NATIONAL HIGH MAGNETIC FIELD LABORATORY

1997

Progress Report to the National Science Foundation

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Florida State University
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Los Alamos National Laboratory

1997 Progress Report
of the
National High Magnetic Field Laboratory

1. SUMMARY: Achievements, Initiatives, Concerns & Issues

Year In Review

The second year of the NSF renewal of the National High Magnetic Field Laboratory (NHMFL) has been very productive with new milestones being achieved and implemented. We knew that the past year would be one of transition from the predominant magnet development activities of the user-oriented research facilities to effective operations and the inauguration of a comprehensive in-house research program. This summary highlights the achievements, new initiatives, and issues for the year. A more thorough discussion can be found in the corresponding sections of this report.

Users Programs

The user program of the NHMFL continues to grow and new users are continuing to request magnet time. The *1996 NHMFL Annual Report* contained fifty more research reports than the previous year. This year, for the first time, the NHMFL maintained a booth at the APS March Meeting trade show. The displays attracted an impressive number of visitors and featured user abstracts along with the cutting-edge research capabilities. This was the first time in the history of the APS that an academic institution had ever participated in the trade show activities. The popularity of the booth convinced us to make this an annual event. Another conference asked the NHMFL to participate in their trade show, and we are exploring this possibility. The First North American FT-ICR Mass Spectrometry Conference was held at the NHMFL in March and attracted over 110 registrants, twice the number originally anticipated.

Working in close consultation with the Users' Committee, both the Tallahassee and Los Alamos facilities added numerous instruments and techniques in response to user requests. The Visitors Program has become an important source for new instrumentation development, since researchers are able to stay for extended periods. There is a serious concern about the resources that will be available in the future to maintain and replace critical instrumentation. These activities have been funded solely out of state resources, which are likely to be exhausted next year.

At the NHMFL Pulsed Field Facility at Los Alamos, all seven of the power supplies were tested and commissioned. The 60 T quasi-continuous magnet was assembled, installed in its dewar, and will be commissioned soon. For the second consecutive year, the NHMFL co-sponsored the Dirac Series of flux compression shots providing researchers access to fields approaching 1000 T for microseconds using Russian generators. The series of four shots reached over 850 T and produced successful data for over twenty scientists from six different countries.

The NHMFL moved ahead with the suggestions made by the 1996 NSF Review Committee to seek input from the magnetic resonance community in establishing a new model for support of user activities within the United States. The NHMFL has proposed and discussed with the NSF the establishment of a National Magnetic Resonance Collaboratorium in response to the science and technology opportunities in this area. The Collaboratorium would include distributed centers strategically located across the country and connected by internet. This distributed user facility would provide remote access for users and would pursue a science and technology agenda critical to advancing magnetic resonance in the biological and chemistry areas. A national Planning Group has been established, and this group is preparing for a national conference to be held in Washington, D.C., in January, 1998. The purpose of the conference will be to define more clearly the scientific and technological drivers for this distributed user facility.

Magnet Science & Technology Program

The Magnet Science and Technology (MS&T) program has had the largest and conceivably the most difficult transition to make of any of the other groups. Unlike the first five years of the NHMFL when MS&T was rapidly building up, designing, and fabricating a variety of magnet systems, the NSF renewal does not provide the resources to maintain comparable momentum. The MS&T will complete the remaining magnet systems from the first five-year plan: the 45 T Hybrid and the 900 MHz ultra wide bore NMR magnet. The MS&T group will continue its efforts to advance the technology and performance of both its resistive and pulse magnets. The NHMFL will commission this fall the 20 T, 200 mm bore, resistive magnet; the 25 T, 52 mm bore, high resolution resistive magnet; and the 60 T quasi-continuous pulsed magnet at the NHMFL Pulsed Field Facility at Los Alamos. In addition, the NHMFL will test a new resistive magnet design that will produce 33 T with reduced power. This new magnet will test design approaches to be used in the 45 T hybrid insert. (Note added in proof: The MS&T program achieved a very significant milestone in its pulse magnet development program during August, 1997. The group successfully tested a 24 mm bore, capacitively driven pulsed magnet to in excessive of 60 T while also achieving a significant reduction in cooling time between pulses. Similar successes were achieved with the 15 mm bore magnet, which successfully operated to 73 T without destruction. These achievements will lead to an increase of nearly 20 percent in field capacity and faster cool down times.) The MS&T initiated several design studies for the next generation of pulse magnets.

The joint 100 T design team has continued its efforts to explore conceptual design options and has pursued a focused materials testing program to define more clearly the materials parameters for this extremely challenging magnet system.

As a result of the changing direction of the NHMFL, Deputy Director Dr. Hans Schneider-Muntau was asked by the Director to assume expanded responsibilities in areas of increasing importance to the NHMFL: establishing new international programs and private sector collaborations. In his dual capacity as Deputy Director and the Director of MS&T, Dr. Schneider-Muntau showed extraordinary leadership in structuring one of the finest magnet science and technology programs in the world. In order to give Dr. Schneider-Muntau the time necessary to pursue his expanded duties, Dr. Steven Van Sciver, a leading expert in cryogenics, an outstanding engineer and professor, and an excellent program manager, was tapped as the interim Director of MS&T.

The intellectual capital that exists in the world-class MS&T group needs to be maintained, because it would be nearly impossible to replicate. Consistent with the recommendations of the NHMFL External Advisory Committee and previous NSF review committees, this can best be achieved by supplementing the in-house MS&T program with work for others, which provides additional financial support as well as intellectual challenge. It is important to balance carefully the work for others with the deliverables to the NSF, and the group is attentive to this delicate balancing process. The resistive magnet group has built several magnet systems for outside organizations, including a 30 T magnet for the Japanese National Research Institute for Metals. The Pulsed Magnet Group has fabricated a number of unique magnet systems for other programs, including 50 T coils that cool down in half the time, thus allowing for twice as many experiments.

Since the NHMFL is reaching its absolute limitations in high field magnets with existing materials, we will be placing greater emphasis and more resources on materials development and characterization. Recruiting is underway for a faculty position to lead this critical endeavor.

As part of the long term strategic planning within the laboratory, the NHMFL will initiate this fall three study projects to develop conceptual designs and assess the costs for three new opportunities for possible consideration in the future. These design studies include the development of (1) a modulation and compensation coil to further the scientific utility of the 60 T quasi-continuous magnet; (2) a single-turn destructive pulsed magnet system that would provide user access to 200+ T for microseconds in a 10 mm bore and save the sample; and (3) a 1.5 GHz (35 T) series connected hybrid that will provide greater stability and uniformity for magnetic resonance studies and at the same time allow more cost effective operation than possible with strictly powered magnet systems. The results of these study projects will be discussed with appropriate committees and based on their input, will become part of the future proposed projects within the NHMFL.

NHMFL In-House Research Program

The In-House Research Program has been in existence now for a little over one year and has operated smoothly for such an infant and major program. Program Director Dr. John Graybeal and Chief Scientist Dr. J. Robert Schrieffer deserve the credit for spearheading and successfully launching the program. The first round of proposals was due in August, 1996, and of the 67 proposals received, 38 proposals were forwarded to external review, and the remaining 29 were returned to their respective PIs with a copy of the internal referee reports. In January, 1997, fifteen proposals were funded, and their first progress reports are due in October.

The second proposal solicitation was released in January, 1997, and a total of 28 proposals were submitted. The number of internal reviewer reports received totaled 51 or an average of 1.8 reports per proposal. Fourteen proposals were submitted to external review—six in magnetic resonance (non-physics), six in condensed matter physics, and two in materials science & engineering. The announcement of the final funding decisions is expected in August.

The third round of proposal solicitations is planned for November, 1997, and a new director of the program will take charge in January, 1998, for the next two years. It was decided in the past by the NHMFL management that having the director of the In-House Research

Program rotate among the participating institutions would help enhance inter-institutional cooperation.

Outreach Activities: Education and Collaborations

The K-12 educational outreach program is just over a year young and its activities and accomplishments are impressive for a shoestring budget and two to three people participating in the program. Just since January, 1997, the program has challenged over 8,000 students to explore adventures in science and magnetism in their classrooms; another 2,000 students have toured the laboratory. Some of the participants have come from considerable distances, for example, the laboratory hosted a group of high school students from the Newport News, Virginia, area, who were affiliated with a program at Hampton University (a historically black university). With the second year of support from the Florida Department of Education, the program just released an exciting curriculum package on magnetism called *MagLab: Alpha-EdVentures in Science.* The product includes reusable, hands-on demonstrations; a teacher's manual; and a complementary CD-ROM for middle grade students to explore magnetism. Almost 200 Florida middle schools will receive this package this fall, and the NHMFL will conduct a workshop for teachers. Discussions are underway to have the curriculum package marketed nationwide.

For the fifth consecutive year, the laboratory sponsored a summer research internship program for women and minority undergraduate students. The number of applicants to this program increases annually because of recruiting assistance from the Florida-Georgia Alliance for Minority Participation (AMP). The NHMFL's partnerships with regional vocational schools have expanded educational opportunities for vocational-technology students at the laboratory.

In March of this year it was announced that EURUS Technologies would be the first company to locate in Tallahassee to be near the NHMFL. EURUS is consolidating operations in a new facility at Innovation Park across the street from the NHMFL. EURUS produces high temperature superconducting current leads; is pursuing other opportunities in the application of HTS technology; and has entered into a three-year, co-development, and testing program with the NHMFL. We look forward to a longstanding and interactive relationship with this growing high-tech company, and it represents the type of industry that can and should be located in a small radius of the NHMFL.

Budget

Budgeting and program expenditures are closely following the budget plan established at the time of the grant renewal. Minor adjustments are made annually reflecting specific situations. Expenditures for 1996 were below the authorized level as anticipated. Delivery of major components, the pulsed magnet power supplies, the 900 MHz development agreement, the 900 MHz conductor, and the Hybrid NbTi coils and resistive insert in 1997 and 1998 will use up the unexpended funds. The 1998 proposed budget does not contemplate any significant changes or new initiatives.

2. USERS PROGRAMS

Introduction

The various user programs of the NHMFL continued to expand during 1996-97. New magnets and instrumentation were added and new users appeared. Listed below are a few highlights of the new support offered users during 1996-97, followed by some program-by-program details.

- *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. Two highlights of this activity were the development on a Magneto Optic Kerr Effect probe and the delivery of the portable dilution refrigerator for use in resistive magnets.
- *New instrumentation in Los Alamos* included a femto/pico second rapid scanning autocorrelator for time resolved spectroscopy; a He-3 system for the 60 T magnets; a microcalorimetry cell for heat capacity measurements on milligram samples; and a special high temperature probe for Hall and magnetoresistance measurements from 4 K to 600 K.
- *Improved technique lowered the noise floor for transport measurements in capacitatively driven magnets an order of magnitude*, making such experiments at NHMFL among the quietest in the world.
- *For the second year the NHMFL co-sponsored the Dirac Series* of flux compression shots using "generators" from VNIIEF in Russia. Four shots that reached 850 T were successfully carried out, along with smaller "strip shots" in the range of 120 T. NHMFL, through Los Alamos, remains the only magnet lab in the world offering general user access to fields up to 1000 T.
- *The 60 T quasi-continuous magnet was assembled, installed in its dewar, and is being commissioned.* It produced its "first field" in tests using a capacitor bank.
- *The Ultra-High B/T Facility in Gainesville received and tested a reduced field version of its 18/20 T sample magnet*. The first demagnetization reached temperatures below 900 μK with the $PrNi_5$ at a residual field of 0.6 T. Temperatures below 500 μK are expected to be attained for demagnetizations below 0.1 T.
- *A Fabry-Perot cavity was added to the electron magnetic resonance facility,* improving the room temperature sensitivity by a factor of 100 and making possible new research in biology and physical chemistry.
- *The NHMFL was designated a beta test site for a high-temperature superconducting NMR probe developed jointly by Varian and Conductus*. The main advantage of this probe is its extremely high sensitivity. A signal-to-noise ratio of 1860:1 was demonstrated on this probe at the NHMFL, compared to 450:1 with a conventional probe.
- *The Magnex Scientific superconducting NMR magnet was put into operation at 19.6 T*. A set of recently delivered passive shims are designed to improve the homogeneity from 1 ppm to 0.1 ppm over a 1 cm diameter spherical volume.
- *A microelectrospray source was constructed and interfaced with the 9.4 T FT-ICR mass spectrometer*. This system separated and detected a three-component peptide mixture in artificial cerebrospinal fluid with each peptide present at only 500 attomoles/microliter!
- *The First North American FT-ICR Mass Spectrometry Conference was convened at the NHMFL in March, 1997*. The meeting drew 110 registrants and potential users from leading FT-ICR research groups from the United States, Canada, United Kingdom, Germany, France, Netherlands, and Japan.

General Purpose DC Field Facilities

General Purpose DC Magnets Available in Tallahassee in July, 1997

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;
15, 45	7/95	1	Specific heat; Transport; Temperatures from 20 mK to 300 K; Pressure from ambient to 13 GPa
14,150	7/95	1	Split coil magnet with 30 X 70 radial access. Stress testing of materials, especially superconducting cable
Resistive			
20, 50	3/94	1	Same as superconducting magnets, except that the temperature range
30,32	3/95	2	is 0.5 K to 900 K. and the possible experiments include broad line
33,32	2/96	1	NMR
24.5, 32[1]	7/95	1	

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

Instruments for Users of the Continuous Field General Purpose Magnets

All of the magnets and major instrumentation used during the past year were in place before August, 1996. Therefore effort went into improving the available instruments and experimental techniques based on our increasing experience meeting users' needs. Those improvements are:

- *A micrometer drive was added to the string rotator* that was developed for the top loading dilution refrigerator. It provides 0.2 degree resolution and repeatability. The rotator can be moved through 360 degrees if the sample leads allow. On change of direction the backlash is 0.6 degrees. The temperature rise generated for a 90 degree rotation is only 80 mK, so recovery of base temperature requires only a few minutes.
- *A linear motion feedthrough system was developed for the top loading dilution refrigerator.* This improvement allows users to move their sample relative to the field center without having to remove the probe from the fridge. This technique is especially useful to experimenters using the cantilever force magnetometer, as it allows them to separate force and torque terms without disturbing other experimental conditions.
- *Cobalt Nuclear Orientation thermometry has been implemented* as a primary low temperature thermometry standard against which to calibrate resistance thermometers for use by experimenters.
- *An RF filter was designed and built* to reduce noise levels and sample heating for experimenters using the top loading dilution refrigerator probes.
- *A computer controlled gas handling system was installed for the top loading dilution refrigerator.* This and a remote operation program called "Timbuktu" enable the staff to perform remote operation/trouble shooting after hours or on weekends without having to drive to the lab. Response time is shorter and wear and tear on the staff is reduced.
- *A new magnet power supply and a new low loss, high capacity dewar were purchased and installed on the 20 T magnet with the dilution refrigerator.* The power supply allows uninterrupted sweeps through zero field and improves the resolution of the magnet set point from 0.5 mT to 0.02 mT steps. The dewar allows users to sweep at the maximum sweep rate for greater than 24 hours before transferring liquid helium.
- *The top loading dilution refrigerator that was purchased for the resistive magnets was delivered.* This facility provides a significant step forward in providing user-friendly low temperatures in some of the world's highest DC fields.
- *Two furnaces allow experiments in the resistive magnets up to 600 C.*
- *A power amplifier and water cooled coils* wound on a dewar tail allow the field to be modulated at up to .05 T (zero to peak) at frequencies up to 30 Hz.

Magneto Optics

- *A new system for Kerr Magneto Optic Effect studies of materials was developed.* It has a temperature range of 2 to 300 K, accuracy of 0.5 millidegree, and background less than 1 millidegree/tesla for both Kerr rotation and Kerr ellipticity measurements.
- *A sample holder for far-infrared reflectance measurements in the 32 mm bore magnets was built.* Its temperature range is 1.8 K to approximately 60 K.
- *Another sample holder allows as many as ten 3 mm diameter samples to be studied* without having to pull the probe to change samples. Two optical fibers cover wavelengths from the ultraviolet to the near infrared. The probe can be used for reflectance and luminescence measurements.
- *Improvements to the suite of software* used for magneto optics include improved file transfer from the data acquisition computer(s) to the user's "home" computer; and a new program that controls the spectrometer, CCD camera, and magnet, and takes spectra at discrete fields very rapidly. The resulting batch of spectra can then be called up together and divided by a reference spectrum, differentiated, integrated, etc.

Magnetization

- *A new, large bore head for the Lake Shore vibrating sample magnetometer was purchased and put into operation.* It allows measurements of magnetic moment of large samples and samples inside pressure clamps and diamond anvil cells.
- *Cantilever force magnetometry* is still the method of choice for temperatures below 1 K, for small samples with small moments, and special experiments.
- *A probe with a platform that can be tilted a few degrees allows better alignment of the cantilever in the field.* This probe can also be used for other kinds of experiments where precise alignment relative to the field is needed.

NMR Spectrometers for High Field, Low to Medium Resolution Experiments

- *Most of the basic instrumentation required for condensed matter NMR research had been completed and operating by August 1, 1996.* Most of the development in the past year has been in improving "user friendliness" and reliability.
- *The 15/16 T superconducting magnet was delivered in March* and after assembly and some on-site modifications it is now being used for in-house research, probe development, and will be available as a staging magnet for the 24.5 NMR powered magnet. A variable temperature insert and probes for a range of experiments were designed, fabricated, and assembled; and data are now being taken.
- *Dr. Arneil Reyes (currently at Motorola, previously LANL and Northwestern University) will arrive September 15* to fill a new permanent position in condensed matter NMR. He will develop his own research program and is expected to push facility development and interact with users. Dr. Reyes will bring the general level of activity back up to what it was before the departure of Alfred Kleinhammes in November, 1996.

DC Facility Operation and User Statistics

Three failures of magnet power supply input transformers limited us to running one magnet at a time or, sometimes, one magnet at full power and a second one at half power. We dealt with the problems in the short term by increasing our hours of operation, thereby providing to the users 80 percent of the time that was normally available. This was possible because of the dedication of the Magnet Operations staff, who agreed to work nights the first time it happened and weekends the second time. The long term solution to the problem has been to work with the manufacturer to analyze the cause of failure, to add surge arrestors to transformer primaries to limit transient voltages, and to reduce the transients associated with turning on the power supplies by modifying the control system to allow us to keep the transformers energized at all times.

