coil B conductor will be marginal for 11 kA operation (normal operation is 10 kA, with 11 kA providing margin for the worst-case insert trip). Further tests will be required to finalize specifications of the operating limits of the magnet.

Resistive Insert Magnet

(See also Hybrid Insert Report that follows)

- Insert housing fabrication is complete and the housing has been pressure tested. It will be shipped to NHMFL soon.
- Copper-silver alloy sheet appears to be the most promising material for the innermost coils of this magnet.
- Investigations are underway with Handy & Harman to develop competence in the production of copper-silver alloy. To date they have been successful in achieving higher uniformity but conductivity and strength are not up to the level of the Japanese suppliers.
- Material design properties and coil design will be finalized in the near future.

Cryogenic System

- The cryogenic system is physically complete and has been undergoing operational tests with a dummy load.
- The 1.8 K heat load is tolerable but high.
- The search is continuing to isolate a minor leak into the insulating vacuum space, which may be contributing to the elevated 1.8 K heat load.
- The dummy load has been removed and the 1.8 K heat load measurement will be repeated in the September-October timeframe.

Outsert Power/Protection System

- Outsert power supply and dump resistor have been tested under load.
- Current bus bars for connection between the power supply and the outsert magnet have been successfully tested, including: room-temperature water-cooled current leads, cryogenic vapor-cooled current leads, and the superconducting buswork.
- The quench-detection approach based on a fast PC has been selected and an Engineering Memo on the design is in process. No hardware has been procured as yet, since the software is still being developed.

Systems Integration

- Site facilities and installation are complete.
- Cooling water piping for the resistive magnet is being fabricated and installation will be completed when the housing is put in place.
- Cryogenic system controls have been 90% computerized, allowing a high degree of automation while retaining manual control options. Selected instrument readouts and trends are displayed on two on-site monitors and the ability for off-site monitoring and control of some functions has been implemented, significantly reducing manpower requirements for operation.
- Power supply controls have not yet been fully developed.

Budget Summary:

Budget data for the Hybrid Project has been re-cast to meet current NHMFL project reporting requirements. A total project budget has been developed based on expenditures to date and estimated cost to complete as of July 31, 1996. These costs are NHMFL costs only and are based on receiving the tested resistive insert housing and 33 NbTi wound pancake coils from FBNML. Cost to complete includes the 33 T resistive insert and the costs of insulating, encapsulating and assembling the NbTi Coil C pancake windings.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Resistive Insert, (includes Resistive Magnet Group)					
Labor	81	176	257	60	-197
Equipment/Subcontracts	0	431	431	0	-431
Travel/Expense	22	5	27	16	-11
Subtotal	103	612	715	76	-639
Superconducting Outsert Magnet— Nb_3Sn Coils					
Labor	1,176	83	1,259	996	-263
Equipment/Subcontracts	3,305	0	3,305	3,290	-15
Travel/Expense	174	12	187	143	-44
Subtotal	4,655	95	4,751	4,429	-322
Superconducting Outsert Magnet—NbTi Coils (Does not include FBNML Costs)					
Labor	109	180	289	0	-289
Equipment/Subcontracts	26	270	296	0	-296
Travel/Expense	13	9	22	0	-22
Subtotal	148	459	607	0	-607

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Superconducting Outsert Assembly & Enclosure					
Labor	308	195	503	360	-143
Equipment/Subcontracts	60	0	60	60	0
Travel/Expense	10	33	43	29	-14
Subtotal	378	228	606	449	-157
Cryogenic System					
Labor	473	45	518	449	-69
Equipment/Subcontracts	1,857	0	1,857	1,858	+1
Travel/Expense	49	5	54	90	+36
Subtotal	2,379	50	2,429	2,397	-32
Outsert Power/Protection System					
Labor	152	90	242	177	-65
Equipment/Subcontracts	382	51	433	475	+42
Travel/Expense	41	0	41	41	0
Subtotal	525	141	716	693	-23
System Integration					
Labor	298	120	418	424	+6
Equipment/Subcontracts	384	0	384	384	0
Travel/Expense	100	80	180	198	+18
Subtotal	782	200	982	1,006	+24
Project Total					
Labor	2,597	889	3,486	2,466	-1,020
Equipment/Subcontracts	6,014	752	6,766	6,067	-699
Travel/Expense	409	145	554	517	-37
Subtotal Direct Costs	9,021	1,785	10,806	9,050	-1,756
Overhead	1,383	475	1,858	1,372	-486
Project Total	10,404	2,260	12,664	10,422	-2,242

Budget Summary—$K (Cont.):

Our previous estimate (September 1995) of the cost of the NHMFL portion of the project, excluding Coil C and the Resistive Insert was $9,050K. The current estimated cost is reconciled as follows:

		Notes
Est. Total Direct Cost, September 1995	$9,050	
Resistive Insert	639	1
Complete Coils A&B	322	2
Complete Coil C	607	1
Complete Outsert Assembly (including Coil C Assembly)	157	3
Complete Cryogenic System	32	4
Complete Power/Protection System	-23	5
Complete System Integration & Test	24	5
Est. Total Direct Cost, September 1996	$10,806	
Overhead	1,858	
Total Project Costs, September 1996	$12,664	

Notes to Budget Reconciliation:

1. Tasks assumed from MIT.
2. Modifications to VPI and heat-treatment equipment and increased effort to improve these processes.
3. Increased scope because of unassembled Coil C.
4. Continuing testing to isolate and correct 1.8-K heat load.
5. Cost estimates not previously assigned.

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Outsert Magnet		
Coil A:		
Winding complete	10/2/96	
Heat treatment complete	11/7/96	
Impregnation complete	12/31/96	
Manufacture complete	2/25/97	
Coil B:		
Heat treatment complete	9/5/96	
Impregnation complete	11/4/96	
Manufacture complete	1/1/97	
Coil C:		
Stacking and joining process qualified	10/9/96	
Start delivery of impregnated pancakes	11/18/96	
Complete pancake delivery	5/5/97	
Coil C assembly complete	5/22/97	

	Schedule	Actual or Rev Schedule
Outsert Magnet Assembled in Vessel	8/7/97	
Cryostat Ready for Inst. of Outsert Magnet	6/1/97	
I&C System Ready for Operation	6/1/97	
Outsert System Ready for Test	9/2/97	
Superconducting Outsert Operational	10/21/97	
Resistive Insert		
Housing delivered to NHMFL	9/30/96	
Purchase and fabricate components complete	5/31/97	
Insert assembly complete	6/30/97	
Insert installed in cryostat warm bore and ready for test	7/15/97	
Resistive tests complete	7/30/97	
45 T Hybrid System		
System ready for combined tests	10/28/97	
System operational for users	11/8/97	

Minor schedule delays have been experienced because of the need for small improvements to both the heat-treatment and VPI processes for the Nb_3Sn coils. The dominant cause of delay, however, has been the increased workload associated with assuming two major tasks from MIT that were originally scheduled for completion by MIT in May 1996: (1) the design, procurement and fabrication tasks necessary to complete the resistive insert magnet and (2) the insulation, impregnation, stacking and joining tasks necessary to complete Coil C of the superconducting outsert.

PROJECT TITLE: HYBRID INSERT

REPORT DATE: July 31, 1996

Objective:

Provide at least 45 T in a 32 mm bore given a 14 T, 616 mm bore superconducting outsert.

Status:

Copper-silver alloy sheet appears to be the most promising material for the innermost coils of this magnet. We have been working with the U.S. company, Handy & Harman, to develop competence in the fabrication of this alloy. To date the Handy & Harman Company has been successful in producing Cu-Ag sheet that is much more uniform than their Japanese competitors. Handy & Harman, however, has not been successful in matching the Japanese strength and conductivity. We will soon determine material design properties and finalize the coil design. At that time we will be ready to purchase sheet metal. Then layout and detailed drawings will take approximately five months. We should be ready to purchase all the internal parts in February 1997 with delivery in September 1997.

Budget Summary—$K:

(NOTE: This cost and budget information is included in the 45 T Hybrid Project report.)

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$59.0	$156.7	$215.7	$215.7	$0.0
Equipment/Materials	26.2	430.5	456.7	456.7	0.0
Travel/Expense					
Subtotal	$85.2	$587.2	$672.4	$672.4	$0.0
Overhead	27.1	72.1	99.2	99.2	
Total	$112.3	$659.3	$771.6	$771.6	$0.0

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Coil Design Complete	10/30/96	
Mechanical Design Complete	2/15/97	
Component Purchase and Fabrication Complete	7/31/97	
Assembly in Housing Complete	8/31/97	
Testing Complete	9/15/97	

PROJECT TITLE: 900 MHz NMR MAGNET PROJECT

REPORT DATE: July 31, 1996

Objective:

The 900 MHz NMR Magnet Project is the first step in the overall program to achieve gigahertz NMR. The gigahertz program concept involves a conventional superconducting outer magnet with a HTS superconducting inner magnet to achieve 25 T. The first part of the program is to build the outer superconducting magnet. Activities in the development of HTS insert coils are carried out in the Delta B Program.

The 900 MHz magnet will generate a field of 21.1 T (900 MHz for proton NMR) in a clear bore of 110 mm, and have a temporal and spatial homogeneity of less than 1 part per billion in a 5 cm DSV. The magnet will operate in persistent mode at 1.8 K. Stored energy is estimated at 35 MJ. The project includes the magnet, cryogenic system, power supplies, and facilities installation.

The 900 MHz Project is a joint development project with IGC. The basic allocation of responsibilities is as follows:

NHMFL

- Engineering Design
- Technology Development
- Fabrication of Nb_3Sn Coils
- Magnet Assembly
- System components including cryostat and electronics

IGC

- Detailed Manufacturing Design
- Fabrication of NbTi Coils

Status:

The analytical part of the Engineering Design is well under way, including field analysis, coil locations, stress analysis, protection analysis and shim concept. The Engineering Design Report will be issued 8/30/96.

The conductor suppliers have been identified and the design values of J_c have been selected. The conductor specification will be issued to the conductor suppliers by 8/30/96.

Technology development accomplishments to date include:

- J_c (B,T) measurements
- Nb_3Sn conductor stress (strain)
- Conductor thermal contraction
- Epoxy composition, processing
- Sizing removal process and equipment design
- Winding composite mechanical properties
- Winding composite thermal contraction
- Free supported lead development
- Mica interface material study
- Heater damage threshold measurement
- Persistent joint facility development
- Persistent joint fabrication process
- NbTi small coil processing

Technology development is proceeding with work on NbTi coil impregnation processing. A number of small NbTi coils have been made and evaluated as part of developing the processing criteria. Lead support and processing has been a significant element in the NbTi development.

A program of epoxy development in conjunction with UF has been completed with the development of a new epoxy, NHMFL 61, which will be used in tests on the small NbTi coils. Epoxy properties including modulus, strain, and thermal contraction will be measured.

Work is starting on small Nb_3Sn coils to develop the processing technology for this portion of the magnet.

IGC will begin the detailed design activities with a review of the engineering design, beginning September 1, 1996. A formal engineering design review will be held during September 1996.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
900 MHz Research & Development					
Labor	966	268	1,234	1,234	
Materials/Subcontract	161	100	261	261	
Travel/Expense	93	25	118	118	
Subtotal	1,220	393	1,613	1,613	
900 MHz Fabrication (NHMFL)					
Labor	0	644	644	644	
Materials/Subcontract	10	2,100	2,110	2,110	
Travel/Expense	7	60	67	67	
Subtotal	17	2,804	2,821	2,821	
IGC Subcontract					
Labor	0	0	0	0	
Materials/Subcontract	150	751	901	901	
Travel/Expense	0	0	0	0	
Subtotal	150	751	901	901	
Facility Completion					
Labor	0	161	161	161	
Materials/Subcontract	0	900	900	900	
Travel/Expense	0	15	15	15	
Subtotal	0	1,076	1,076	1,076	
Project Total					
Labor	966	1,073	2,039	2,039	
Materials/Subcontract	321	3,851	4,172	4,172	
Travel/Expense	100	100	200	200	
Subtotal	1,387	5,024	6,411	6,411	
Overhead	545	594	1,138	1,138	
Total	1,932	5,618	7,549	7,549	

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Issue Engineering Design (NHMFL)	8/30/96	
Issue Conductor Specification (NHMFL)	8/30/96	
Order conductors	10/1/96	
NbTi conductor delivery	10/1/97	
Nb_3Sn conductor delivery	10/1/97	
900 MHz Research and Development (NHMFL)		
Nb_3Sn J_c (B.T) development complete	6/30/97	
Nb_3Sn mechanical properties, thermal	11/30/96	
Epoxy-fiber composites development	1/31/96	
Winding composites— Nb_3Sn	3/31/97	
Persistent joint development	5/31/97	
Persistent switches development	6/15/97	
Magnet Mechanical Design (Joint NHMFL/IGC Activity)		
Start	9/1/96	
Complete	12/15/96	
IGC Program		
Start manufacturing design	12/16/96	
Manufacturing design complete	11/15/97	
Fabricate NbTi Coils		
Ti coil forms and tooling delivered	2/2/98	
Start winding of Ti coils	2/2/98	
Ship Ti coil sets to NHMFL	9/30/98	
Fabricate Shim Coils		
Shim coil tooling received	1/10/98	
Complete winding of shim coils	2/15/98	
Assemble shim coil set	7/10/98	
Ship shim coil set to NHMFL	9/30/98	
NHMFL Fabrication Program		
Fabricate Nb_3Sn Coils		
Sn coil forms and tooling delivered	11/20/97	
Start winding Sn coils	11/21/97	
Complete Sn coil assembly	9/30/98	
Cryostat and Cryogenic System		
Start cryogenic system design	TBD	
Receive cryostat and components	4/15/98	
Install cryostat and test without magnet	8/30/98	
Power Supply and Protection Controls		
Start electronic components design	TBD	
Complete system assembly and test	8/30/98	
Facility Installation		
Start facility installation design	TBD	
Complete facility installation	8/30/98	

	Schedule	Actual or Rev Schedule
Final Assembly and Test		
Start final assembly of magnet	10/1/98	
Complete magnet assembly	11/1/98	
Complete installation of magnet in cryostat	12/23/98	
Complete system testing	12/26/98	

PROJECT TITLE: ΔB PROGRAM

REPORT DATE: July 31, 1996

Objective:

To develop high temperature superconducting (HTS) materials and magnets for high field magnet systems. The specific goals of this program are:

- technology development for HTS high field insert coils, and
- their application for superconducting magnets, especially NMR spectrometers.

