THE FLORIDA STATE UNIVERSITY

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Research and Science Education Subcommittee
Committee on Science, Space, and Technology
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NSF Major Multi-user Research Facilities Management:
Ensuring Fiscal Responsibility and Accountability

SUMMARY OF MAJOR POINTS

The National High Magnetic Field Laboratory (MagLab) is a multi-user research facility with campuses at Florida State University, the University of Florida and Los Alamos National Laboratory and an annual budget from all funding sources of approximately $50M. The MagLab annually hosts 1200 scientists representing more than 110 home institutions across the United States who together comprise an interdisciplinary scientific community spanning materials science, condensed matter physics, magnet technology and engineering, chemistry, biology, and biomedicine.

The MagLab management, scientists and engineering staff, as well as the MagLab user community and its three partner institutions all support competitive funding of scientific research and multi-user research facilities.

Competitive review and funding the MagLab as a multi-user research facility comes in three discrete stages:

- A full ("winner-take-all") recompetition, such as occurred for the MagLab in 1990 and is expected to be launched sometime in the near future.
- The MagLab Renewal Proposal process that occurs nominally every five years and includes a rigorous NSF review as well as the articulation of a new scientific vision and zero-baseline budget for the laboratory.
- The annual review of the MagLab by its User Committee and the NSF Site Visit Committee from which the NSF decides MagLab funding for the coming year.

Decisions to launch full recompetitions must be cognizant of the unique and complex circumstances of each multi-user research facility. For the MagLab, these include:

- The value of the integration of the MagLab with its three partner institutions.
- The ownership of MagLab infrastructure, equipment, buildings and land, such that a full recompetition is not for a management contract to operate an existing and ongoing research facility but rather for the almost certain relocation of the US high-magnetic-field, multi-user research facility.
- Provision of a level playing field for a "winner-take-all" recompetition, which is accompanied by a financial burden on the NSF and the MagLab partner institutions as well as a severe restriction on communications between the NSF and the multi-user research facility during the multi-year recompetition process.

The criteria for commencing a full recompetition should include a cost-benefit analysis that formally assesses:

- Performance of the present facility in providing the infrastructure and support needed by the scientific community to pursue its cutting-edge research and technology development.
- Impact of recompetition on future scientific and business management performance, and
- Suitability of existing infrastructure and whether a major infrastructure replacement is necessary.
- Impact of recompetition on non-federal funding partners who have invested significantly in the current national facility.

The National Science Board's recompetition policy should factor in these and other relevant issues and should give the NSF flexibility in its implementation of the policy.

Introduction

Chairman Brooks, Ranking Member Lipinski, and distinguished members of the Subcommittee, thank you for the opportunity to testify about NSF Major Multi-user Research Facilities Management. In addition to being Director of the National High Magnetic Field Laboratory, I serve as Principal Investigator on the Cooperative Agreement between NSF and Florida State University for operation of the MagLab.

Overview of the National High Magnetic Field Laboratory

The National Science Foundation established the MagLab in 1990 following a stringent peer-review competition. However, the MagLab story begins in the late 1980s, when a small group of visionary scientists crafted a plan for a premier facility that would build and operate the world's most powerful research magnets. These leaders from Florida State University in Tallahassee, Florida; The Los Alamos National Laboratory in New Mexico; and the University of Florida in Gainesville, Florida crafted a proposal for this new entity, to be operated collaboratively by the three institutions and headquartered near Florida State University. The vision included the incorporation of existing infrastructure at each of the three partner institutions into a single laboratory to develop the country's greatest magnet-related tools, resources and expertise. It was clear that this model would not only be efficient and cost-effective, but would also encourage fruitful, collaborative research at the highest level to nurture the next generation of scientists, engineers and technologists. The team submitted its proposal to the National Science Foundation in 1989 and successfully challenged an incumbent magnet laboratory founded a quarter of a century earlier. The bold three-site plan submitted by Florida State University and its collaborators articulated a novel vision for a national laboratory that would:

- Provide a centralized, high magnetic field resource for scientists nationwide;
- Feature a model federal-state partnership;
- Promote interdisciplinary research;
- Support science and technology education; and
- Work in partnership with industry to enhance the competitive position of the United States in crucial areas such as energy, materials, and biomedicine

The MagLab provides research infrastructure, as well as engineering and scientific expertise in service to a nationwide and world-leading User Program for research using high magnetic fields. The MagLab consists of three campuses: our main campus and headquarters are at Florida State University. Our branch campuses are at the University of Florida and Los Alamos National Laboratory.