User activity is summarized in the following table for the one-year period August 1, 1996, through July 31, 1997. A magnet day equals seven hours in a resistive magnet or up to twenty-four hours in a superconducting magnet.

DC Field Facility Activity

Number of projects	115		
Number of principal investigators	89		
Number of users	295		
Number of students	83		
Number of postdoctorals	15		
Number of magnet-days	Resistive	Superconductor	
NHMFL, UF, FSU, FAMU, LANL	278	256	37%
U. S. University	261	201	33%
U. S. Govt. Lab.	0	9	0.5%
Industry	4	5	0.5%
Overseas	113	37	10%
Maintenance	60	63	9%
Idle	6	145	10%
Total: 1438	**722**	**716**	**100%**

Pulsed Field Facility
The NHMFL at Los Alamos National Laboratory

General Purpose Magnets Available in Los Alamos in July, 1997

Field (T), Bore (mm)	First Use	Pulse, rise/duration (ms)	Supported Research
Pulsed, General Purpose			
50-55, 24	12/92	6/30	Magneto-optics, ultra-violet through far infrared; Magnetization; Mechanical Properties; 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		As above, plus Thermal expansion; Specific heat
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 within the general guidelines established by the NHMFL Executive Committee 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 and Instrumentation Update

- *20 T superconducting magnet.* Two new measurement capabilities were developed in-house and added to the suite of user instruments: (1) a microcalorimetry cell for heat capacity measurements on milligram samples from 1.5 K to 30 K and (2) a special high temperature probe for Hall and magnetoresistance measurements from 4 K to 600 K.
- *Capacitively driven magnets.* Improved technique lowered the noise floor for transport measurements an order of magnitude, making such experiments at the NHMFL among the quietest in the world. Magnetization coils with #56 wire on 0.5 mm diameter forms can now be wound at the pulsed field facility. These yield magnetization and de Haas-van Alphen measurements with sensitivities among the highest in the world. A He-3 system was built for the 60 T magnets and is the only one in the world currently operating at such fields. The magnet testing station ("blast box") was modified to allow experiments concurrent with destructive magnet testing at the highest fields. This increases to five the number of pulsed magnet stations where experiments can be conducted. Experiments with the dilution refrigerator (attached to a 50 T magnet) were made more user friendly by designing a standard sample holder that can be mailed to users for prior sample mounting.
- *Flux compression.* For the second year, the NHMFL co-sponsored the Dirac Series of flux compression shots using "generators" from VNIIEF in Russia. This latest series occurred in June, 1997, and brought together over twenty scientists from six countries, including the directors of pulsed magnet laboratories in Germany, Belgium, Australia, and Japan. Four shots that reached 850 T were successfully carried out, along with smaller "strip shots" in the range of 120 T. The NHMFL, through Los Alamos, remains the only magnet lab in the world offering general user access to fields up to 1000 T. Critical to these shots is the disposable plastic He-4 cryostat designed at the pulsed field facility that can hold a temperature of 1.6 K for more than an hour.

- *Optics.* A femto/pico second rapid scanning autocorrelator was acquired along with electronics for time resolved spectroscopy. A frequency doubler, driven by a Ti-sapphire laser, was built that has an output of 350 to 500 nm. An FIR laser was installed and is undergoing tests.
- *60 T quasi-continuous magnet.* The magnet was assembled, installed in its dewar, and is being commissioned. It produced its "first field" in tests using a capacitor bank. The designated power supply is a 1.4 GVA motor-generator, whose output is transformed and rectified by five 80 MVA power converters, whose commissioning was completed in June, 1997. This magnet will produce a variety of pulse shapes, including a 100 ms flat-top at maximum field. A variable temperature cryostat has been delivered and tested, and a dilution refrigerator has been ordered.

Staff

In July, 1997, the user support staff at Los Alamos comprised the director of Pulsed Field Facility; operations manager; low temperature scientist; postdoctoral - transport; postdoctoral - magnetization; postdoctorals - optics (2); mechanical technicians (3); electrical technician; generator technician; cryogenic technician; and secretary.

Pulsed Field Facility User Statistics

The user activity is summarized in the following table for the one-year period August 1, 1996, through July 31, 1997.

Pulsed Field Facility Activity

Number of experiments	121		
Number of principal investigators	62		
Total number of magnet-days used	560		(20 T: 310)
Number of magnet-days used for testing	14		
Number of principal investigator-days	720		(20 T: 450)
University PI-days		393	55%
NHMFL PI-days		160	22%
Govt. Lab. PI-days		167	23%
Total		**720**	**100%**

Ultra-High B/T Facility
The NHMFL Annex at the University of Florida

A specialized facility for studies of materials at ultra-high values of the ratio of magnetic field to temperature (B/T) is being developed as a user facility at the University of Florida. Users will be able to explore new phenomena that require both high fields and very low temperatures simultaneously.

The magnet system includes a demagnetization magnet (8 T) for a $PrNi_5$ nuclear refrigerator, a high field magnet for the experiments (18/20 T), and a corrective coil to reduce the field variations in the experimental region during demagnetization. The magnet system was developed as a special project with Cryomagnetics, Inc., and is an example of the work of NHMFL with industry to enhance its capabilities.

Accomplishments in 1997

- *The high field magnet was tested*, including an NMR field mapping and a test of the field persistence.
- *The 8 T demagnetization system was assembled and tested.*
- *The $PrNi_5$ nuclear demagnetization refrigerator was tested*, including measurements of the heat leaks.

The high field system is currently limited to 15.3 T as one of the Nb_3Sn coils failed when tested. A full field capability of 18/20 T (for 4.2/1.5 K) is expected when this coil is rebuilt. The first demagnetization reached the nuclear magnetic ordering temperature of solid ^{3}He (943 μK) with the $PrNi_5$ at a residual field of 0.6 T. The cooling capacity is high, and estimated better than 5 nW at 500 μK. Temperatures below 500 μK are expected to be attained for demagnetizations below 0.1 T.

The facility features include a design B/T of 4 x 10^4 T/K for 20 T at 500 μK. A high cooling capacity (> 10 nW at 1 mK), and both top and bottom loading capabilities. The system is located in a "tempest" quality shielded room to provide an ultra-quiet environment for high sensitivity measurements. The broadband UHF NMR spectrometer developed for field mapping will be developed further for high sensitivity pulsed and continuous wave NMR measurements.

Field Characteristics

- *Main Magnet*

Maximum field	15.3 T (20 T upon replacement of damaged coil)
Homogeneity	1.8 10^{-5} over 1 cm DSV
Persistent mode decay	1.6 10^{-5} per day

- *Demagnetization Magnet*

Maximum field	8 T
Central field profile	7.5 T for +/- 10 cm
Persistent mode decay	1.5 10^{-4} per day

Users and Experiments

The Ultra-High B/T facility was officially opened for users at the end of the reporting period. Some of the experiments planned with users in the near future are as follows:

Researchers with time scheduled:

Quantum Hall Systems
 H. Störmer, AT&T
Polarized Liquid ^{3}He-^{4}He Mixtures
 D. Candela, U. Mass.
Bc2 Critical Field, Solid ^{3}He
 D. Adams, U. Florida

Research time requests:

A1-A2 Phase Splitting in ^{3}He
 D. Lee, Cornell
2D Electrons (GaAs-AlGaAs)
 R. Du, U. Utah
Leggett-Rice Effect in Solid ^{3}He
 B. Cowan, U. London
Superconductor-Insulator Transitions
 A. Hebard, U. Florida
Melting Pressure ^{3}He in High B
 G. Frosatti, U. Leiden
2D Solid ^{3}He Films
 N. Sullivan, U. Florida
Magnetoresistance of Polymers
 G. Ihas, U. of Florida

Applications for use of the Ultra-High B/T facility follow the same procedures as for all NHMFL facilities. In view of the long turn-around time and special design considerations needed for ultra-low temperature studies, potential users should contact the local user group to plan their experiments.

Center for Interdisciplinary Magnetic Resonance (CIMAR)

The magnetic resonance program (including staff, instrumentation, and research activity) 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 spin resonance), ion cyclotron resonance (ICR), and geochemistry are housed in Tallahassee. The primary site for magnetic resonance imaging and *in vivo* spectroscopy (MRI/S) is at the University of Florida. Condensed matter physics, high field NMR is discussed earlier in this section of the Progress Report, as part of the General Purpose DC Field Facilities.

NMR Spectroscopy

New Hardware

During this first year of Keck Foundation support for the development of 25 T magnetic resonance spectroscopy, a 52 mm bore resistive magnet and its housing were designed for 1 ppm stability and homogeneity. The housing, Bitter plates, and other magnet-related components have been ordered. ICR instrumentation is ready for the magnet and both EMR and double resonance NMR instrumentation are being developed. In the meantime 1 ppm stability of the magnetic field was demonstrated in a prototype resistive magnet operating at 24 T with a 32 mm bore.

The Magnex Scientific superconducting NMR magnet with a 31 mm bore has stabilized with a drift of 0.02 ppm/hr at 19.6 T. While it was persistent at 20 T and 2.2 K, the drift rate was two orders of magnitude greater. Therefore, it was put into operation at 19.6 T corresponding to 830 MHz for H-1. A single resonance TecMag spectrometer is currently available on this magnet for NMR spectroscopy. A set of passive shims that are designed to improve the homogeneity from 1 ppm to 0.1 ppm over a 1 cm diameter spherical volume (DSV) was recently delivered from Magnex.

During the past year, the high resolution NMR program added new equipment to the 400, 500, and 720 MHz instruments. The NHMFL is serving as a beta test site for a high-temperature superconducting probe that was developed jointly between Varian and Conductus. The main advantage of this probe is its extremely high sensitivity. A signal-to-noise ratio of 1860:1 has been demonstrated on this probe at the NHMFL, compared to 450:1 on a conventional probe on the 400. The NHMFL will test the spectroscopic properties and chemical applications of this probe, with the aim of developing, with industrial colleagues, the next generation of superconducting probes with multinuclear capability at a variety of magnetic field strengths.

Additional probes were added to the 720 MHz instrument, as well. These include a 5 mm indirect detection probe (Nalorac), and a 10 mm probe for observing low gamma nuclei. The large diameter and high magnetic field will permit investigation of nuclei that are inherently insensitive.

The NHMFL was one of the first external sites to receive delivery of a triple-resonance high resolution probe with three-axis pulsed-field gradient accessory from Varian. The additional gradients will improve the performance of numerous experiments, and indicates the close working relationship developing between NHMFL and industrial NMR manufacturers.

Other upgrades of existing spectrometers include the acquisition and installation of two 4 GByte memories on the wide bore 600 MHz spectrometer. The extended memories are essential for storing the huge data (usually in microimaging experiments) during experiments. In addition, an extended VT CPMAS H-X probe for the 300 spectrometer was ordered through Dr. Dalal's NHMFL In-House Research Program grant. The probe will allow us to investigate dynamics of phase transitions in the temperature range of -150 C to 250 C.

Finally, twenty faculty of the CIMAR program participated in writing a proposal to NSF for two NMR consoles: a triple resonance spectrometer for the 19.6 T magnet designed for solid state NMR and high resolution micro samples; and a five channel spectrometer for a 900 MHz 110 mm bore superconducting high resolution magnet. The latter spectrometer is for the magnet being designed and built by the NHMFL's Magnet Science and Technology group. Because of its high resolution specifications and its very wide bore, the spectrometer is designed for microimaging, solution and solid state NMR spectroscopy.

Instrument Maintenance

The 720 MHz was out of service for approximately three months during this period due to the need to replace a needle valve in the He dewar. Oxford redesigned and replaced the existing valve after de-energizing the magnet. The magnet was successfully re-energized, and brought back to its previous performance specifications.

NMR User Activity

The high resolution NMR program has had six external groups spend a considerable amount of time working on a wide range of activities from stray field imaging to double rotation spinning for odd halves quadrupole nuclei, and from liquid crystal phase diagram studies and oriented bilayer preparations to macromolecular solution NMR spectroscopy and solid state NMR of soil samples.

NMR Imaging and *In Vivo* Spectroscopy

The 3 T whole-body magnet system at the University of Florida Brain Institute/VA Hospital is now in service and is being used in support of several NIH-funded projects. The advantages of this system over most other whole body systems include spatial resolution of 250 microns/pixel and rapid image acquisition rates (10 per second, compared to 1-3 per second obtainable in other systems).

NMR Imaging/Spectroscopy User Activity

The wide bore 600 MHz Bruker/Magnex spectrometer at the NHMFL was formally accepted from the vendor in May, 1996, making the present reporting period the first full service year for this system. The capabilities of this instrument include multinuclear spectroscopy of liquids and NMR microimaging and spectroscopy of solids. It supported the research of sixteen different user groups during the reporting period, representing investigators from FSU, UF, FSU/FAMU, elsewhere in the United States (not directly affiliated with the NHMFL), and two international groups. Operators include graduate and undergraduate students, as well as postdoctoral fellows. Uses included: high-resolution NMR microscopy of biological specimens and samples from materials science, *in vivo* spectroscopy, diffusion and transport measurements by pulsed field gradient techniques, and MAS and DOR spectroscopy of solids.

Electron Magnetic Resonance

The EMR program experienced increasing user and visitor activity on a collaborative basis. A "user" is at the NHMFL for a few days to a week; a "visitor" is at the lab for a period of one month to one year.

New Developments

There were recent developments in four different areas during the last year:

- *Development of a Fabry-Perot cavity.* One of the milestones of the last year was the completion of a Fabry-Perot cavity. The system used until now was based on the single pass technique: the advantage is a very broad band capability; the main shortcoming of this technique is a sensitivity limited to 10^{12} spin/gauss at room temperature. Such a sensitivity is well adapted to most of the research projects in solid state physics, but not for small samples of interest in most biological systems. Consequently, we developed a Fabry-Perot cavity, using a mesh coupling device, and working from room temperature down to 4.2 K. With this cavity a sensitivity better than 10^{10} spin/gauss at room temperature was achieved for a frequency of 330 GHz (10^{8} spin/gauss at 4.2 K for the same frequency). Such a sensitivity opens new avenues in the fields of physical chemistry and biology.
- *Development of a gyrotron.* Continuous wave (CW) submm sources (above 300 GHz) are limited in power; the situation is even worse for pulse spectroscopy; and there is no convenient device above 140 GHz. Consequently, the development of a CW and pulse gyrotron is of considerable interest. In a first step our effort is directed toward the feasibility of a gyrotron as a source for both CW and short pulse radiations in the 150 to 600 GHz range with pulses in the nanosecond range. This project is supported by NHMFL In-House Research Program funding and involves three universities and two private companies. Our final goal is to build a spectrometer based on such a gyrotron.
- *Very high field spectrometer: the Keck magnet.* A 25 T, 52 mm bore, and high homogeneity (1 ppm over 10 mm DSV) resistive magnet is under construction with support from the Keck Foundation. This magnet will enable us to work up to 700 GHz. The EMR spectrometer is under construction.
- *Transient EMR.* With support from NSF and matching funds from three different universities (FSU, University of Chicago, and University of North Carolina), we are developing a transient EMR spectrometer. The instrument will operate in the nanosecond and picosecond range with a field of 14

T and a 88 mm room temperature bore. Ten investigators from four different universities are involved in this project, which will considerably enhance the NHMFL facility.

EMR User Activity

The research efforts of the last year were all performed on the only spectrometer currently available. This instrument has the highest high homogeneity magnet built for EMR (15/17 T with an inhomogeneity of 1 ppm for a 10 mm DSV). Thirty researchers from fifteen different groups used the machine during the period. Among these fifteen groups, five were from Florida, five were from others U.S. universities, and five were from outside the United States. The research projects were in the fields of solid state physics (magnetic semiconductors, antiferromagnets), physical chemistry (spin labels, spin clusters, large zero field systems), and biophysics (photosynthesis, spin labels). It should be noted that, within the users groups, four graduate students used the NHMFL machine as their main experimental tool. One visitor, Dr. A.L. Maniero from the University of Padova was with the EMR program for four months.

The number of U.S. users from outside Florida is increasing with respect to both the number of users from Florida and the number of overseas users. During the coming year we expect to have at least four visitors, three of whom are from non-Florida U.S. universities.

Fourier Transform Ion Cyclotron Resonance Mass Spectroscopy

The First North American FT-ICR Mass Spectrometry Conference was convened at the NHMFL in Tallahassee, Florida, on March 13-15, 1997. The meeting drew 110 registrants from leading FT-ICR research groups from the United States, Canada, United Kingdom, Germany, France, Netherlands, and Japan, and consisted of an intensive two days of twenty-four oral and fifty-two poster presentations. The meeting was sponsored by the NSF National High-Field FT-ICR MS Facility, with additional support from Finnigan and Bruker. The technical program featured four symposia: Instrumentation; Polymers/Electrospray; Laser Applications (MALDI, Photodissociation, Ion Spectroscopy); and Ion Chemistry and Ion-Molecule Reactions, plus several invited posters on industrial applications. Based on the strong attendance at this conference, the organizers were asked to repeat the meeting in Tallahassee in March, 1999.

Our 9.4 T FT-ICR mass spectrometer with home-built electrospray source and dual octupole ion guides is currently the world's highest performance FT-ICR mass spectrometer and is available to external users. It offers improvements in dynamic range, scanning speed, and mass resolving power at high mass compared to the best other instrument anywhere. Mass resolving power of 150,000 for a 112,000 dalton molecular weight protein was achieved, and hundreds of combinatorial peptides can be detected simultaneously in a mixture. Mass accuracy of 0.07 ppm was achieved for an oligosaccharide (2,778 Da) from an industrial collaborator. An eight-stage ("tandem") mass spectrometry experiment was achieved, in sequencing a decapeptide from a group at the University of North Carolina.

A microelectrospray source was constructed and interfaced with the 9.4 T FT-ICR mass spectrometer for high performance liquid chromatography (HPLC) mass analysis. The interface allows trace components in biological fluids to be collected, concentrated, purified, and separated prior to detection in the mass spectrometer. This system separated and detected a three-component peptide mixture in artificial cerebrospinal fluid with each peptide present at only 500 attomoles/microliter! This result represents an improvement in sensitivity of ~2,000,000-fold over the best previously published HPLC/FT-ICR report.