Status:

Most of the recent effort in the ΔB program has been directed toward developing in-house capability to fabricate and characterize BSCCO 2212 composite conductors and, using our own material plus that available through collaborations with industry build a set of small "1 T" class magnets. This work is divided into four tasks: (1) wire development; (2) characterization; (3) insulation and joint studies and (4) coil development. Specific progress is listed below.

HTS Conductor Development

- NHMFL wire development facility can now routinely produce 50 m lengths of Ag/BSCCO 2122 conductor—June 1, 1996.
- Optimization of heat treatment schedules for Ic> 100 A by January 1997.
- Development of continuous processing techniques by January 1998.

Conductor Insulation & Joining

- Selection of a spray ceramic insulation—June 1, 1996.
- Develop continuous coating and curing set up by December 1996.
- Production of persistent current joints in mono-core and multi-core Ag-BSCCO conductors—August 1996.
- Measurement of the electrical and mechanical properties J_c (B,T,e)—July 31, 1996.

Characterization

- Transport measurements on short samples of HTS through 1997.
- Fabrication of test probes for 20 T and 33 T resistive and 45 T hybrid magnets complete November 1996.
- Development and use of strain measurement techniques through 1997.
- Testing of "1 T" class insert coils to 18 T through June 1997.
- Testing of large radius mini-coils in 20 T resistive magnet through December 1997.
- Testing of 2.5 T insert coil in 20 T resistive magnet July 1997.
- Optical and analytical instrument study of HTS conductors, joints and insulation materials using SEM.
- Fabrication of 2.5 T insert coil in collaboration with IGC.
- Development of a design for 1.1 GHz NMR insert coil.

Coil Development

- Fabrication of mini-coils using NHMFL produced and commercial conductor through December 1996.
- Application of insulation, epoxy impregnation through 1997.
- Development of a design for 2.5 T insert coil.
- Development of NMR shim coils by October 1996.
- Fabrication of "1 T" class insert coils through 1977.

Industrial Collaborations

Agreements and cooperative R&D activities with major industries involved in the development of HTS conductors and magnets:

- Oxford Superconductor (K. Marken): Characterization of dip coat and PIT 2212 short samples and small coils
- IGC (D. Hazelton): High field insert coils for NMR applications

- IGC Advanced Superconductors (L. Motowidlo): Hot rolling of oxide dispersion strengthened PIT 2212
- American Superconductor Corporation (L. Masur, C. Thieme, A. Otto): Hot rolling of PIT conductors; metallic precursor PIT 2212.

PROJECT TITLE: LARGE BORE RESISTIVE MAGNET

REPORT DATE: July 31, 1996

Objective:

Provide 20 T in a 195.8 mm bore using 20 MW of power. This magnet is an international collaboration between the NHMFL and the Grenoble High Magnetic Field Laboratory in Grenoble, France. Two similar magnets will be constructed. The one in Grenoble will provide 10.8 T in a 365 mm bore using 13 MW of power.

Status:

Design is completed. A Cooperative Research and Development Agreement between the HMFL-Grenoble and NHMFL-USA has been written and purchase orders are being issued. Delivery: May 1997.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$151.4	$58.0	$209.4	$209.4	$0.0
Equipment/Materials	534.0	131.0	665.0	800.0	+135.0
Travel/Expense					
Subtotal	$685.4	$189.0	874.4	$1009.4	+$135.0
Overhead	69.6	26.7	96.3	96.3	0.0
Total	$755.0	$215.7	$970.7	$1,105.7	+$135.0

Milestone Schedule Summary:

Key project milestones are as follows:

	Schedule	Actual or Rev Schedule
Complete Coil Design	7/15/95	7/15/95
Complete Mechanical Design	4/15/96	4/15/96
Order and Fabricate Components Complete	3/15/97	
Assemble Magnet Complete	5/15/97	
Test magnet complete	5/30/97	

PROJECT TITLE: 33 T MAGNET I

REPORT DATE: July 31, 1996

Objective:

Provide a 33 T resistive magnet for the user community. Design objective is 34 T, 20 MW maximum power, 32 mm bore. Magnet will utilize existing housing and cell set-up.

Status:

Magnet is complete and has been tested to 33.6 T at 19.5 MW. Magnet is in regular experimental use. Inner coils have experienced problems with plate alignment and blockage of cooling holes. Inner coil problem has been corrected by using Cu-Be rather than Cu-Ag.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$173.6	0	$173.6	N/A	
Equipment/Materials	129.2	0	129.2	N/A	
Expense/Travel					
Subtotal	$302.8		$302.8		
Overhead	79.9		79.9		
Total	$382.7	0	$382.7	N/A	

Schedule Summary:

Magnet achieved a field of 33.6 T on Feb. 29, 1996. Magnet is currently operating at a routine field of 33.1 T.

PROJECT TITLE: 33 T MAGNET II
REPORT DATE: July 30, 1996

Objective:

Provide a second 33 T magnet to the user community and provide a facility for testing new concepts in magnet design to determine the limits attainable in terms of operating stresses, heat fluxes, and power densities in view of the design of the hybrid magnet insert. This magnet is essentially a set of spare coils for the existing magnets and can be used to upgrade one 30 T magnet to 33 T.

Status:

Await hybrid insert design and receipt of materials (Cu-Ag) to be tested.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$8.0	$17.9	$25.9	$25.9	0.0
Equipment/Materials	0.0	110.0	110.0	110.0	0.0
Expense/Travel					
Subtotal	$8.0	$127.9	$135.9	$135.9	0.0
Overhead	3.7	8.3	12.0	12.0	0.0
Total	$11.7	$136.2	$147.9	$147.9	0.0

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Design Complete	9/15/96	
Component Purchase and Fabrication Complete	5/31/97	
Assembly in Housing Complete	7/15/97	
Testing Complete	7/30/97	

PROJECT TITLE: HYDRAULIC TEST STAND

REPORT DATE: July 31, 1996

Objective:

This facility will permit operation of individual coils by themselves to develop a better understanding of heat and momentum transfer in turbulent flow through the very rough channels of resistive magnets. This information is critical to the development of any future high power density magnets such as the Hybrid insert, a 34 T magnet, the KECK magnet, a split pair, etc. The device also will serve to benchmark theoretical calculations on turbulent flow in channels with periodic roughness structures.

Status:

Most of the parts and materials have been purchased. Many of the parts are being made in the NHMFL machine shop. We have recently performed a minor redesign and will be purchasing a few more parts. Operational November 1996.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$6.8	$35.8	$42.6	$42.6	$0.0
Equipment/Materials	18.5	7.0	25.5	46.1	+20.6
Expense/Travel					
Subtotal	$25.3	$42.8	$68.1	$88.7	+$20.6
Overhead	11.6	19.7	31.3	40.8	+9.5
Total	$39.6	$62.5	$99.4	$129.5	+$30.1

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Complete Test Stand Mechanical Design	3/15/96	3/15/96
Order and Fabricate Components Complete	9/15/96	
Assemble & Install Test Stand Complete	10/15/96	

PROJECT TITLE: CAPACITOR BANK DRIVEN PULSED MAGNET PROGRAM

REPORT DATE: July 31, 1996

Objective:

Provide a relatively easy and inexpensive route to fields between 40 and 70 T. Provide field duration and field volumes large enough that users can employ instruments for measurements at different temperatures and pressures, and data acquisition that is reasonably close to those used for continuous fields.

Status:

The Magnet Science & Technology Group at NHMFL is responsible for both the upkeep and improvement of the capacitor-bank powered pulsed magnets that support the NHMFL Los Alamos Pulsed Field Facilities, where magnet tests, training, and installation, as well as use, occurs.

- User Facility Support—24 mm bore 50 T magnets and 15 mm bore 60 T magnets are provided on an as needed basis to the user facility. Approximately four to six magnets per year are provided on a four- to six-week lead time basis.
- During the last year, in response to user requests, a 24 mm bore, long pulse magnet capable of producing 40 T with a pulse length of approximately 500 ms has been placed in operation. Not only does this add significantly to the user facilities in its own right but can also serve as a staging magnet for the 60 T quasi-continuous magnet. Adding this magnet to the repertoire required upgrading the capacitor bank by 500 kJ.

- There is an ongoing program to develop a new 70 T high field design for the capacitor driven pulsed magnets. Coils utilizing high strength uniaxial carbon fiber reinforcements in an effort to compensate for conductor strength, indicate that there are significant drawbacks to the use of composites at low temperatures. A wide variety of composite and other reinforcement types are being studied at present to gain a greater understanding of the mechanisms involved. A series of 20 test magnets have been built and will be tested at the Pulsed Field Facility in August 1996. The results from the test magnets as well as from tensile specimens, will have significant impact not only of the 70 T high field magnet but also on the design of the insert coil for the 100 T system. Short lengths of CuNb conductor from Bochvar and CuAg from Showa have been received. These will be incorporated into test magnets utilizing the knowledge gained from the fiber composite test magnets.
- In the interim, the standard 50 and 60 T magnets will be operated at slightly higher fields (about 55 and 65 T, respectively) for users willing to risk earlier failure (which could damage the sample). Such higher fields are expected to shorten the magnet lifetime by about 40%. This could increase the number of magnets needed to support the user operations.

Work for Others:

The Pulsed Magnet Group also has undertaken several projects that are funded from outside sources and will result in magnets delivered to other facilities:

Pegasus—Pegasus is a University of Wisconsin-based spherical Tokamak project. The Tallahassee group has been asked to collaborate on this in the form of design and construction of a high stress central solenoid used to furnish the inductive current drive. The NHMFL expertise in high stress solenoids has generated significant interest in the Tokamak community and inquiries have also been received from a similar project at the Princeton University Plasma Physics Laboratory.

30 T Water Cooled Neutron Scattering Magnet—Work has now started at the NHMFL on materials evaluation for a 10 mm split magnet capable of being producing 30 T at a pulse repetition rate of 2 Hz, destined for neutron diffraction studies at Los Alamos National Laboratory.

Australian National Magnet Laboratory—The National Pulse Magnet Laboratory of Australia has been particularly impressed with the reliability of NHMFL pulsed magnets and has asked the NHMFL to provide a standard 50 T magnet for evaluation with a view to becoming a steady customer.

Project Status Reports for the various elements of the Capacitor Bank Driven Pulsed Magnet Program are provided.

PROJECT TITLE: PULSED MAGNET USER FACILITY SUPPORT

REPORT DATE: July 31, 1996

Objective:

Provide the magnets necessary to sustain the NHMFL Pulsed Field Facility at LANL. Upgrade magnet performance as technology becomes available.

Status:

- User Facility Support—24 mm bore 50 T magnets and 15 mm bore 60 T magnets are provided on an as needed basis to the user facility. Approximately four to six magnets per year are provided on a four- to six-week lead time basis.
- Upgrading of User Facility Magnets—Several approaches to upgrading the base field of the user magnets are being investigated.

A design utilizing Glidcop and carbon fiber has indicated severe problems with uniaxial fiber reinforcements. A series of twenty test magnets have been built and will be tested at the Pulsed Field Facility in August 1996.

Short lengths of CuNb conductor from Bochvar and CuAg from Showa have been received. These will be incorporated into test magnets utilizing the knowledge gained from the fiber composite test magnets.

Budget Summary—$K—Annual Budget—1996

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	8.1	8.2	16.3	16.3	0
Equipment/Materials	12.0	8.0	20.0	20.0	0
Expense/Travel	2.5	0	2.5	3.0	+0.5
Subtotal	22.6	16.2	38.8	39.3	+0.5
Overhead			8.7	8.9	+0.2
Total			47.5	48.2	+0.7

Milestone Schedule Summary:

Replacement Magnet Program Schedule	Schedule	Actual or Rev Schedule
50 T Replacement Magnet #1 (Delivered)	6/30/96	6/30/96
50 T Replacement Magnet #2	2/28/97	
50 T Replacement Magnet #3	7/15/97	
60 T Replacement Magnet #1	8/31/96	7/31/96
60 T Replacement Magnet #2	1/31/97	
60 T Replacement Magnet #3	6/30/97	
70 T Replacement Magnet	8/30/97	
40 T Long Pulse Magnet Replacement	2/28/97	

PROJECT TITLE: 60 T QUASI-CONTINUOUS MAGNET

REPORT DATE: August 16, 1996

Objective:

Provide a generator-driven, controlled-power pulsed magnet capable of sustaining a constant field of 60 T in a cold bore of 34 mm for 100 ms. In addition, furnish a variety of pulsed shapes including steps, linear ramps, field reversals, and long decays, in response to user needs. This magnet will be upgradable, with the installation of additional power modules (seven total), to 65 T and approximately double the pulse widths at lower fields. The system design includes the following:

- Magnet: Nine mechanically independent coils designed to operate in the elastic strain regime for 10,000 pulses
- Power Supply
- An existing 1.4 GVA motor-generator to provide the primary energy from inertial storage
- New 400 MVA pulsed power supply driven from the generator consisting of five 80 MW power modules (rectifier-transformer units). Two additional 80 MW modules are being provided that will power the 100 T magnet and can be used to enhance the performance of the 60 T magnet.