Research Mission

Our magnet systems are sophisticated tools used by visiting researchers to study a wide range of materials and processes. The lab's most powerful magnets produce fields one-to-two-million times stronger than the Earth's magnetic field. What happens in experiments under such conditions give scientists important insights that pave the way for advances in physics, biology, bioengineering, chemistry, geochemistry, biochemistry, materials science and engineering.

High magnetic fields play a critical role in developing new materials that affect nearly every modern technology. Our entire electricity-driven lifestyle – motors, computers, high-speed transistors – as well as important biomedical tools – such as Magnetic Resonance Imaging (MRI) all came about after researchers learned more about materials through magnet-related research. The vast scope of work currently underway at the MagLab includes the study of new superconductors and energy storage materials with the potential to revolutionize how power is efficiently delivered; a search for new medicines; and analysis of petroleum and biofuel samples that could lead to better fuel production.

The magnets at the MagLab are far larger, far more powerful and far more complex than the everyday magnets with which most people are familiar. Our magnet systems were designed, developed and built by our magnet engineering and design team, widely recognized as the finest in the world. The MagLab employs 375 scientists, engineers, technicians and support staff, who currently hold 14 world records for high magnetic fields and other key measures of the power and utility of the instruments.

Access to MagLab facilities is awarded via peer review to the most meritorious proposals submitted from an interdisciplinary scientific community spanning materials science, condensed matter physics, magnet technology and engineering, chemistry, biology, biophysics, biochemistry and biomedicine. The MagLab User Program annually provides >7000 days of magnet time for high-magnetic-field experiments of ~1200 visiting scientists. These scientists travel from more than 110 home institutions across the United States and constitute an expanding and ever-changing user community: approximately 20% of all experiments performed by MagLab users are by Principal Investigators (PIs) new to the lab. MagLab users determine the lab's research directions; they have published more than 2000 papers over the past five years in the most prominent scientific journals.

Educational Mission

The MagLab's nationally recognized education and public outreach programs utilize the MagLab's scientists, educators and infrastructure to provide face-to-face educational and experimental opportunities every year for more than 10,000 K-12 students. The lab hosts more than 5,000 visitors of all ages at our annual Open House. MagLab scientists provide research mentorship opportunities for hundreds of K-12 teachers and middle, high school and undergraduate students. The lab's education group is a national leader in research that explores the challenges and opportunities for women and minorities pursuing careers in STEM fields.

The MagLab User Program provides critical data to more than 300 Ph.D. students and 150 postdoctoral researchers annually. From 2006-2010, at least 310 Ph.D. and 70 M.S. degrees contained data collected at the MagLab. Multi-user research facilities, including the MagLab, play a valuable role in supporting professors at smaller institutions with limited access to research funding and infrastructure, including professors at undergraduate and minority-serving colleges and universities.

Management Structure and Funding Mechanism

The National High Magnetic Field Laboratory is managed via a Cooperative Agreement (CA) with the NSF by the MagLab's three-institutional partnership. The CA establishes the lab's goals and objectives. Florida State University is responsible for establishing and maintaining administrative and financial oversight of the lab.

The MagLab's scientific direction is overseen by the Science Council, a multi-disciplinary group of distinguished faculty that serves as a think tank working with the user community to guide the lab's scientific mission.

Two external committees meet regularly to provide advice and direction to MagLab management. The User Committee represents the scientists who conduct research at the lab and provides guidance on the development and use of facilities and services in support of visiting scientists. The External Advisory Committee, comprised of representatives from academia, government and industry, offers advice to leaders of the MagLab's three partner institutions on matters critical to the successful management of the lab.

The National Science Board typically approves MagLab operating budgets in five-year increments. However, due to NSF budgetary constraints, annual budgets under the CY 2008-2012 Cooperative Agreement have often been lower than the not-to-exceed funding levels that were established by the National Science Board.

Stakeholder Contributions to the MagLab

Since 1990, the MagLab has received over 925 million dollars in funding from multiple sources. Half of the lab's funding was provided via the NSF-FSU Cooperative Agreement, while more than 35% of the total funding was provided by the State of Florida. The MagLab's strong state support was a key reason for the initial award from NSF and it continues to help the MagLab leverage other resources. The balance of funding was received from other competitive grants. This financial support from multiple stakeholders has created and sustained a modern infrastructure and operating model that provides both flexibility and accountability.

