NSF MAJOR MULTI–USER RESEARCH FACILITIES MANAGEMENT: ENSURING FISCAL RESPONSIBILITY AND ACCOUNTABILITY

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

WEDNESDAY, APRIL 18, 2012

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Wednesday, April 18, 2012

NSF MAJOR MULTI–USER RESEARCH FACILITIES MANAGEMENT: ENSURING FISCAL RESPONSIBILITY AND ACCOUNTABILITY

WEDNESDAY, APRIL 18, 2012

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:07 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Mo Brooks [Chairman of the Subcommittee] presiding.

RALPH M. HALL, TEXAS
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U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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Subcommittee on Research & Science Education Hearing

NSF Major Multi-User Research Facilities Management: Ensuring Fiscal Responsibility and Accountability

Wednesday, April 18, 2012
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Dr. Ethan J. Schreier, President, Associated Universities, Inc.

Dr. William S. Smith, Jr., President, Association of Universities for Research in Astronomy

Dr. David Divins, Vice President and Director, Ocean Drilling Programs, Consortium for Ocean Leadership, Inc.

Dr. Gregory S. Boebinger, Director, National High Magnetic Field Laboratory and Professor of Physics, Florida State University and University of Florida

Dr. Sol Michael Gruner, Director, Cornell High Energy Synchrotorn Source and The John L. Wetherill Professor of Physics, Cornell University

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

HEARING CHARTER

NSF Major Multi-User Research Facilities Management: Ensuring Fiscal Responsibility and Accountability

Wednesday, April 18, 2012
10:00 a.m. - 12:00 p.m.
2318 Rayburn House Office Building

1. Purpose

On Wednesday, April 18, 2012, the Committee on Science, Space, and Technology Subcommittee on Research and Science Education will hold a hearing to examine the planning, management, operations, and stewardship of major multi-user research facilities funded through the National Science Foundation.

2. Witnesses

Dr. Ethan J. Schreier, President, Associated Universities, Inc.

Dr. William S. Smith, Jr., President, Association of Universities for Research in Astronomy

Dr. David Divins, Vice President and Director, Ocean Drilling Programs, Consortium for Ocean Leadership, Inc.

Dr. Gregory S. Boebinger, Director, National High Magnetic Field Laboratory and Professor of Physics, Florida State University and University of Florida

Dr. Sol Michael Gruner, Director, Cornell High Energy Synchrotron Source and The John L. Wetherill Professor of Physics, Cornell University

3. Overview

- Providing support for major multi-user research equipment and facilities is a component of support for basic research.
- According to the most recent National Science Foundation (NSF) Strategic Plan for 2011 through 2016, "A major element in the ability to expand S&E knowledge in general, as well as transform the frontiers, is having tools that enable new capabilities for measurement, observation, manipulation, and experimentation." [1]

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[1] *NSF Strategic Plan FY2011-2016*, p. 9.

- The Fiscal Year 2013 NSF budget request includes $1119.47 million for major multi-user research facilities, including $923.30 million from the Research and Related Activities account for operations and maintenance of existing facilities, federally funded research and development centers, operations and maintenance of facilities under construction, and planning and concept development.[2]

- The operations and maintenance of existing facilities, funded by NSF, is reviewed annually. Every five years facilities are considered for renewal or recompetition. In 2008, the National Science Board endorsed the principle that "all expiring awards are to be recompeted, because rarely will it be in the best interest of U.S. science and engineering research and education not to do so."[3]

- The National Science Foundation supports three of the thirty-nine Federally Funded Research and Development Centers (FFRDC). FFRDCs "provide the sponsoring federal agencies with capabilities to meet special long-term R&D needs that cannot be met as effectively by existing in-house or by contractor resources."[4]

4. Background

A component of support for basic research is providing researchers, students, and teachers access to powerful, cutting-edge equipment and facilities. This research infrastructure has a major impact on broad segments of scientific and engineering disciplines. Large and up-to-date research equipment and facilities enhance the fundamental processes of basic research. These equipment and facilities may consist of multi-user facilities, large-scale computational infrastructures, or networked instrumentation and equipment. Telescopes, particle accelerators, gravitational wave observatories, and research vessels are only a handful of examples of major research infrastructure projects.

Major Multi-User Research Facilities and the National Science Foundation

As the primary federal agency supporting basic scientific research, the National Science Foundation (NSF) funds a variety of large research projects, from multi-user research facilities to tools for research and education and distributed instrumentation networks. This funding provides state-of-the-art tools for research and education, distributed instrumentation networks and arrays, accelerators, telescopes, research vessels, aircraft, and earthquake simulators. In addition, support for internet-based and distributed user facilities is increasing as a result of rapid advances in computer, information, and communication technologies. Funding support for these major projects is coordinated with other agencies, organizations, and international partners to ensure projects are integrated and complementary. Infrastructure construction is funded out of the Major Research Equipment and Facilities (MREFC) account at NSF. Planning, and operations and maintenance of multiuser facilities are funded through NSF's Research and

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[2] NSF FY13 Budget Request – Facilities, p. 1.
[3] The National Science Board, Committee on Programs and Plans, NSB-08-12, http://www.nsf.gov/nsb/publications/2008/nsb0812_comp_recomp.pdf
[4] NCSES InfoBrief, March 2012, NSF 12-315, p. 1.

Related Activities (RRA) account. The NSF Fiscal Year 2013 (FY13) budget request for the major multi-user research facilities is $1119.47 million.[5]

Major Multi-User Research Facilities Funding[6]

(dollars in millions)

	FY11 Actual	FY12 Estimate	FY13 Request	Change Over FY12 Estimate Amount	Change Over FY12 Estimate Percent
Total, Research and Related Activities	**913.54**	**909.70**	**923/30**	**13.6**	**1.5**
Operations and Maintenance (O&M) of Existing Facilities	*673.63*	*655.37*	*647.35*	*-8.02*	*-1.2*
Federally Funded R&D Centers	*195.25*	*195.85*	*191.71*	*-4.14*	*-2.1*
O&M of Facilities under Construction	*17.49*	*44.73*	*72.49*	*27.76*	*62.1*
R&RA Planning and Concept Devcelopment	*27.17*	*13.75*	*11.75*	*-2.00*	*-14.5*
Major Research Equipment and Facilities Construction	**125.37**	**197.06**	**196.17**	**-0.86**	**-0.5**
Total, Major Multi-User Research Facilities	**1038.91**	**1106.76**	**1119.47**	**12.71**	**1.1**

The MREFC account was formally established in 1995, as an NSF-wide budgetary account to promote effective planning and management in the Foundation's support for large investments in major research equipment and facilities. The MREFC account supports the acquisition, construction, and commissioning of major research facilities and equipment. "The MREFC account was created to separate the construction funding for a large facility – which can rise and fall dramatically over the course of a few years – from the more continuous funding of facility operations and individual-investigator research."[7]

Since the creation of the MREFC account, NSF has funded 17 projects. In the FY13 budget request, NSF is requesting funding for four facilities: Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO); Advanced Technology Solar Telescope (ATST); National Ecological Observatory Network (NEON); and Ocean Observatories Initiative (OOI). Two other facilities, Atacama Large Millimeter Array (ALMA) and IceCube Neutrino Observatory (IceCube) are transitioning from the MREFC account to the appropriate research directorates for operations and maintenance. At this time, there are no new proposed facilities. The FY13 budget request for the MREFC account is $196.17 million.