Status:

The nine magnet coils have been fabricated and delivered to NHMFL where they are currently being assembled. The magnet dewar is in place and is being plumbed to the LN delivery system. Three of the five power modules are in place, awaiting commissioning. The remaining two power modules have been ordered, along with two upgrade modules. Work on the control system is underway.

No outstanding issues are identified at this time. Orders for experimental equipment such as refrigerators and cryostats have been placed in anticipation of imminent operation. (The operation will be limited to 45 T until the remaining two power modules are installed.)

Budget Summary—$K—Cost To Complete Only.

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor		$110.0	$110.0	$110.0	
Equipment/Materials		225.0	225.0	225.0	
Expense/Travel					
Subtotal		$335.0	$335.0	$335.0	
Overhead (LANL)			174.2	174.2	
Total			$509.2	$509.2	

Power supply modules are funded through FSU. Purchase price was $3,000 versus a budget of $3,400.

Milestone Schedule Summary

	Schedule	Actual or Rev Schedule
60 T Magnet		
Design	Done	
Assembly and installation	10/96	
Commissioning	12/96	

	Schedule	Actual or Rev Schedule
Dewar		
Design	Done	
Assembly and installation	7/96	
Commissioning	9/96	
Control system		
Design	10/96	
Assemble and installation	0/96	
Commissioning	12/96	
Power Modules (3; 45 T)		
Design	Done	
Assemble and installation	9/96	
Commissioning	12/96	
Power Modules (2; 60 T) (2; 65 T)		
Design	Done	
Assemble and installation	6/97	
Commissioning	9/97	

PROJECT TITLE: 100 T NON-DESTRUCTIVE PULSED MAGNET

REPORT DATE: August 16, 1996

Objective:

Design, build, and use a 100 T non-destructive magnet for studying the properties of materials at high fields. The design goal for the 100 T magnet is a time duration above 80 T of about 15 ms in a cold bore of 24 mm. The magnet is to be designed within the constraints of available power and the target user experimental environment. These constraints include a maximum of 7 power modules rated at 80 kVA connected in a maximum of 4 independent circuits; a one-hour cool-down time; a 24 mm inner bore; lifetimes of 10,000 full pulses for the outsert and 100 full pulses for the insert; and a maximum of 2.4 MJ of capacitive energy for the insert.

The design concept for the 100 T magnet calls for two components: a relatively small capacitor-driven magnet at the center (called the 'insert') and an outer set of mechanically independent, nested coils (called the 'outsert') driven by inertial energy stored in the motor-generator. Each component will produce approximately 50 T.

Management Plan:

The 100 T program management plan reflects the responsibilities assumed by the funding agencies. Don Parkin is the Project Manager responsible for the DoE funded part of the project; Jack Crow has the corresponding responsibility of the NSF portion of the project. LANL has lead responsibility for the design of the outsert magnet and overall integration of the magnet design and installation. NHMFL has lead responsibility for the insert magnet design and construction and providing the 560 MW of power supplies.

Budget Summary:

The funds for the outsert magnet, dewar, capacitor bank, and control system derive from the DoE BES (LANL Proposal Number ERWE438) and, therefore, are not listed here. A Project Status Report is included for the NHMFL insert magnet activity.

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Insert		
Design complete	12/96	
Fabrication complete	6/98	
Outsert		
Design complete	9/96	
Fabrication complete	3/98	
Dewar/Frame/Busbar		
Design complete	9/96	
Fabrication complete	6/98	
Capacitor Bank Upgrade		
Design complete	6/97	
Fabrication complete	12/97	
Commissioning complete	3/98	
Control System		
Design complete	3/97	
Fabrication complete	12/97	
Commissioning complete	3/98	

	Schedule	Actual or Rev Schedule
Power Modules		
Design	Completed	
Delivery	6/97	
Commissioning complete	12/97	
Final Assembly And Installation		
Start assembly	4/98	
Complete assembly & installation	8/98	
System commissioning complete	12/98	

PROJECT TITLE: 100 T INSERT MAGNET PROJECT

REPORT DATE: July 31, 1996

Objective:

Design, construct, and test a 24 mm bore insert coil powered by a 2,400 kJ capacitor bank capable of producing 50 T in a pulse of approximately 10 ms when installed in the bore of a 50 T outsert magnet powered by seven 80 MW pulsed power supply modules. The interface bore diameter is approximately 220 mm. The insert coil is the NHMFL part of the DOE/NHMFL joint 100 T magnet project.

Status:

The insert coil project is organized into four phases:

- Material Evaluation of Reinforcement Systems. An uniaxial composite test sample has been designed. A number of test magnets for both composite reinforcement and steel reinforcement have been constructed. Additional reinforcement tests will be developed using pearlitic steel wires and high moduli carbon and Kevlar fiber. The objective is to obtain sufficient data through tensile and magnet tests to realistically model magnet composites and to select an appropriate reinforcement system.
- Material Evaluation of Conductor Systems. Samples of CuNb, CUAg and CuSS have been obtained for test. A development program has been set up with Brush-Wellman for Cu-CuBe conductor materials. An SBIR proposal has been developed with Supercon for ternary compounds and work has started on Glidcop-Nb material with SCM Metals. The next steps will be to conduct tensile and fatigue tests on samples and construct test magnets for conductor testing to obtain the information necessary to select an appropriate conductor material.
- Proof of Concept 80 T Insert Magnet. The program plan is to prove the concept design for the 100 T inner coil by building a prototype coil that will produce a combined field of 80 T in the outer coils of the 60 T long pulse magnet.
- 100 T Insert Magnet. The final step will be the design and construction of the 100 T insert magnet.

Budget Summary—$K—Project Budget:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$8.1	$47.9	$56.0	$56.0	
Equipment/Materials	43.9	180.0	223.9	223.9	
Expense/Travel	1.4	10.0	11.4	11.4	
Subtotal	$53.4	$237.9	$291.3	$291.3	
Overhead			31.0	31.0	
Total			$322.3	$322.3	

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Material Evaluation—Reinforcement Systems		
Evaluation complete and materials selected	12/15/96	
Materials Evaluation—Conductor Systems		
Evaluation complete and materials selected	5/30/97	

	Schedule	Actual or Rev Schedule
Proof of Concept 80 T Insert Magnet		
Order conductor material	10/30/96	
Complete magnet	6/30/97	
Complete test and evaluation	7/31/97	
100 T Insert Magnet		
Review preliminary insert design	11/30/96	
Review final insert design	7/31/97	
Order materials	8/31/97	
Start construction of insert	3/1/98	
Deliver 100 T insert magnet	4/15/98	

PROJECT TITLE: **KECK MAGNET**

(Funded by a grant from the Keck Foundation and matching funds from NHMFL)

REPORT DATE: July 31, 1996

Objective:

This magnet will provide 25 T in a 52 mm bore with inhomogeneity less than 1 ppm over a 1 cm diameter spherical volume using less than 20 MW. It will be used primarily for magnetic resonance experiments.

Status:

The grant was received in July. Preliminary design is underway. Delivery December 1997.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	0	$85.4	$85.4	$85.4	0.0
Equipment/Materials	0	456.0	456.0	456.0	0.0
Expense/Travel					
Subtotal	0	$541.4	$541.4	$541.4	0.0
Overhead	0	249.0	249.0	249.0	0.0
Total	0	$790.4	$790.4	$790.4	0.0

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Complete coil design	9/30/96	
Complete mechanical design	1/15/97	
Order and fabricate components complete	9/30/97	
Assemble magnet complete	11/30/97	
Test magnet complete	12/15/97	

PROJECT TITLE: NASA MAGNET PROJECT

(Funded by NASA Huntsville)

REPORT DATE: July 31, 1996

Objective:

This magnet is being fabricated for NASA under a cost reimbursement grant from NASA Huntsville. The magnet will be a prototype for one used to grow high purity crystals in microgravity on the space station. It will provide 0.16 T in a 184 mm bore consuming 3 kW of power.

Status:

The design is finished, all the purchase orders are out, the parts are arriving, and we intend to assemble the magnet well before the due date of November 1, 1996.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$17.5	$4.6	$22.1	$22.1	0.0
Equipment/Materials	38.1	0.0	38.1	38.1	0.0
Expense/Travel		1.0	1.0	1.0	0.0
Subtotal	$55.6	$5.6	$61.2	$61.2	0.0
Overhead	28.2	0	28.2	28.2	0.0
Total	$83.8	$5.6	$89.4	$89.4	0.0

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Order and fabricate components complete	8/30/96	
Assemble magnet complete	9/15/96	
Test magnet complete	9/30/96	
Required delivery	10/30/96	

PROJECT TITLE: NRIM MAGNET (TOSHIBA AMERICA)

(Funded by NRIM, Japan through Toshiba America)

REPORT DATE: July 31, 1996

Objective:

This magnet is being built for the National Research Institute for Metals (NRIM) in Tsukuba, Japan on a fixed price contract with Toshiba America. The magnet should provide 30 T in a 32 mm bore using 15 MW of power.

Status:

Design is complete. All purchase orders have been issued. We are waiting delivery of parts. Delivery of the completed magnet is scheduled for March 1997.

Budget Summary—$K:

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	$44.2			$102.9	
Equipment/Materials	241.3			332.9	
Expense/Travel				19.1	
Subtotal	$285.5			$459.9	
Overhead	202.8			202.8	
Total	$488.3			$657.7	

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Complete coil design	3/30/96	3/30/96
Complete mechanical design	4/30/96	4/30/96
Order and fabricate components complete	1/31/97	
Assemble magnet complete	3/15/97	
Ship to NRIM	3/15/97	
Complete installation & test at NRIM	6/15/97	

PROJECT TITLE: 30 T WATER COOLED NEUTRON SCATTERING MAGNET (LANL)

REPORT DATE: July 31, 1996

Objective:

This project is funded by the Department of Energy through Los Alamos National Laboratory. NHMFL tasks consist of the design of a 2 Hz, 30 T split-pair (1 cm gap) pulsed magnet suitable for neutron scattering measurements.

Status:

This work has been planned to be performed in two phases, Phase I consists of materials testing and conceptual design, Phase II consists of detailed design and fabrication of the magnet. Phase I has not yet been authorized.

Budget Summary—$K—Phase I

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	0	13.2	13.2	13.2	
Equipment/Materials	0	28.5	28.5	28.5	
Expense/Travel	0				
Subtotal	0	41.7	41.7	41.7	
Overhead	0	6.1	6.1	6.1	
Total	0	47.8	47.8	47.8	

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Milestone schedule not yet established.		
Interim report	8/30/96	
Final report & conceptual design	8/30/97	

PROJECT TITLE: WISCONSIN PEGASUS SOLENOID
REPORT DATE: July 31, 1996

Objective:

This project is a collaboration with the University of Wisconsin Phaedrus Laboratory for Plasma Science to design and construct a 60 mm bore, 1.5m long 20 T solenoid for the Wisconsin DOE funded Pegasus Tokamak Project. NHMFL will provide labor, UW will purchase materials and fund any subcontracts. It is likely that two coils will be provided, one in the fall of 1996 at 14 T followed by a 20 T coil in 1997.

Status:

Preliminary design analyses have begun.

Budget Summary—$K: (Costs Paid By NHMFL)

	Cost to Date	Cost to Complete	Total Estimated Cost	Budget	Variance - (over) +(under)
Labor	0	9.0	9.0	9.0	
Equipment/Materials	0				
Expense/Travel	0				
Subtotal	0	9.0	9.0	9.0	
Overhead	0	4.1	4.1	4.1	
Total	0	13.1	13.1	13.1	

Milestone Schedule Summary:

	Schedule	Actual or Rev Schedule
Milestone schedule not yet established.		
14 T, 60 mm, 1.5m long solenoid delivered	11/96	
20 T, 60 mm, 1.5m long solenoid delivered	11/97	

IV. NHMFL IN-HOUSE RESEARCH PROGRAM

In-House Research Program Goals

The National Science Foundation charged the National High Magnetic Field Laboratory (NHMFL) with developing an in-house research program that:

- utilizes the NHMFL facilities to carry out high quality research at the forefront of science and engineering; and
- advances the NHMFL facilities and their scientific and technical capabilities.

To this end, the NHMFL envisions an in-house research program that not only guides and stimulates magnet and facility development, but additionally provides intellectual leadership for experimental and theoretical research in magnetic materials and phenomena. The In-House Research Program (IHRP) seeks to achieve these objectives through funded research projects of normally one to two years duration in the following categories:

- small, seeded collaborations between internal and/or external investigators that utilize their complementary expertise;
- bold but risky efforts that hold significant potential to extend the range and type of experiments; and
- initial seed support for new faculty and research staff, targeted to magnet laboratory enhancements.