Return on Investment for the US Taxpayer and the State of Florida

In addition to the members of the consortium, the MagLab has built effective partnerships with industry and government laboratories and with high magnetic field laboratories around the world. Partners include the Department of Energy (Spallation Neutron Source and the Advanced Photon Source), the Hahn-Meitner Institute in Berlin, the Korea Basic Science Institute, the McKnight Brain Institute and over 60 industrial organizations including American Superconductor, Oxford Instruments and Exxon Mobil Corporation.

These organizations routinely seek access to the unique scientific and technical capabilities of the MagLab to address materials and technical questions, including on superconductors, rare earth materials and petroleum. An advantage of operating a facility with multiple types and sources of funding is that the MagLab is able to rapidly respond to unexpected opportunities while ensuring fiscal responsibility and accountability.

As the profile of the research capabilities has increased, the MagLab has helped to establish or recruit other research organizations. These include the Center for Advanced Power

Systems (CAPS), an organization that researches advanced power technologies with particular emphasis on transportation and the electrical grid.

In 2005, the MagLab and FSU successfully recruited the Applied Superconductivity Center (ASC) from its previous home at the University of Wisconsin-Madison, where the center had been for 20 years. Now a materials research division at the MagLab, ASC brought to Tallahassee researchers, grants and sophisticated laboratory equipment that are vertically integrated with many world-record magnet development programs at the MagLab.

Florida has identified science, technology, engineering and mathematics (STEM) occupations as imperatives for strategic growth of the state economy. The scope of the MagLab's science and educational programs support requirements for STEM careers ranging from a high school diploma and on-the-job training to a Ph.D. Beyond the laboratory, the MagLab is an active participant in many economic development efforts that target specific industry sectors – Renewable Energy and Environment; Aviation, Aerospace, Defense and National Security; Health Sciences and Human Performance Management; Information Technology; Research and Engineering and Transportation and Logistics.

Florida is building a world-class biotechnology sector with a foundation provided by its strong research universities and leading institutes. An example of the MagLab's direct involvement in this business sector is the collaborations between Scripps Florida and the MagLab that require use of unique instruments at the MagLab.

According to a 2009 report by the Florida State University Center for Economic Forecasting and Analysis, the State of Florida investment in the MagLab between 2006 and 2016 will generate $1.66 billion in output (value of goods and services produced) and $689 million in income, generating 15,554 jobs across the state economy.

Stewardship of American Tax Dollars

The Cooperative Agreement between the NSF and Florida State University ensures that an efficient and effective project governing structure is in place throughout the award period. The CA includes the following key points:

1. FSU has the responsibility for the management, operation, safety, cyber security, and maintenance of the NHMFL.
2. Dr. Gregory S. Boebinger is the Principal Investigator and NHMFL Director. The Director, in consultation with NSF staff, appoints the NHMFL User Collaboration Grant (UCG) Committee and the Directors of the User Programs. The Director is responsible for final decisions on scheduling of magnet time based on recommendations by the Directors of the User Programs.
3. A Director of User Program (DUP) is assigned to each of the seven user facilities at NHMFL: the DC user facility, the ICR user facility, the NMR user facility, the EMR user facility, the AMRIS user facility, the High B/T facility, and the Pulsed Field user facility.

The Directors of User Programs are selected from among MagLab scientists to manage the respective user facilities. The DUPs recommend magnet time allocations to the Director with inputs from the User Proposal Review Committee (UPRC). The DUPs appoint the members of the UPRC.

4. The President of FSU appoints the NHMFL External Advisory Committee (EAC). The EAC meets at least annually in order to assess the overall performance, policies, objectives and mission of the MagLab and to recommend changes as appropriate.
5. Members of the NHMFL User Collaboration Grant (UCG) Committee are selected from among MagLab staff and external users. They conduct reviews of all UCG proposals submitted to the MagLab for in-house research, using policy that is consistent with the NSF proposal review criteria. MagLab users come from US academic institutions, national laboratories, other federal agencies, industry and international institutions. User time at the MagLab is allocated on the basis of competitive proposal review. Users elect the NHMFL User Committee.
6. The NHMFL User Committee consists of experienced researchers who represent the entire community of scientists using the MagLab's high magnetic field facilities. The Committee meets at least annually to provide advice to the NHMFL Director on the use and development of MagLab facilities and instrumentation. The User Committee annually submits a written report to the NSF's Division of Materials Research.
7. Members of the NHMFL User Proposal Review Committees (UPRC) are chosen for their scientific expertise from among MagLab staff, users and prominent members of the scientific community at large. They are responsible for anonymous peer review of user proposals for magnet time.
8. The NHMFL Magnet Science and Technology Division maintains the substantial research infrastructure and develops new magnet technologies and engineering at the MagLab in response to user needs. The group builds research systems for the MagLab and accepts commissioned projects for labs worldwide. This division also collaborates with industry to address new opportunities in magnet-related technologies.
9. Members of the NHMFL Diversity Committee are appointed by the MagLab Director. The Diversity Committee is responsible for developing, implementing and annually evaluating the lab's Diversity Action Plan, a strategic plan to increase diversity at the MagLab and in STEM disciplines nationwide.