Pre-construction planning and concept and development for MREFC projects are funded from the RRA account. This funding supports activities including design, cost estimates, and other actions that prepare potential projects for oversight review, agency decisions milestones, and potential implementation. The FY13 budget request for planning and development is $11.75 million.[8]

The continued operations and maintenance (O&M) of major multi-user research facilities is also funded through the RRA account. NSF Directorate support for O&M is essential for major

[5] NSF FY13 Budget Request – Facilities, p. 1.
[6] NSF FY13 Budget Request – Facilities, p. 1.
[7] The National Academy of Sciences, *Setting Priorities for Large Research Facility Projects Supported fy the National Science Foundation*, p. 8.
[8] NSF FY13 Budget Request – Facilities, p. 66.

multi-user research facilities. Currently, the Engineering, Geosciences, and Mathematical and Physical Sciences Directorates, as well as the Office of Polar Programs, support existing facilities, see below. The FY13 budget request for O&M is $647.35 million.

Major Multi-User Research Facilities Funding Request[9]

(dollars in millions)

	FY11 Actual	FY12 Estimate	FY13 Request	Change Over FY12 Estimate Amount	Change Over FY12 Estimate Percent
Operations and Maintenance of Existing Facilities	**673.63**	**655.37**	**647.35**	**-8.02**	**-1.2**
Engineering					
National Nanotechnology Infrastructure Network (NNIN)	16.36	15.86	15.36	-0.50	-3.2
Network for Earthquake Engineering Simulation	20.10	20.50	20.50	0	0
Geosciences					
Academic Research Fleet[A]	81.67	76.75	72.00	-4.75	-6.2
EarthScope: USArray, SAFOD, POB	26.02	25.05	26.17	1.12	4.5
Incorporated Research Institutions for Seismology	12.37	12.36	11.25	-1.11	-9.0
Integrated Ocean Drilling Program	53.35	44.40	38.90	-5.50	-12.4
Mathematical and Physical Sciences					
Arecibo Observatory (formerly NAIC)[B]	9.26	8.70	8.20	-0.50	-5.7
Cornell High Energy Synchrotron Source (CHESS)/ Cornell Electron Storage Ring (CESR)	14.12	19.67	20.00	0.33	1.7
Gemini Observatory	19.50	22.07	18.15	-3.92	-17.8
IceCube	6.90	6.90	6.90	0	0
Large Hadron Collider	18.00	18.00	18.00	0	0
Laser Interferometer Gravitational Wave Observatory	30.30	30.40	30.50	0.10	0.3
National High Magnetic Field Laboratory	32.68	25.80	31.75	5.95	23.1
National Solar Observatory	9.10	9.10	8.00	-1.10	-12.1
National Superconducting Cyclotron Laboratory	21.50	21.50	21.50	0	0
Other Facilities[C]	4.86	2.52	2.66	0.14	5.6
Polar Programs					
Polar Facilities and Logistics[D]	297.54	295.79	297.51	1.72	0.6
Federally Funded Research and Development Centers[E]	**195.25**	**195.85**	**191.71**	**-4.14**	**-2.1**
National Center for Atmospheric Research (NCAR)	98.10	98.60	92.29	-6.31	-6.4
National Optical Astronomy Observatory (NOAO)	29.50	25.50	25.50	0	0
National Radio Astronomy Observatory (NRAO)[F]	67.65	71.75	73.92	2.17	3.0
Operations and Maintenance of Facilities under Construction	17.49	44.73	72.49	27.76	62.1
Advanced Technology Solar Telescope (ATST)	2.00	2.00	2.00	0	0
National Ecological Observatory Network (NEON)		15.93	30.39	14.46	90.8
Ocean Observatories Initiative (OOI)	15.49	26.80	40.10	13.30	49.6
RRA Planning and Concept Development	**27.17**	**13.75**	**11.75**	**-2.00**	**-14.5**
Pre-construction Planning[G]	17.50	6.75	8.75	2.00	29.6
Concept and Development for MREFC projects	9.67	7.00	3.00	-4.00	-57.1
Major Research Equipment and Facilities Construction	**125.37**	**197.06**	**196.10**	**-0.89**	**-0.5**
Total, Major Multi-User Research Facilities	**1038.91**	**1106.76**	**1119.47**	**12.71**	**1.1**

[9] NSF FY13 Budget Request – Facilities, p. 2.

Totals may not add due to rounding.
[A] An additional \$2.0 million in FY12 and \$1.0 million in FY13 for Regional Class Research Vessels is included in pre-construction planning.
[B] The National Astronomy and Ionosphere Center (NAIC) was decertified as an FFRDC in FY 2011 and renamed Arecibo Observatory.
[C] Other Facilities includes support for other physics and materials research facilities.
[D] In FY 2011, Polar Facilities and Logistics excludes a one-time appropriation transfer of \$54.0 million to U.S. Coast Guard per P.L. 112-10.
[E] Federally Funded R&D Centers does not include support for the Science and Technology Policy Institute, which is an FFRDC but not a multi-user research facility
[F] Operations and Maintenance of ALMA are included in NRAO.
[G] Pre-construction planning includes R&RA funding for potential next-generation major multi-user facilities.

Major multi-user facilities work through contracts or cooperative agreements between NSF and principal investigators (PI) responsible for the facility. These agreements identify the governance and structure for the facilities, specify the roles and responsibilities of the PI, and require regular reviews and audits. The majority of the NSF funded multi-user facilities have transitioned to five-year cooperative agreements. Every five years, the NSF program officer responsible for the facility makes a recommendation to the National Science Board (NSB) as to the renewal, recompetition, or termination of support for the facility.