New techniques from the NHMFL FT-ICR Program generated features in *Analytical Chemistry* 1997, 69, p. 157A and p. 278A; *Chemistry & Industry 1997*, March issue, p. 19; and triggered a ten-page cover article on the NHMFL and the NSF National FT-ICR Mass Spectrometry User Facility in *Chemical & Engineering News 1997*, 75, pp. 30-40.

FT-ICR User Activity

Seventy-seven researchers used the facility during the reporting period. Of these, thirty-two were local; thirty-eight were from other U.S. universities; two were from U.S. government laboratories; two were from U.S. industry; and three were from overseas. The total of forty-five external users represents a 400 percent increase over the previous reporting period. Instrument use on the two systems available to outside users breaks down as follows: The 6 T FT-ICR instrument is available 10 percent internal and 90 percent external; the 9.4 T FT-ICR instrument is available 50 percent internal and 50 percent external.

Geochemistry

During the last year the facility added one piece of major equipment: a Finnigan ELEMENT inductive coupled plasma mass spectrometer (ICP-MS). This instrument was installed and made operational.

A new research initiative that applies magnet-based technologies to the environmental sciences was started. This initiative integrates several parts of CIMAR (Geochemistry, FT-ICR, and EPR group), as well as faculty from FSU and FAMU. Currently we are focusing on three techniques that hold promise for environmental and ecological research. FT-ICR mass spectrometry (FT-ICR-MS) is used to identify the compounds that make up naturally occurring organic matter. ICP-MS is used to determine heavy metal and elemental concentrations. EPR spectroscopy is used to characterize the binding environment and valence state of transition metals. The combination of these three techniques potentially allows understanding of an ecosystem at a molecular level. One of the first applications for this new research initiative is the investigation of the sources and cycling of phosphorous in wetlands of the Florida Everglades, through a grant that Dr. Vincent Salters received from the South Florida Water Management District. Studies were initiated to investigate which heavy element isotopes would be useful in deciphering environmentally significant processes. Major advances have been made with a study of Pb-isotopes in rainwater in south Florida, where it has been shown that a large component of the Pb (and by inference other heavy metals) is derived from easterly air masses that find their origin in Europe.

Significant progress was made with our research with respect to mid-ocean ridge basalt (MORB) genesis. Progress was made on several aspects of MORB genesis:

- U-Th disequilibria in MORB has shown global variations with ridge depths, which can be interpreted as variations in the degree and depth of melting.
- New trace element partition experiments relax the requirements for extreme small porosities and fast magma transport during MORB melting and resolve the apparent contradiction in the estimates of the amount of melting in the presence of garnet provided by the Hf-Nd isotope systematics and the U-Th disequilibria.

Furthermore a study on the U-Th disequilibria in Icelandic basalts (as analog to MORBs) was initiated. The better field and age control on these samples will allow for a better evaluation of the effects of melting on U-Th-systematics in basalts.

Geochemistry User Activity

During the year the Geochemistry group supported eight external users/visitors of the facility, five of whom were from outside the State of Florida.

3. Magnet Science and Technology Program

Introduction

The Magnet Science and Technology (MS&T) group contributes to the NHMFL in three activity areas: major magnet-related projects; development programs; and services to others.

The first and largest of these activities is the major magnet development projects—both in-house magnet systems and work for others. MS&T has developed this dual role in order to ensure the long term future of the group. Occasionally, however, the external projects have the potential to negatively affect the schedule of in-house magnet systems. Setting priorities and completing projects in a timely fashion requires continuous attention by MS&T staff and the NHMFL Executive Committee.

To support development of future magnets and raise the overall competence of the MS&T group, we also maintain healthy programs in several related technology areas. Much of this work is co-sponsored by agencies external to the National Science Foundation or the State of Florida; and frequently, these programs involve collaboration with scientists outside the NHMFL.

As the MS&T group matures, it is playing an increasing role in the supply of services to the NHMFL user community. This trend is seen as a positive step in the direction of providing the best facilities for high field magnet research. MS&T user services appear in different forms including: fabrication of magnets and other kinds of hardware for users; providing specialized measurement techniques for technology development projects; and carrying out analysis and review for user proposed projects.

Over the past year, MS&T achieved a number of major milestones in all of these activity areas. Several highlights are presented here, with details on these and other MS&T projects provided in the following pages.

- *The 200 mm bore, 20 T resistive magnet is nearing completion.* The design for the insert cryostat is complete and the entire system should be operational by mid-December.
- *The Keck 25 T, 52 mm bore high homogeneity magnet is nearing completion and should be operational by November.* This project is funded by the NHMFL and a grant from the Keck Foundation.
- *The 45 T Hybrid magnet project also made significant progress.* All superconducting coils have been wound and should be received at the NHMFL by October. Final assembly will then begin with an anticipated completion date for the magnet of spring 1998.
- *A major milestone in the 900 MHz project was completed with the issuing of the final design specification for the magnet.* The Nb_3Sn wire has been ordered and now individual components are beginning fabrication.
- *The pulsed magnet group is in the process of upgrading the capacitively driven magnets for the LANL user facility.* The 24 mm bore magnets will go from 50 to 60 T, the 15 mm bore from 60 to 70 T. Testing of the upgraded magnets is scheduled for late August. The next generation of capacitive pulsed magnets achieved all their expected design specifications and will give the NHMFL Pulsed Facility the finest magnets available in the world.
- *The 60 T quasi-continuous magnet at LANL is undergoing testing, with full field testing by late fall 1997.* The five 80 MVA power converters were commissioned in June, 1997.
- *The HTS Magnets and Materials group recently completed and tested a 1.2 T, 50 mm (outer diameter) high Tc superconducting coil in a background field of 17 T.* This coil used NHMFL developed Sol-gel insulation. The conductor was provided by Oxford Superconductor Technologies. The group collaborates extensively with industry in the development of this technology. A few examples include: hot roll processing of BSCCO wire for the American Superconductor Corporation and bend strain tolerance and thermal cycling measurements on HTS conductors for Southwire.
- *The Materials Development and Characterization group performed a variety of tests on a collaborative basis.* A few examples carried out during the past year include: tensile testing of aluminum alloy for the FSU Nuclear Physics group; resistivity ratio measurements on braided cable for Babcock and Wilcox; and strength characterization work of high strength/high conductivity wires for Brush-Wellman.
- *The Analysis group performed a number of scoping studies for different magnet systems.* A few examples include: design of a special resistive magnet for the University of Arizona and analysis of an NMR magnet design for American Magnetics.

Project Title: **45 T Hybrid Magnet Project**
Report Date: **July 31, 1997**

Objective:

The objective of this project is to produce a versatile, reliable, user-friendly magnet system providing at least 45 T in a 32 mm bore. The 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, and
- technology that significantly advances the state of the art for large, high-field superconducting magnets.

The superconducting outsert will have a minimum 10-year life and be capable of accepting upgraded resistive inserts with potential for extending the combined field to 50 T.

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.

(1) Superconducting Outsert Magnet

- Coils A and B were successfully heat treated on February 17, 1997, and November 9, 1996, respectively, using in-house facilities especially assembled for this task. Projections from tests of full-scale witness samples heat treated along with the coils suggest that the superconductor performance will meet or exceed the requirements of the Outsert Magnet.
- The cleaning and soldering processes for terminals and joints on both Coils A and B were successfully completed on March 4, 1997, according to in-house developed procedures and specifications.
- The Vacuum/Pressure Impregnation (VPI) processes for Coils A and B were successfully completed on April 24, 1997, and May 15, 1997, using in-house-developed processes and facilities supplemented by special equipment (impregnation/curing tank) on loan from Intermagnetics General Corporation, Latham, NY (IGC-Latham).
- Procedures and specifications for the insulation and impregnation of Coil C double pancakes were fully developed at Everson Electric Company, Bethlehem, PA, in close collaboration with the NHMFL. Approximately two-thirds of the total 33 double pancakes required (four extras for spares) have been successfully insulated and impregnated. Development of the terminating, stacking, and joining processes for Coil C at the NHMFL is nearing completion.
- Final preparations of Coils A and B (e.g. cleanup after coil-form removal and room-temperature electrical testing) are presently being carried out at IGC - Latham. Shipment is due in early October, 1997 (non-critical).

(2) Cryogenic System

- The dummy load used in earlier tests of the outsert cryostat has been removed, and the fitup of the outsert magnet vessel to the cryostat support column has been checked. Adequate tolerances were found between the vessel surfaces and neighboring thermal shields.
- Although it is believed that the minor gas leak to the vacuum space observed in previous tests was associated with piping on the dummy load, a permanent, full-time pumping system, with sufficient capacity to handle the leak, has been installed on the cryostat.
- Final tests of the cryostat without the outsert magnet will be completed by the end of November, 1997, and the cryostat will be prepared for accepting the outsert by the end of December, 1997.

(3) Resistive Insert Magnet

(See the following report, "Hybrid Insert")

(4) Outsert Power/Protection System

- A conceptual design has been developed for the outsert quench-detection system, modified somewhat from previous concepts to deal better with the high inductive voltage experienced between some voltage taps during an insert trip or insert failure. Key circuit components are being procured and benchtop testing will begin soon.

(5) System Integration and Test

- Full system tests of the superconducting outsert are planned for the first quarter of 1998.
- Tests of the combined system will follow completion of the resistive insert.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Est. Cost	Budget 7/31/96	Variance - (over) + (under)
Resistive Insert System (includes Resistive Magnet Group)*					
Labor	154	142	296	297	1
Equipment/Subcontracts	26	572	598	457	-141
Travel/Expense	23	1	24	22	-2
Subtotal	**203**	**715**	**918**	**776**	**-142**
Superconducting Outsert/Nb_3Sn coils					
Labor	1,386	8	1,394	1,259	-135
Equipment/Subcontracts	3,305	0	3,305	3,305	0
Travel/Expense	203	5	208	187	-21
Subtotal	**4,894**	**13**	**4,907**	**4,751**	**-156**
Superconducting Outsert/NbTi coil					
Labor	221	75	296	289	-7
Equipment/Subcontracts	371	0	371	296	-75
Travel/Expense	26	11	37	22	-15
Subtotal	**618**	**86**	**704**	**607**	**-97**
Superconducting Outsert/Assembly & Enclosure					
Labor	458	38	495	503	8
Equipment/Subcontracts	60	0	60	60	0
Travel/Expense	47	18	65	43	-22
Subtotal	**565**	**56**	**620**	**606**	**-14**
Cryogenic System					
Labor	536	25	561	518	-43
Equipment/Subcontracts	1,857	0	1,857	1,857	0
Travel/Expense	54	3	57	54	-3
Subtotal	**2,447**	**28**	**2,475**	**2,429**	**-46**
Outsert Power/Protection System					
Labor	171	90	261	242	-19
Equipment/Subcontracts	382	51	433	433	0
Travel/Expense	44	5	49	41	-8
Subtotal	**597**	**146**	**743**	**716**	**-27**
System Integration					
Labor	332	113	445	418	-27
Equipment/Subcontracts	384	0	384	384	0
Travel/Expense	109	70	179	180	1
Subtotal	**825**	**183**	**1,008**	**982**	**-26**
Project Totals					
Labor	3,258	491	3,748	3,526	-222
Equipment/Subcontracts	6,385	623	7,008	6,792	--216
Travel/Expense	506	113	619	549	-70
Subtotal	**10,149**	**1,227**	**11,375**	**10,867**	**-508**
Overhead	1,731	278	2,008	1,875	-133
Project Grand Total	**11,880**	**1,505**	**13,383**	**12,742**	**-641**

* Includes NHMFL costs of $103.5K charged against the resistive magnet insert prior to 7/31/96.

Milestone Schedule Summary:

	7/31/96 Schedule	Actual (A) or Current Schedule (S)
Coil A		
Heat Treatment Complete	11/7/96	2/17/97 (A)
Impregnation Complete	12/31/96	4/24/97 (A)
Manufacture Complete	2/25/97	10/6/97 (S)
Coil B		
Heat Treatment Complete	9/5/96	11/9/96 (A)
Impregnation Complete	11/4/96	5/15/97 (A)
Manufacture Complete	1/1/97	10/6/97 (S)
Coil C		
Complete Pancake Delivery	5/5/97	10/15/97 (S)
Coil C Assembly Complete	5/22/97	11/5/97 (S)
Outsert Magnet Assembled in Vessel	8/7/97	12/15/97 (S)
I&C System Ready for Operation	6/1/97	12/15/97 (S)
Outsert System Ready for Test	9/2/97	1/30/98 (S)
Superconducting Outsert Operational	10/21/97	4/1/98 (S)
Resistive Insert		
Insert Installed in Cryostat Warm Bore	7/15/97	7/31/98 (S)
Resistive Insert Tests Complete	7/30/97	8/30/98 (S)
45 T Hybrid System		
System Ready for Combined Tests	10/28/97	9/14/98 (S)
System Operational for Users	11/8/97	10/5/98 (S)

***Project Title*: 45 T Hybrid Insert**

***Report Date*: July 31, 1997**

Objective:

The objective of this project is to provide at least 45 T in a 32 mm bore given a 14 T, 616 mm bore superconducting outsert.

Status:

Cu-Ag sheet appears to be the most promising alloy for the innermost coils of the magnet. This material was developed by the Tsukuba Magnet Laboratory operated by the Japanese National Research Institute for Metals (NRIM). The first commercial material was fabricated by Tanaka Kikinzoku International K.K. of Japan (TKK). An American vendor, Handy and Harman, expressed some interest in fabricating this material but was unable to reproduce the quality of the Japanese material. This material is rather anisotropic and inhomogeneous (10% to 15% variation in strength depending upon orientation), which complicates the design and fabrication of parts. In the past year we have worked with our etching company to reduce the variation in finished hole sizes by a factor of two. In addition, we have worked with TKK to improve the homogeneity of the material (25% improvement in thickness tolerance, significant but as yet unmeasured improvement in microstructural uniformity). A new vendor, Toshiba Corp., began making Cu-Ag sheet late in 1996. The Toshiba material is very promising because while its strength and conductivity are similar to that available from TKK, the available widths are substantially different. TKK is able to provide material up to 160 mm wide while Toshiba has produced material 250 mm wide. Preliminary optimization of the Hybrid Insert indicates an optimal Cu-Ag size of 240 mm.

Also, we are building a test stand in which we will perform heat transfer and friction factor measurements to help optimize the design. In addition, we have built a new magnet for the NRIM using the Cu-Ag sheet that worked quite well, and we are building another 33 T magnet using the Cu-Ag sheet to further explore the manufacturing issues for a Hybrid Insert.

A preliminary coil design for the Hybrid Insert has been completed. The mechanical layout is underway. The material parameters for the design should be finalized by October, 1997, at which point we will be able to finalize the coil design and the mechanical design. We should be able to purchase parts by January, 1998, and deliver the insert by the end of July, 1998.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) + (under)
Labor (incl. fringes)	72.7	141.9	214.6	215.7	1.1
Equipment/Materials	26.2	571.8	598.0	456.7	-141.3
Travel/Expense	0.6	0.5	1.1	0.0	-1.1
Subtotal	**99.5**	**714.2**	**813.7**	**672.4**	**-141.3**
Overhead	33.7	65.5	99.2	99.2	0.0
Total	**133.2**	**779.7**	**912.9**	**771.6**	**-141.3**

Milestone Schedule Summary:

	7/31/96 Schedule	Actual (A) or Current Schedule (S)
Coil Design Complete	10/31/96	10/1/97 (S)
Mechanical Design Complete	2/15/97	12/31/97 (S)
Component Fabrication Complete	7/31/97	6/30/98 (S)
Assembly Complete	8/31/97	7/31/98 (S)
Testing Complete	9/15/97	8/30/98 (S)

Project Title: 900 MHz (21 T) NMR Magnet
Report Date: July 31, 1997

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 manufacturing design is proceeding with the configuration design of critical components and structures. The 900 MHz magnet is characterized by a relatively large number of individual coils, each having a number of critical hardware design features associated with penetrations, support and routing of leads for conductor, reinforcement and protection heaters. In addition, basic concepts for the structural design associated with the upper support structure for persistent joints and the compensation coils are being established. This phase of the design is near completion to the extent required to initiate the next major phase of the program, namely the preparation of detailed manufacturing drawings by IGC.

The Engineering Design was completed on 9/12/96, and established the configuration, size, and conductor requirements of the magnet. The analytical design revealed the performance of the protection system, and identified the need for special technology development associated with the reinforcement. On the basis of the Engineering Design, the long lead Nb_3Sn conductor was ordered.

The fundamental requirement of the long coils of this NMR magnet is the need for radial impregnation by the epoxy. Given the size of the magnet, a guarantee of quality impregnation is essential, and the design must provide that assurance. Two approaches were initially evaluated, and a selection was made to employ a standard film insulated wire with an additional, non-standard finely wrapped layer of fiber to provide for radial porosity. The selected configuration was expected to be immediately available, but proved to be quite problematic. Samples of conductor with acceptable insulation have in fact been obtained, but a lack of industrial capacity for this process is evident in the available equipment, the multiplicity of vendors that are required to generate product, high price and continual uncertainty for quality. The standard braid process, initially not included due to expectations of high cost, is now being re-evaluated. The order for the NbTi conductor is being held subject to resolution of the insulation issue.

The protection analysis revealed the need for additional heat transfer into the reinforcement during quench. The design solution which was adopted employs the reinforcement as a coupled secondary. The conductivity of the reinforcement is addressed through the use of copper/steel composite wire. Trial production of this material, initially characterized as a standard product, revealed a number of issues needing further development. Initial quantities of reinforcement have now been produced. Demonstration of the production of sufficiently long lengths and the insulation system are still in progress.

While these and other technology developments were underway, detailed consideration was given to fabrication tolerances associated with coil construction, including thin bore tubes, the insulation system, and the winding and reinforcement packs. The conductor and reinforcement wire dimensions were derived to provide compatibility with the requirement for even integral layers in each coil. The full dimensionally consistent design was issued as the Even/Integral Design on 3/26/97.