Accountability is demonstrated via:

1. An Annual Report describing scientific, engineering and technical accomplishments of users; detailed user statistics; magnet acquisition; construction and development; instrumentation acquisition and development; collaborations with industry; international cooperation; education and outreach achievements; patents and other innovations resulting from MagLab activities. Detailed budgetary information is reported for each area.
2. The NSF convenes a comprehensive site visit each year. The NSF Program Director appoints nominally ten scientists to an NSF Site Visit Committee. The Committee

submits a written report to the NSF Division of Materials Research and Chemistry Division.

3. FSU is the awardee and, accordingly, the FSU Office of Sponsored Research Services provides routine oversight of MagLab activities.
4. An NSF Business System Review (BSR) was begun in mid-2009 and concluded in November 2011. The NSF examined the business systems of eight functional areas of MagLab management: general management, award management, budget and planning, financial management, financial reporting, human resources, procurement and property). The MagLab passed the BSR with flying colors: the NSF BSR team determined that "*business systems supporting the MagLab are aligned with governing federal policies and regulations and meet NSF's expectations with regard to stewardship of federal funds*". The NSF BSR furthermore identified several areas of *Best Practices*, whereby the facility's operational and administrative practices exceed the performance of a proficient business system.

Competitive Rigor of the Five-Year Renewal Proposal Process

It is important to note that each renewal proposal involves a multi-year process of strategic planning, peer review and competition for limited research dollars. Moreover, the cost of developing the renewal proposal is a nontrivial matter in terms of resources and effort expended. The MagLab is in the midst of the 2013-2017 renewal proposal review process, outlined below:

Mid-2010	MagLab scientists and user community began strategic planning of the scientific and technological opportunities for the coming decade.
Aug 2010	Review of the early strategic planning by the NHMFL External Advisory Committee, who provided feedback to leaders of the three-institution partnership and MagLab.
Late 2010	Presentation of strategic plans to the NHMFL User Committee and 2010 NSF Site Visit, each of whom provided review in formal reports.
Early 2011	Development of research white papers and integration of those white papers into a first draft of the renewal proposal.
Mid-2011	Detailed development of the zero-baseline 2013-2017 budget to be included in the renewal proposal.
Aug 2011	Review of the near-final draft of the 2013-2017 NHMFL Renewal Proposal by the NHMFL External Advisory Committee, who provided feedback to leaders of the three-institution partnership and MagLab.
Aug 31, 2011	Submission of the 660-page 2013-2017 Renewal Proposal to the NSF.
	The NSF ensured that the 2013-2017 Renewal Proposal was reviewed by twenty external peer reviewers, who provided a detailed 37-page assessment of the proposal. MagLab management prepared a 46-page response to all requests for additional information from the reviewers prior to an on-site visit by the NSF Site Visit Review Committee.

Dec 6-8, 2011 On-site review of the 2013-2017 Renewal Proposal by the NSF Site Visit Review Committee, who provided a formal written report to which MagLab management responded in a formal written response.

Early 2012 National Science Foundation assesses the proposal and reviews of the proposal and presents its recommendation to the National Science Board.

Mid 2012 National Science Board will approve or decline the proposed award, and if approved, will establish a recommended maximum funding level for the NHMFL over the 2013-2017 funding period.

Jan 1, 2013 Funding under the new Cooperative Agreement will begin. Actual annual funding levels for the MagLab will be determined after critical review by an NSF Site Visit Committee, which will have as input the annual formal report from the NHMFL User Committee.

Complexity of a Full "Winner-Take-All" Recompetition

The MagLab management and its three partner institutions, its scientists and engineering staff, as well as the MagLab's user community and advisory committees all support competitive funding of scientific research and multi-user research facilities.

Competition for funding the MagLab as a multi-user research facility comes in three stages. The first is a full recompetition, such as occurred in 1990 for the MagLab and, per National Science Board policy, is expected again in 2016. A full recompetition is a "winner-take-all" contest to win the right to operate a national magnet lab. The resulting award takes the form of a five year cooperative agreement between NSF and the winning institution.