Renewal and Recompetition of Multi-User Research Facilities

In 2008, the NSB drafted a resolution outlining its support for the regular recompetition of NSF supported multi-user research facilities:

> WHEREAS, the Committee on Programs and Plans has reassessed, at its meeting of February 6-7, 2008, the major principles and key issues in a statement "Competition, Recompetition and Renewal of NSF Awards" (NSB/CPP-08-4) in the context of the various types of NSF awards.
>
> Therefore, be it RESOLVED that the National Science Board (the Board) endorsed strongly the principle that all expiring awards are to be recompeted, because rarely will it be in the best interest of U.S. science and engineering research and education not to do so. Furthermore, the Board endorsed a recompetition policy for major facility awards which is transparent to the research community such that after construction of major facilities is completed, followed by an appropriate time period to bring the facility to sustainable operations, full and open competition of the operations award will be required.
>
> This position was based on the conviction that peer-reviewed competition and recompetition is the process most likely to assure the best use of NSF funds for supporting research and education.
>
> The Board requested that the Director, NSF, take such steps necessary to ensure that all NSF practices embody this principle.[10]

Since that time, NSF has worked to implement the resolution, forming an ad hoc Subcommittee of the Business and Operations Advisory Committee to advise on implementation. In 2010 and

[10] The National Science Board, Committee on Programs and Plans, NSB-08-12, http://www.nsf.gov/nsb/publications/2008/nsb0812_comp_recomp.pdf

2011, the Subcommittee, made up of influential senior researchers in fields served by multi-user facilities, met to produce a report recommending implementation practices. The Subcommittee brought in facility users and directors for input. The NSB will review the report in May of this year.

Federally Funded Research and Development Centers

The category of major multi-user research facilities represents a broad array of facilities and equipment. From university based synchrotrons to the academic research fleet these equipment and facilities vary greatly. Included in this category are federally funded research and development centers (FFRDCs). FFRDCs were established by the federal government during and immediately following World War II.[11]

FFRDCs are privately operated not-for-profit organizations financed exclusively or substantially by federal agencies. To minimize conflicts of interest, FFRDCs cannot compete with for-profit companies for additional government contracts and are not allowed to produce and market commercial products. Each FFRDC is administered, through a contract with the sponsoring federal agency, by a university or university consortium, a nonprofit organization, or an industrial firm. "FFRDCs provide the sponsoring federal agencies with capabilities to meet special long-term R&D needs that cannot be met as effectively by existing in-house or by contractor resources."[12] NSF supports four FFRDCs: the National Center for Atmospheric Research (NCAR), the National Optical Astronomy Observatory (NOAO), and the National Radio Astronomy Observatory (NRAO), and the Science and Technology Policy Institute (STPI)[13].

Associated Universities, Inc. (AUI)[14]

Associated Universities, Inc. (AUI) was established in 1946 by nine universities: Columbia University, Cornell University, Harvard University, the Johns Hopkins University, Massachusetts Institute of Technology, the University of Pennsylvania, Princeton University, the University of Rochester, and Yale University.[15]

AUI operates National Radio Astronomy Observatory (NRAO) and is responsible for oversight and audit of the operation of the FFRDC. AUI appoints the Observatory Director, approves appointments of tenured staff and senior managers; reviews ongoing programs and budget; and oversees long-range planning and proposals for new, major facilities. These actions are reviewed by the NSF, with NSF approval required for major commitments. AUI employs a Visiting Committee of independent experts to review the quality and scope of ongoing and planned

[11] CRS Report for Congress, Department of Homeland Security: Issues Concerning the Establishment of Federally Funded Research and Development Centers (FFRDCs), p. 1-4.
[12] NCSES InfoBrief, March 2012, NSF 12-315, p. 1.
[13] STPI provides analytical support to the Office of Science and Technology Policy but is not a multi-user facility. It is managed by the Institute for Defense Analysis and funded through NSF. FY 12 Appropriations for STPI were $3.04 million.
[14] NSF FY13 Budget Request – Facilities, p. 64.
[15] http://www.aui.edu/about.php?q=history

scientific programs at NRAO. This Committee is composed of distinguished scientists drawn from universities and industrial organizations all over the world.

NRAO provides state-of-the-art radio telescope facilities for scientific users. NRAO conceives, designs, builds, operates, and maintains radio telescopes used by scientists from around the world to study virtually all types of astronomical objects known, from planets and comets in our own Solar System to quasars and galaxies billions of light-years away.

As a FFRDC, NRAO operates major radio telescopes in Green Bank, West Virginia, near Socorro, New Mexico, and at ten telescope array sites spanning the U.S. from the Virgin Islands to Hawaii. Headquartered in Charlottesville, Virginia, NRAO is also the North American implementing organization for the international Atacama Large Millimeter Array (ALMA) project, which in FY 2013 will be in the final stages of construction, funded through the MREFC account.

These federally funded, ground-based observing facilities for radio astronomy are available to any qualified astronomer, regardless of affiliation or nationality, on the basis of scientific peer-reviewed proposals, and annually serve over 1,500 users worldwide. The Observatory allocates telescope time on the basis of merit but provides no financial support. NSF does not provide individual investigator awards targeted specifically for use of NRAO facilities. Many users are supported through NSF or NASA grants to pursue scientific programs that require use of the facilities.

NRAO supplements Division of Astronomical Sciences (AST) support with funding provided by other NSF sources, other federal agencies, and non-federal sources. Management is through a cooperative agreement with AUI. AUI manages the observatory through its own community-based oversight and users' committees. The NRAO director reports to the president of AUI. The current cooperative agreement is in place for the years FY10 through FY15. Preparations are underway for a solicitation for the management and operation of NRAO that will be promulgated in FY13 for a new cooperative agreement to begin October 1, 2015.

Association of Universities for Research in Astronomy (AURA)[16]

Association of Universities for Research in Astronomy (AURA) is a consortium of universities, and educational and other non-profit institutions that operates astronomical observatories. AURA membership includes 37 U.S. Institutions and seven international affiliates.[17] AURA operates several multi-user facilities, including National Optical Astronomy Observatory (NOAO), the Gemini Observatory, and the National Solar Observatory.

<u>NOAO</u>

NOAO was established in 1982 by uniting operations of the Kitt Peak National Observatory (KPNO) in Arizona and the Cerro Tololo Inter-American Observatory (CTIO) in Chile. NOAO is a FFRDC for research in ground-based, nighttime, optical, and infrared (OIR) astronomy. NOAO also is the gateway for the U.S. astronomical community to the International Gemini

[16] NSF FY13 Budget Request – Facilities, p. 20, 45, 61.
[17] http://www.aura-astronomy.org/about.asp

Observatory and to the "System" of federally-funded and non-federally-funded OIR telescopes through the Telescope System Instrumentation Program (TSIP) and the Renewing Small Telescopes for Astronomical Research (ReSTAR) program.