As required input to the preparation of detailed manufacturing drawings, a variety of information is being assembled including detailed design of critical components, concepts for major structures and supporting structural stress analysis. As indicated above, this present activity will allow for initiation of detailed design, scheduled for September, 1997.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) +(under)
900 MHz Research & Development					
Labor	1,300.0	200.0	1,500	1,234	-266
Materials/Subcontract	162.6	98.4	261	261	0
Travel/Expense	112.5	6.5	118	118	0
Subtotal	**1,575.1**	**304.9**	**1879**	**1,613**	**-266**
900 MHz Fabrication (NHMFL)					
Labor	44.0	600.0	644	644	0
Materials/Subcontract	282.3	1,827.7	2,110	2,110	0
Travel/Expense	15.6	51.4	67	67	0
Subtotal	**341.9**	**2,479.1**	**2,821**	**2,821**	**0**
IGC Subcontract					
Labor	0	0	9	0	0
Materials/Subcontract	150.0	810.0	960	901	-59
Travel/Expense	0	0	0	0	0
Subtotal	**150.0**	**810.0**	**960**	**901**	**-59**
Facility Completion					
Labor	41.0	80.0	121	161	40
Materials/Subcontract	110.0	790.0	900	900	0
Travel/Expense	34.5	5.5	40	15	-25
Subtotal	**185.5**	**875.5**	**1,061**	**1,076**	**15**
Project Total					
Labor	1,385.0	880.0	2,265	2039	-226
Materials/Subcontract	605.9	3,526.1	4,232	4,172	-60
Travel/Expense	162.6	63.4	226	200	-26
Subtotal	**2,153.5**	**4,469.5**	**6,723**	**6,411**	**-312**
Overhead	711.9	434.1	1,146	1,138	-8
Total	**2,865.4**	**4,903.5**	**7,869**	**7,549**	**-320**

Milestone Schedule Summary:

	7/31/96 Schedule	Actual (A) or Current Schedule (S)
Issue Engineering Design (NHMFL)		
Engineering Design	8/30/96	9/12/96 (A)
Even/Integer Design		3/26/97 (A)
Conductor Procurement (NHMFL)		
Nb_3Sn Specification	8/30/96	8/30/97 (A)
Nb_3Sn Order	10/1/96	10/1/96 (A)
Nb_3Sn Delivery	10/1/97	8/15/97-12/30/97 (S)
NbTi Specification		5/6/97 (A)
NbTi Order		TBD
NbTi Delivery		TBD
900 MHz Research And Development (NHMFL)		
Nb_3Sn J_c (B,T) Development	6/30/96	6/30/96 (A)
Nb_3Sn Mechanical Properties	11/30/96	11/30/96 (A)
Epoxy-Fiber Composites Development	1/31/97	1/31/97 (A)
Winding Composites	3/31/97	3/31/97 (A)
Persistent Joint Development	5/31/97	TBD
Persistent Switch Development	6/15/97	TBD
Model/Test Coils Fabrication		TBD
Mechanical Configuration and Structural Design (NHMFL)		
Initial Concepts Review		5/15/97 (A)
Design Initial Inputs Complete	8/15/97	9/15/97 (S)
Configuration Design Complete		TBD

IGC Design and Fabrication

Prepare Manufacturing Drawings		
Start Manufacturing Design	12/16/96	9/22/97 (S)
Complete Manufacturing Design	11/15/97	5/29/98 (S)
Fabricate NbTi Coils		
Ti Coil Forms and Tooling Delivered	2/2/98	7/10/98 (S)
Start winding of Ti Coils	2/2/98	8/10/98 (S)
Ship Ti Coil Set to NHMFL	9/30/98	12/10/98 (S)
Fabricate Shim Coils		
Shim Coil Tooling Received	1/10/98	8/1/98 (S)
Complete Winding of Shim Coils	2/15/98	9/15/98 (S)
Assemble Shim Coil Set	7/10/98	11/20/98 (S)
Ship Shim Coil Set to NHMFL	9/30/98	12/10/98 (S)

NHMFL Fabrication Program

Fabricate Nb_3Sn Coils		
Sn Coil Forms and Tooling Delivered	11/20/97	1/20/98 (S)
Start Winding Sn Coils	11/21/97	2/1/98 (S)
Complete Sn Coil Assembly	9/30/98	12/10/98 (S)

Cryostat And Cryogenic System		
Start Cryogenic System Design	TBD	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	TBD
Complete System Assembly and Test	8/30/98	
Magnet Assembly and Test		
Start Final Magnet Assembly	10/1/98	1/1/99 (S)
Installation of Magnet in Cryostat	12/23/98	2/15/99 (S)
Magnet Testing	12/26/98	3/1/99 (S)

Project Title: **ΔB Program**
Report Date: **July 31, 1997**

Objective:

The objective of the ΔB Program is to develop high temperature superconducting (HTS) magnets and related technologies 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 characterize BSCCO 2212 composite conductors; developing HTS magnet-related technologies; and, using our own material (plus that available through collaborations with industry) to build a set of small "1 T class" magnets. This work is divided into three tasks: (1) insulation and joint studies; (2) characterization, and (3) coil development. Specific progress and current activities (with target dates) are listed below.

(1) Insulation and Joining

- A proprietary NHMFL sol-gel insulation process was developed.
- A wheel-to-wheel continuous sol-gel dip insulation system was designed and constructed.
- Several 14 m lengths of powder-in-tube Ag/BSCCO 2212 tape conductors were insulated and used successfully for several double pancake coils.
- A 15 m length of sol-gel insulated conductor was provided to Oxford Instruments for layer winding.
- Microstructural development of the insulation is well understood and coupled to performance.
- The sol-gel insulation process is being evaluated for application to wind-and-react Nb_3Sn solenoids.
- Joining of green Ag/BSCCO 2212 monofilamentary and multifilamentary conductors was accomplished with I_c in the joint greater than in the conductors.
- Heat-treated double pancake coils were successfully joined with heat treated Ag/BSCCO 2212 tape conductor.
- Several solders were studied for lap joints between heat-treated Ag/BSCCO 2212 tape conductors.
- An etch, expose, and lap-joint approach was successful for green tapes and will be studied for heat treated multifilamentary tapes.

(2) Characterization

- Routine transport measurements were performed on short samples of BSCCO 2212 and BSCCO 2223 as a function of temperature and in magnetic fields up to 30 T.
- New probes were designed and constructed including a compact coaxial test probe for the 20 T, 33 T, and 45 T hybrid magnets and a multi-sample probe (6 samples) for routine short-sample transport measurements.
- Three techniques were developed for characterizing mechanical strain effects on HTS conductors: *in-situ* Lorentz Force Stressing (ILFS), bend straining, and room temperature linear tensile testing. These were used to characterize powder-in-tube and surface coated BSCCO 2212 conductors.
- The magnetoresistivity of candidate HTS sheath materials was characterized, including Ag, Ag-Mg, Ag-Al and Ag-Zr, as a function of temperature in magnetic fields up to 17 T and at 4.2 K and 77 K in fields up to 30 T.
- Double pancakes and a "1 T class" coil were tested in magnetic fields up to 17 T.
- Larger react-and-wind coils were tested in fields up to 9 T.
- A 2.5 T insert coil in the 20 T large bore resistive magnet will be tested soon (December 1997).
- Optical and analytical studies were performed on HTS conductors and joints; mechanical stress testing was done on powder-in-tube BSCCO 2212 conductors; and a 1.2 T coil was developed.
- Microstructural studies by optical microscopy and SEM were carried out on all the samples used in magnets and in support of other ongoing experiments, including powder-in-tube and surface-coated conductors, insulation development, mechanical effects studies, and magnetoresistivity studies.

(3) **Coil Development**

- An insert coil was constructed using powder-in-tube BSCCO 2212 conductor (in collaboration with Oxford Superconductor Technology and Oxford Instruments). This coil generated 1.2 T at 4.2 K in a 17 T background field.
- Several wind-and-react coils were built and tested using powder-in-tube conductors.
- Several react-and-wind pancake coils were built and tested using surface coated conductors (in collaboration with Intermagnetics General Corporation).
- An HTS shim coil was built and tested for the 17 T Oxford superconducting magnet. This achieved almost an order of magnitude improvement in the field homogeneity of the magnet. The insert has a clear bore of 15 mm with a variable temperature.
- Construction and testing of layer wound coils using powder-in-tube and/or surface coated conductors is currently underway (1997-98).
- Analysis and design of a 2.5 T insert coil in a 20 T background field is in progress (1997-98).

Budget Summary:

The ΔB program is jointly funded by the NSF (24%), the State of Florida (39%), and the National Institutes for Health through a Phase-II Small Business Innovation Research Grant in collaboration with Intermagnetics General Corporation (37%).

Industrial Collaborations:

Agreements and cooperative research and development activities with industries involved in HTS conductor and magnet development are listed alphabetically by company.

- Intermagnetics General Corporation (D. Hazelton, M. Walker): High field insert coils for NMR applications using react-and-wind and wind-and-react technology; Characterization of mechanical effects on surface-coated conductor.
- Oxford Research Instruments and Oxford Superconductor Technology (L. Cowey, K. Marken, and M. Wilson): Heat treatment, insulation, and characterization (microstructure and transport properties in high magnetic fields and under mechanical stress) of powder-in-tube BSCCO 2212 conductor; development of a 1.2 T coil.
- Southwire Corporation (U. Sinha): Characterization of bend strain and thermal cycling effects on BSCCO 2223 powder-in-tube conductor.

Project Title: **Large Bore Resistive Magnet: 20 T, 195 mm Warm Bore**
Report Date: **July 31, 1997**

Objective:

The objective of this project is to provide 20 T in a 195 mm bore using 20 MW of power. This magnet is an international collaboration between the NHMFL and the High Magnetic Field Laboratory of Grenoble, France. Two similar magnets will be constructed. The one in Grenoble will provide 36 T in a 34 mm bore using 24 MW of power.

Status:

All the magnet parts are in-house. The housing has been received and is in place and plumbed. The platform is under construction. The stacking fixtures should arrive in August. The magnet should be stacked in September and October and operational in November, 1997.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) + (under)
Labor (incl. fringes)	195.4	26.0	221.4	209.4	-12.0
Equipment/Materials	541.9	20.0	561.9	800.0	238.1
Travel/Expense	4.3	0.0	4.3	0.0	-4.3
Subtotal	**741.6**	**46.0**	**787.6**	**1,009.4**	**221.8**
Overhead	91.9	12.0	103.8	96.3	-7.5
Total	**833.5**	**58.0**	**891.4**	**1,105.7**	**214.3**

Milestone Schedule Summary:

	7/31/96 Schedule	Actual (A) or Current Schedule (S)
Complete Coil Design	7/15/95	7/15/97 (A)
Complete Mechanical Design	4/15/96	4/15/96 (A)
Component Fabrication Complete	3/15/97	8/12/97 (S)
Magnet Assembly Complete	5/15/97	11/24/97 (S)
Test Magnet Complete	5/30/97	12/15/97 (S)

Project Title: **33 T Magnet II: Prototype Test for Hybrid Insert**
Report Date: **July 31, 1997**

Objective:

The objective of the 33 T Magnet II project is to provide a second 33 T magnet to the user community and to 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 critical to the design of the hybrid magnet insert.

Status:

The Cu-Ag sheet metal is in-house. All the magnet parts are on order and should be delivered in February 1998 and the magnet should be completed in March 1998.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) + (under)
Labor (incl. fringes)	13.9	12.0	25.9	25.9	0.0
Equipment/Materials	108.1	1.4	109.5	110.0	0.5
Travel/Expense	0.0	0.5	0.5	0.0	-0.5
Subtotal	**122.0**	**13.9**	**135.9**	**135.9**	**0.0**
Overhead	6.4	5.8	12.1	12.0	-0.1
Total	**128.4**	**19.7**	**148.0**	**147.9**	**-0.1**

Milestone Schedule Summary:

	7/31/96 Schedule	Actual (A) or Current Schedule (S)
Coil Design Complete		10/31/96 (A)
Mechanical Design Complete	9/15/96	1/6/97 (A)
Component Fabrication Complete	5/31/97	2/6/98 (S)
Assembly Complete	7/15/97	3/6/98 (S)

***Project Title*:** **Hydraulic Test Stand**

***Report Date*:** **July 31, 1997**

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 lower power 33 T magnet, a split pair, etc. The device also will serve to benchmark theoretical calculations on turbulent flow in channels with periodic roughness structures.

Status:

The construction is complete. Installation and testing coils will continue for several months.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) + (under)
Labor (incl. fringes)	21.7	20.9	42.6	42.6	0.0
Equipment/Materials	31.6	10.0	41.6	46.1	4.5
Travel/Expense	0.0	0.0	0.0	0.0	0.0
Subtotal	**53.3**	**30.9**	**84.2**	**88.7**	**4.5**
Overhead	10.0	9.6	19.6	40.8	21.2
Total	**63.3**	**40.5**	**103.8**	**129.5**	**25.7**

Milestone Schedule Summary:

	7/31/96 Schedule	Actual (A) or Current Schedule (S)
Complete Test Stand Mechanical Design	3/15/96	3/15/96 (A)
Fabrication of Components Complete	9/15/96	5/19/97 (A)
Assemble and Install Test Stand Complete	10/15/96	8/30/97 (S)

***Project Title*:** **Multipurpose Resistive Magnet: New Project**
***Report Date*:** **July 31, 1997**

Objective:

This magnet will provide high modulation, gradient and/or homogeneity in a 32 mm bore. The magnet will consist of three (Florida) Bitter coils and some small wire wound coils on the bore tube to provide the various field quality modifications. The DC field should be 30 T or more. Preliminary calculations show a modulation amplitude of 0.1 T, gradient of 0.05 T/cm, and homogeneity better than 10 ppm could be attained.

Status:

Coil design is nearly finished. Mechanical layout should begin in September, 1997. Parts should be ordered in November, 1997. Magnet should be operational in December, 1998.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/97 Budget	Variance - (over) + (under)
Labor (incl. fringes)	1.6	36.3	37.9	37.9	0.0
Equipment/Materials	0.0	130.0	130.0	130.0	0.0
Travel/Expense	0.0	0.5	0.5	0.5	0.0
Subtotal	**1.6**	**166.8**	**168.4**	**168.4**	**0.0**
Overhead	0.7	16.9	17.7	17.7	0.0
Total	**2.3**	**183.7**	**186.1**	**186.1**	**0.0**

Milestone Schedule Summary:

	7/31/97 Schedule	Actual (A) or Current Schedule (S)
Coil Design Complete	9/6/97	
Mechanical Design Complete	10/6/97	
Component Fabrication Complete	10/4/98	
Assembly Complete	12/4/98	

***Project Title*:** **Keck Magnet**

***Report Date*:** **July 31, 1997**

Objective:

This magnet will provide 25 T in a 52 mm bore with inhomogeneity less than 1 ppm over a 10 mm diameter spherical volume using less than 20 MW. It will be installed at the NHMFL and will be used primarily for magnetic resonance experiments.

Status:

Magnet design is complete. Parts have been ordered. The housing is expected to be delivered the first week of September, 1997. The magnet should be operational in November, 1997.

Budget Summary ($K):

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) + (under)
Labor (incl. fringes)	71.2	37.8	109.0	85.4	-23.6
Equipment/Materials	244.8	56.2	301.0	456.0	155.0
Travel/Expense	0.0	1.1	1.1	0.0	-1.1
Subtotal	**316.0**	**95.1**	**411.1**	**541.4**	**130.3**
Overhead	145.4	43.7	189.1	249.0	59.9
Total	**461.4**	**138.8**	**600.2**	**790.4**	**190.2**

This project is funded by a grant from the Keck Foundation and matching funds from the NHMFL.

Milestone Schedule Summary:

	7/31/97 Schedule	Actual (A) or Current Schedule (S)
Coil Design Complete	9/30/96	10/31/96 (A)
Mechanical Design Complete	1/15/97	5/7/97 (A)
Component Fabrication Complete	9/30/97	10/10/97 (S)
Assembly Complete	11/30/97	11/7/97 (S)
Test Magnet Complete	12/15/97	11/30/97 (S)

Project Title: **Pulsed Magnet User Facility Support**
Report Date: **July 31, 1997**

Objective:

The objective of this activity is to 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, 60 T magnets are provided on an as-needed basis for the user facility. Approximately six to eight magnets per year are provided on a four- to six-week lead time basis.
- Pulsed magnet tests scheduled for August, 1997, will hopefully permit the upgrade of the 60 T, 15 mm bore magnets to operate safely at 70 T. The 50 T, 24 mm bore magnet is also being upgraded to user fields of 60 T. Both 15 mm and 24 mm magnet systems have been redesigned with steel shells to shorten cool down times.
- Test magnets are constructed on a continuous basis to evaluate new fiber composites, conductors and reinforcement techniques. Approximately forty of these are made per year.
- Note added in proof: The test of the next generation of pulsed magnets was extremely successful leading to a new design with superior performance specifications. As a result of these successes, operation of the 50 T, 24 mm bore magnets will be upgraded to 60 T, 24 mm bore, and the 60 T, 15 mm bore magnets will be upgraded to 70 T, 15 mm bore. This represents approximately a 20 percent enhancement of field performance. The coil design also provides for a more rapid cool down, which will permit great repetition rates for users.

Budget Summary ($K):

	Cost June 96 - June 97	Budget June 96 - June 97	Variance -(over) +(under)	Future per annum
Labor	13.7	21.6	+7.9	30.5
Equipment/Materials	18.3	20.0	+1.7	58.0
Expense/Travel	6.0	6.0		6.0
Total	**38.0**	**47.6**	**+9.6**	**94.5**

Project Title: **60 T Quasi-Continuous Magnet**
Report Date: **July 31, 1997**

Objective:

The objective of this project is to provide a generator-driven, controlled-power pulsed magnet capable of sustaining a constant field of 60 T in a cold bore of 32 mm for 100 ms. In addition, the magnet is to 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 assembled and placed in the LN dewar. They have been successfully tested above the working voltage at both room temperature and LN temperature. Further successful tests involved energizing the three separate magnet circuits with a 1.6 MJ capacitor bank—in this way the magnet produced its first field. All five of the 80 MVA power converters have been installed and commissioned. (In all, seven power converters were installed; the additional two are needed for upgrades beyond 60 T.) A variable temperature cryostat for experiments has been delivered and is ready for use. A dilution refrigerator has been ordered and is expected to be ready no later than early 1999.