The NHMFL IHRP strongly encourages collaboration across host-institutional boundaries and between internal and external investigators in academia, national laboratories, and industry, as well as interaction between theory and experiment. Projects are also encouraged to drive new or unique research, i.e., serve as seed money to develop initial data leading to external funding of a larger program. In accord with NSF policies, the NHMFL cannot fund clinical studies.

Proposal Solicitation & Review

The NHMFL IHRP will solicit proposals at least once yearly. Faculty and staff of the three host institutions (FSU, UF, and LANL) may submit proposals in response to this solicitation. Scientists and engineers from outside organizations may be named as active collaborators on proposals in collaboration with on-site faculty and staff. As a complement to this solicitation, LANL staff are encouraged to pursue funding opportunities provided through the LANL with University of California faculty. Funding will only be provided for research taking place at NHMFL facilities. Proposals submitted by young researchers, i.e., researchers within seven years of the most advanced degree, will be given a higher funding priority. The IHRP will strictly adhere to the guidelines stated in the NSF Cooperative Agreement DMR-9527035.

The primary review criteria of the IHRP are:

1. **Research performance competence**—This criterion relates to the capability of the investigator(s), the technical soundness of the proposed research, and the adequacy of the institutional resources available.
2. **Intrinsic merit of the research**—This criterion is used to assess the likelihood that the research will lead to new discoveries or fundamental advances in the fields of high-magnetic-field science or engineering, or have substantial impact on progress in those fields.
3. **Utility or relevance of the research to the NHMFL mission**—This criterion is used to assess the likelihood that the research can contribute to the achievement of the IHRP objectives, and thereby serve as the basis for driving, enhancing, or improving the NHMFL user facilities, capabilities, or expertise.
4. **Effect of the research on the infrastructure of high-magnetic field science and engineering**—This criterion relates to the potential of the proposed research to contribute to better understanding or improvement of the quality, distribution or effectiveness of the nation's high-magnetic-field scientific and engineering research, education, and manpower base.

Funded projects must be of the highest quality and will be reviewed using a three-part review process. These steps are:

1. **Initial review by the NHMFL Research Program Committee**—As determined by the IHRP Director, the members of this internal review team may be augmented by additional investigators in order to ensure fairness and/or adequate representation of various research disciplines. Proposals deemed to hold the highest merit will then pass on to the second review step.
2. **Subsequent review by an external review panel**—The members of this review panel will be chosen by the IHRP Director in consultation with the Research Program Committee. The external reviewers will provide evaluations of the proposals based upon the goals and criteria stated in the solicitation.

3. **Final determination of project funding by the NHMFL Chief Scientist—** The NHMFL Chief Scientist, J. Robert Schrieffer, will make the final funding decisions based upon the internal and external review reports.

The present membership of the NHMFL Research Program Committee is Geoffrey Bodenhausen, James Brooks, Zachary Fisk, Lev Gor'kov, Alan Marshall, Stephan von Molnár, and Stan Tozer (FSU); John Graybeal, Kevin Ingersent, and Thomas Mareci (UF); Alan Bishop, Chris Hammel, and Joe Thompson (LANL).

Funded projects will be reviewed periodically and continuation of funding will depend upon adequate performance. The principal investigator(s) of funded projects must file a progress report to the NHMFL IHRP Director every six months for the duration of funding. A final report also must be provided at the end of the funded period.

In-House Research Program Budget

The NHMFL has budgeted the following funds for the in-house research program.

Year	Research Budget (includes indirect cost loading)	% of NHMFL budget
1996	1,120,000	6.4
1997	1,530,000	8.7
1998	1,700,000	9.7
1999	1,870,000	10.7
2000	1,870,000	10.7

1996 Program Status

The 1996 NHMFL IHRP solicitation was released on May 10, 1996, immediately following verbal approval from the National Science Foundation. Sixty-seven proposals were received on or before the proposal submission deadline of August 16, 1996. The proposals span a very significant intellectual breadth, consistent with the intentions of the NHMFL. Their approximate breakdown by research discipline and/or technique is shown in the following table.

Research Area	Subarea	Number
Magnetic Resonance	System & hardware development	11
30 proposals—breakdown by technique	Biochemistry	4
NMR - 11	Solid-state chemistry	4
EMR/ENDOR - 6	Biology	4
MRI - 6	Chemistry	4
ICR - 6	Geochemistry	1
AFR - 1	Biomedicine	1
	Hydrodynamics	1
Condensed Matter Physics	Heterostructures/Quantum Hall effect	8
27 proposals	Oxides	7
	Theory	4
	Heavy fermions	3
	Quasi-1D systems	2
	General magnetism	2
	Quantum fluids	1
Materials Science & Engineering	Materials science & processing	5
10 proposals	Applied superconductivity	4
	Biology	1

At the time of this writing, the internal review has just begun. The internal review is scheduled to be complete shortly before the NSF site visit in Los Alamos, and the external review is scheduled for early- to mid-October. External reviewer candidates have been identified, and these individuals are being contacted by the Director of the IHRP.

V. MAGNETIC RESONANCE: OVERVIEW AND THE FUTURE

The Seitz-Richardson Report, NHMFL advisory committees, NSF External Review Committees, and the NHMFL all recognize that chemistry and the life-sciences offer some of the greatest potential for new scientific and technological discoveries using high magnetic fields. As an entire group, chemistry and the life-sciences have been predominately overlooked at high magnetic field facilities worldwide. The extension of magnetic resonance to higher magnetic fields and to special field configurations along with advances in electronics and magnetic resonance techniques provide promising new opportunities in chemistry, biosciences, materials science, physics, environmental science and process control. Support of these programs has been central to the planning of the NHMFL from the beginning and is reflected in the membership of the laboratory's Users' Committee and External Advisory Committee.

The NHMFL's commitment to this area is also reflected in the enormous and somewhat unbalanced investment of resources provided by the State of Florida to this area. The NHMFL, UF, and FSU have hired fifteen new permanent faculty and staff to support the development of a science-driven, broad-based magnetic resonance program in chemistry and the life sciences. This program has been formalized as the Center for Interdisciplinary Magnetic Resonance (CIMAR), which is a coordinating organization. In addition to the permanent faculty and staff, the laboratory and its institutions have provided in excess of $10 million in start-up funding and instrumentation support along with ongoing funding of nearly $1 million per year. The State of Florida investment in CIMAR has lead to the creation of a unique program offering state-of-the-art instrumentation and in developing interdisciplinary research programs at the forefront of chemistry, biosciences, materials science, and condensed matter physics for users in all leading areas of magnetic resonance technologies: nuclear magnetic resonance (NMR), electron magnetic resonance (EMR), magnetic resonance imaging (MRI) and Ion Cyclotron Resonance Mass-Spectroscopy (ICR MS). The magnetic resonance program at the NHMFL is unique in the world in its breadth and scope of interdisciplinary science and its unique synergy with the development of magnetic resonance technologies. Since funding to seed the development of this program has been provided almost exclusively by the State of Florida, it is not clear that this large state investment can continue without some long-term support provided by the federal government. The present NSF core support is not sufficient to meet this challenge while supporting other critical aspects of the laboratory.

As with all programs, the laboratory is continually reevaluating its vision and priorities, to improve the structure and delivery system to better meet the needs of the expanding user community and new science opportunities. To respond to these challenges, the laboratory has been required to and should focus on identifying leveraged support to address the long-term needs of such programs. Even with some of the uncertainties imposed on the long-term vision of the NHMFL's magnetic resonance program by budget constraints, a substantial external user community has developed: ten users in the EMR program, fifteen users in the ICR program, twenty-seven users in the NMR program (fifteen users in materials science and physics up to 30 T, and twelve users in liquid and solid state chemistry), and five users in MRI spectroscopy (MRIS). It should be noted that each of these programs started very recently (1995-96). This early user activity is only a glimpse of the potential user demand for unique facilities and expanding research opportunities. Any successful magnetic resonance program must be developed through a partnership of the laboratory, external users, and the private sector. The partnership with the private sector is more relevant to this area of research than others because of the potential for science and the technology-driven economic impact in both the development of advanced instrumentation and in the applications of magnetic resonance to important technological problems, such as drug screening and process control.

The questions to be answered are: "What are the scientific and technological drivers for a national center?"; "What aspects of the laboratory justify the establishment of a national magnetic resonance center within the NHMFL?"; "How should a national center be structured and what are its strategic goals?" and "How will the scientific and technology-driven activities within this center be supported?" Below, we briefly address these questions.

Scientific and Technological Drivers for a National Center

The new scientific opportunities that magnetic resonance studies can open at the highest fields need a strong coordinated interdisciplinary effort to develop both the technologies and the new science disciplines (such as biophysics and microimaging) that use very high field MR applications. The NHMFL has a unique opportunity in providing these synergies both for using

MR to explore new phenomena induced by high fields and to use high fields to significantly enhance the MR measurement sensitivities. We list below the major technical and scientific goals proposed by the MR Center.

- The annual world market in magnetic resonance is between $1.3-1.5 billion. The annual sales of NMR systems is approximately $250 million and **not a single commercial 500, 600 or 750 MHz NMR magnet system in the United States was built by a U.S. company**. Only one (non-U.S.) company sells EMR spectrometers. The laboratory offers opportunities to establish partnerships with U.S. industry to develop a U.S. capacity to respond to this expanding market. The partnership with IGC on the 900 MHz NMR wide bore magnet is an excellent example. The existence of a broad-based magnetic resonance center exploring new science and technological opportunities should be the underpinning for effective private sector partnerships.
- The **cost** of many advanced magnetic resonance systems are rapidly growing beyond reasonable funding levels for such equipment except at a national center. For example, development of the 900 MHz NMR system will cost in excess of $7 million and the duplication of a second system without development costs or contingencies would be between $4-5 million. This latter price includes only the cost of hardware and fabrication. The cost of the superconducting wire alone in the 900 MHz NMR solenoid is $1.6-2.0 million.
- High fields open possibilities for studying very low gyromagnetic ratio nuclei either by NMR or ENDOR (Electron Nuclear DOble Resonance). In NMR, because second-order effects are reduced in direct proportion to field strength, **solid state spectra of odd-halves quadrupolar nuclei**, such as ^{23}Na, ^{27}Al and ^{17}O, are significantly improved generating new opportunities for observation of materials and molecular structures. The high sensitivity of ENDOR is of paramount importance for some metal-containing proteins.
- Fourier transform ICR MS provides the most versatile and highest performance technique for mass analysis. **Higher magnetic fields dramatically enhance ICR MS performance parameters**, e.g., mass resolving power μ B, upper mass limit μ B^2, ion translational energy μ B^2, and ion radial diffusional loss rate μ B^{-2}.
- Commercial electron magnetic resonance spectrometers are available only up to 3.4 tesla. During a workshop held at the NHMFL in July 1994, the U.S. scientific community recognized the **need for continuous-wave and/or pulsed instruments operating above 10 tesla.** Europe supports six EMR Centers with high-field spectrometers in operation or under development. High field pulsed instruments have high potential impact for EMR (as well as for NMR and ICR).

Aspects of the Laboratory that Justify the Establishment of a National High Field Magnetic Resonance Center within the NHMFL

- The NHMFL is in a unique position to create a national high field maagnetic resonance facility centered around the above four magnetic resonance technologies and coupled with an outstanding magnet science and technology program. No other institution has the combination of **instrumentation, infrastructure, and scientific and technological expertise** necessary to initiate and develop such a facility directed at supporting a users program, along with a strong effort in **technique and instrumentation development.**
- The NHMFL already has demonstrated the ability to operate and support broad-based users programs, and the new National High Field Magnetic Resonance Center would leverage infrastructure capacity already being supported.
- The NHMFL power supply has a stability approaching 1 ppm and recent successes with field-locked stabilization where very early measurements have demonstrated that sub-ppm stability is possible provide a unique capacity for the development of extremely high field magnetic resonance in powered and hybrid systems. These capabilities would not be available at any other place in the world. The potential within this area has already been demonstrated by successful NMR, EMR, and ICR experiments in existing powered magnets at the NHMFL.
- An important aspect of this facility will be its emphasis on interdisciplinary science and the strong **synergy** of the magnetic resonance technologies. The existence of such a magnetic resonance facility will allow the development of several areas of scientific study rendered newly accessible to magnetic resonance. The synergy among the technologies has led to such prior developments as electron-nuclear double resonance, and optical

detection of magnetic resonance, and continues at the NHMFL (e.g. the adaptation of two-dimensional and broadband inversion pulse methods from NMR to ICR spectroscopy).