As the final year of the cooperative agreement approaches, the second stage of competition for continued funding of the multi-user research facility begins with the submittal of a new five year MagLab Renewal Proposal. This proposal is subjected to the same rigorous review as all other proposals for funding from the NSF's limited research budget. The process includes the development of a new scientific vision and zero-baseline budget, as well as the anonymous, written peer review by NSF-chosen scientific experts. Subsequent peer review is provided by a three-day, NSF-convened Site Visit to the MagLab by ten experts. If the Renewal proposal is approved by the National Science Board, then a new five year maximum funding level is set and a new cooperative agreement executed.

The third stage of the competitive review process comes when the NSF determines the annual funding level for the MagLab via the annual budget development process. NSF takes into consideration the written evaluations of MagLab performance in the annual reports from the User Committee and NSF Site Visit Committee meetings.

It is important that NSF's Policy governing full ("winner-take-all") recompetitions be cognizant of and adequately flexible to address the unique and complex circumstances of each multi-user research facility. For the MagLab, these include:

- The MagLab is an integral part of its three partner institutions, each of which contributes unique infrastructure and expertise, including professors serving in management roles, research scientists providing scientific and technical support for user research, and the vast intellectual and collaborative resource offered by the 150 research affiliates at our three partner institutions who are not paid by the MagLab.

- Ownership of MagLab infrastructure and equipment, whether funded by the state or the NSF operating grants, as well as ownership of the buildings and land at the MagLab's university campuses, is held by the universities. As such, a full recompetition of the MagLab would be fundamentally different than, e.g. a recompetition for a Department of Energy management contract to operate an existing and ongoing research facility.

- Provision of a level playing field for a "winner-take-all" recompetition is accompanied by a financial burden on both the NSF and the MagLab partner institutions, as the non-trivial costs to develop a recompetition proposal are (correctly) not allowed to use NSF funds from the existing facility grant. Provision of a level playing field has historically included a severe restriction on communications between the NSF and the multi-user research facility during the multi-year competition so as to avoid providing a favored position for the existing facility.

- The criteria for commencing a full recompetition could include a cost-benefit analysis that might include a formal scientific and business management review to determine whether the present multi-user research facility is underperforming such that a full recompetition is warranted. The criteria could also include an assessment of whether existing infrastructure at the facility is sufficiently old and out-of-date that a major infrastructure replacement is necessary. This last point was an issue in the 1990 recompetition for the national magnet laboratory.

- Finally a decision to commence a full recompetition should recognize that state governments and other funding partners will be sensitive to the duration of commitments made by the Federal government to the multi-user research facility.

Major Challenges Facing the MagLab

The MagLab's user program and facilities are thriving under the stewardship of the NSF's Division of Materials Research. As summarized in the 2007 NSF Site Visit Committee Report, the report that reviewed the MagLab's 2008-2012 Renewal Proposal: *"By virtue of its size, prominence and excellence, the NHMFL plays a critically important role for the scientific training of a future generation of scientists, for its outreach programs…, for increasing the diversity of our scientific workforce, and for the overall vitality…of the national scientific enterprise. It is truly a jewel in the crown of US science."*

Nonetheless, there are substantial challenges facing any multi-user research facility. For the MagLab, these include:

1. **Maintaining the critical mass of engineering and technical expertise** required to retain the key skill sets needed to support the user program. The initial focus of MagLab engineers and technical staff was the completion of the "Big Three" large-magnet design and construction projects:
    a. the 60-tesla, long-pulse magnet in 1998,
    b. the 45 tesla continuous-field hybrid magnet in 1999, and
    c. the 900 megahertz ultra-wide-bore magnet for nuclear magnetic resonance and magnetic resonance imaging in 2005.

To address this challenge, MagLab scientists and engineers initiated a sustained record of seeking new grants to cover roughly half the payroll of the MagLab's Magnet Science and Technology division and Applied Superconductivity Center:
    a. Large magnet projects to upgrade the MagLab's infrastructure. Per NSF policy, these projects are to be funded from separate competitive grants rather than under the CA that provides NSF funding for the MagLab's core operations.
    b. Magnets and technology development for other scientific institutions, including particle accelerators, neutron-scattering facilities, US Department of Energy laboratories and magnet laboratories in Europe and Asia.

Many of these major projects are listed in the "Competitive Funding and Infrastructure Investments" timeline given below.