No outstanding issues are identified at this time. The magnet was recently partially disassembled to insert more insulation at two places that showed lower than desirable resistance during high potential tests. This corrected the problem and no further problems have been encountered.

Budget Summary ($K): Cost to complete from 7/31/96

	Cost to 7/31/97	Cost to Complete	Total Estimated Cost	7/31/96 Budget	Variance - (over) + (under)
Labor (incl. fringes)	494.1	35.0	529.1	110.0	-419.1
Equipment/Materials	3.1	5.0	8.1	225.0	216.9
Travel/Expense	54.5	0	54.5	0.0	-54.5
Subtotal	**551.7**	**40.0**	**591.7**	**335.0**	**-256.7**
Overhead (LANL)	286.9	20.8	307.7	174.2	-133.5
Total	**838.6**	**60.8**	**899.4**	**509.2**	**-390.2**

Power supply modules are funded through FSU. Purchase price was $3,000K versus a budget of $3,400K. There are additional costs totaling $160K at the direct cost level required to complete the generator system.

Milestone Schedule Summary:

	7/31/97 Schedule	Actual (A) or Current Schedule (S)
60 T Magnet		
Design	Done	
Assembly & Installation	10/96	8/97 (S)
Commissioning	12/96	10/97 (S)
Dewar		
Design	Done	
Assembly & Installation	7/96	
Commissioning	9/96	
Control system (power supplies)		
Design	10/96	
Assembly & Installation	11/96	
Commissioning	12/96	1/97 (A)
Power Modules (3)		
Design	Done	
Assembly & Installation	9/96	11/96 (A)
Commissioning	12/96	1/97 (A)
Power Modules (4)		
Design	Done	
Assembly & Installation	6/97	5/97 (A)
Commissioning	9/97	6/97 (A)

Project Title: **100 T Insert Magnet Project**
Report Date: **July 31, 1997**

Objective:

The objective of this project is to design, construct, and test a 24 mm bore insert coil powered by a 2.4 MJ capacitor bank capable of producing a 10 ms, 50 T pulse when installed in the bore of a 50 T outsert magnet. The outer diameter of the insert is to be 220 mm. This is the NHMFL part of the DOE/NHMFL joint 100 T magnet project.

Status:

- Material Evaluation of Reinforcement Schemes. Testing of various fiber composites have revealed serious shortcomings when used in large thicknesses for magnet reinforcements. Test magnets were constructed and tested to evaluate various reinforcement schemes and extensive analysis used to model behavior. NHMFL is working with the TOYOBO company of Japan to evaluate a new high strength fiber material.
- Material Evaluation of Conductor Systems. Materials were tested and evaluated. Development projects/contracts are underway with IGC for steel reinforced copper, Supercon for high strength CuNb, and Brush-Wellman for Cu-CuBe. Tensile tests so far have revealed that of the available materials, CuNb has the best degree of strength versus reliability of manufacture.
- 100 T Insert Magnet. Substantial design work was done. Latest figures indicate that a 53 T insert in a 50 T coil is possible assuming 1.3 GPa wire. As yet no wire of this strength is available or suitable.

Budget Summary ($K):

	Cost June 96 - June 97	**Budget June 96 - June 97**	**Variance -(over) +(under)**	**Future per annum**
Labor	5.2	2.7	-2.5	29.5
Equipment/Materials	85.0	50.0	-35.0	50.0
Expense/Travel	0	0	0	3.0
Total	**90.2**	**52.7**	**-37.5**	**82.5**

Schedule Summary:

	Schedule	Actual or Revised
Material Evaluation - Reinforcement Systems	12/15/96	ongoing
Material Evaluation - Conductor Systems	5/30/97	ongoing
100 T Insert	TBD	TBD

Project Title: MS&T Work for Others

In an effort to diversity and help stabilize the intellectual capital within MS&T and as suggested by previous NSF external review committees and the NHMFL Advisory Committee, we have made considerable effort toward bringing in externally funded activities. This is viewed as a long term trend within MS&T, as we complete in-house projects. A brief summary of these main projects is given below.

NASA Magnet Project

This magnet was fabricated for NASA under a cost reimbursement grant from NASA-Huntsville. The magnet is a prototype for one to be used to grow diffusion controlled crystals in microgravity on the International Space Station. It provides 0.14 T in a 184 mm bore while consuming 3 kW of power.

This project was completed at the end of March at a total cost of $89.4K. All expenses for the project were covered by NASA-Huntsville.

NRIM Magnet

This magnet is being built for the National Research Institute for Metals (NRIM) in Tsukuba, Japan, on a fixed price contract with Toshiba America valued at $643.8K. The magnet provides 30 T in a 32 mm bore using 15.5 MW of power.

The housing has been installed at the Tsukuba magnet laboratory. The coils were tested to full power at the NHMFL and have arrived in Japan. The coils will be installed and tested to full power in Japan in October, 1997.

Australian Pulse Magnet Laboratory

The objective of this project is to supply user magnets for the Australian National Pulse Magnet Laboratory in Sydney. The NHMFL is now the sole supplier of magnets for the laboratory, which has expressed the desire for this to be a permanent arrangement. Thus far the NHMFL has paid the cost of coil fabrication in exchange for travel funding for scientific exchange involving NHMFL researchers.

Since June, 1996, three magnets have been supplied. The first, a 24 mm bore, 50 T, was provided in October, 1996, for evaluation purposes. While functional, it was not considered ideal due to long cooling time between shots. Two additional 24 mm, 50 T coils were tested in Sydney in April and May 1997, with steel rather than composite shells.

Although the first set of coils was developed on a collaborative basis with in-kind financial support, in the future the Australian Laboratory will purchase their magnets from us at full cost recovery.

Harvard Wetwind

This project consisted of the wetwinding of a kevlar composite shell for a dipole magnet constructed at Harvard University. Labor and expertise were provided by the NHMFL. Harvard University provided materials. Surplus materials were donated for composite research at the NHMFL. The magnet was completed and shipped in February, 1997.

SNL Pulsed Magnet

The objective of this project was to supply three 24 mm bore magnets to Sandia National Laboratory (SNL) for use as focusing magnets in X-ray radiography experiments.

Four magnets have been supplied to SNL. One of these was a 40 T coil of an old design that was on the shelf in Tallahassee; two others were custom built magnets. A fourth coil built by Tallahassee and retired from the LANL user facility had been donated by them. This coil was modified and refurbished to match the custom built ones. All magnets were tested to the stated field at the user facility at LANL and delivered to Sandia on schedule and Sandia provided full cost recovery.

Wisconsin Pegasus Solenoid

This project is a collaboration with the University of Wisconsin (UW) Phaedrus Laboratory for Plasma Science to design and construct a 60 mm bore, 1.5 m long, 20 T solenoid for the Wisconsin-DOE-funded Pegasus Tokamak Project. NHMFL provided labor, UW purchased materials and funded any subcontracts. The first coil was provided in the fall of 1996. The second will be tested in the fall of 1997 and delivered in 1998.

The first phase of the project is complete. The initial coil was delivered in February, 1997, and is currently being tested. Calculations indicate that it will reach 20 T. Subject to installation and operation, a second identical coil is expected to be requested in Fall, 1997. Payment in kind has been provided by UW in the form of 2 MJ of 10 kV capacitors (shipping June 17, 1997) plus ignitrons and development of switching gear necessary for bank charging and installation. These capacitors may be used to develop a test facility to support pulsed magnet development.

30 T Water Cooled Neutron Scattering Magnet

This project is funded by the Department of Energy and is focused on the developmeant of a water cooled pulsed magnet for a Neutron Scattering experiment at Los Alamos. The magnet is to be a 30 T split solenoid that can be pulsed at 2 Hz. This project is considerably different from other pulsed magnet projects because of the need for water cooling.

A grant of $125K from Los Alamos funded a preliminary conceptual design and materials characterization effort. The report will be delivered to Los Alamos by the end of August, 1997. The NHMFL is negotiating for supply of the completed system.

This project is an example of how the intellectual resources developed under NSF funding can be directed to magnet science opportunities at other institutions and represents another facet of inter-agency cooperation.

ATLAS Program

The NHMFL recently submitted a preproposal to the NSF to construct the end-cap magnets for ATLAS at the Large Hadron Collider at CERN, and the Magnet Test Facility. The central and most important part of the ATLAS detector is the magnet system, which provides the required axial and toroidal field components. It is an extremely large magnet system, even on a scale of previous detector magnets. Each of the two end-cap toroids consists of eight end-cap coils of about 4 meters by 4.5 meters. The total assembly is about 11 meters high. Much of the work will be performed by U.S. industry under the technical guidance and management of the NHMFL.

Project Title: **Cryogenic Component Development**
Report Date: **July 31, 1997**

Objective:

The objectives of this program are threefold:

- To develop technology in support of large scale superconducting magnet systems (hybrid, NMR, etc.),
- To provide support in the form of cryogenic services to NHMFL users, and
- To collaborate with industry in development of cryogenic technology.

Status:

Over the last year the Cryogenic Component Development (CCD) Group has concentrated its efforts on three main projects. These are as follows:

- Completion of the 45 T Hybrid cryostat in preparation for the installation of the superconducting outsert magnet. The dummy load has been removed from the system and the vessel reassembled in preparation for another test in early fall 1997. To date, heat leak measurements have indicated a value somewhat over specification; however, we are confident that the source of this extra heat leak will be identified in the next set of tests.
- Design of the cryostat for the 900 MHz NMR magnet. This design effort has proceeded at a relatively low level pending the issuance of the final design for the magnet. With this milestone accomplished, the cryostat design has increased its efforts. A preliminary design review is planned for early fall 1997. The cryostat will be available in time to install the coil system upon its completion.
- Design of a dewar and insert for the 20 T, 200 mm resistive magnet. The design of the dewar is nearing completion and will go out for bid in September, 1997. We also are beginning the design of a high current, variable temperature insert for transport measurements.

In addition, the CCD group is pursuing several research and development activities. These are partially funded by outside grants as indicated:

- He II heat exchanger development. A model has been developed to better understand the design and performance of saturated bath He II heat exchangers, like those being used in the 45 T Hybrid. We have also performed an experiment to confirm the model characteristics.
- Cooling of structural supports and current leads. A model has been developed to optimize the design of structural supports and current leads that are cooled continuously by vapor helium.
- He II two phase flow and heat transfer. This grant-funded project is studying two phase He II as it is used to cool future accelerators. Both numerical modeling and experimental confirmation are included in the project.

Collaborations:

- DESY- Hamburg. We are working together on a He II two phase flow experiment to confirm the operating characteristics of the cooling system for the TESLA electron accelerator. In June, we completed the first experimental test and are modifying the apparatus for further testing in fall 1997.
- CERN liquid helium pump test. We are performing tests of a liquid helium pump for the CERN Laboratory. These tests are to confirm performance and study cavitation for application to the ATLAS detector system for the Large Hadron Collider (LHC).

Project Title: **High Strength/Conductivity Materials**
Report Date: **July 31, 1997**

Objective:

The objective of this project is to develop new conductor materials for Bitter magnet and pulse magnet applications. Specifically:

- To optimize existing materials and find new ways to combine very high mechanical strength with high electrical conductivity
- To manufacture materials on a laboratory scale for testing and microscopy and develop a processing that can be applied in industry to supply better high strength conductors to the NHMFL.

Status:

- Optimization studies on eutectic Ag-Cu. A comprehensive set of quantitative scanning and transmission electron microscopy data has been collected and used for a correlation of microstructure and properties. An optimization scheme has been developed and applied to determine the optimal eutectic lamellae thickness for a combination of ultimate tensile strength and electrical resistivity at room and cryogenic temperatures.
- Dissolution and precipitation studies on Cu-4at.%Ag and Ag-13.6at.%Cu. Heat treatments have been carried out in order to solutionize the material and to achieve a state in which optimal precipitation strengthening can be performed. A complete solid solution was not reached, however, effective strengthening was observed. Alterations of the behavior were observed as a function of pre-deformation.
- Ternary Cu base composites. Initial microstructure analyses were carried out on Cu-Cr-Ag and Cu-Nb-Ag composites, and mechanical as well as physical properties were measured. The properties varied as a response to high plastic deformation and thermal treatments. The goal is to achieve additional strengthening in the Cu matrix from small Ag precipitates.
- Comparison of properties and microstructure of swaged and drawn wires. Wire specimens of Cu and Cu-8%Ag were prepared by solely swaging, solely drawing, and a combination of both. The mechanical and electrical properties are being measured and microstructure as well as texture analysis will be carried out. The goal is to collect information on the influence of the type of deformation process on the performance of the material.
- Optimization of a copper-Al_2O_3-Nb composite. A commercially processed composite of GlidCop® Al-15 with addition of 10% Nb is under investigation for its capability to combine the composite strengthening of the Nb with an additional matrix strengthening by alumina particles. The tensile strength and the electrical resistivity are investigated as a function of temperature.

Project Title: **Materials Development and Characterization**
Report Date: **July 31, 1997**

Objective:

The Materials Development and Characterization (MD&C) group investigates the physical and mechanical properties of state-of-the-art materials for use in superconducting and resistive magnets. The group's work can be divided into three areas:

- Internal basic applied research for the improvement of magnet materials,
- Internal support for MS&T design groups, and
- External contract research supported by funding from outside sources.

The research and developmental nature of the work also serves as an excellent resource for educational opportunity and interaction with the laboratory's educational outreach programs. This past year we had two middle school mentorship program students, one FSU graduate research student, one foreign exchange undergraduate student intern, and one FSU undergraduate engineering student intern.

Status:

Specific accomplishments over the past year include the following:

- Verification tests of critical components of the 45 T Hybrid magnet. Critical current measurements as a function of strain and magnetic field were made on full scale witness sample conductors to verify heat treatment process of the Nb_3Sn coils. Also, mechanical tests of the prototype model of Nb_3Sn Coil A were conducted to ensure manufacturing integrity.
- Implementation of new fatigue test machine and generation of high cycle fatigue data base in support of 30 T LANSCE program.
- Ongoing characterization of high strength/high conductivity, commercial conductors for both the Resistive Magnet and Pulse Magnet design groups.

Collaborations:

During the reporting period, there were several cooperative R&D activities with industry, government, and universities to characterize new materials, including the following:

- General Atomics Inc, (Will Creedon). Characterization of large scale support struts for Naval Superconducting Mine Countermeasures Systems.
- CEA, Saclay, France. Thermal and mechanical characterization of aluminum stabilized composite superconductor.
- VAMAS. Participation in Round-Robin Test Program of test methods for compression and shear properties of fiber-reinforced composite laminates.

Project Title: **High T_c Conductor Development**
Report Date: **July 31, 1997**

Objective:

The objective of this program is to develop high temperature superconducting (HTS) conductors for high field, low temperature superconducting magnets. The specific goals of this program are:

- Homogeneous multifilamentary Ag-alloy sheathed powder-in-tube BSCCO 2212 conductors on the 50 m lengthscale, and
- Increased critical current density at high field and in increasing temperatures by improved mechanical deformation, heat treatment, and flux pinning.

Status:

Recent efforts in the high-T_c conductor development program have been directed toward improving the deformation processing and flux pinning. Specific progress and current activities (with target dates) are listed below.

- Modifications to the NHMFL wire deformation facility have lead to significant improvements in the deformation processing of BSCCO 2212 conductor.
- Elimination of bubbling and tunneling in partial-melt processed tapes via powder pre-processing and improved powder handling protocols.
- Demonstration of a react-wind-sinter approach that represents "proof of concept" for a continuous heat treatment and coil winding approach.
- Optimization of the deformation and heat treatment has resulted in $I_c > 200$ A.
- Routine production of 50 m lengths of multifilamentary AgMg/BSCCO 2212 (December 1997).
- Optimization of deformation and heat treatment for multifilamentary conductor (March 1998).
- Increased processing speed and critical current density via the continuous react-wind-sinter approach (March 1998).
- Integration of continuous react-wind-sinter approach with insulation deposition technology (see ΔB progress report; June 1998).
- Improved flux pinning at intermediate temperatures via nano-scale MgO additions (in collaboration with the University of Queensland, Australia).
- Improved flux pinning at 4.2 K, high fields via BaO_2 additions.
- Further understanding and improvements in flux pinning at temperatures up to 30 K in high magnetic fields (1997-98).
- The translation of flux pinning enhancements into further increases in high field transport critical current density (1997-98).

Budget Summary:

The high-T_c conductor program is jointly funded by the NSF (19%), the State of Florida (23%), the Department of Energy through the Argonne National Laboratory (19%), and the Defense Advanced Research Projects Agency through the Naval Research Laboratory (39%).

Industrial Collaborations:

Agreements and cooperative research and development activities with industries involved in HTS conductor development (listed by company alphabetically):

- American Superconductor Corporation (C. Thieme, L. Masur). Hot rolling of powder-in-tube tapes
- Oxford Research Instruments and Oxford Superconductor Technology (L. Cowey and K. Marken). Continuous react-wind-sinter approach for heat treatment of conductors.

Project Title: MS&T Study Projects

60 T Quasi-Continuous Modulation Coil

It has been recognized that a "deep" modulation capability of the 60 T quasi-continuous magnet would be highly beneficial to magnet users. This capability would, for example, increase sensitivity of magnetization and cyclotron resonance measurements, enable magnetic field stabilization and noise cancellation. Such an installation would increase the quality of the magnet system markedly.

An effective field modulation system would require modulation currents of several kiloamperes at frequencies of several kilohertz. There are in existence modulation power supplies that can produce the required power to drive the modulation coil. The conductors carrying these currents would be subjected to severe stresses when in the presence of a 60 T background field. Fortuitously the modular construction of the 60 T quasi-continuous magnet permits us to easily deal with the stress problem by simply using the inner coil of the magnet as the modulation coil. By doing this no volume is lost by the insertion of a modulation coil.