For all NOAO and "System" telescopes, peer-review telescope allocation committees provide merit-based telescope time but no financial support. NOAO manages national community involvement in the development of potential future infrastructure projects and is closely involved in the design, development, and potential construction and operations of the Large Synoptic Survey Telescope (LSST). NOAO telescopes are open to all astronomers regardless of institutional affiliation on the basis of peer reviewed observing proposals.

In FY 2011, NOAO received $15.77 million for reimbursed services from partnerships and tenant observatory support, from the Kitt Peak Visitors' Center, grants from other federal agencies, and NSF supplemental funding for LSST and for the Research Experiences for Undergraduates (REU) program.

An NSF AST program director provides continuing oversight, including consultation with an annual NSF program review panel. The program director reviews detailed annual program plans, annual long range plans, quarterly technical and financial reports, and annual reports submitted by NOAO, and attends AURA governance committee meetings.

The NOAO director reports to the president of AURA, who is the principal investigator on the FY10 NSF cooperative agreement. AURA receives management advice from an observatory council composed of members of its scientific and management communities. NOAO employs separate visiting and users committees for the purposes of self-evaluation and prioritization.

In addition to reviews held mid-way through all cooperative agreements, NSF conducts both periodic and ad hoc external reviews of AURA management. A Business Systems Review (BSR) to evaluate the restructuring of NOAO's business services began in FY12. A mid-term management review is scheduled for FY12. A full BSR will be conducted in FY13.

A management review of AURA's performance was carried out in August 2006. In response to the review, the NSB extended the previous cooperative agreement with AURA for eighteen months, through September 30, 2009. A proposal for renewal of the cooperative agreement was received from AURA in December 2007 and underwent review in 2008. The NSB authorized a new cooperative agreement with AURA for the management and operation of NOAO for the period October 1, 2009, through March 31, 2014. A solicitation is being developed and will be promulgated in late 2012 for the management of NOAO under a new cooperative agreement to begin April 1, 2014.

Gemini

The Gemini Observatory (Gemini) consists of two infrared-optimized 8-meter telescopes, one in the northern hemisphere, in Hawaii, and one in the southern hemisphere, in Chile. This siting of the two telescopes assures complete coverage of the sky and complements the observations from space-based observatories.

Gemini is an international partnership with the United Kingdom, Canada, Australia, Chile, Argentina, and Brazil. Construction of the telescopes and their instrumentation has involved a large number of industrial entities in several partner and non-partner countries.

Peer-review telescope allocation committees provide merit-based telescope time but no financial support. NSF does not provide awards targeted specifically for use of Gemini. Many U.S. users are supported through separate NSF or NASA grants to pursue scientific programs that require use of Gemini.

NSO

The National Solar Observatory (NSO) operates facilities in New Mexico and Arizona as well as a coordinated worldwide network of six telescopes specifically designed to study solar oscillations. NSO leads the community in design and development of the Advanced Technology Solar Telescope (ATST). NSO makes available to qualified scientists the world's largest collection of optical and infrared solar telescopes and auxiliary instrumentation for observation of the solar photosphere, chromosphere, and corona. NSO also provides routine and detailed, synoptic solar data used by many researchers and other agencies through its online archive and data delivery system. NSO telescopes are open to all astronomers regardless of institutional affiliation on the basis of peer-reviewed observing proposals.

NSO partners include the U.S. Air Force Office of Scientific Research, U.S. Air Force Weather Agency, NASA, and industrial entities. Many universities and institutes collaborate with NSO on solar instrumentation development and on the design and development of ATST.

An NSF AST program director provides continuing oversight, including consultation with an annual NSF program review panel. The program director makes use of detailed annual program plans, annual long-range plans, quarterly technical and financial reports, and annual reports submitted by NSO as well as attending AURA Solar Observatory Council meetings.

The NSO director reports to the president of AURA, who is the principal investigator on the FY10 NSF cooperative agreement. AURA receives management advice from its Solar Observatory Council, composed of members of its scientific and management communities. NSO employs visiting and users' committees for the purposes of self-evaluation and prioritization. In addition to reviews held mid-way through all cooperative agreements, NSF conducts both periodic and ad hoc reviews of AURA management, as needed, by external committees. The last extensive review for NSO was in FY08 that led to the award of a new cooperative agreement at the beginning of FY10. Annual reviews are anticipated for both NSO program plans and the ATST project, beginning in spring 2011. A Business Systems Review is scheduled for spring 2012.

A management review of AURA's performance was carried out in August 2006. In response to the favorable review, the NSB extended the current cooperative agreement with AURA for eighteen months, through September 30, 2009. A proposal for renewal of the cooperative agreement was received from AURA in December 2007 and underwent review in 2008. The NSB authorized a new cooperative agreement with AURA for management and operation of NSO for the period October 1, 2009, through March 31, 2014. Since NSO is the home for the

ATST project, which is expected to begin operation in 2018, it is anticipated that the current cooperative agreement will be renewed without competition upon its expiration in 2014.

Consortium for Ocean Leadership, Inc. (COL)[18]

The Consortium for Ocean Leadership, Inc. (COL) is a nonprofit organization that represents 99 public and private ocean research education institutions, aquaria and industry; working to advance research, education and sound ocean policy. COL also manages ocean research and education programs in areas of scientific ocean drilling, ocean observing, ocean exploration, and ocean partnerships.[19]

The Integrated Ocean Drilling Program (IODP), which began in FY04, is an expanded successor program to the Ocean Drilling Program (ODP) and represents an international partnership of the scientists, research institutions, and funding organizations of 25 nations to explore the evolution and structure of Earth as recorded in the ocean basins. The IODP is co-led by NSF and the Ministry of Education, Culture, Sport, Science and Technology (MEXT) of Japan.

IODP platforms provide sediment and rock samples (cores), in-situ monitoring, sampling, and measurement from borehole observatories, shipboard and shorebased descriptive and analytical facilities, downhole geophysical and geochemical measurements (logging), and opportunities to conduct experiments to determine in-situ conditions beneath the sea floor.

Annual operations and maintenance support for IODP includes the costs of operating the *Joides Resolution*, the primary platform of IODP. NSF provides support for U.S. scientists to sail on IODP drilling platforms and to participate in the IODP Science Advisory Structure through an associated grants program.

NSF and MEXT are equal partners in IODP and contribute approximately equal amounts to program operation costs. The European Consortium for Ocean Research Drilling (ECORD), representing 16 European countries and Canada; the People's Republic of China; Korea; India; Australia; and New Zealand have also officially joined IODP and provide financial contributions. IODP partners, including NSF, support IODP integrative activities including science planning, review, data management, drilling science-related engineering development, core and sample archiving, publishing, and international outreach.