2. **Growing worldwide competition** in high-magnetic-field facilities and research. The success of user research and technology development at the MagLab has spurred renewed funding in high magnetic field research overseas:
    a. Two of the leading magnet laboratories in Europe - the pulsed magnet laboratory in Dresden, Germany and the continuous field magnet laboratory in Nijmegen, The Netherlands – have received increased funding to double their capacity for user research.
    b. The pulsed magnet laboratory in Kashiwa, Japan recently commissioned a large generator to energize its magnets, providing operations on a scale that now rival the MagLab's Pulsed Field Facility.
    c. China is opening two laboratories modeled after the MagLab – in Wuhan for pulsed magnets and in Hefei for continuous-field magnets.

To address this challenge, the MagLab has concentrated on unique capabilities and infrastructure, discontinuing less-competitive research directions to continue world-leadership in the most critical areas of energy, materials and biomedicine. US leadership in high-magnetic-field research and technology cannot be taken for granted. Full recompetition of the US research facilities would pull focus and effort from maintaining the world-leading status of our present facilities.

3. **Sustaining an interdisciplinary research environment** when both universities and funding agencies are organized along traditional disciplinary lines. This challenge becomes acute during times of tight budgets, because each institution is naturally inclined to focus its vision on the core of its specific discipline.

A number of MagLab practices and circumstances help to mitigate this challenge:

   a. Magnets (and other MagLab facilities) are sufficiently flexible research tools that most are suitable for use by several of the traditional disciplines.
   b. MagLab funding comes from a diverse spectrum of funding agencies and State of Florida funding, in particular, is not linked to any specific traditional discipline.
   c. MagLab strategic planning, internal seminars and outreach publications seek to build communications and collaborations across traditional disciplines.
   d. The NSF Division of Materials Research is historically multi-disciplinary, spanning condensed matter physics, materials engineering and solid state chemistry. In its stewardship of the MagLab, it has supported additional breadth to include areas of research for which new applications of the highest magnetic fields can support truly transformational research. One example is the MagLab's technology development for Magnetic Resonance Imaging, which initially focused exclusively on biomedicine but has recently nucleated research in energy and materials.

Major Accomplishments of MagLab User Research

User research at the MagLab is reported in more than 400 refereed publications annually. Highlights under the present 2008-2012 renewal proposal include:

1. "High Definition" Magnetic Resonance Imaging (MRI)

   a. Medical MRI's have virtually replaced exploratory surgery, because magnetic fields enable the imaging of organs and other soft tissue. Technology developed at the MagLab accesses the highest magnetic fields for MRI, which sharpens the focus of MRI's, such that researchers can now image *single cells* and track *individual nerve fibers* in the brain and spinal cord.
   b. All medical MRI's create images by detecting the water throughout the body. MagLab scientists and visiting collaborators now use higher magnetic fields to pioneer the detection of sodium. Sodium MRI can detect within a few days whether chemotherapy is successfully attacking a cancer tumor *even before the tumor cells die.* Traditional MRI must wait weeks until the tumor cells die and the tumor starts to shrink in size.
   c. In a beautiful example of the value of interdisciplinary research, advances in new forms of MRI in biomedical research are now bearing fruit in materials research for energy storage: Lithium MRI, which relies on MagLab magnets and technology, can literally see the discharge and recharge of lithium batteries, a critically important visualization tool for increasing the energy storage and lifetime of present-day and future batteries and fuel cells.

2. **Petroleum and biofuel research**
    a. MagLab researchers created "petroleomics", the detection and identification of *every* compound in nature's most complex fluid: petroleum. The latest detailed analysis of petroleum is reducing the cost of producing and refining low-grade petroleum into high-grade fuel products.
    b. These same techniques are being brought to bear on the development of biofuels, including algae byproducts, to determine which compounds in a candidate biofuel contribute to its use as a "green" energy source.

3. **Superconductor research**
    a. Fundamental research by dozens of MagLab user groups is contributing to an ultimate solution of the puzzle of high-temperature superconductivity.
    b. MagLab scientists and engineers, in collaboration with US industries, are leading the world in applied research on superconducting tape and wires, particularly in the transformational development of high-temperature superconducting magnets that will revolutionize particle accelerators, magnetic resonance imaging, and other magnet applications.

Properly managed, a multi-disciplinary, multi-user research facility enables *completely unanticipated* research accomplishments through flexible application of existing facilities:

4. **Testing magnet wire**

   Upon discovery of problems with superconducting wires intended to be wound into superconducting magnets, MagLab scientists and engineers partnered with collaborators from US national laboratories to test large superconducting cables exposed to high magnetic fields, a critical test prior to their future use in superconducting magnets.

5. **Tracking the Deepwater Horizon oil spill using "petroleomics" techniques**

   Within weeks of the oil spill, MagLab and Woods Hole scientists began partnering to:
    a. measure the unique "fingerprint" of the oil at the underwater well-head to determine whether oil samples found elsewhere originated from this spill.
    b. track the long-term evolution of oil in the environment. Some compounds are "eaten" by naturally-occurring bacteria while other compounds remain.