- **Optical spectroscopy of mass-selected gas-phase ions**: Mass spectrometry today is done the way chemistry was done 100 years ago: weigh the sample, let it react, then weigh it again. Chemistry was revolutionized by the introduction of spectroscopy to determine molecular structure. In pilot experiments at low-field (3.0 T) earlier this year, the NHMFL ICR group detected fluorescence from mass-selected (i.e., "purified") gas-phase ions. We propose to build a full-scale high-field (9.4 T) instrument dedicated to optical spectroscopy of gas-phase ions, ultimately proteins and nucleic acids, available to external users.
- The development of high-field pulsed EMR instruments is hindered by the absence of high frequency sources; one route is to **develop pulsed gyrotrons**, and the NHMFL is perfectly poised to collaborate with the private sector to build such machines—in fact, the Seitz-Richardson report stressed the need to develop gyrotrons in a high magnetic field facility.
- Biological macromolecules exhibit rotational correlation times ranging from 10^{-12} to 10^{-3} (and slower). Measurement at a single frequency emphasizes modes close to that Larmor frequency. A multifrequency approach, such as field-dependent measurements of relaxation times, probes the *whole spectral density* of motional modes. Field-dependent NMR/EPR experiments of macromolecules have been restricted to a narrow field range, from a minimum of ~400 MHz for NMR (for minimum sensitivity) and 9 GHz for EMR to the recently installed 800 MHz (NMR) and 90 GHz (EMR) systems. Increase in field to 1.1 GHz (NMR) or 550 GHz (EMR) nearly **doubles (for NMR) and quintuples (for EMR) the working *range* of field strengths for motional dynamics of biological macromolecules.** This area of research focus could benefit significantly from the ability to extend magnetic resonance to the 1.5 GHz range and beyond.
- Molecular diffusion and transport with unique chemical element sensitivity on length scales ranging from micrometers to millimeters and time scales from milliseconds to seconds in optically opaque systems become accessible by non-invasive pulsed field gradient (PFG) NMR methods. Coupled with MRI/MRIS, PFG techniques provide chemically- and spatially-resolved information. **Increased strength and precision of control of the applied magnetic field gradients will lead to direct gains in sensitivity to motion.** Theory shows that accessible improvements in gradient performance can push **water displacement measurements from the current limit of ~1 μm to the sub-μm range**, for improved characterization of porous separation media as well as intracellular transport in living systems: e.g., cytoplasmic streaming, and transport of low molecular weight solute molecules (e.g., high energy phosphates), endogenous proteins (e.g., myoglobin) and microinjected tagged macromolecules.

Structure and Strategic Goals of a National High Field Magnetic Resonance Center

The proposed facility will design, develop, operate, maintain, and continuously upgrade state-of-the-art MR instruments, optimized for various combinations of high-field EMR, ICR, MRIS, and NMR. The facility will focus on the following three objectives:

- **Science must drive the facility.** The facility will emphasize interdisciplinary science and the strong synergy of the magnetic resonance technologies. The existence of such a magnetic resonance facility will allow the development of several areas of scientific study rendered newly accessible to magnetic resonance.
- The facility will be **user-oriented** and structured around participating research teams broadening the impact on science and technology. All instrumentation and scientific expertise will be available to support research of the scientific community worldwide. This will include an educational program and strong programmatic development of support for, and interaction with, industrial users. Private sector partners will be integral to the magnetic resonance participating research teams.
- The facility will be a **center for technique and instrumentation development.** Instrumentation research will be directed at optimization of hardware and software for data acquisition and processing (e.g. time-domain EMR), as well as technique development in support of users' scientific studies. The NHMFL is looking to external institutional-based researchers and private sector partners to play a significant role in the driving the technology and instrumentation development.

In contrast to a service-only program, the interaction of the facility with the user community will take on two forms:

- **Participating Research Teams** of facility staff and users to develop and apply a specific technique and/or type of instrumentation that is needed by the users program and benefits from users' expertise.
- **Proposal-based user access** to facilities and support infrastructure.

Support for the Scientific and Technologically-Driven Activities within the Center

Immediately identifiable needs for funding support will be sought from multiple federal sources (NSF, NIH, DoD, DoE), foundations, and the State of Florida. A white paper has been developed and proposals will be submitted during 1996-1997 seeking support for the National High Field Magnetic Resonance Center.

VI. EDUCATION PROGRAMS

Educational outreach activities at the NHMFL have continued to expand in a comprehensive manner this year with particular emphasis on K-12 education. Since January 1996, approximately 1,690 elementary and secondary students have participated in hands-on lessons conducted by NHMFL personnel at the schools. Another 1,460 students have toured the laboratory during this same period. Tours typically include a lecture with demonstration, an overview integrating several science and technology areas, and a guided tour of the facilities. A science educator has been hired to direct and grow the K-12 educational outreach programs and activities. The following highlights describe recent educational outreach activities at all levels of the pedagogical spectrum.

- In a program designed to expose local middle school students to the hands-on experiences of science and math, twenty-three students spent one morning a week for a semester at the lab with a scientist mentor working on a science project. Their results were given at a poster session and presentation workshop that was widely publicized in the community.
- A parallel program provided local high school students the opportunity to work alongside scientists in their laboratories after school for a semester to earn credit. Several of these students continued to work at the laboratory during the summer with their mentors.
- An educational outreach program for K-12 students was launched for regional schools to excite and educate students about science and related concepts. In just six months, this popular program reached almost 1700 students.
- Nine middle school teachers worked at the NHMFL this summer developing new science curriculum materials for students. They produced a video, twenty-two hands-on student activities, valuable teacher resources, and an interactive new website accessible through the NHMFL homepage *(http://www.magnet.fsu.edu)*. This unique program was supported by the Florida Department of Education.
- The NHMFL in conjunction with the State of Florida has developed a teacher resource laboratory. The laboratory houses state-of-the-art multimedia development equipment, manipulative development equipment, curriculum materials for review, and instructional resources.
- The laboratory is developing interactive curriculum products that utilize a variety of delivery formats such as an interactive CD-ROM series with supporting text and laboratory manipulatives. These products will allow students to explore the magnet laboratory and its resources, investigate a variety of related scientific concepts and careers.
- The equipment circulation van program will provide teachers with the education and access to high-level laboratory equipment necessary to conduct multidisciplinary investigations with their students. The laboratory is seeking funding to design and equip a van or truck with the necessary and supplies.
- The NHMFL is developing a regional or statewide competition for high school students (sophomores and juniors) to develop a research plan to conduct an experiment at the NHMFL. The winners will be selected by a board from the laboratory and will be provided transportation and housing to conduct their experiments next summer. NHMFL faculty working with the students to analyze the results also will seek publication of their findings.
- The NHMFL has developed partnerships with the Tampa Museum of Science and Industry, Odyssey Science Museum of Tallahassee, and the Orlando Science Center to design and develop interactive traveling and permanent exhibits.
- This is the fourth consecutive year that the NHMFL has sponsored a Summer Minority Internship Program. The laboratory received sixty applications (more than double the previous year), which came from fifteen states. Eighteen undergraduate students accepted offers and participated in the program at all three consortium sites.
- The NHMFL offered a new course for college science teachers as part of the National Science Foundation's National Chautauqua Short Course Program. Entitled *Magnetic Fields in Science and Technology*, the presentations to twenty-one educators focused on the generation of magnetic fields, the application of magnet technology, and various magnetic resonance techniques.

- The NHMFL and Florida A&M University co-hosted the Fourth Annual NSF Alliances for Minority Participation (AMP) Student Research Conference this summer. Over 150 college students from throughout the United States and Puerto Rico, along with AMP project directors and NSF officials, attended the three-day conference in Tallahassee. The students' research posters and presentations were judged by local faculty; distinguished lectures were given by Nobel Laureate Dr. Robert Schrieffer and former astronaut and professor Dr. Norm Thagard; and an afternoon was spent at the NHMFL learning about magnet-related research and technology and touring the laboratory.

VII. COLLABORATIONS:
INDUSTRIAL, INTER-AGENCY, AND INTERNATIONAL PROGRAMS

The NHMFL continues to expand its affiliations with private industry and to pursue new development opportunities in materials and magnet technology areas as an important component of its NSF mission. The leadership of the laboratory is devoting more time and resources to encouraging economic development opportunities in this region of Florida, which has been a vacuum for such high-tech activities in the past. By targeting several industrial partnerships that have a need to be in closer proximity to the laboratory and its resources, the NHMFL hopes to relocate a coterie of firms that may benefit from mutual development opportunities.

Inter-agency and international collaborations have always played an integral part in the development of the laboratory's unique user facilities. These collaborations continue to flourish and grow as all faculty and staff are encouraged to pursue new avenues for cooperation and expansion.

The NHMFL has continuing industry and international collaborations with Handy & Harman, DuPont Experimental Station, Intermagnetics General Corp., A.A. Bochvar Institute, All Russian Institute of Experimental Physics, National Research Institute for Metals in Japan, and the Chinese High Magnetic Field Laboratory. A complete list of ongoing collaborations are highlighted in Section Five (page 231) of the *1995 NHMFL Annual Report*. The laboratory has established the following new initiatives since the report's publication.

EURUS Technologies, Inc., East Hampton, NY

The NHMFL and EURUS Technologies recently initiated a co-development and testing program for high temperature superconducting (HTS) current leads. The program will measure the mechanical, electrical, and thermal properties of a new class of current leads under varying cryogenic conditions. It will culminate in the production of the world's first commercially available 10,000-amp-class, encapsulated, HTS leads, which may be adapted for use in NHMFL magnet systems, such as the 45 tesla hybrid. The NHMFL will provide EURUS with space at the facility for these joint development activities.

Varian Associates, Palo Alto, CA

The NHMFL and its Center of Interdisciplinary Magnetic Resonance (CIMAR) is a beta test site for a new high temperature superconducting (HTS) probe for NMR spectrometers. The prototype HTS probe is on loan to the laboratory and is the result of a joint venture between Varian Associates and Conductus Inc. HTS probes are expected to open a wide range of novel applications in solution-state NMR, as the sensitivity, which has been a major source of concern since NMR was discovered fifty-one years ago, increases dramatically. The HTS probe utilizes radio-frequency coils made from the high temperature superconductor YBCO.

Brush Wellman, Cleveland, OH

Interactions between Brush Wellman, a copper and alloy firm, and the NHMFL's high pressure diamond anvil group have resulted in new magnet development activities. The company and Prof. Meigan Aronson of the University of Michigan have recently developed and produced a magnetically cleaner form of BeCu. They have found that the new material has a higher conductivity than previously available alloys. Brush Wellman is providing the NHMFL with the new BeCu material for testing and potential use in the 33-tesla class resistive magnets. The company is also supplying this new alloy in the form of BeCu-clad wire for the NHMFL's pulsed magnet development program.

Westinghouse, Pittsburgh, PA and the Department of the Navy

The NHMFL will be the testing site for the superconducting magnetic energy storage (SMES) device developed by Westinghouse for the Navy. Westinghouse and the Navy are interested in using the laboratory because of its unique testing facilities and its personnel expertise in building large-scale magnet systems, such as the 45 tesla hybrid system. The large SMES magnet was developed and built by Westinghouse and is the process of being shipped to Tallahassee. Upon completion of the testing, Westinghouse will leave behind their magnet-related equipment for use by the NHMFL as a large coil test facility.

National Research Institute for Metals (NRIM), Tsukuba, Japan

The NHMFL and NRIM have entered into a cooperative program for the Florida laboratory to build a 30 tesla resistive magnet as the first such class of magnet for the Japanese facility. Collaborative activities continue to prosper for developing higher strength and higher conductivity plates and wire for our resistive and pulsed field magnet programs.

Deepstar, Houston, TX

Fourteen oil companies have formed a research and development consortium, Deepstar, to study problems confronting the industry. The NHMFL was approached by Deepstar to organize a research team from the laboratory, University of Florida, and the FAMU/FSU College of Engineering to establish the validity and scientific bases of magnetic field treatment devices used in industry. For the Deepstar consortium, the NHMFL organized a workshop held in December 1995 with invited talks on magnetic field treatment devices.

Royal Holloway College, University of London

Researchers at the University of Florida are collaborating with the Royal Holloway College's Millikelvin Laboratory on two-dimensional quantum nuclear magnets. The English scientists are planning cooperative experiments at the NHMFL's new high B/T facilities at the University of Florida.

Institute of Low Temperature Physics & Engineering, National Academy of Sciences, Ukraine

Collaborations between the Institute's group working on the low temperature properties of cryocrystals and the thermodynamic measurements and the University of Florida scientists using NMR to study the microscopic dynamics have been funded by the U.S. Civilian Research & Development Foundation for the Independent States of the Former Soviet Union.

University of Manchester, England

Researchers from England will use the NHMFL's Ion Cyclotron Resonance (ICR) facilities to determine the mechanism of fragmentation and rearrangement reactions of peptides.

University of Queensland, Australia

The two groups have been collaborating on the use of nanoscale particle inclusions into high temperature superconducting tapes. A research team at Queensland are experts in the synthesis of such particles and have produced extremely high-quality, ultrafine MgO powder. NHMFL scientists have incorporated their MgO powder into BSCCO tapes and have demonstrated significantly improved superconducting properties.

Physical Sciences Inc., Andover, MA

The development of high frequency pulse Electron Magnetic Resonance (EMR) is one of the greatest challenges in magnetic resonance. This development is hindered mainly by the lack of high frequency sources. The EMR group of the NHMFL has recently initiated a collaboration with Physical Sciences Inc. to develop a pulsed gyrotron at high frequency (150 up to 600 GHz) with a very good time resolution in the nanosecond range.

Northeastern University

The Electron Magnetic Resonance (EMR) facility at the NHMFL represents the culmination of recent worldwide efforts to push EMR beyond its traditional operating range at centimeter wavelengths to the millimeter and submillimeter wavelength region of the electromagnetic spectrum. This thrust has vastly increased the potential of EMR but requires technology significantly different from conventional EMR technology, which remains to be fully optimized. The EMR group of the NHMFL and colleagues at Northeastern University have recently initiated a collaboration to extend quasioptical methods, developed at millimeter wavelength, and apply them in the submillimeter range. This research effort will tremendously enhance the potentiality of the EMR facility.