Ultra High Field Single-Turn Coil

The opportunity for NHMFL to routinely provide fields exceeding 100 T in a single-turn coil recently came much closer with the no-cost acquisition of the proper high-voltage capacitor bank from another Los Alamos program. Such single-turn coils are in popular service for research at two magnet laboratories in Japan and Germany but, to this time, have never been available in the United States. Although the magnets are destroyed with each usage, they are inexpensive to replace and they disassemble so symmetrically that the experimentalist's sample and cryogenic container typically survive undamaged. This facility could also become a different kind of feeder magnet for the non-destructive 100 T, millisecond, magnet that is now being designed by providing the same 100 T field in microseconds compared to other NHMFL pulsed magnets which give the same millisecond pulse length at lower fields.

The decision to pursue this project is currently under review, with attention focused not so much on the costs to complete, which are modest, but on the longer term implications for user support and instrumentation.

Series-Connected Hybrid Design Study

The Series-Connected Hybrid concept departs from traditional hybrid design in that the superconducting outsert is connected electrically in series with the resistive insert. This feature constrains the design in that the windings of the superconducting outsert must be designed to operate at the higher currents typically used in resistive magnet designs. There are, however, important advantages to this configuration, for example:

- The higher inductance derived by connecting the insert and outsert in series helps to reduce current ripple and noise,
- The power requirement at full field can be significantly reduced (typically to a value in the range of one-third to one-fifth that of a fully resistive design, depending on the field level and uniformity requirements), and
- Some off-normal and fault scenarios that drive the design of the outsert of a conventional hybrid are significantly ameliorated.

Properly designed, a system incorporating these features can be expected to be significantly less expensive to build than a conventional hybrid system and significantly less expensive to operate than a conventional resistive system. The objective of this study is to quantify these expectations by:

- Producing a conceptual design of a series-connected hybrid system aimed at satisfying a specific set of user requirements,
- Assessing whether such a system can be a cost-effective solution to those requirements, and
- Carrying out development on key enabling technologies that are crucial to assumptions in the conceptual design and cost studies (e.g., 20-kA class HTS current leads operating with one-half or less the refrigeration requirement of conventional leads).

4. 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 NHMFL In-House Research Program (IHRP) seeks to achieve these objectives through funded research projects of normally one- to two-year durations 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 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 and Review

The 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. 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, (2) intrinsic merit of the research, (3) utility or relevance of the research to the NHMFL mission, and (4) effect on the infrastructure of high-magnetic field science and engineering. Funded projects must be of the highest quality and will be reviewed using a three-part review process. These review steps are:

1. Initial review by the NHMFL Research Program Committee. As determined by the Director of the In-House Research Programs, the members of this internal review committee may be augmented by additional investigators in order to assure 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 shall be chosen by the Director of the In-House Research Programs in consultation with the Research Program Committee. The external reviewers shall 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, shall make the final funding decisions based upon the internal and external review reports.

The present membership of the NHMFL Research Program Committee is: Louis-Claude Brunel, Timothy Cross, Zachary Fisk, Lev Gor'kov, Alan Marshall, and Stephan von Molnár (FSU); John Graybeal, Kevin Ingersent, and Thomas Mareci (UF); Alan Bishop, Chris Hammel, and Joe Thompson (LANL). Funded projects will be periodically reviewed and continuation of funding will depend upon adequate performance. The PI(s) of funded projects must file a progress report to the NHMFL Director of the In-House Research Programs every six months for the duration of funding. A final report must also be provided at the end of the funded period. Detailed grievance procedures have been established for the review process, and have been approved by the NSF. In accord with NSF policy, individuals may grieve the handling of their proposal but not the content of the reviewer reports. Grievances are to be handled by the NHMFL Director and Executive Committee.

1996 Solicitation - Review Process

The first NHMFL In-House Research Program solicitation was released on May 10, 1996, following verbal approval from the National Science Foundation. Formal NSF approval to proceed with the program was received in late 1996. A total of 67 proposals were submitted by the proposal submission deadline of August 16, 1996. The proposals spanned a very significant intellectual breadth, consistent with the intentions of the NHMFL. Their approximate breakdown by area is: magnetic resonance (non-physics) - 30 proposals; condensed matter physics - 27 proposals; and materials science & engineering - 10 proposals.

An internal review of the submitted proposals was performed by the NHMFL Research Program Committee (RPC), in conjunction with internal researchers (i.e., FSU, UF, LANL) as deemed appropriate by the committee. Reviewer selection criteria were: (1) reviewers must be highly qualified in the proposal's stated research area, and (2) reviewers must not have a conflict of interest or close association with proposal PI or collaborators. Reviewer identities were held strictly confidential. RPC members abstained from involvement on their own proposals. A total of 125 internal reviewer reports were received, an average of 1.9 reports per proposal. Based upon the reviews received, designated RPC program managers in the areas of physics, magnetic resonance, and materials & engineering made the final internal review decisions.

Of the 67 proposals submitted, the 38 proposals were forwarded to external review. The remaining 29 proposals were returned to their respective PIs together with a copy of the referee reports. A detailed external peer review was performed by mail, with external reviewers chosen by the IHRP Director in consultation with the Chief Scientist and members of the RPC. When a conflict of interest arose involving the IHRP Director, reviewer selection was performed by the NHMFL Chief Scientist. Reviewer selection was based upon the following criteria: (1) reviewers must be highly distinguished leaders in their respective fields, and (2) reviewers must have an absence of conflict of interest or close association with the proposal PI(s). External reviewer identities were held strictly confidential. Again, two reviews were sought for each proposal. Each reviewer received a copy of the proposal, a description of the IHRP goals and criteria, plus a reviewer rating form. In all, 63 reviews were received from 26 reviewers, an average of 1.7 reviews per proposal and 2.4 reports per reviewer. Final funding decisions were determined by the NHMFL Chief Scientist based upon the external peer review reports, and were announced in January, 1997.

1996 Solicitation - Funded Projects

Project abstracts (excerpted from the proposals) are provided below, together with their internal and external collaborators, and the project funding level. Funds for these projects were officially released to the investigators during the period of April-May, 1997. Accordingly, their first 6-month progress reports are due in October, 1997.

Project Title: "Experimental & Theoretical Aspects of Quasi-3D Quantum Hall Systems"
Lead PI: James Brooks (FSU - Physics)
External Collaborators: Z. Wang (Boston College); J. Simmons (Sandia); R.G. Clark, B. Kane, A. Dzurak (U. New South Wales)
Funding: $86,185 over 2 years

This project will investigate both experimentally and theoretically the low temperature, high magnetic field transport properties of quasi-3D electronic materials. The regime of physical interest to us is where the individual layer of two dimensional electron gas (2DEG) exhibits the quantum Hall effect (QHE) in isolation, a large number of layers are coupled, and the tunneling strength between the layers may be varied. We propose to carry out systematic temperature and magnetic field dependent transport measurements on GaAs/GaAlAs superlattice structures of variable layer number, interlayer coupling, and carrier concentration where the integer QHE reaches the quantum limit by 30 tesla. We further propose to vary the interlayer coupling of individual samples over significant ranges by uniaxial stress. The proposed work will bring together the expertise of three principals, Brooks (experiment), Wang (theory), and Simmons (materials), and collaborators from the University of New South Wales, Sydney (and the facilities of the Semiconductor Nanofabrication Laboratory at UNSW). The project will provide on completion a uniaxial stress probe for general use at the NHMFL.

Project Title: "Development of a High Frequency Short-Pulse Gyrotron for Pulsed EPR"
Lead PI: Louis-Claude Brunel (FSU - CIMAR)
Internal Collaborators: A. Angerhofer (UF); J. Krzystek, P. Fajer (FSU)
External Collaborators: M. Read (Physical Science Inc.); G. Nusinovich (Maryland); S. Selier (Almes Associates)
Funding: $79,491 for 1 year

The project's goal is to determine the feasibility of a gyrotron as a source for a short pulse, high frequency Electron Paramagnetic Resonance (EPR) spectrometer. It is driven by the need to perform EPR measurements at higher magnetic fields and with shorter pulses (to observe over wider bandwidths). The program will include the design of a gyrotron producing radiation in multiple frequencies between 150 GHz and 600 GHz, with power levels of about 1 kW. The pulse width will be between 1 - 10 ns. The capacity to produce a train of at least 3 pulses, with spacing varying from 1 - 20 ns will be included. The development of such a gyrotron is extremely relevant to the NHMFL In-House Research Program Objectives. This project is being carried out in collaboration with scientists from three universities and two private companies. The EPR spectrometer we envision to build will be unique in the world and will be eventually installed as a new user facility at the NHMFL.

Project Title: "Study of Spin Gapped Quasi-One-Dimensional Compounds Using ESR Techniques and Numerical Simulations"
Lead PI: Elbio Dagotto (FSU - Physics)
Internal Collaborators: L.C. Brunel, G. Cao, J. Crow, A. Moreo (FSU); M. Meisel (UF)
External Collaborators: L. Lévy (Grenoble); D. Pohlblanc (Toulouse); J. Riera (Argentina)
Funding: $138,061 over 2 years

Research on recently synthesized quasi-one-dimensional inorganic compounds that have a spin gap in their spectrum is proposed. These materials include $CuGeO_3$ with spin Peierls behavior, as well as $Y_{2-x}Ca_xBaNiO_5$, $(VO)_2P_2O_7$, $SrCu_2O_3$ and others where their spin gap is induced by purely quantum mechanical (QM) effects. It is expected that this proposal, which includes experimentalists and theorists from FSU, UF and abroad, will foster greater understanding of the characteristics of magnetic excitations in these systems and their behavior in the presence of large magnetic fields. The influence of Zn-doping on these spin-gapped compounds will also be studied. End-chain state in Haldane systems will be investigated. The project utilizes the high field facilities to explore the field dependence of QM ground states and enhances the electron spin resonance (ESR) facilities at the NHMFL. Expertise to interpret the ESR spectra of many-body systems will be achieved through the analysis of quantum mechanical models for the compounds under study. The phase diagram with and without intense magnetic fields and Zn impurities will be calculated using a variety of numerical techniques. The PI and collaborators have common interests and complementary expertise in the subject of this project.

Project Title: "High-Resolution Solid-State NMR Techniques & Applications to Materials Science"
Lead PI: Naresh Dalal (FSU - Chemistry)
Internal Collaborators: R. Fu (FSU)
External Collaborators: G. Bodenhausen (Ecole Normale Superieure)
Funding: $109,070 over 2 years

It has been reported for NMR spectroscopy and imaging of solid, nonrubbery organics, that higher Zeeman fields B_0 may not substantially improve (and may even degrade) resolution. If true, this would deter future development of high field NMR of solids. This proposal addresses several questions in this regard. We will develop new experimental and theoretical methodologies for enhancing the resolution of NMR as applied to anisotropic solids (liquid crystals, single crystals and powders), especially at high B_0. The nuclei that will be selected, including protons, ^{13}C and ^{31}P, and quadrupolar nuclei with half-integer spins such as ^{17}O, ^{39}K, and ^{85}Rb, should provide complementary information on the role of different sites in cooperative phenomena. Proton NMR studies are important because obtaining high resolution NMR spectra of protons is a key challenge of solid state NMR. The chief cause of broadening is strong dipole-dipole interaction between the (usually abundant) protons. An attractive approach is to dilute the protons by partial deuteration, so that the homonuclear interactions between protons are weakened, while the heteronuclear dipolar interactions can be removed by deuterium decoupling. For this purpose, we will extend the scope of our PAD and CHIRP-95 decoupling techniques. Our preliminary results indicate that the resolution enhancement obtained in this manner improves at higher fields. For quadrupolar nuclei with half-integer spins, the signal from the central transition is to first order independent of the quadrupolar interaction and thus best studied at high fields where the sensitivity is most favorable. However, even at very high fields, the signal is broadened by the second-order quadrupolar interaction. Recently a novel multi-quantum (MQ) technique has been introduced whose only significant investment is a high-speed spinning probe. We will develop new pulse sequences to efficiently excite MQ coherences and to separate the isotropic chemical shifts from the second-order quadrupolar shifts. Methods for obtaining high-resolution spectra will be extended to variable-temperature solid-state NMR measurements and NMR applications to materials science, in particular to structural and dynamics studies of solids in the vicinity of co-operative phase transitions. We expect that these investigations will lead to significant improvements in high resolution NMR techniques in solids, and in turn, point to the benefits of employing high fields.

Project Title: "Doped Hole Physics in Single-Layer Perovskite"
Lead PI: Zachary Fisk (FSU - Physics)
Internal Collaborators: J. Sarrao (LANL), P.C. Hammel (LANL), J.M. Graybeal (UF)
External Collaborators: S.B. Oseroff (San Diego State)
Funding: $138,194 over 2 years

Sr- and Li-doped La_2NiO_4 will be studied using optical transmission and reflection measurements, NMR, and EPR, utilizing the high magnetic fields available at the NHMFL. The study will compare the physical changes resulting from out-of-plane doping with those due to in-plane hole doping in La_2NiO_4, as well as with the companion La_2CuO_4 systems. The rapid evolution of magnetic and electronic properties with doping is important both to the high-T_c superconductivity problem and the much more general understanding of oxide materials. The reduced scale of J in the nickelates makes measurements in high magnetic fields an important extra dimension in the study of the layered perovskites.

Project Title: "Applications of Magnetic Resonance Imaging Velocimetry to Flow in Media & Fiber/Composite Manufacturing"
Lead PI: Stephen Gibbs (FSU - Chem. Eng.)
Internal Collaborators: K. Han, C. Zhang, A. Deshmukh, B. Wang (FSU)
Funding: $141,543 over 2 years

This project will investigate and model fluid behaviors at the interface or boundary layer between a channel flow (bulk liquid) and a flow through a porous media. Many investigations show that the boundary layers of a porous material block dominate the mass and energy exchange with the environment. Numerous models describing the flow profiles at the boundary layers have been proposed, however a reliable measurement has not been found to validate them. Flow in porous media is important in a wide variety of disciplines and applications, although the specific emphasis of this project will emphasize fiber composite manufacturing applications. Traditional flow measurement techniques (x-ray, optical, ultrasound, hot wire, dye,...) have important limitations. Hence high-field NMR imaging, with its ability to penetrate dielectric materials and its fine spatial resolution, represents a unique technique for this task. In this project, NMR flow imaging will be used to measure velocity fields in a simple model geometry, a tube with a concentric ring made of a fiber preform, thus making an annular space with a permeable inner core and an impermeable outer wall. In this way a Poiseuille flow with and without possible slip boundary conditions at the interface can be easily generated. The relationship between the velocity at the interface and the porous material characteristics such as permeability, porosity, pore size, anisotropy, and relate orientation of the porous medium and the flow field will be determined. Based upon our results, current models to describe the slip boundary will be tested and a simplified model will be developed. In addition, in-house facilities and capabilities for NMR flow imaging and study of flow through porous media will be developed.

Project Title: "NMR Studies of Superconducting and Magnetic Cuprates and Low Dimensional Electron Systems at High Magnetic Fields"
Lead PI: William G. Moulton (FSU - Physics)
Internal Collaborators: P. Kuhns, A. Kleinhammes, J. Crow, G. Cao, J.S. Brooks (FSU)
External Collaborators: W.P. Halperin (Northwestern), W.G. Clark (UCLA)
Funding: $73,045 over 2 years

This project will investigate the fundamental nature of the correlations (spin and charge, and the interplay between magnetism and superconductivity) in highly correlated electron systems and low dimensional magnetic systems in high magnetic fields. The systems proposed for study include ^{157}Tb NMR in Tb doped $YBa_2Cu_3O_7$. This will help to understand the important questions of why, unlike Ce or Pr which also have mixed-valent substituting for the RE, Tb doping does not decrease T_c. ^{17}O NMR studies of the flux melting transition at high fields in $YBa_2Cu_3O_7$ will carry these investigations to fields where other microprobes become ineffective. Studies in previously little understood field induced spin density waves in low dimensional organic conductors by ^{77}Se NMR will also be carried out. Experiments will be performed in the "Florida Bitter" magnet with homogeneity of 5 ppm/mm DSV at 25 T, a unique facility for high-field NMR which became operational in September 1995.

Project Title: "Materials Processing in Magnetic Fields: High-Strength Polymers"
Lead PI: Elliot Douglas (UF - Matls. Sci. & Eng.)
Internal Collaborators: B.C. Benicewicz (LANL)
External Collaborators: J.D. Earls (Dow Chemical)
Funding: $112,819 over 2 years

High magnetic fields hold great promise for materials processing, leading to new materials that cannot be obtained by other techniques. In particular, orientation of liquid crystalline polymers using high magnetic fields holds tremendous potential for creating high strength materials without the use of fillers or complex fabrication techniques. It is well known that magnetic fields can orient crystalline polymers, and a few studies have examined the physical properties of magnetically processed polymers which indicate that substantial improvements in properties are achievable. However, all studies to date have resulted in uniaxially aligned materials, with properties perpendicular to the field direction that are inferior to those in the parallel direction. For practical applications, a way must be found to create reinforcement in multiple directions. To create multidimensional reinforcement using high magnetic fields, we will utilize a novel approach using blends of an unreacted liquid crystalline thermoset (LCT) and a B-staged (partially reacted) LCT. The reinforcement approach is a two-step process. In the first step, a flow field is used to orient the B-staged resin. In the second, a magnetic field is applied perpendicular to the flow direction. Since the orientation kinetics for the B-staged resin are significantly slower than for the unreacted resin, the unreacted thermoset will be oriented perpendicular to the orientation of the B-staged resin. Complete reaction of both resins then locks in the biaxial orientation induced by this process. As a number of variables can affect this process, this study will systematically examine the effects of the extent of B-staging, the mixing process, the magnetic field strength, and the processing time in field. Scattering, thermal expansion measurements and mechanical property measurements will be used to characterize the orientation process. Successful demonstration of this technique will provide new opportunities for the use of high magnetic fields in materials processing.

Project Title: "Novel Syntheses and Fourier Transform Mass Spectrometric Analyses of Combinatorial Libraries"
Lead PIs John Eyler and Steven Benner (UF - Chemistry)
Internal Collaborators: C.H. Watson (UF)
Funding: $148,897 over 2 years

A collaborative research project that combines novel syntheses of combinatorial libraries with mass spectrometric analyses utilizing high field magnets at the NHMFL is proposed. Successful completion of the proposed research will demonstrate new methods for synthesizing combinatorial libraries and identify promising "lead" compounds for interaction with HIV reverse transcriptase, which participates in the first stages of the infection that causes AIDS, and different varieties of SH2-domains, which are involved in intracellular signal transduction pathways and, therefore, of crucial interest to cancer research. Of equal importance will be the establishment of high field Fourier transform ion cyclotron resonance (FTICR) mass spectrometry as the analytical method of choice for assessing the degeneracy and diversity of newly-synthesized combinatorial libraries, as well as for identifying the masses and structures of favored "lead" compounds from these libraries which bind preferentially to receptors of biochemical and pharmaceutical interest.