The Scientific Ocean Drilling Vessel (SODV) project was funded through the MREFC account and supported the contracting, conversion, outfitting, and acceptance trials of a deepsea drilling vessel for long-term use in the IODP. The total NSF cost of the project was $115 million, appropriated through the MREFC account over three years, with FY07 representing the final year of appropriations. The ship owner and operator, Overseas Drilling Limited (ODL), covered an additional $15 million in construction costs in exchange for a higher day-rate charge during operations. This higher day-rate charge will expire at the end of FY13, with reversion to the lower base day-rate for a contractually guaranteed ten years if IODP is renewed.

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[18] NSF FY13 Budget Request – Facilities, p. 28.
[19] http://www.oceanleadership.org/about-ocean-leadership/mission/

The Division of Ocean Sciences (OCE) in the Directorate for Geosciences (GEO) manages the SODV and the IODP under the NSF Ocean Drilling Program. NSF's Ocean Drilling Program is located within the Marine Geosciences Section, with several program officers dedicated to its oversight.

NSF and MEXT have signed a Memorandum of Cooperation, which identifies procedures for joint management of a contract to an IODP Central Management Office (CMO). A non-profit corporation of U.S., Japanese, and other international institutions (IODP Management International, Inc.) has been contracted by NSF for the CMO activity. The CMO coordinates and supports scientific planning, drilling platform activity, data and sample distribution, and publication and outreach activities through its management of commingled international science funds, collected and provided by NSF. Drillship providers are responsible for platform operational management and costs. NSF provides a light drillship through a contract with the U.S. systems integration contractor, an alliance formed by COL together with subcontractors at Texas A&M University and Lamont-Doherty Earth Observatory, Columbia University. MEXT manages its drillship through the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), while the British Geological Survey manages ECORD drilling contributions.

Scientific advice and guidance for IODP is provided through the science advisory structure (SAS), recently streamlined and made more efficient in response to independent, contractual management review. Representation in the SAS is proportional to IODP member financial contributions.

Both the CMO and SIC contracts call for management reviews every three years by independent, external panels. Both the SIC and CMO contracts underwent external review in FY10. Performance under both contracts will be reviewed again in FY13. Reviews for each expedition are carried out on a regular basis to evaluate operational and scientific performance, with review of scientific progress in broader thematic areas conducted by an independent panel every several years.

The current IODP program officially ends in 2013, with IODP international agreements and contracts covering activities through FY13. NSF activities regarding a possible IODP renewal, including overall program review, commenced in FY10. IODP scientific community planning efforts for a possible post-FY13 science program commenced in FY09.

National High Magnetic Field Laboratory (NHMFL)[20]

The National High Magnetic Field Laboratory (NHMFL) is operated by Florida State University (FSU), the University of Florida (UF), and Los Alamos National Laboratory (LANL). NHMFL develops and operates high magnetic field facilities that scientists and engineers use for research in core areas of condensed matter and material physics, materials science and engineering, solid state chemistry and various areas of the biological and biochemical sciences, as well as work on energy and the environment.

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[20] NSF FY13 Budget Request – Facilities, p. 39.

NHMFL facilities are available to all qualified scientists and engineers through a peer-reviewed proposal process. In 2011, the lab set the world's record for the highest nondestructive pulsed magnetic field reaching 97.4 tesla. The 45 tesla hybrid magnet currently provides the highest steady state magnetic fields in the world. Both magnets enable scientists to get new insights on the electronic structure of novel materials such as graphene, topological insulators, high temperature superconductors and more.

NHMFL collaborates with more than 60 private sector companies, including Cryomagnetics, Pfizer, SuperPower, and Oxford Superconductor Technologies, and national laboratories and FFRDCs, including those supported by the Department of Energy (DOE) such as the Spallation Neutron Source and the Advanced Photon Source at Argonne National Laboratory. International collaboration includes magnet development with the Helmholtz-Zentrum Berlin (HZB) (previously known as the Hahn-Meitner-Institute Berlin), the International Thermonuclear Experimental Reactor (ITER) in France, and national magnet labs in France, the Netherlands, Germany, and China.

NHMFL is supported by the Division of Materials Research (DMR) and the Division of Chemistry (CHE) in the Directorate for Mathematical and Physical Sciences (MPS). DMR is the steward supporting the broad mission of the facility, providing 95 percent of the funds. CHE supports the Fourier Transform Ion Cyclotron Resonance Laboratory and provides about 5 percent. Primary responsibility for NSF oversight is with the national facilities program director in DMR, with guidance from an *ad hoc* working group with members from CHE and the Directorate for Biological Sciences.

A consortium of the three institutions (FSU, UF, and LANL) operates NHMFL under a cooperative agreement. FSU, as the signatory of the agreement, has the responsibility for appropriate administrative and financial oversight and for ensuring that operations of the laboratory are of high quality and consistent with the objectives of the cooperative agreement. The principal investigator serves as the NHMFL Director.

NSF conducts annual external reviews, which assess user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, and operations, maintenance, and new facility development. Annual reviews also assess the status of education training and outreach, operations and management efficiency, and diversity plans. Recent and upcoming reviews include: Business Systems Review (BSR), final report issued in September 2009; Renewal Review by external panel of site visitors, December 2011; National Research Council study on the future of high field magnetic science, started in FY12.

A comprehensive renewal review was conducted in FY07. On August 8, 2007 the NSB approved a five-year renewal award not to exceed $162 million for FY08-FY12. A five-year renewal proposal for the operation of the NHMFL from FY13 through FY17 was submitted to NSF in summer 2011 and is currently under review, with results expected in summer 2012. NSF has initiated broad-based community input through the National Research Council to plan for the Nation's long-term investment in high magnetic field research.

Cornell High Energy Synchrotron Source/Cornell Electron Storage Ring (CHESS/CESR)[21]

The Cornell High Energy Synchrotron Source (CHESS) is a first generation, high-intensity, high-energy X-ray facility supported by NSF with partial interagency support from the National Institutes of Health (NIH). It uses synchrotron light given off by charged particles, both electrons and positrons, as they circulate at nearly the speed of light around the Cornell Electron Storage Ring (CESR). CHESS provides capabilities for X-ray research in physics, chemistry, biology, materials, and environmental sciences.

Stewardship and oversight of CHESS is provided through the NSF DMR, though the majority of CHESS users come from disciplines outside of materials science. CHESS is also supported by the National Institutes of Health (NIH). CHESS also hosts MacCHESS, a NIH-funded macromolecular crystallography program at Cornell. NSF and NIH provide oversight of CHESS through regular site visits by external reviewers.