VIII. MANAGEMENT PLAN

Introduction

The management plan for an organization is a formalization and codification of procedures that are designed to bring to the decision makers the information necessary to permit informed decisions regarding the development and operation of the organization and to provide the framework within which the organization pursues its objectives. Fundamentally, the process is one of (1) setting strategic goals and objectives consistent with a clearly articulated vision, (2) allocating resources to the various activities, (3) measuring and evaluating performance against the strategic goals, and finally (4) a continuing re-evaluation of the vision in light of external events, recommendations from advisory bodies, and progress toward strategic goals. The ultimate success of an organization depends upon its ability to understand the needs for which it was created and its success in serving those needs. Management is the process by which the leaders of the organization define what is needed to achieve the mission of the organization, then set internal objectives and allocate resources in order to achieve the organization's end objectives. The Management Plan of the laboratory reflects a recognition of the mission that the NHMFL was created *to serve* and the basic functions that must be performed in order to serve that mission effectively.

NHMFL Objectives and Organization

The objectives of the NHMFL were first set forth in the Seitz-Richardson Report and further defined in the NSF solicitation of 1989 and the Florida-Los Alamos response to the NSF solicitation. The NHMFL is expected to have three main functions:

- The laboratory will be operated as a user facility open to all qualified scientists and engineers.
- The laboratory will engage in development of future magnet technology including new materials for high field magnets.
- The laboratory will create a stimulating in-house research environment involving physics, chemistry, materials science, engineering and biology that utilized the high field facilities of the laboratory and leads to the development of the facilities.

Secondary functions are to integrate the laboratory into the academic programs of the participating institutions, provide educational and research opportunities for all levels of students and teachers, maintain significant scientific and technical exchanges with groups in other academic institutions, government laboratories, and industry. Both the primary and secondary functions are included in the Cooperative Agreement with NSF.

The NHMFL organization has been structured to serve these objectives. There are three main functional elements in the organization:

- **Users Program** — responsible for operating and maintaining the high field user facilities and the instrumentation of the laboratory.
- **Magnet Science & Technology (MS&T) Program** — responsible for developing the high field magnets and magnet technology necessary to support the requirements of the users and the future needs of science and industry.
- **Research Programs** — responsible for managing the in-house research activity and ensuring that the research is of the highest quality and that it utilizes the high field facilities and leads to further development of the facilities.

A fourth functional element is the management organization, which consists of two basic elements:

- **Laboratory Management** — responsible for setting policy and objectives, allocating resources, and evaluating the performance of the functional elements of the laboratory.
- **Administration** — provides a supporting service to the Director by operating and maintaining the fiscal and administrative functions, which provide management with the necessary controls and performance evaluations. In addition, the Administration monitors and coordinates the secondary functions to make sure that they are integrated into the overall laboratory operations.

NSF requires and the NHMFL has implemented a number of formalized mechanisms for assessing the performance of the laboratory in achieving its required objectives and for re-evaluating the objectives. These consist primarily of input from external sources.

- **External Advisory Committee** — This committee reports to the Chancellor of the State University System. It is made up of representatives from academia, industry, and other laboratories or research organizations with significant user representation. It assesses overall performance, policies, objectives, and mission and recommends changes as appropriate.

- **Users' Committee** — This group is nominated and elected by external users of the NHMFL. It meets twice per year and reviews the services provided by the NHMFL to the user community. The Users' Committee advises the NHMFL on the facilities needed (magnets, instrumentation, user support) to meet the users' scientific needs.
- **NHMFL Review Committee** — This committee reviews proposals submitted by prospective users and advises the NHMFL on the overall quality of the proposals.
- **NSF Annual Site Visit Review Panels** — These panels, appointed by NSF, review the entire NHMFL operations annually and provide evaluations and recommendations to NSF (and to the NHMFL) regarding policy, operations, objectives and mission.

In addition, the NHMFL has created several internal mechanisms for self review and evaluation. These provide input from internal sources.

- **Institutional Oversight Committee** — This committee is chaired by the Chancellor of the State University System and has representatives from each of the participating institutions. It provides direction regarding administrative policy as well as advice on the academic and research relationships with the participating institutions.
- **Research Program Committee** — This committee is drawn from the ranks of the in-house researchers using the NHMFL facilities. It advises on the overall quality of the in-house research and provides recommendations on the relative merits of in-house research proposals.
- **Executive Committee** — Consisting of the senior management of the laboratory, this committee is the primary forum for internal review, evaluation, and development of priorities and mission. The committee is formally charged with reviewing and advising on organization, staffing and resource allocation/budget review, taking into account the objectives and mission of the laboratory, external reviews, and internal evaluation of the overall program. This committee is chaired by the Director and makes recommendations to the Director.

Summary of Policy Decision Making Process

The Director of the NHMFL is ultimately responsible, in conjunction with the Co-Principal Investigators, to NSF for the NHMFL's performance with respect to the mission set forth in the Cooperative Agreement. They rely on the Executive Committee, Chief Scientist, and Deputy Director for input and recommendations regarding the overall operation of the laboratory and allocation of resources.

The Executive Committee provides a forum for the key managers of the various laboratory functions, the Chief Scientist, the Deputy Director, and the Co-Principal Investigators to discuss and evaluate laboratory priorities and operations, review the recommendations of the various panels, and provide additional guidance in the form of policy recommendations to the Director. Formalized budget processes and project reviews are designed to ensure that the Executive Committee is well informed about the issues. In addition, the formal actions ensure that the Executive Committee is involved in setting priorities and allocating budgets along with evaluating the effectiveness of various programs. The Director, as Chair of the Executive Committee, must maintain the focus of the debate on the overall objectives of the laboratory as set forth in the Cooperative Agreement and strive to develop consensus within the Committee regarding the basic policies and allocation of resources. The results of this process to date can be shown in an evaluation of the current and planned allocation of resources.

Resource Allocation and Rationale

Figure VIII-1 shows the actual allocation of total NSF resources for the NHMFL through 1996 and the planned allocation through the current grant period ending December 31, 2000. The allocation of resources is and has been driven by the needs to meet the basic objectives of the laboratory. In the early years, 1990 through 1993, the primary focus was on building the lab, staffing MS&T, building the early magnets and the DC power supplies at both Tallahassee and Los Alamos. In 1994, when the facilities became operational, the Users Program activities began with the staffing of the user instrumentation capabilities and the operating staff. The costs of electric power that are a significant part of the Users Program have grown as the numbers and the intensity of users of the magnets have increased. By 1996, the staffing of the science positions was essentially complete, lab facilities and research programs were initiated, and the laboratory was in a position to implement a science program. Funding was provided in the renewal award and that is reflected on the chart.

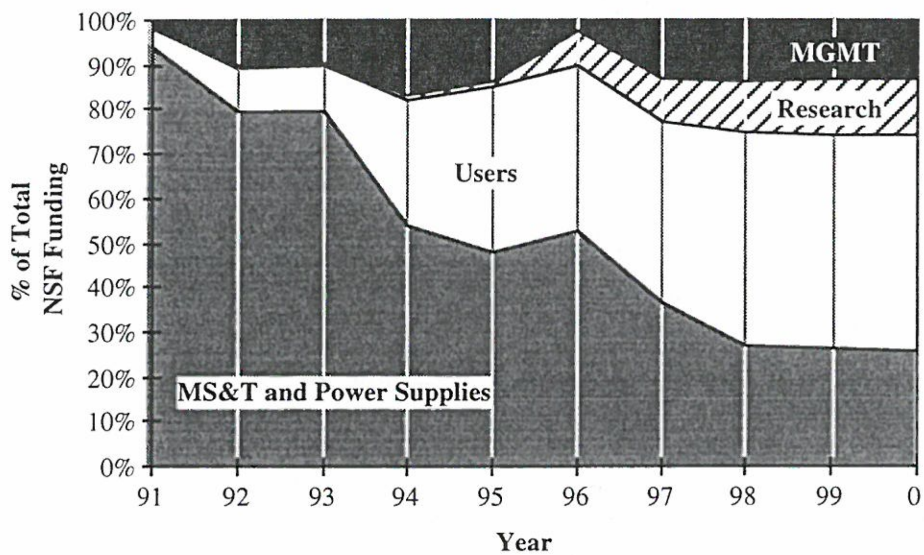

Figure VIII-1 NHMFL Resource Allocation

The first priority in funding decisions is always the Users Program, as that is the driving mission of the NHMFL. Input from the Users' Committee, the broader scientific community, and most important the user proposals received are weighed very heavily in determining what services and level of activity to fund. Essentially, the NHMFL must satisfy the requirements of the users if it is to be successful. In the long term, Users Programs are projected to require about 50% of the program funding. These projections do not include support of a users program in magnetic resonance other than the use of resistive magnets for magnetic resonance experiments. Given the funding available for the second five-year period, it was determined that adding an expensive magnetic resonance program to the Users Program would result in insufficient funds to adequately meet the minimum requirements of an in-house research program and/or a magnet science and technology program. The consensus was that the NHMFL must have a balanced program, even if it meant that one area was not included. Hence the decision to seek supplementary sources of funding for the Magnetic Resonance Users Program.

Decisions regarding the level of support for Magnet Science and Technology are guided by several drivers. First, the NSF has charged the lab with developing and maintaining a core capability in magnet science and technology and with developing future research magnets. During the first two years of the renewal period, MS&T is funded to complete the major magnet programs that have carried over from the first grant period: the 45 T Hybrid, the 900 MHz NMR magnet, the 60 T quasi-continuous pulsed magnet, and the new joint 100 T program with DoE. In addition, the development of future new magnet building programs is driven by the needs of the user community, such as the current interest in developing high field magnetic resonance capability in resistive magnets to get beyond the limits inherent in superconducting magnets. The long range level of support for MS&T is at about 25% of the total support and reflects the funding required to maintain the core capability, meet new user needs, and maintain existing magnet systems. MS&T has developed a world class capability and reputation in magnet technology, and we expect that applying that capability to other programs will provide support at least equal to the in-house magnet activities.

The Research Program has been developed on a competitive peer reviewed proposal basis. Awards are open to researchers from any of the three participating institutions. The average size of a grant is expected to be in the same order of magnitude as a typical NSF single investigator award, i.e. about $80,000 per year. The size of the program is established by several factors: (1) the number of researchers eligible to apply, (2) the facility time available to support in-house research and (3) ultimately the number and quality of proposals. The In-House Research Program is further limited by the fact that approved awards must use the high field facilities and/or result in an improvement of the facilities. In-house research is expected to include magnet technology and materials development activities, as well as basic science in physics, chemistry, material science, and biology. The Research budget is expected to level off at about 12% of the total, and the quality and impact that this funding has on the future of the laboratory will be carefully monitored by external reviewers. Adjustments in funding will be made based on these reviews.

The management portion of the budget includes the basic administrative functions of the Director's Office, the fiscal operations, the Safety and Health Program, and educational programs focused at K-12, undergraduate internships, and programs directed at under-represented groups. In addition, it includes funding for publications, industrial liaison programs, public outreach, and international programs. These activities account for about 13% of the program total funding.

Resource allocations are reviewed annually as a part of the budgetary process. Individual projects are evaluated in terms of their overall value to the NHMFL and their contribution to the mission of the laboratory. The priorities of the NHMFL mission are continually reviewed in the context of the reports of advisory groups, scientific developments, the expressed needs of the scientific community, and the priorities and objectives of the National Science Foundation.

Organizational Structure

The codification of the NHMFL Management Plan has two parts: (1) the organizational structure that allocates operational responsibility and sets up the structure for formalizing the flow of information to the decision makers, and (2) a budget and project management process that provides a mechanism for distributing resources, monitoring their use, and measuring performance against stated objectives.

Considerable effort has been devoted to formalizing our management plan and putting the companion financial reporting programs into place. A budget control procedure and a project management procedure have been authorized by the Executive Committee and implemented. Our cost accounting system is fully operational, the fiscal staff has been trained in its utilization, and all management personnel can obtain access to any project cost data on-line and current via the American Fundware System. The Magnet Science and Technology project reports are examples of the monthly project reporting that is being established for significant NHMFL projects.

Another major milestone was the finalization of the Institutional Operating Agreement, which resolves many of the inter-institutional issues between the University of Florida, Los Alamos National Laboratory and the Florida State University.

The organizational structure of the NHMFL is documented in a series of Organizational and Management Directives that have been reviewed and recommended by the Executive Committee and implemented by the Director. These directives define the policy decision making structure of the NHMFL as well as the day-to-day administrative and operating structure. A summary of the contents of that document follows:

Section	Summary of Contents
Organizational Structure	Defines the overall organizational structure, the basic responsibilities of key personnel, and the role of the various oversight committees and organizations that evaluate the overall performance of the NHMFL.
Executive Committee Organization	Defines the membership of the Executive Committee, its duties, responsibilities, and operations procedures.
In-house Research Program Committee Organization	Defines the membership, organization, and functional responsibilities of the Science Program and the procedures governing the administration of the in-house research program.
Committee Organizational Requirements	Defines the permanent committees and the process for creating ad-hoc committees and the guidelines for committee administration.
Users' Committee Organization	Defines the Users' Committee organization and operations.
User Proposal Review Process	Defines the organization and operation of the NHMFL Proposal Review Committee and the policies to be followed in reviewing user proposals.
Budget Priority Process	This procedure defines the overall NHMFL budget process including setting priorities within the laboratory along with the budget breakdown, development and review process, and the monitoring process.
Cost Reporting System	Provides basic policies and direction regarding the allocation and reporting of costs to ensure consistency and continuity in the cost records.
Project Management System	Establishes project management and reporting policies to provide a consistent basis for planning, monitoring, and reviewing project performance.
Health and Safety Program	Defines the NHMFL Health and Safety Program and policies as implemented in response to the NSF cooperative agreement.
Staffing and Personnel	Defines basic personnel policies including appointments, evaluations, and other actions.
Inter-Institutional Operating Agreement	Reference document that provides direction to NHMFL management.
Los Alamos Statement of Work	Reference document; contractual statement of work for the LANL subcontract.
Los Alamos Management Plan	Reference document describing the administration of Los Alamos operations.