In addition to conventional bead-bound library syntheses of small peptide libraries to aid in the implementation of FTICR analysis methods, Receptor Assisted Combinatorial Synthesis (RACS) will be developed and exploited to produce complete libraries of compounds for screening. Both the high mass resolution of the extremely high field FTICR mass spectrometers at the NHMFL, and the ability to carry out collisionally-activated dissociation, photodissociation, and selective ion/molecule reactions to determine ion structure will be exploited and further refined when characterizing the combinatorial libraries and identifying lead compounds.
The proposed experiments will demonstrate the applicability of NHMFL instrumentation and techniques to the solution of an entirely new class of problems for an entirely new clientele (e.g., biochemists and pharmaceutical chemists) which differs significantly from currently making most use of the NHMFL facility (physicists and chemists). In addition, compounds that may be quite important in AIDS and cancer research should be identified from "lead" compounds produced by RACS synthesis of combinatorial libraries.

Project Title: "High Field, High Frequency RF Coils for NMR Spectroscopy and Microscopy of Small Samples"
Lead PI: Thomas Mareci (UF - Biochemistry, Center for Structural Biology)
Internal Collaborators: S.J. Blackband (UF)
External Collaborators: A. Webb (Illinois, Champaign-Urbana)
Funding: $51,487 over 1 year

The overall goal of this project is to construct and optimize a range of small diameter (0.15-1.5 mm) volume radio-frequency (RF) coils for NMR spectroscopy and microscopy at 300, 500, 600, 720, 850 and 1000 MHz (magnetic fields of 7 to 25 T) in order to maximize the available signal-to-noise ratio (SNR) of higher resolution studies (both spectral and spatial) on small samples. Theoretical and practical design considerations will be explored, in particular the SNR, susceptibility effects, and the limitations imposed at high frequencies as the self resonant frequency of the coils is reached. The impact of tuning some of the coils to multiple frequencies will also be explored. The final objective will be to make a range of general purpose robust coils available to outside users of the NHMFL, and to provide the resources and expertise to construct dedicated submillimeter coils for specialized applications.

Project Title: "Comparing Magnetic Langmuir-Blodgett Films to their Isostructural Solid-State Analogs Using Antiferromagnetic Resonance"
Lead PI: Daniel Talham (UF - Chemistry)
Internal Collaborators: M. Meisel (UF), L.C. Brunel, J. Krzystek (FSU)
External Collaborators: P. Day (Royal Inst., Great Britain)
Funding: $116,136 over 2 years

This project will utilize antiferromagnetic resonance (AFMR) to investigate the ordered state of the first known examples of magnetic Langmuir-Blodgett (LB) films. As part of the investigation, a series of isostructural powder and single crystal solid-state analogs of the LB films will also be studied, in order to compare the magnetic behavior in the solids to that of the two-dimensional LB films. Magnetic interactions in layered materials are currently of high interest from a fundamental point of view, partially because of their relationship to layered superconductors. Magnetic thin films are also of interest as potential information storage media and as components of multilayered heterostructures, which have lead to unusual phenomena such as giant magnetoresistance. The chemistry group at UF has recently developed LB films of manganese octadecylphosphonate and demonstrated that these films undergo a transition to long-range magnetic order at 13.5 K, exhibiting a spontaneous magnetization characteristic of a canted antiferromagnet. These results are the first demonstration of cooperative ordering phenomena in LB films. The LB films are isostructural with a series of layered organic/inorganic solid-state manganese phosphonates, which are also canted antiferromagnets. The project will use AFMR to investigate three solid-state manganese salts, the phenylphosphonate, $Mn(O_3PC_6H_5)\text{-}H_2O$, the propylphosphonate, $Mn(O_3PC_3H_7)\text{-}H_2O$, and the purely inorganic analog, $KMnPO_4\text{-}H_2O$, in addition to two LB film materials, manganese octadecylphosphonate and manganese octadecoxyphenylphosphonate which are the corresponding LB analogs of the manganese propylphosphonate and phenylphosphonate solids, respectively. Since the LB films are single layer analogs of the solid-state manganese phosphonates, they offer a unique opportunity to explore the ordered state of a truly two-dimensional magnetic lattice and to compare the behavior to the isostructural solids. The proposed project is a collaborative effort between the solid-state chemistry group at UF and the high-field EPR group at the NHMFL.

Project Title: "High Field Optical Studies of Highly Correlated Metals"
Lead PI: David Tanner (UF - Physics)
Internal Collaborators: J. Reynolds (UF)
External Collaborators: T. Timusk (McMaster), J.T. Markert (Texas), M. Onellion (Wisconsin), K. Kamarás (SZFKI, Budapest), Wolf (Karlsruhe), Berger (Lausanne)
Funding: $141,634 over 2 years

Infrared measurements on a variety of highly correlated metals will be carried out at the NHMFL. The materials to be studied include cuprate superconductors, cuprate antiferromagnetic insulators, organic conductors, and heavy-Fermion metals. In addition, an improved detector cryostat would be constructed, allowing transmission and reflection studies in fields up to 30 T and at temperatures between 4 and 300 K.

Project Title: "Very High Magnetic Field NMR Studies of the Cuprate Spin Gap"
Lead PI: P. Chris Hammel (LANL - MST-10)
Internal Collaborators: Z. Fisk, W. Moulton (FSU)
External Collaborators: C. Pennington, J.A. Martindale (Ohio State)
Funding: $143,759 over 2 years

Experimental tests of various theories of the origin of the spin gap in the high-T_c cuprates shall be carried out using NOR studies performed in very high magnetic fields. Both the static uniform susceptibility and the dynamical spin susceptibility of underdoped cuprates are strongly suppressed with increasing temperature as shown by reductions of the Knight shift and $(T_1T)^{-1}$. ARPES measurements have shown that electronic excitations near the Fermi surface are also gapped in underdoped cuprates. Commonly referred to as the "spin-gap," this phenomena has been the subject of a great deal of study, both experimental and theoretical. It is now clear that the spin gap is a dominant feature of the normal state of the underdoped cuprates, and a full understanding of these materials is contingent upon a knowledge of the microscopic origin of the spin gap. It is further likely that the physics leading to the spin gap plays a crucial role in the mechanism responsible for superconductivity. Obtaining an improved understanding of this phenomenon is thus a matter of central importance.

There will be three specific objectives in the proposed work. First, we hope to determine whether the spin gap temperature scale is most closely related to the superconducting T_c. or tied to a normal state energy scale. Second, we seek to determine if a spin gap exists in the single layer compounds such as $La_{2-x}Sr_xCuO_4$ independent of superconductivity. Third, we seek to clarify the relationship between the normal state transport and the AF spin fluctuations. This project will exploit the 24 T resistive NMR magnet at the NHMFL and will improve development of an NMR probe appropriate to performing NMR in that magnet, software for measuring the nuclear spin relaxation rates and technique development in general.

Project Title: "Heat Capacity Measurements in NHMFL 60 Tesla Quasi-Continuous Magnet"
Lead PI: Roman Movshovich (LANL - MST-10)
Internal Collaborators: G.R. Stewart (UF)
External Collaborators: W.P. Beyerman (UC Riverside)
Funding: $127,860 over 2 years

This project is centered on developing heat capacity measurements in NHMFL 60 T quasi-continuous magnet and using this capability to study several correlated electron systems. Two compounds to be investigated are high temperature superconductor $La_{2-x}Sr_xCuO_4$ and Kondo insulator $Ce_3Bi_4Pt_3$, both of which have shown interesting behavior in resistivity in the pulsed fields of up to 60 Tesla. The project will contribute to general understanding of the high temperature superconductors and Kondo insulators. It will also result in the heat capacity measurements in pulsed magnetic fields. There is a great potential for this new and powerful tool in investigating a wide variety of systems such as high-T_c superconductors, Kondo insulators and various other f-electron systems, organics, metamagnetics, and many others. Successful completion of this project will serve as a basis for advancing NHMFL facilities and introduction of heat capacity in pulsed magnetic field as a tool available for NHMFL users.

Project Title: "Time-Resolved Photoluminescence Studies of Semiconductor Heterostructures in Ultra-High Magnetic Fields"
Lead PI: Dwight Rickel (LANL - DX)
External Collaborators: C.H. Perry (Northeastern)
Funding: $128,390 over 2 years

The intent of this project is to install a gatable photon counting system to study time-resolved magnetophoto-luminescence from semiconductor heterostructures. The facility will be incorporated into the current laser-spectroscopy lab previously established in pulsed and dc magnetic fields at LANL by the principal investigators and co-workers. The instrumentation development and its implementation is planned to coincide closely with the introduction of the 60T quasi-continuous magnet due to come on-line in the near future and to be a proven asset when the 100T project is complete.

The research component has the potential for providing significant information of the optical properties of newly developed and higher quality electronic materials. Attention will be focused on studies of electron-electron interactions in confined semiconductor heterostructures subjected to intense magnetic fields. Specifically, the photoluminescence decay dynamics (lifetimes) of interband Landau transitions and magneto-excitons will be examined. Collaborative programs with others have been established to probe many novel magnetic properties associated with correlated electron interactions. It is anticipated that when the time-resolved instrumentation is operational, it will encourage more potential users of the NHMFL spectroscopic facilities.

1997 IHRP Solicitation - Present Status

The second IHRP proposal solicitation was released in January, 1997, with a proposal deadline of April 7, 1997. A total of 28 proposals were submitted, whose breakdown by area is: magnetic resonance (non-physics) - 10 proposals; condensed matter physics - 10 proposals; and materials science & engineering - 8 proposals.

An internal review of the submitted proposals was performed by RPC as before. The total number of internal reviewer reports received totaled 51, an average of 1.8 reports per proposal. Of the 28 proposals submitted, the RPC forwarded 15 proposals to external review. Their breakdown by area is magnetic resonance (non-physics) - 6 proposals; condensed matter physics - 7 proposals; and materials science & engineering - 2 proposals. External review reports are due by July 28, 1997. The total number of internal reviewer reports (when received) will total 29, an average of 1.9 reports per proposal. Barring late reviews, the announcement of the final funding decisions is scheduled for late August 1997.

1998 IHRP Solicitation - Present Plans

The third IHRP solicitation is planned for release this November, 1997.

5. Education Programs

Undergraduate, high school, and middle school students and teachers were abundant in the laboratory this summer, performing research that will result in a publication, developing a CD-ROM on magnetism, building computers, and levitating frogs for a Discovery Channel film crew. Educational outreach activities have expanded and matured significantly under the direction of a science educator this last year. In just seven months, 8,200 students in grades K-12 have participated in lectures and demonstrations on science and magnetism at the laboratory or in their classrooms. Another 2,000 students have toured the laboratory, as well as 400 individuals from the general public. With these types of numbers, nearly every NHMFL employee participates in outreach activities, and their continuing support and enthusiasm is refreshing. The following describes some of the highlights of these activities at all educational levels.

- *MagLab: Alpha.* Although the principles of magnetism intrigue and challenge many young minds, we have found that many of the instructional units are lacking in quality. With the second year of grant support from the Florida Department of Education, the NHMFL has just released a curriculum package on magnetism that includes reusable hands-on demonstrations, a teacher's manual, and a complementary CD-ROM, for middle school students to explore magnetism. The CD-ROM was created by a dozen high school students working with their science and art teachers in the NHMFL multimedia resource lab this summer. The first 200 of these educational units will be distributed to Florida middle schools with a training workshop conducted by the NHMFL. Negotiations are underway to market nationwide the instructional unit, *MagLab: Alpha—EdVentures in Science. MagLab: Alpha* also will be showcased in December at the National Science Teachers Association meeting in Nashville.
- *The NHMFL education web site has a new link, "Ask an Expert,"* developed by several local high school students. Students of all ages and from around the world have asked questions of in-house scientists and experts. Lately there has been considerable interest in how magnetic fields influence plant growth. As part of this web site, the NHMFL now has the first phase of a virtual tour available (*http://k12.magnet.fsu/tour)*. This tour allows visitors to explore the various research areas of the NHMFL.
- *For the third consecutive year, twenty-four gifted middle school students from Tallahassee presented the results of their semester-long research* to a packed audience that included their fourteen NHMFL mentors, parents, and local media. The students' research encompassed a wide range of activities including determining the lowest temperature limits of a standard helium-3 cryostat; testing superconducting tape for winding high temperature superconductor magnets; and designing architecturally interesting houses using computer-aided design (CAD) programs. As one parent related, "My daughter entered the program hesitantly, but after the first week she was so enthralled that she is now considering a career in computers or science."
- *The NHMFL participated again this summer in the NSF National Chautauqua Short Course Program for undergraduate college science teachers.* The course entitled "Who Needs Magnetic Fields" provided participants with the choice of three subtopics: Physics, Engineering, and Biology & Chemistry. The college teachers conducted a research project in an NHMFL laboratory, interacted and discussed research with top laboratory scientists, and examined and developed strategies that incorporated these new understandings into their curriculum.
- *The Fifth Annual Minority/Women Research Internship Program has just concluded* with eighteen undergraduate students, most of them female, participating in research projects under the direction of NHMFL scientists. One of the intern's research in condensed matter physics will result in a published paper. One of last summer's students recently wrote to her mentor: "In great part, thanks to the opportunity given to me last summer and your letter of recommendation, I have been accepted in a Ph.D. program at the University of Delaware and am currently working on my own research project here at Argonne National Lab. The summer internship last year helped me a great deal in building my own picture of the physics field and deciding on the direction in which I would like to continue to pursue in my career."
- *Every October, in recognition of the dedication of the NHMFL in 1994, the laboratory hosts an Open House for the general public.* A record number of 1,600 guests experienced a self-guided tour of the facility in 1996. Throughout the laboratory there are

numerous science-related activities and demonstrations, such as making your voice print in the Electronics Shop, making ice cream with liquid nitrogen in the Cryogenics Lab, shooting caps five feet into the air using the energy created by a magnetic field, and learning how contaminants get into well water as they dissipate through the soil. The 1997 Open House will begin with a 5 K walk and jog around Innovation Park, with a popular local radio station broadcasting from the laboratory.

- *In the first half of 1997, the Educational Outreach Program challenged over 8,000 students to "look, think, ask, and solve," as they explore the magnetic world around them through science.* This program brings the science and resources of the laboratory to schools throughout the state of Florida and has been presented at the new Orlando Science Museum. The program includes a series of presentations and workshops, such as "What Does a Scientist Do?," "Magnets—What's the Attraction?," and "What's a Matter—Molecules, Resistance, and Superconductivity."
- *The NHMFL sponsored a local three-county competition for two high school students* to spend the summer working with NHMFL researchers and earn a scholarship. One student worked on high temperature superconductors and the other conducted research using the electron microscope and was able to examine a meteorite from Mars on loan from NASA. Five middle school students spent the summer working on various NHMFL web sites and learned how to build computers.
- *The Educational Resource Laboratory with its multimedia development equipment, manipulative development equipment, curriculum materials, and instructional resources is a popular facility for regional educators and students.* Students and teachers from local "critical needs" elementary schools created tutorial programs for other students at their schools. Other students created quicktime movies and video clips for use in the NHMFL tour program.
- *In cooperation with Florida A&M University, the NHMFL hosted several high school students this summer selected by the NASA Sharp Plus Apprenticeship Program.* This research-based mentorship program sets high academic standards and seeks to increase the participation and success rates of talented students who are underrepresented in challenging mathematics and science courses at the pre-college level.
- *The laboratory continues its cooperative programs with several regional vocational and technical schools.* The students rotate through the NHMFL on a regular basis and work in various Operations and Facilities sections, including electrical and the engineering group that utilizes AutoCad.

6. Collaborations: Industrial, Inter-Agency, and International Programs

Collaborations, partnerships, and outreach programs are a natural extension of the NHMFL, considering that the laboratory was conceived and developed on the basis of a strong federal/state partnership combined with unique inter-agency and intra-state collaborations. A collaborative culture has developed within the NHMFL that is evidenced by the increasing number of private sector companies and other organizations that have contacted the laboratory for its expertise and partnering on proposals. The laboratory is perhaps most pleased, however, that a recent collaboration with EURUS Technologies, Inc., resulted in that company moving its headquarters to Innovation Park, Tallahassee, across the street from the NHMFL. More information on EURUS is provided below.

The laboratory has found workshops and conferences to be important vehicles to develop relationships with industry and other institutions. After all, the collaboration with EURUS began at an industry workshop held at the NHMFL. In October, 1996, the University of Florida Physics Department, in cooperation with the NHMFL, held a small workshop on *Properties of Molecules in Strong Magnetic Fields*. The workshop focused on the calculation and measurement of various properties of molecules in ultra high magnetic fields, particularly 100 T and above. The proceedings will be referred and published in an issue of the *International Journal of Quantum Chemistry*. In January, 1997, the University of Florida and the NHMFL honored Raymond Andrew on the occasion of his 75th anniversary in recognition of his many far-reaching contributions to magnetic resonance, solid state physics, and magnetic resonance imaging. Rightfully, the international leaders in these fields gathered in Gainesville to participate in Dr. Andrew's celebration. In response to the continued rapid growth and interest in mass spectrometry and Fourier Transform-Ion Cyclotron Resonance mass spectrometry, the first North American FT-ICR was held at the NHMFL in March, 1997. Over 110 attendees, representing industry, academia, and national laboratories participated in two days of invited oral and poster presentations.