Both CESR and CHESS are administered by the Cornell Laboratory of Accelerator-based Sciences and Education (CLASSE), which reports to Cornell's Vice-Provost for Research. CHESS/CESR is operated by Cornell University in accordance with a cooperative agreement with NSF that set goals and objectives for the facility.

Several CHESS/CESR users are from industry, including pharmaceutical corporations (such as Rib-x Pharmaceuticals) and the research arms of Xerox, and General Motors. Some medical institutions also make use of CHESS/CESR (Dana Farber Cancer Institute, Boston Biomedical Research Institute, and Memorial Sloan-Kettering Institute). CHESS/CESR also has collaborations with DOE-supported synchrotron facilities such as the Advanced Photon Source and National Synchrotron Light Source.

CHESS plays a key role as a training ground for X-ray science and accelerator physics with CHESS students and postdoctorates going to staff other X-ray facilities in the U.S. and around the world.

CHESS is a national user facility accessed on the basis of competitive proposal review. The primary function of the CHESS staff is to maintain and operate the facility and to assist users. A policy and advisory board, appointed by the Cornell Vice President for Research, provides advice to the director of CHESS on policies related to the use and development of CHESS facilities and equipment for user experiments. A users committee appointed by the users of CHESS advises the director on matters of facilities operations and priorities for the users. An annual users meeting and several workshops help disseminate results from the facility.

In FY09, NSF completed the review of a proposal for the continued operation of CHESS/CESR in support of X-ray photon science. In December 2009, the NSB authorized NSF to make a four-year award. The cooperative agreement between NSF and Cornell University funds operations until March 2014. Future support will be determined through interagency discussions on the stewardship of CHESS as a national multidisciplinary user facility.

[21] NSF FY13 Budget Request – Facilities, p. 14.

Chairman BROOKS. The Subcommittee on Research and Science Education will come to order.

Good morning. Welcome to today's hearing entitled "NSF Major Multi-User Research Facilities Management: Ensuring Fiscal Responsibility and Accountability." The purpose of today's hearing is to examine the planning, management, operations and stewardship of major multi-user research facilities funded through the National Science Foundation. I now recognize myself for five minutes for an opening statement.

We all are pleased to have all of our witnesses joining us this morning to continue our discussion concerning oversight of the NSF's multi-user equipment and facilities. I look to my colleague, Mr. Lipinski, and my fellow Subcommittee members on both sides of the aisle to work with us to continue to ensure the Subcommittee performs its legislative, oversight and investigative duties with due diligence on matters within its jurisdiction throughout the 112th Congress and, as always, appreciate their valued experience and insights.

As mentioned in our last hearing, investments in major multi-user research facilities comprise approximately 15 percent of the National Science Foundation's portfolio. The total fiscal year 2013 National Science Foundation budget request for major multi-user research facilities is $1.1 billion. Of that amount, $196 million is requested for the major research equipment and facilities construction line item and $923 million is requested for the Research and Related Activities line item. We looked primarily at the major research equipment and facilities construction account in our last hearing. This hearing will focus more on the Research and Related Activities funding side as those funds support the operations and maintenance of existing facilities, Federally Funded Research and Development Centers, and planning and development activities.

Major multi-user facilities can include telescopes, accelerators, distributed instrumentation networks and arrays, and research vessels. This research infrastructure has a significant impact on large segments of the science and engineering population. We in Congress need to ensure the planning, operations, management and overall stewardship of these projects is being carried out responsibly and in the best interest of the American taxpayer.

The National Science Board and National Science Foundation are currently involved in examining the process of recompetition for these major multi-user facilities in order to "assure the best use of National Science Foundation funds for supporting research and education." Our hearing today will look at the way these facilities are run and managed as well as the issue of recompetition.

I am eager to hear more about how these important facilities are managed, including recompetition practices, and to discuss how we in Congress can continue to support these worthwhile endeavors while ensuring financial and fiscal responsibility.

[The prepared statement of Mr. Brooks follows:]

PREPARED STATEMENT OF CHAIRMAN MO BROOKS

Good morning and welcome. We are pleased to have all of our witnesses joining us this morning to continue our discussion concerning oversight of NSF's multi-user equipment and facilities. I look to my colleague, Mr. Lipinski, and my fellow Subcommittee members on both sides of the aisle to work with me continue to ensure the Subcommittee performs its legislative, oversight, and investigative duties with due diligence on matters within its jurisdiction throughout the 112th Congress and, as always, appreciate their valued experience and insights.

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I am eager to hear more about how these important facilities are managed, including recompetition practices, and to discuss how we in Congress can continue to support these worthwhile endeavors while ensuring fiscal responsibility.

Chairman BROOKS. The Chair now recognizes Mr. Lipinski for an opening statement.

Mr. LIPINSKI. Thank you, Chairman Brooks.

As I stated at last month's hearing on NSF's MREFC account, how we prioritize, fund, manage and oversee major research facilities, and also how we balance facility funding with research grant funding, are all important subjects for oversight by our subcommittee. So I am pleased we are having this series of hearings.

At last month's hearing we had a very interesting discussion about facility planning and construction, including how facility managers calculate and manage contingency budgets and how NSF oversees the whole process. So today's hearing begins where the last one left off.

My understanding is that this hearing is not the result of any specific oversight concern, but rather a broad examination of the status of NSF's policies for and oversight of the management and operations of large facilities. It has been about ten years since the Subcommittee last formally reviewed NSF's facilities policies, and much has changed in the interim. Most importantly, I wasn't on the Subcommittee or even in Congress ten years ago, and neither was the chairman. So I appreciate the effort by the chairman to educate Subcommittee members on where things stand so that we will be better equipped to anticipate and mitigate any problems in the future.

To that end, the policy topic today that is of particular interest to me is recompetition of management contracts. In 2008, the National Science Board strongly endorsed a recompetition policy for major facility awards. How this is to be implemented across the full spectrum of facility types and management structures remains unresolved. How would recompetition work for the MagLab or CHESS, for example, which physically sit on land owned by the respective universities that manage them? How would recompetition work for any of the facilities with significant international partnerships?

I would also like to discuss the process for decommissioning user facilities. That includes how a decision to decommission a facility is made and how decommissioning costs are allocated. Without an agency or Board witness present, I don't think we can get into a full discussion of recompetition or decommissioning policy this morning but I certainly would be interested to hear this panel's perspectives on these issues so that we can further pursue it with the agency itself.

With that, I look forward to hearing about each of your respective facilities, both the exciting science you are doing and your stewardship of the taxpayer dollars that support these facilities.