Budget Management

The key element of budget management is an effective cost reporting system. We have finally achieved our objectives of an on-line, real time cost reporting system based on a project structure. Up-to-date reports of actual costs incurred in the current period and year or project to date are available on-line to any authorized person. The system tracks salaries and wages, as well as purchases, subcontracts, and expenses. Commitments are entered at the time requisitions are received and updated as the requisition goes through the purchasing cycle. The report formats and the cost allocation rules are in accordance with the Executive Committee directives.

A companion element of effective budget management is the project management system. This system ensures that consistent project budgeting and reporting have been implemented. The reports on the major magnet projects included in this report are examples of the monthly reporting required for each significant project.

The project reports are distributed to the Executive Committee for review with the Executive Committee requiring more focused reporting on a periodic basis.

Environmental Health and Safety

The Environmental Health and Safety Program is fully operational. The NHMFL experience in terms of incidents per 100 man-years (MY) of time has been lower than the National Safety Council-reported averages for research and development laboratories. We intend to continue to pursue a no-accident policy.

The NHMFL conducts a number of specific training programs directed to specific laboratory activities as well as general programs. We have conducted nineteen

This process greatly improves the coordination of project activities and dissemination of project information within the NHMFL organization.

different training programs for a total of 895 attendees (many people have attended more than one training program). We continue to develop and expand training program materials.

We have developed twenty-one safety procedures specifically tailored to the needs of the NHMFL. The procedures are available to all laboratory personnel on-line. We have an additional twenty procedures in development.

The success of the Environmental Health and Safety Program can be measured by the Accident/Incident History:

Year	Total Cases	First Aid Accidents	Lost Time Accidents	Work Days Lost	Incident Rate Per 100 MY
1992	1	1	0	0	0.56
1993	1	1	0	0	0.39
1994	9	9	0	0	3.02
1995	11	8	3	6	3.22
1996 *(to date)*	5	5	0	0	1.27

IX. 1997 BUDGET

The proposed budget for 1997 recognizes the limitations imposed by the NSF renewal grant award of $17.5 million per year. The budget has been developed within the overall plans and guidelines for allocation of resources as set forth in Section 8 of this report—Management Plan. Details of the 1997 budget and an analysis of this budget are provided within the context of the Management Plan as determined by the level of award funding. Comparisons of the 1997 budget with the renewal request are also provided for reference purposes. The significant changes from 1996 are as follows:

- Salaries and ongoing expense items have been adjusted to reflect twelve months. The 1996 budget was a ten-month budget with the remaining two months of funding dedicated to several major equipment expenditures, specifically the pulsed power supplies for the 60 T and 100 T magnet projects at the Pulsed Field Facility at Los Alamos, the major conductor purchase for the 900 MHz NMR magnet project, and the final commitments for the hybrid project and the 20 T large bore resistive magnet.
- Salaries for NHMFL personnel have been increased an average of 3% in accordance with the Florida Legislature mandate effective January 1, 1997.
- The allowance for electric power has been increased from $1.34 million to $1.6 million on an annual basis. This increase reflects an actual growth in power consumption as a result of increased magnet usage (we have consistently run two magnets per shift) and increased energy consumption resulting from users spending more time at higher fields (resistive magnet NMR has been a significant contributor).
- A planned increase in the In-house Research Program awards from $1.12 million to $1.58 million as recommended by the Renewal Site Review Committee.

As a result of the above increases, the funds available for investment in new systems and equipment have decreased to $2.69 million from the 1996 level of $5.99 million.

The proposed budget is subject to modifications as a result of the Site Review and further in-house review. Final budget data will be submitted to NSF at a later date.

Budget Background

The NHMFL renewal proposal budget request submitted in June of 1995 presented a five-year program totaling $111 million. This proposal reflected a baseline funding of $79 million and new initiatives totaling $32 million over the five-year period. The actual renewal award was $87.5 million, which reduced new initiatives to $8.5 million over the five-year period. This has resulted in the deferral, reduction, or elimination of several program initiatives as set forth in the renewal proposal.

The staffing profiles are shown in the following table:

Staffing Projections

	1995 Baseline	Renewal Request 1996	Award 1996	Renewal Request 1997	Award 1997
Management	25	24	21	24	21
User Operations	56	56	46	59	46
Research	0	14	5	14	5
Magnet Science & Technology	51	52	42	52	42
Total	**132**	**146**	**114***	**149**	**114***

* Totals do not include summer interns (14).

Decreases in staffing have been accomplished by reducing the numbers of temporary staff personnel and by shifting some staff to state resources.

The following table shows the allocation of funds planned for 1997 versus the allocation of funds requested in the renewal proposal for 1997.

Current Budget vs. Requested Funding — $K

	Planned Award 1997	Renewal Request 1997
Management	$2,451	$3,753
User Operations	7,247	9,735
Research	1,719	1,353
Magnet Science & Technology	6,083	5,364
Total	**$17,500**	**$20,205**

Management (which includes facilities) was cut back primarily by transferring the entire facilities maintenance personnel responsible for the magnet power supplies and cooling water systems from the NSF grant to state resources funded by the grant overhead. The reduction in User Operations reflects the deferral of the CIMAR user program, postponing expanded instrumentation systems, and deferring funding of replacement allowances for existing instrumentation. The Research Program shows a modest increase in response to the Site Review Committee's strong recommendation to protect the In-house Research Program. Magnet Science and Technology shows an increase primarily due to a shift in the schedule of spending for the 900 MHz program.

A comparison of the total five-year budget allocations shows that the reductions in scope over the five-year program have been reasonably balanced among the laboratory functions.

5-Year Budget Functional Allocation

	5-Year Request	5-Year Award
Management	19.2%	16.4%
User Operations	44.8%	43.9%
Research	7.0%	10.6%
Magnet Science & Technology	28.9%	29.2%

A review of the allocation of funds between personnel, travel, expense, capital equipment, and overhead provides a good picture of the real effect the reduced budget award has on the future of the laboratory.

Award Budget 5-Year Use of Funds

	1996	1997	1998	1999	2000
Salaries & Wages	21%	26%	30%	30%	30%
Permanent Equipment	35%	21%	7%	7%	6%
Travel	1%	1%	1%	1%	2%
Expense	24%	30%	36%	36%	36%
Indirect cost	19%	22%	26%	26%	26%

Inflation, planned at 3% per year drives staff salaries and wages upward along with expenses. Increased magnet usage resulting in both higher power demand and energy costs, as well as the escalation of power costs, will have a major effect on expenses. The combined power budgets for Los Alamos and Tallahassee represent about 35% of the direct expense in 1997. This will grow in the out-years. The inevitable cost growth required to maintain the User Operations, Research, and Magnet Technology capabilities put a major squeeze on available funds for investment in permanent equipment such as new magnet systems or user instrumentation. In addition, there is little room for establishing new user program activities. A discussion of each functional area follows.

Director's Office

There are no changes or new initiatives in the Director's Office. The K-12 program and the Summer Fellowship program for under-represented groups remain at the same level as before.

Facilities and Administration

A primary activity funded in Facilities and Administration is the Health and Safety Program for the laboratory. In addition we have included an increase in other direct expenses to help cover costs of spare parts and service calls for the power supplies and magnet cooling plant equipment. The total amount allocated for equipment maintenance is $240,000, an increase of $65,000 from the previous year. This is justified because of aging equipment and the fact that some of our long-term warranties are expiring.

Instrumentation and Operations

Instrumentation and Operations remains unchanged except for one additional permanent operator position in the DC facility, which will be needed as the number of magnet shifts increase and as the Hybrid magnet is brought on-line. The position will be filled in early 1997 to provide sufficient time for training. The other significant change is in the budget for electric power. The annual rate is increased to $1.6 million an increase of about 20% to reflect the growth of power usage. The chart below shows the history of electric power costs for the Tallahassee DC facilities. The budget for 1997 allows for ten months of operation at $160,000 per month or eleven months at $145,000 per month.

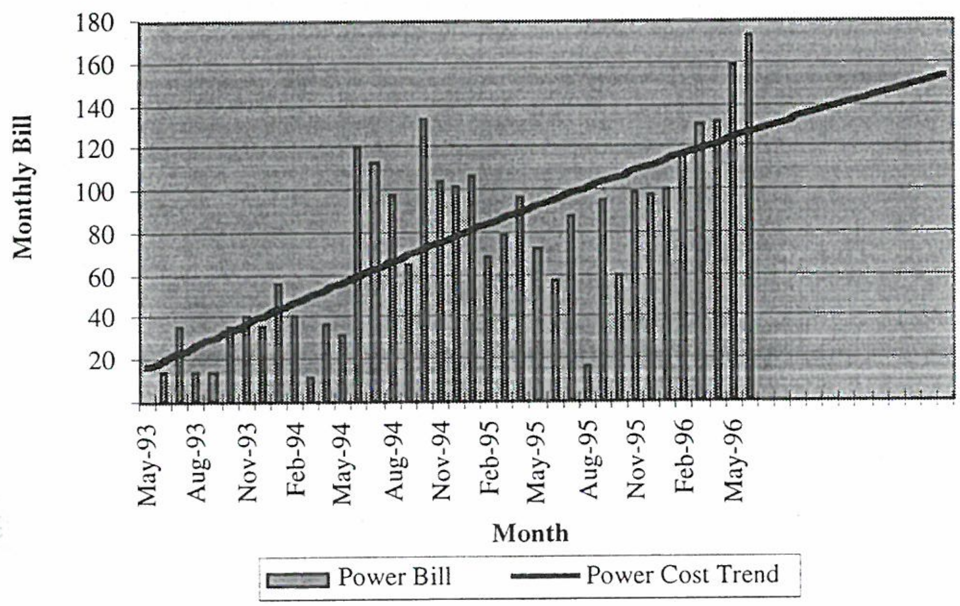

Figure IX-1 Electric Power Costs: DC Facilities — Tallahassee

Electric power costs will continue to be a significant element of the laboratory's budget in future years. New magnet systems and new experiments in resistive magnets will have a significant impact on the electric power costs. The above chart shows significant increases in power costs over the past six months. This has been due primarily to an increase in energy consumption and coincides with the increased use of resistive magnets for high field NMR. These experiments generally require much longer times at high fields. As the Keck magnet and other high resolution resistive magnets come on line, we can expect further increases in magnet energy consumption.

The High B/T facility operations started in Gainesville in 1995 and will continue this year with the final installation of the magnets and the inauguration of the user facility.

Two additional science positions were authorized for the Pulsed Field facilities last year. One was filled and a search is being conducted for the second position.

Research Program

The Research Program budget reflects the planned increase in projected awards to $1.53 million for 1997. The total award allocation for 1996 was $1.12 million.

Magnet Science & Technology

Funding for ongoing programs includes the following: maintenance of existing two-power supply resistive magnets, 45 T hybrid and the resistive insert, the 900 MHz NMR magnet, the 60 T quasi-continuous magnet, the 100 T pulsed magnet cooperative program with DoE, capacitor driven pulsed field magnets, and personnel and expenses to support the basic magnet research activities. There are no new magnet initiatives for 1997, other than preliminary feasibility studies.

These are the separately funded programs as outlined in the MS&T section of this report.

Basis of Estimates

Budget estimates are based on the following parameters:

Escalation	3% per year salaries in FL 3% per year expense in FL 4% per year all costs at Los Alamos
Fringe Benefits — FSU	
Permanent Staff	30.1% of salary
Temporary Staff	8.0% of salary
Students	0.3% of salary
Fringe Benefits LANL	Included in direct salaries
Indirect costs — FSU	46% of salaries, fringes and direct expenses (permanent equipment and electric power excluded). Research programs awards will include appropriate institutional overheads, therefore no additional overhead will be shown in this budget.
Indirect costs — LANL	52% of total costs (excluding permanent equipment) plus $500K per year facility support. (This reflects the modified total cost allocation methodology which LANL currently uses.)

Expense budgets reflect the expendables, office supplies, telephone, graphics, and other expenses directly associated with the operation of the NSF programs of the NHMFL. Administrative and clerical salaries are budgeted as listed in the budget sheets. Direct expenses for the Tallahassee User Operations and Magnet Science and Technology groups include local phone service, postage, express mail, and office supplies as direct charges. These charges are justified because the activities supported are primarily in support of NSF objectives for the User Operations.

Attachments

NSF Budget forms for both FSU and LANL for 1997 are attached. In addition a summary of the budget by function is attached. Additional details are available.