Later this fall, 1997, the NHMFL will organize and host a workshop at the urging of the private sector and the Department of Navy to explore the technological and engineering research that will be needed to advance the next generation of high speed ferry and ship transport with large freight capacity at speeds in excess of 60 miles per hour. The NHMFL also will host a workshop on *Physics of Manganites, Ruthenates, and Related Materials*; and the *8th U.S.-Japan Workshop on High-Tc Superconductors*. In Gainesville this fall, the University of Florida with host the *29th Annual Southeastern Magnetic Resonance Conference*—the 27th SEMRC was held in Tallahassee in 1995. Planning is well underway for two large conferences that the NHMFL will host in 1998: the *8th International Conference on Megagauss Magnetic Field Generation and Related Topics* and *Physical Phenomena at High Magnetic Fields-III.*

During the past several months, there has been a flurry of activity with industry that will result in submitted proposals or groundbreaking workshops. One proposal will be submitted to the Department of Energy to use the laboratory and its electrical substation as a demonstration site for a high temperature superconducting transmission line; this proposal involves private companies and electric utilities. A preproposal was submitted to the NSF to build the end-cap magnets for ATLAS at the LHC. We believe that the NHMFL's world-class capabilities to design, fabricate, and test very large magnet systems make it ideally suited to oversee this project with industry and other international laboratories.

The following are highlights of the past year's activities. A more comprehensive discussion may be found in the *1996 NHMFL Annual Report.*

- *EURUS Technologies, Inc.* The first company to locate near the NHMFL occurred in March, 1997, when EURUS Technologies consolidated operations in a new facility in Innovation Park, across the street from the laboratory. The NHMFL has provided EURUS with an R&D facility within the laboratory to encourage active collaborations between researchers at both organizations. EURUS produces and integrates high temperature superconducting technology into commercially viable products. The EURUS current leads are being tested at the NHMFL to improve performance.
- *Intermagnetics General Corp. (IGC), Latham, NY.* Collaborations on the design of the 45 T (tesla) Hybrid magnet already have resulted in unique and new manufacturing capabilities for the United States. IGC in cooperation with Gibson Tube developed a manufacturing process to produce world-record lengths of high quality superconducting cable-in-conduit conductors. IGC also had the primary responsibility, under the

direction of the NHMFL, for the coil winding and electrical joint fabrication. Presently, IGC is removing the coil forms of coils A and B, after which they will finalize the end structures and ship to the NHMFL for assembly into the outsert magnet vessel. This collaboration has increased U.S. competitiveness in large magnet systems, e.g., magnet systems responding to the need for the fusion program and superconducting magnetic energy storage devices.

- *Intermagnetics General Corp.* and the NHMFL are developing together a 900 MHz NMR magnet with an ultra wide bore. This high resolution NMR magnet will be the most advanced system worldwide. The ambitious magnet system is designed in such a way that it can be upgraded to 1 GHz and beyond by insert coils. IGC honors the technology transfer from NHMFL through a contribution of $1 million to the construction of the first prototype magnet. Market studies have shown a need for about ten systems per year. The collaboration will relocate the production of high-field, high-resolution NMR magnets and spectrometers to the United States.
- *Oxford Superconductor Technology, Cateret, NJ.* The NHMFL ΔB group recently completed fabrication and testing of a 1.2 T, 50 mm outer diameter, high temperature superconducting coil with a background field of 17 T. The coil uses conductor provided by OST and a sol-gel insulator process developed at the NHMFL. This coil is the highest field HTS insert coil produced in the United States.
- *Everson Electric, Allentown, PA.* Everson Electric and the NHMFL have jointly developed and implemented the insulation and impregnation procedures along with a comprehensive quality control system for the 33 double pancakes that will be used to fabricate coil C of the 45 T magnet. These double pancakes are cable-in-conduit conductors made from NbTi superconductors. To date, 23 of the 33 double pancakes have been successfully insulated and impregnated at Everson Electric and subsequently received at the NHMFL. This cooperation signifies another example of successful technology transfer from government laboratories to U.S. industry.
- *National Research Institute For Metals (NRIM), Tsukuba, Japan.* On April 23, the NHMFL successfully tested the 30 T magnet under contract for NRIM. The magnet is very similar to the NHMFL's own 30 T magnets but uses Cu-Ag sheet in the innermost coil instead of the Cu-Be, in order to be compatible with NRIM's power and cooling water supplies. Representatives from Toshiba Corporation were on hand for the testing to 30+ T and the magnet met all specifications.
- *National Pulse Magnet Laboratory, University of New South Wales, Sydney, Australia.* In May, the NHMFL Pulse Magnet Group completed the commissioning of two 50 T coils for this laboratory. The coils were redesigned by replacing the carbon composite outer reinforcement shell of the magnets with a custom machined steel shell. This new configuration has the advantage of reducing the cooling down time by 50 percent, thus allowing twice as many high field experiments per day.
- *Department of the Navy.* The NHMFL is the official test site for the superconducting magnetic energy storage (SMES) device developed by Westinghouse Corp. for the Navy. The Navy's contract with Westinghouse expired in late July, however, and the NHMFL is finishing those components of the SMES system before testing can be undertaken. The Navy is interested in using the laboratory's unique testing facilities and its engineering expertise in building large-scale magnet systems such as the 45 T hybrid magnet system. Upon completion of these tests, the Navy will leave behind their magnet-related equipment for use by the NHMFL as a large coil and conductor test facility.

7. 1998 BUDGET

Budget Background

The proposed budget for 1998 recognizes the limitations imposed by the NSF renewal grant award of $17.5 million per year. The five-year target budgets by department are summarized in the following table:

Table 7.1 Five-Year Budget Plan

			$(000)		
Function	**1996**	**1997**	**1998**	**1999**	**2000**
Director's Office	$600	$682	$685	$679	$693
Facilities & Administration	1,893	2,161	372	384	397
Instrumentation & Operations	3,106	3,990	4,128	4,236	4,357
Magnet Science & Technology	5,361	3,023	2,391	2,383	2,296
Science Program	1,227	1,647	1,818	2,015	2,016
Pulsed Field Program (Los Alamos)	1,809	2,258	2,348	2,441	2,540
CIMAR	62	77	90	92	95
High B/T and MRI (University of Florida)	237	178	215	291	300
Total Direct Costs	**$14,295**	**$14,016**	**$12,047**	**$12,521**	**$12694**
Indirect Costs	3,205	3,849	4,029	4,194	4,422
Program Total	**$17,500**	**$17,865**	**$16,076**	**$16,715**	**$17,116**

1996 Actual Expenditures

Actual versus budgeted direct costs for the first grant year are given in Table 7.2.

Table 7.2 1996 Cost Performance

Function	**1996 Budget**	**1996 Actual**	**Variance over/(under)**
Director's Office	$600	$236	($364)
Facilities & Administration	1,893	485	(1,408)
Instrumentation & Operations	3,106	2,768	(338)
Magnet Science & Technology	5,361	1972	(3,389)
Science Program	1,227	106	(1,121)
Pulsed Field Program (Los Alamos)	1,809	940	(869)
CIMAR	62	99	37
High B/T and MRI (University of Florida)	237	0	(237)
Total Direct Costs	**$14,295**	**$6,606**	**($7,689)**

The first year of the renewal—1996—was funded at the full $17.5 million rate for a period of ten months, which provided capital funds to cover needs in the magnet program. The under-expenditures that year are related to specific programs. The activities are as follows:

- **Facilities and Administration**. These were funds for the Los Alamos Pulsed power supplies that will be commissioned and paid for in 1997.
- **Instrumentation and Operations**. These are funds reserved for instrumentation that will be delivered in 1997.
- **Magnet Science and Technology**. These are funds for completion of the hybrid magnet (the superconducting outsert fabrication will be completed in 1997, the resistive insert in 1998); and the 900 MHz magnet cooperative development program and conductor purchase—the majority of these funds will be spent in 1997 and 1998.
- **Science Program**. The In-House Research Program (IHRP–see chapter 4) awards were not made until 1997 and many of the programs are over two years so expenditures will build up over 1997 and 1998 and beyond.
- **Pulsed Field Program**. A significant portion of the under-run was due to the use of funds left from the initial award being used for the first several months of operation, the balance is related to 60 T magnet work that will be done primarily in 1997. Some of the accumulated funds will be used for improved user facilities to be provided when the Pulsed Field Facility is moved to a new location in 1998.
- **High B/T Program**. The 1996 funds were not spent because the magnet system was not completed and delivered by the vendor. The magnet is now in place and the facility will be operational in 1998.

1997 Projected Expenditures

Projected expenditures for 1997 based on seven months of actual data (through July 1997) are presented in Table 7.3. The 1997 budget is the final budget approved by the NHMFL Executive Committee. It is based on, but differs slightly, from the budget presented in the 1996 Progress Report. The projected actual expenditures reflect spending against new funding budgeted. Committed funds carried forward from 1996 are not included in Table 7.3.

Table 7.3 1997 Cost Performance

Function	1997 Budget	1997 Proj. Actual	Variance over/(under)
Director's Office	$849	$203	($646)
Facilities & Administration	380	652	272
Instrumentation & Operations	3,973	3,210	(763)
Magnet Science & Technology	4,235	3,302	(933)
Science Program	1,676	86	(1,590)
Pulsed Field Program (Los Alamos)	2,195	2,089	(106)
CIMAR	72	111	39
High B/T and MRI (University of Florida)	102	50	(52)
Total Direct Costs	**$13,482**	**$9,703**	**($3,778)**

The primary reasons for the expenditure variations are enumerated below.

- **Director's Office**. The under-run reflects a non-expenditure of the director's reserve funds.
- **Facilities & Administration**. The over-expenditure represents the fact that personnel that are responsible for maintaining the magnet power supplies, cooling systems and related systems were not charged against indirect costs by FSU as originally intended.
- **Instrumentation and Operations**. The indicated under-run is due to reduced utility charges resulting from demand limits caused by transformer failures which limited operation to two power supplies and 25 MW demand for about five months.
- **Magnet Science and Technology**. The indicated under-run is due to slippage in schedules of Hybrid Magnet resistive insert and the 900 MHz magnet. These funds will be needed next year.
- **Science Program**. The awards for solicitations in 1997 have not been made. The awards from the 1996 solicitation were accomplished in the first half of 1997. The awards totaled $974K for the first year and $780K for the second year. The status of the Science Program awards is:

1996 Funds Available	$1,121K
1997 Funds Available	1,590K
Total Funds Available	$2,711K
1996 Solicitation Awards (two years)	1,754K
Available for New 1997 Awards	$957K

- **Pulsed Field Program (LANL).** This is essentially proceeding on budget.
- **CIMAR.** Temporary salaries, postdocs and graduate students, have increased during the year.
- **High B/T and MRI (UF).** The estimated under-expenditure is due to the later than expected start-up of the High B/T Facility.

Staffing Analysis

A summary of the staffing situation at the NHMFL is given in Table 7.4.

Table 7.4 Staffing Summary

	1996 Five Year Plan	1997 Five Year Plan	1997 Actual	1998 Five Year Plan	1998 Budget Plan
Director's Office	8	8	8	8	9
Facilities & Administration	2	2	10	2	10
Instrumentation & Operations	32	35	31	35	35
Magnet Science & Technology	36	35	35	35	35
Science Program	2	2	2	2	2
Pulsed Field Program (Los Alamos)	13.5	12.5	12.5	12.5	12.5
CIMAR	2	2	0	2	2
High B/T and MRI (University of Florida)	2	2	3	4	1
Total*	**97.5**	**98.5**	**101.5**	**100.5**	**106.5**

* Totals do not include summer interns (14).
1997 Actual Staffing is staff on board as of 7/31/97

Staffing has reached the levels planned in the five-year renewal budget. The 1998 budgeted increases in Facilities and Administration correspond to the actual levels resulting from FSU administration decisions to keep magnet power and cooling water systems maintenance personnel on the NSF grant budget rather than on indirect cost funds.

1998 Proposed Budget

The proposed budget by department is given in the attached table. Budget estimates are based on the following parameters:

Escalation	3% per year salaries in FL 3% per year expense in FL 3% 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). Science 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 expendable, office supplies, telephone reprographics, 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 and 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 Facilities.

The impact of the budgets by functional area follows.

- **Director's Office.** There are no new changes or initiatives in the Director's Office. We have allowed for one additional support person in K-12 activities.
- **Facilities & Administration.** We have added maintenance personnel for the magnet power supplies, cooling systems, and related facilities to the budget. We are not able to continue these functions under other funding sources. We have also added two persons in Educational Media in support of graphics activities related to publications, displays, and general laboratory promotion.
- **Instrumentation & Operations.** There are no significant changes in Instrumentation and Operations. We have taken into account cost savings that can be generated by shifting a portion of the machine shop to an auxiliary. The electric power budget has been increased to $1.8 million, a 13% increase over 1997. Figure 7.1 shows the electric power monthly bills. The trend appears to be flattening, however, that is probably due to the limitations on operation in the first half of 1997 due to the transformer problems. Two-magnet operation coupled with an increased demand for use of the magnets for NMR will increase both demand and energy charges.
- **Science Program.** The Science Program budget reflects the planned In-house Research Program awards and the cost of managing the solicitations, reviews, and awards.
- **Magnet Science & Technology.** The proposed budget reflects funding of the staff to continue to support the 900 MHz, Hybrid, and the 60 T quasi-continuous magnet programs. Capital costs for these programs have essentially been committed out of funds for 1996 and 1997. Small capital allowances are provided to support continued replacement coil activities for the resistive magnets and the small pulsed magnets. In addition, a small capital allowance has been provided to support initial studies of a series connected hybrid magnet, which could have several objectives: prototype for a 1.5 GHz NMR magnet or an energy saving general research magnet.

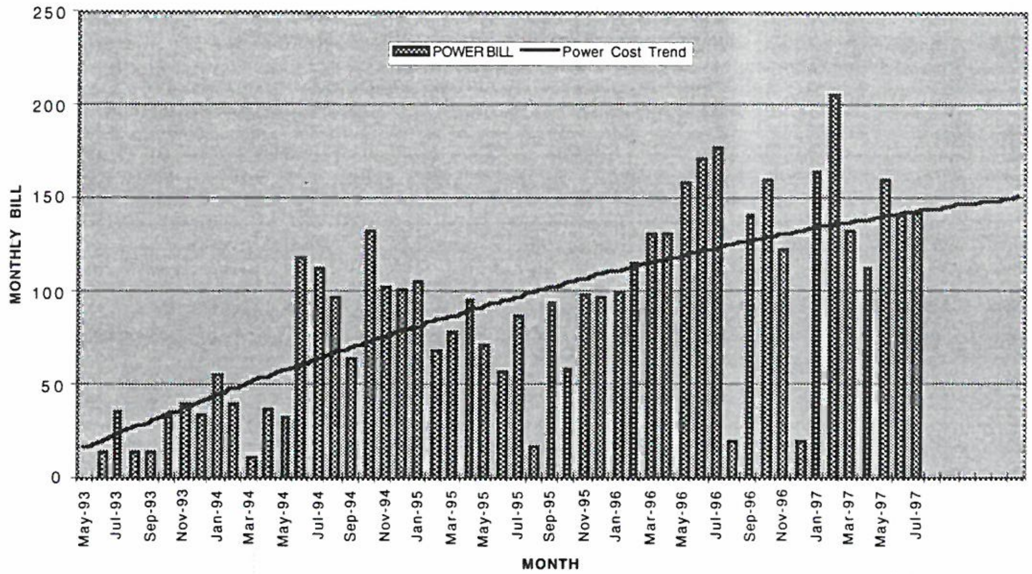

Figure 7.1 Electric Power Costs - DC Facilites Tallahassee

Attachments

The 1998 Proposed Budget by function is attached. Additional details are available. NSF Budget forms for both FSU and LANL for 1998 with institutional approval will be provided after the Site Review to provide an opportunity to adjust the budget allocations to reflect the review's recommendations.

The University of Florida has provided or committed university funds for equipment for NHMFL-related facilities as follows.

University of Florida Contributions

	Amount $ (thousands)
High circulation rate dilution refrigerator for High B/T Facility	$125
Matching funds for 500 MHz and 600 MHz high resolution NMR spectrometers	900
Start-up funds from UF resources for NHMFL faculty	800
Total	**$1,825**

New outside funding received, current grant year

Source	Amount $ (thousands)
US Navy, Office of Naval Research- SMES Conductor Test Facility (installation and initial operation, equipment furnished by the US Navy)(value of equipment and support)	$3,000
Molecular Expressions and other royalty income available to the NHMFL	160
ATLAS Detector End Cap Coils (Proposal Pending)	30,800
Work for Others	
Australian National Magnet Laboratory (pulsed magnet)	8
Sandia National Laboratory Pulsed Magnet coils	13
University of Wisconsin Pegasus magnet (In-kind contribution of equipment)	14
LANL — 30 T Neutron Scattering Magnet (Initial funds)	47
India Institute for Plasma Research (Superconducting Cable in Conduit)	58
Total Awarded	**$3,300**
Pending	**$30,800**

Other Leveraged Support
(Start of Laboratory to 12/31/97)

Source	Amount $ (thousands)
Department of Energy Los Alamos National Laboratory	
Value of pulsed power facilities	$30,000
Construction of quasi-continuous bus bar and other facilities work to date	2,550
Staff salaries to date	1,705
Collaborative development program for high strength, high conductivity composites — NHMFL-LANL and Bochvar Institute, Russia — awarded	150
CRADA's and other research activity to date	625
Department of Defense/UF University of Florida	
DoD award to UF Brain Institute for a 12 T 40 cm warm bore imaging magnet	5,000
Construction of NHMFL-MRI facility within Brain Institute, estimated —awarded	4,000
Department of Energy	
100 T Magnet at Los Alamos	
Initial Study — awarded	640
Capital and initial operating cost — requested	1,500
Ongoing operating cost and science per year — requested	1,000
NSF Chemistry Division	
National ICR Mass Spectroscopy Center — awarded	2,000
Private Foundations	
Keck Foundation award for NMR/ICR/EMR resistive magnet system	600
Industrial Sources	
EURUS Technologies, Inc. Cooperative Research and Development Agreement (in-kind services 3 years)	815
Oxford Instruments and Varian 720 MHz NMR spectrometer — received	1,300
Intermagnetics General	
900 MHz magnet R&D, contract executed	1,000
Hybrid Project support — awarded	700
Keithley Instruments	
donation of cash and instruments — awarded	200
Apple Corporation	
equipment and services awarded	120
Various Work for Other projects (prior years)	**793**
Totals	
Awarded	**$52,198**
Requested	**$2,500**