With that, I will yield back.

[The prepared statement of Mr. Lipinski follows:]

PREPARED STATEMENT OF RANKING MEMBER DANIEL LIPINSKI

Thank you Chairman Brooks. As I stated at last month's hearing on NSF's MREFC Account, how we prioritize, fund, manage, and oversee major research facilities, and also how we balance facility funding with research grant funding, are all important subjects for oversight by our subcommittee. So I am pleased we are having this series of hearings.

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With that, I look forward to hearing about each of your respective facilities—both the exciting science you are doing and your stewardship of the taxpayer dollars that support these facilities.

I yield back.

Chairman BROOKS. Thank you, Mr. Lipinski.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I would like to introduce our witness panel for today's hearing. Our first witness will be Dr. Ethan J. Schreier, President of the Associated Universities, Inc. Associated Universities, Inc. manages the National Radio Astronomy Observatory for the National Science Foundation and is the North American Executive for the international Atacama Large Millimeter Array under construction in northern Chile.

Our second witness is Dr. William S. Smith, Jr., President of the Association of Universities for Research and Astronomy. At the Association of Universities for Research and Astronomy, Dr. Smith acts as the Chief Executive Officer and sets the overall direction and policy for the Space Telescope Science Institute, the International Gemini Program, the National Optical Astronomy Observatory, and the National Solar Observatory.

Our third witness is Dr. David Divins. He is the Vice President and Director of the Ocean Drilling Programs at the Consortium for Ocean Leadership, Inc. Dr. Divins serves as the Program Director and Principal Investigator of the System Integration Contract for the Integrated Ocean Drilling Program.

Our fourth witness is Dr. Gregory S. Boebinger, the Director of the National High Magnetic Field Laboratory and Professor of Physics at Florida State University and the University of Florida. Dr. Boebinger is responsible for all three campuses of the National High Magnetic Field Laboratory, the headquarters at Florida State University, the Pulse Magnet Laboratory at Los Alamos National Laboratory, and the Ultra Low Temperature and Magnetic Resonance Imaging Laboratories at the University of Florida.

Our final witness is Dr. Sol Michael Gruner, the Director of the Cornell High Energy Synchrotron Source and the John L. Wetherill Professor of Physics at Cornell University. In 1997, Dr. Gruner joined Cornell University as Director and Principal Investigator of the Cornell High Energy Synchrotron Source Facility and as a Faculty Member in the physics department and the Laboratory of Applied and Solid State Research.

As our witnesses should know, spoken testimony is limited to five minutes each after which the Members of the Committee will have five minutes each to ask questions. Given our time availability and our having at this point three Congressmen, while we prefer that you limit yourself to five minutes, you will be given a little bit of latitude as will the Congressmen as they ask questions.

So with that, I now recognize our first witness, Dr. Ethan Schreier. Dr. Schreier, you are recognized for five minutes.

STATEMENT OF DR. ETHAN J. SCHREIER, PRESIDENT, ASSOCIATED UNIVERSITIES, INC.

Dr. SCHREIER. Thank you, Chairman Brooks, Ranking Member Lipinski and distinguished Members. Thank you for this opportunity. I am Ethan Schreier, President of AUI, a nonprofit research management corporation that operates the National Radio Astronomy Observatory, NRAO, under cooperative agreement with NSF.

AUI's stated mission is to promote education, discovery and innovation by uniting resources of universities, research organizations and the government, and building and operating forefront multiuser scientific facilities. We have been in operation since 1946.

NRAO provides transformational scientific capabilities in radio astronomy that enable astronomers to answer fundamental questions about the universe. Radio astronomy has opened new vistas into the universe and uncovering the birthplace of stars and planets, studying super-massive black holes, neutron stars, gravitational waves and the remnant heat of the Big Bang.

AUI created NRAO over 50 years ago at the request of the university research community. NRAO has been the world's premier radio astronomy observatory ever since. Under AUI stewardship, NRAO has built and operated the most advanced radio telescopes in the world, developed state-of-the-art technology, brought benefits to the public, promoting, science, technology, engineering and math education.

NRAO currently operates four unique world-leading telescopes: the iconic Very Large Array in New Mexico, the very large Green Bank Telescope in West Virginia, the transcontinental Very Long Baseline Array, which has ten dishes spread over 5,000 miles across the United States from the Virgin Islands to Hawaii, and of course, the new international Atacama Large Millimeter/submillimeter Array, ALMA, in Chile at an altitude of 16,000 feet for which AUI is the North American lead.

AUI closely manages NRAO with very active goverance, with continuing technical, programmatic, fiscal review and oversight, and close communication with both NSF and with the research community. Public support for fundamental research has consistently resulted in very practical benefits as well for the Nation. For example, NRAO pioneered technology that was later adopted for medical imaging, and technology used in cell phones. AUI and NRAO also actively leverage radio astronomy investments to promote STEM education, as I mentioned, with proven outreach and dissemination activities across the country. For example, in the NSF-funded Pulse Search Collaboratory, high school students and, for that matter, their teachers, search for pulsars using NRAO data and then they can publish their discoveries with active astronomers. Surveys have shown that female students, in particular, gain substantial confidence in math and science after participating. In programs we have our student interns learn by working at NRAO in engineering as well as science.

The current fiscal environment presents a unique challenge to AUI in maintaining its status as the world's forefront radio observatory. We may, for the first time in our history, be forced to close a telescope that is still a forefront observatory and one of the leading observatories of the world. Previously, NRAO would retire telescopes only after they became obsolete. This chart shows that we have retired seven. None of NRAO's first-generation telescopes dating back to the 1950s, 1960s, 1970s are still in operation.

To protect the operation of our current world-leading facilities, we are actively continuing to seek external partners and leverage their contributions to maintain leadership, U.S. leadership. U.S. leadership and our core competence in radio astronomy, which we do have, is also threatened by the potential spilt of domestic NRAO facilities and ALMA.

The National Science Board issued a resolution urging recompetition of ALMA separately from the rest of NRAO when the cooperative agreement with NSF is competed next year. Separating ALMA from NRAO would put the success of ALMA at great risk, compromising three decades of work by experienced and expert NRAO staff in the planning of ALMA, the design, the construction, and the operation, working in close collaboration with the astronomy community and our foreign partners. It would result in an enormous loss of efficiency and expertise, increase complexity and cost, and put U.S. scientists at a disadvantage in the international ALMA partnership in using the facility. AUI sees its role as ensuring that U.S. research has reaped the benefits of the large U.S. investment in ALMA, the world's newest and most transformational radio facility.