6. **Processing materials in magnetic fields**
    a. Newly-invented "Bucky Paper" is a composite material of great interest to airplane manufacturers because it is stronger than present-day carbon-reinforced composites. Researchers using MagLab facilities have found that Bucky-Paper is made even stronger when processed in high magnetic fields.
    b. Cognizant of the developing crisis in availability of rare earth elements, MagLab scientists are using high magnetic fields to research and develop new and powerful permanent magnets that might one day reduce dependence on foreign sources for rare earth elements.

Conclusion

The National Research Council report on Opportunities in High Magnetic Field Science concluded that “high magnetic field science and technology are thriving...and the prospects are bright for future gains from high-field research.” Noting that “high-field magnet science is intrinsically multidisciplinary,” the report cites as its single most important recommendation that “the United States should maintain a national laboratory that gives its scientific community access to magnets operating at the highest possible fields.” The National High Magnetic Field Laboratory provides the scientific community – and the Nation – with just such a unique facility through the partnership between the National Science Foundation and the State of Florida.

I appreciate the opportunity to present this information to the Subcommittee and I would be pleased to answer any questions as well as provide additional information as necessary and appropriate.

Appendix: MagLab Competitive Funding and Infrastructure Investments

The timeline below highlights in bold face the successful conclusion of the 1990 recompetition and each subsequent renewal proposal.

Key events (in italics) are selected to illustrate the initial and ongoing upgrading of infrastructure via the NSF Cooperative Agreement, the MagLab's partner institutions, and other funding sources.

<u>Key work-for-others contracts (underlined) are also included as they enable the retention of the necessary critical mass of magnet engineering talent at the MagLab.</u>

Note: Magnetic field strength is measured in "teslas", where 50 teslas is one million times the Earth's magnetic field.

Sep 1990 **National High Magnetic Field Laboratory is awarded its first operating grant as the result of the "winner-take-all" recompetition.**

Dec 1992 *MagLab branch at Los Alamos National Laboratory launches its scientific user program using a $1.4M pulsed magnet power supply provided by LANL.*

Sep 1993 *Construction and renovation of MagLab buildings by FSU is completed.*

Jun 1994 *First MagLab engineered and built resistive continuous-field magnet is operational, setting a new world record of 27 teslas for resistive magnets.*

Sep 1994 *NSF's Chemistry Division awards $5 million to develop the MagLab Ion Cyclotron Resonance facility. State of Florida matches with $2 million to acquire high-field superconducting magnets*

Oct 1994 MagLab dedication ceremony. Keynote address by Vice-President Al Gore.

Oct 1994 MagLab's High B/T facility at the University of Florida begins user operation.

Mar 1994 *MagLab engineers produce a 30-tesla resistive magnet with the invention of new "Florida Bitter" magnet technology and tying the world record for highest continuous magnetic fields.*

Jul 1995 *MagLab engineers produce 24-tesla high-homogeneity magnet, eclipsing the mark previously held by the Grenoble, France magnet lab.*

Sep 1995 *MagLab installs a world-record 9.4-tesla ion cyclotron resonance magnet system and a world-record 17-tesla high-resolution electron magnetic resonance spectrometer.*

Feb 1996 *MagLab commissions a 33-tesla resistive magnet, breaking its own record.*

Mar 1996 **Successful renewal proposal results in award of second operating grant.**

Oct 1997 *MagLab Pulsed Field Facility begins commissioning of 60-tesla long-pulse magnet, powered by the largest motor-generator in the U.S., a $30M installation provided for MagLab use by Los Alamos National Laboratory.*

<u>Nov 1997 MagLab engineers install a 30-tesla magnet in Tsukuba, Japan – the highest field resistive magnet in Asia.</u>

Feb 1998 *MagLab engineers complete 25-tesla magnet with 12 parts per million (ppm) homogeneity over a 10-mm diameter spherical volume, surpassing their own 24-tesla mark in both field intensity and uniformity.*

April 1998 *MagLab Pulsed Field Facility completes commissioning of 60-tesla long-pulse magnet, turning the world-unique facility over to user research.*

Oct 1998 MagLab's Advanced Magnetic Resonance Imaging and Spectroscopy facility debuts at the University of Florida, with six of seven NMR/MRI magnets purchased using $2M from the Department of Defense.