NATIONAL HIGH MAGNETIC FIELD LABORATORY													
SUMMARY BUDGET													
DEPARTMENT:													
SUMMARY													
DEPARTMENT NUMBER:													
ALL													
PROJECT NUMBER	100	200	300	400	500	600	700	800	900	Total	Total	Total	Total
PROJECT TITLE	Director's Office	Facilites & Admin	Instrument & Operations	Magnet Sci & Tech	Science	Los Alamos	CIMAR	UF/FSU Committment(Incl HiB/T)	Start-up Committment s	Laboratory Budget 1997	Budget 1997 - without Los alamos	NSF 5 Year Allocation with LANL	Actual 1996 5 mo.
CATEGORY													
NSF BUDGET 12 MO 1997													
SALARIES & FRINGES													
Number of Employees	3	2	26	26	1	12	2	0	0	72	60		
Permanent Salaries	88,065	75,911	1,156,820	1,237,820	18,025	857,792	50,676	50,183	0	3,535,292	2,677,500		
Permanent Fringes	26,420	22,773	347,046	371,346	5,408	0	1,520	15,055	0	789,567	789,567		
TOTAL PERMANENT SALARIES	114,485	98,684	1,503,866	1,609,166	23,433	857,792	52,196	65,238	0	4,324,859	3,467,067		2,189,653
Post Doc Salaries	0	0	46,350	64,890	0	113,568	0	0	0	224,808	111,240		
Grad Student Salaries	0	0	15,450	32,960	0	0	18,540	0	0	66,950	66,950		
Other students	63,205	0	20,600	0	0	0	0	0	0	83,805	83,805		
Honoraria	0	0	0	0	0	0	0	0	0	0	0		
Visiting Faculty	0	0	0	0	0	0	0	0	0	0	0		
Non-Student Temporary	0	0	63,832	64,167	15,000	0	0	0	0	142,999	142,999		
OPS Fringes	5,056	0	10,659	12,961	1,200	0	1,483	0	0	31,360	31,360		
TOTAL OPS	68,261	0	156,891	174,978	16,200	113,568	20,023	0	0	549,922	436,354		1,392,514
TOTAL SALARIES & FRINGES	182,746	98,684	1,660,757	1,784,144	39,633	971,360	72,219	65,238	0	4,874,781	3,903,421	4,573,603	3,582,167
TOTAL PERMANENT EQUIPMEN	511,190	0	124,706	2,146,000	1,580,000	95,680	0	20,000	0	4,477,576	4,381,896	3,698,280	89,939
TRAVEL													
Domestic Travel	23,500	7,000	45,000	65,000	31,000	34,320	0	2,400	0	208,220	173,900	196,010	357,343
Foreign Travel	9,000	0	5,000	10,000	0	17,680	0	2,500	0	44,180	26,500	36,475	105,495
TOTAL TRAVEL	32,500	7,000	50,000	75,000	31,000	52,000	0	4,900	0	252,400	200,400	232,485	462,838
TOTAL OTHER DIRECT EXPENSI	91,000	273,700	2,137,885	230,000	25,000	1,097,200	0	12,000	0	3,866,785	2,769,585	5,433,948	1,026,772
NSF PROJECT TOTAL DIRECT	817,436	379,384	3,973,348	4,235,144	1,675,633	2,216,240	72,219	102,138		13,471,542	11,255,302	13,938,316	5,161,716
INDIRECT COSTS	140,873	174,517	1,034,375	961,006	43,991	1,602,691	33,221	37,783	2,425,767	4,028,458	2,425,767	3,926,594	
										LANL Subcontract	3,818,931		
NSF PROJECT TOTAL	958,309	553,901	5,007,723	5,196,150	1,719,623	3,818,931	105,440	139,921		17,500,000	17,500,000	17,864,910	
5 Year Target Budget excl OH	681,709	2,161,201	4,167,881	3,023,117	1,646,583	2,257,827	0	0		13,938,318	11,680,491		

National High Magnetic Field Laboratory
Proposed Budget 1997 - Year 7

ORGANIZATION Florida State University	FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed	 Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Jack E. Crow, Neil S. Sullivan, Don M. Parkin	AWARD NO.		

A. SENIOR PERSONNEL:PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title:A.6, show number in brackets)	NSF FUNDED PERSON MOS CAL	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1 Bruce Brandt, Director, Cont. Field Fac.	12			$101,803	
2 Scott Hannahs, Scientist	12			$72,134	
3 Eric Palm, Scientist	12			$61,083	
4 Y. Eyssa, Scientist	12			$98,175	
5. (2)OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	24			$177,591	
6. (6) TOTAL SENIOR PERSONNEL (1-5)	72			$510,787	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (4) POST DOCTORAL ASSOCIATES (See Explaination Page for Names)	48			$145,300	
2. (60) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	720			$1,045,702	
3. (9) GRADUATE STUDENTS				$133,931	
4. (22) UNDERGRADUATE STUDENTS				$154,598	
5. (5) SECRETARIAL-CLERICAL				$74,155	
6. (12) OTHER - Minority Undergraduate Program				$47,000	
TOTAL SALARIES AND WAGES (A+B)				$3,082,494	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$820,927	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$3,903,421	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1000:) See Attached Supplemental Data					
TOTAL PERMANENT EQUIPMENT				$2,689,349	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				$173,900	
2. FOREIGN - World wide travel for Meetings & conferences and Equipment testing				$26,500	
Countries include but are not limited to England, Netherlands, Germany, Switzerland, France, Japan, Finland,Italy and possibly others.					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES (includes $1,600,000 electric power excluded from overhead base)				$2,549,585	
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES (Research Program Awards, total includes inst overheads)				$1,580,000	
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS (4 excluded from overhead base) LOS ALAMOS, Res Prog, Maintenance, Mag Dev				$3,931,478	
6. OTHER tolls, Mail, Reprographics				$220,000	
TOTAL OTHER DIRECT COSTS				$8,281,063	
H. TOTAL DIRECT COSTS (A THROUGH G)				$15,074,233	
I. INDIRECT COSTS (SPECIFY) 46% MTDC*** ***0.97% of this rate is for statewide central svc costs					
TOTAL INDIRECT COSTS				$2,425,767	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$17,500,000	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROGECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OF (J MINUS K)					
M. COST SHARING: Proposed level $ | Agreed level if different $					

PI/PD TYPED NAME & SIGNATURE Jack E. Crow	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE Susan D. Allen Vice President Research	DATE	Date Checked	Date of rate sheet	Initials-DCG Program

BUDGT EXPLANATION PAGE
FLORIDA STATE UNIVERSITY
Proposed Budget 1997 - Year 7

OTHER SENIOR STAFF	NSF FUNDED PERSON MOS CAL	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
M. Bird, Scientist	12			$75,680	
D. Markiewicz, Scientist	12			101,911	
Total Other Senior Staff	24			$177,591	

OVERHEAD CALCULATION

Overhead is calculated on base of Salaries and Fringe Benefits plus Travel plus Other Direct Costs (excluding subcontracts and electric power)

Salaries, Wages and Fringe Benefits	$3,903,421
Travel	200,400
Other Direct Costs	8,281,063
Total	$12,384,884

FRINGE BENEFITS

PERMANENT STAFF - 25.61% OF WAGES + 4.53% for Health Ins.

TEMPORARY STAFF - 7.95% OF WAGES

STUDENTS - 0.3% OF WAGES

Excluding LANL Subcontract	3,831,478
Excluding Science Program Awards	1,580,000
Excluding Electric Power	1,600,000
Overhead Base	$6,953,406
Overhead at 46%	$3,198,567

Permanent Equipment Detail

Director's Equipment Reserve	$399,143
Test Instrument Replacement	15,000
New User's Research (Mech, Thermal Ground State, Transport & Hi Pressure	10,000
UV-Visible Magneto-Optics	10,000
IR Magneto-Optics	10,000
Magnetic Measurements	3,750
Computer Network Equipment	24,500
Computer Network Replacements	
New Machine Tools	20,623
Electronic Instrumentation	15,000
New Millikelvin Instruments Instruments	15,833
CIMAR Instrumentation	
MRI Facility Instrumentation	
High B/T Facility Instrumentation	20,000
Research Equipment and Instruments (Science Program	
2 Power Supply Resistive Magnets	110,000
2 Power Supply Modified Inserts (Modulation, Gradient)	
4 Power Supply 20T, 200mm Bore Resistive Magnet	
31T Hybrid Insert	430,500
4 Power Supply Split Coil Magnet	
High Homogeniety Inserts - 1.5GHz	
45T Hybrid	21,000
1.5GHz Outsert	
900 MHz NMR Magnet	1,351,000
1 GHz NMR Magnet	
Pulsed Magnet coils	20,000
100T Pulsed Magnet Insert	213,000
Total Permanent Equipment	$2,689,349

National High Magnetic Field Laboratory
Proposed Budget 1997 - Year 7

ORGANIZATION Florida State University/Los Alamos National Laboratory				FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed / Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Jack E. Crow, Neil Sullivan, Dan Parkin				AWARD NO.	

A. SENIOR PERSONNEL:PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title:A.6, show number in brackets)	NSF FUNDED PERSON MOS CAL	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1 D. Rickels, Scientist	12			$125,424	
2 J. Sims, Mech Engineer	6			$47,736	
3 H. Boenig, Power engineer	6			$47,736	
4 J. Schillig, Elec. Engineer	6			$47,736	
5.(2)OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	24			$190,944	
6. (6) TOTAL SENIOR PERSONNEL (1-5)	54			$459,576	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (2) POST DOCTORAL ASSOCIATES (See Explaination Page for Names)	24			$113,568	
2. (6) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	72			$360,048	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. (1) SECRETARIAL-CLERICAL				$38,168	
6. ( ) OTHER - Minority Undergraduate Program					
TOTAL SALARIES AND WAGES (A+B)				$971,360	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) (inlcuded in salary base)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$971,360	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1000:) See Attached Supplemental Data					
TOTAL PERMANENT EQUIPMENT				$95,680	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				$34,320	
2. FOREIGN - World wide travel for Meetings & conferences and Equipment testing				$17,680	
Countries include but are not limited to England, Netherlands, Germany, Switzerland, France, Japan, Finland,Italy and possibly others.					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$1,097,200	
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER tolls, Mail, Reprographics					
TOTAL OTHER DIRECT COSTS				$1,097,200	
H. TOTAL DIRECT COSTS (A THROUGH G)				$2,216,240	
I. INDIRECT COSTS (SPECIFY) (See Attached Supplemental Data)					
TOTAL INDIRECT COSTS				$1,602,691	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$3,818,931	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROGECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OF (J MINUS K)					
M. COST SHARING: Proposed level $ | Agreed level if different $					

PI/PD TYPED NAME & SIGNATURE Jack E. Crow	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE Susan D. Allen, Vice Ppresident Research	DATE	Date Checked	Date of rate sheet	Initials-DCG Program

BUDGT EXPLANATION PAGE
FLORIDA STATE UNIVERSITY/LOS ALAMOS NATIONAL LABORATORY
Proposed Budget 1997 - Year 7

OTHER SENIOR STAFF	NSF FUNDED PERSON MOS CAL	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
TBD, Scientist	0				
TBD, Scientist	12			$95,472	
TBD, Scientist	12			$95,472	
Total Other Senior Staff	24			$190,944	

OVERHEAD CALCULATION

LABORATORY BURDEN - 46.5% of Total cost, less permanent equipment

FACILITIES SUPPORT - Lump Sum $700,000

Total Cost	$2,216,240
Less Perm Equip	-95,680
Overhead Base	$2,120,560
Overhead at 52%	$1,102,691
Facility support	500,000
Total overhead	$1,602,691

Permanent Equipment Detail

Magnet Instrumentation	$33,280
User Instrumentation	$62,400
Total Permanent Equipment	$95,680

X. INSTITUTIONAL AND OTHER SUPPORT

This section summarizes the additional support received by the laboratory from inception to date.

The State of Florida has continued its excellent support for the National High Magnetic Field Laboratory, and the table below summarizes the state support to date. The state has continued to provide operating support in 1996 and has provided an additional $1.5 million in support of a 12 T ICR magnet in state fiscal 1996-97 appropriations.

State and NSF Funding, $ (million)

State Fiscal Year	State Capital Funds	State Operating Funds	State Facility Operating Funds	NSF Funds
90-91	$10	$2.5		$ 6
91-92	49.3	4.4		10
92-93	12.3	7.3	$0.6	14
93-94	4	7.3	1.8	12
94-95	3	7.3	1.8	12
95-96	2	7.5	1.8	12
1996	1.5	7.4	1.8	17.5

The state operating funds provide twenty-four faculty lines and thirteen non-faculty support lines that are dedicated full-time to the NHMFL as well as regular nine-month faculty positions, thirteen at University of Florida (UF), thirteen at Florida State University (FSU), and one University Professor line. The combined funding totals about $7.4 million for the 1996-1997 fiscal year and includes a reduction of about $200,000 in non-salary accounts due to a legislative mandate shifting funds to instructional activities. This, along with previous reductions of $60,000, has resulted in a reduction in the Visitor's Program allocations to $960,000. The non-salary funds must also fund expenses such as telephones, supplies, and travel. This funding is expected to continue as part of the base funding of the State University System.

Finally, during the initial grant period, FSU returned all of the overhead earnings of the grant, estimated to total $12.7 million, to the laboratory as a contingency fund. These funds were used to supplement the construction, to purchase equipment for users' convenience such as cranes over the magnet cells, to supplement equipment funding, and to provide additional staff required for administrative activities, and equipment installation and fit up activities. The participating institutions have further agreed that beginning with the renewal grant, certain laboratory costs, specifically the fiscal management, facilities management, maintenance staff, and certain assessments on FSU will be funded directly out of the laboratory overhead. The remaining overhead funds will be divided between FSU, UF, and the NHMFL with the NHMFL receiving one-third of the residual. The net benefit to the NHMFL is estimated to be $1.3 million for the initial grant year, $1.0 million in salaries and $0.3 million in discretionary funds.