Oct 1999 *The new LANL-funded Experimental Hall opens at the Pulsed Field Facility.*

Dec 1999 The world's strongest continuous-field magnet – the MagLab's 45-tesla hybrid magnet - reaches full field and is commissioned for user service.

Jul 2000 *Center for Advanced Power Systems – a research spin-off of the MagLab – is founded with a $10.9 million grant from the US Office of Naval Research.*

Apr 2001 **Successful renewal proposal results in award of third operating grant.**

May 2001 *AMRIS is awarded a $5.2 million National Institutes of Health (NIH) grant to develop new radio frequency (RF) coils for nuclear magnetic resonance and magnetic resonance imaging.*

Oct 2001 *NIH awards MagLab's Nuclear Magnetic Resonance program $8 million grant.*

<u>Apr 2003 MagLab commissions the highest-field (33 tesla) resistive magnet in Europe in collaboration with Radboud University in Nijmegen, The Netherlands.</u>

<u>Apr 2004 MagLab commissions the "Sweeper Magnet" at Michigan State University for nuclear physics research using the particle accelerator at the National Superconducting Cyclotron Laboratory</u>

Apr 2004 *The Florida Legislature allocates $10 million for infrastructure upgrades at the FSU and UF branches of the MagLab.*

Jun 2004 *Magnet Lab awarded $1.8 million NSF grant for conceptual and engineering design of a revolutionary Series Connected Hybrid magnet system.*

Sep 2004 *A 14.5-tesla ICR magnet system – the highest field ICR system in the world – is commissioned for research.*

Jul 2005 *The 900 megahertz ultra-wide-bore magnet - engineered and built at the MagLab for nuclear magnetic resonance and magnetic resonance imaging - is commissioned.*

Oct 2005 *The Applied Superconductivity Center at the University of Wisconsin moves to the MagLab, a relocation made possible by a $4M building renovation and instrumentation investment by Florida State University.*

Dec 2005 *MagLab-engineered 35-tesla resistive magnet is commissioned, setting a new world record for a continuous field electromagnet.*

Aug 2006 *MagLab engineers complete a new high-homogeneity magnet that provides 28 teslas, eclipsing their previous mark of 25 teslas.*

Sep 2006 *The NSF awards the MagLab $11.7 million to build the next-generation energy-efficient Series Connected Hybrid magnet.*

Oct 2006 *Commissioning of the 100-tesla multi-shot magnet for initial user operation at 85 teslas at the MagLab's Los Alamos Pulsed Field Facility, a project jointly funded by the NSF and Department of Energy.*

Apr 2007 The Helmholtz Centre Berlin contracts with the MagLab to build an $8.7 million high-field magnet for neutron scattering.

Jul 2007 The MagLab and industry partner SuperPower, Inc. collaborate to set a new world record for magnetic field created by a superconducting magnet: 26.8 teslas. The world-record magnet's test coil is wound with well-known high-temperature superconductor yttrium barium copper oxide (YBCO).

Jan 2008 Successful renewal proposal results in award of fourth operating grant.

Sep 2008 A small test coil made from the superconducting material yttrium barium copper oxide (YBCO) achieves 33.8 teslas at a current of 325 amps, setting a new record for field strength and current density for superconducting coils.

Oct 2008 MagLab engineers construct a bismuth strontium calcium copper oxide (BSCCO) 2212 round wire test coil that achieves 32 teslas, demonstrating a second superconductor capable of reaching fields higher than 30 teslas.

Jul 2009 YBCO test coil reaches 27.4-tesla, another record for magnetic field strength generated by a superconductor.

Oct 2009 NSF awards the MagLab $2 million to build a 32-tesla, all superconducting magnet made with YBCO superconductor.

Dec 2009 NSF awards $15 million to purchase a state-of-the-art, 21-tesla superconducting magnet system for the lab's ICR user program.

April 2010 Federal stimulus funds provide $1.8 million to the University of Florida and $3.8M to the MagLab at FSU to modernize and upgrade critical helium gas purification and liquification infrastructure. These awards were augmented by $3.2M in funding from the MagLab partner institutions.

Jun 2011 Commissioning the first 28MW magnet - the 25-tesla split magnet – that utilizes the State-of-Florida-funded $7.5M upgrade of the DC power supplies

Aug 2011 Commissioning of the 100-tesla multi-shot magnet at the MagLab's Los Alamos Pulsed Field Facility for user experiments at 97.4 teslas

Mar 2012 Commissioning of the 100-tesla multi-shot magnet for user experiments at 100.7 teslas, the successful culmination of the fifteen-year joint NSF/DOE project, co-funded by an investment of $10 million each.