AUI's NRAO has been a pioneer in radio astronomy for 56 years now. The experience gained in building and operating the world's leading radio facilities is guiding our way forward in these rather difficult fiscal times. Our goal is to keep the United States in the lead of this key scientific discipline and to continue unlocking the secrets of the universe.

Again, thank you for giving me the opportunity to testify today. I have provided additional details and recommendations in my written testimony. Thank you.

[The prepared statement of Dr. Schreier follows:]

Associated Universities, Inc.

U.S. House of Representatives Committee on Science, Space, and Technology
Subcommittee on Research and Science Education

Hearing on NSF Multi-User Research Facilities
April 18, 2012

Written Testimony Regarding the National Radio Astronomy Observatory

Dr. Ethan J. Schreier
President, Associated Universities, Incorporated
Adjunct Professor, The Johns Hopkins University

Chairman Brooks, Ranking Member Lipinski, and distinguished members of the committee, I thank you for this opportunity to testify. My name is Ethan Schreier, President of Associated Universities, Incorporated (AUI), a non-profit corporation that operates the National Radio Astronomy Observatory under a Cooperative Agreement with the National Science Foundation.

The National Radio Astronomy Observatory (NRAO) is a Federally Funded Research and Development Center (FFRDC) that enables forefront research into the universe at radio wavelengths. Radio astronomy is a relatively new branch of science, having started in 1932, but it has opened new vistas into the Universe, uncovering neutron stars, the birthplaces of stars and planets, super-massive black holes, gravitational waves and the remnant heat of the Big Bang, not possible via conventional optical astronomy. Radio astronomy has been responsible for several Nobel prizes.

AUI is the legal entity responsible for executing the responsibilities contained in its Cooperative Agreement with NSF. AUI established NRAO over 50 years ago, and NRAO has been the world's premier radio astronomy observatory ever since, building and operating the world's most advanced radio telescopes for use by the US astronomy community, as well as by astronomers from the rest of the world, under an *Open Skies* policy. Under the stewardship of AUI, NRAO has developed state-of-the-art technology in support of its facilities, and for the development of future facilities in the US community, maintaining US leadership in this important discipline. At the same time, it has promoted science, technology, engineering, and

Associated Universities, Inc. promotes education, discovery, and innovation by uniting the resources of universities, research organizations and government in the planning, construction, and operation of forefront scientific facilities.

mathematics (STEM) education through a variety of programs to inspire students and foster the next generation of scientists and engineers.

Certain physical phenomena are only observable by their radio signals. Just as visible light from space carries information about stars and things illuminated by them, radio waves are emitted by important celestial phenomena that are often invisible to our best optical telescopes. For example, stars form from collapsing cold clouds of molecules and dust, too cold and obscured to be observed by any other technique. The earliest stages of star formation, one of the most basic processes of astrophysics, are invisible even to the Hubble Space Telescope or the future James Webb Telescope and can only be studied using the techniques of radio astronomy. Radio astronomy also offers cost-effective methods to complement other techniques. For example, radio astronomers are using accurate timing of pulsars – fast-spinning, highly dense, collapsed (*neutron*) stars – to search for the gravitational waves predicted by Einstein's Theory of General Relativity. This technique, which uses NRAO's Green Bank Telescope among other facilities, is a complement to LIGO and other gravitational wave detectors.

NRAO currently operates four world-leading telescopes for use by the scientific community: the Jansky Very Large Array (JVLA) in New Mexico, the most productive, ground-based telescope in history; the Green Bank Telescope (GBT) in West Virginia, the world's largest, fully-steerable telescope; the Very Long Baseline Array (VLBA), the world's largest scientific instrument with 10 dishes spanning North America that enable the most precise angular measurements of any telescope; and the new international Atacama Large Millimeter/ submillimeter Array (ALMA), the largest ground-based astronomy project ever conceived and built, for which AUI is the North American lead (*Executive*), overseeing NRAO's construction and operations for the North American portion of ALMA. Each of these telescopes fills a unique and essential science role, and each is the best in the world in its category. NRAO's Headquarters, and the focus of its radio technology developments, is in Virginia.

Importantly, NRAO facilities provide transformational and unique scientific capabilities that enable the astronomy community to answer many fundamental questions about the universe including those highlighted by the recent National Academy's Decadal Survey, *New Worlds New Horizons*, studying galaxies as they form and grow since the earliest times of the Universe, directly imaging planets in formation around nearby stars, and directly detecting gravitational waves from the merging of massive black holes.

While these telescopes are geographically dispersed, now in South as well as North America, NRAO management effectively coordinates science operations, technical development, and administration to achieve synergies across the Observatory and to leverage each telescope to the maximal scientific benefit. Functions that are fundamentally site or telescope specific are delegated to site directors. AUI and its Board of Trustees maintain overall responsibility for

Observatory performance, including programmatic, administrative and budgetary oversight, with special attention to research community relations and to major construction projects.

The NRAO telescopes are national multi-user facilities operating under the "Open Skies" policy, with access governed solely by the scientific merit of proposals and not the national origin or affiliation of the applicants. Scientists may propose for observing time at regular, open proposal deadlines. The proposals are evaluated through a peer review process that is administered by NRAO, using independent reviewers and panel chairs who are members of the community. NRAO staff scientists receive no preference in the selection of projects or awarding of observing time. As ALMA is an international partnership, its proposals are evaluated by the international Joint ALMA Observatory, but the process is similar to the NRAO system. North American scientists receive 32.5% of total ALMA observing time, with the balance distributed to the European and East Asian partners and the Chilean hosts, in proportions determined by their respective contributions toward the project.

Historical Overview

Associated Universities, Inc. is a 501(c)(3) non-profit research management and educational organization, originally established after World War II by nine major US research universities. Its original purpose was to enable basic and applied research that had been started during the war to continue for the benefit of the country and the research community, initially by building and operating Brookhaven National Laboratory, a large civilian research facility, funded by the Atomic Energy Commission. The establishment of a national laboratory in the US to design, construct and operate large scientific machines that individual institutions could not afford to develop on their own, was a new development. Yet, the model created by AUI was so successful that it was then adapted and used by other disciplines across the sciences.

The National Radio Astronomy Observatory was created in 1956 when AUI responded to a need that arose in the US research community for a national radio astronomy facility. While radio astronomy had been invented in the United States in the 1930s, by the 1950s other countries were taking the lead. Recognizing the importance of this field to astronomical research and technological innovation, as well as the pioneering role the U.S. had played in its formation, AUI responded by submitting a proposal to NSF to build and operate NRAO. This proposal was accepted in November 1956. Within a few years, AUI had established NRAO and built two major radio telescopes, and the U.S. regained leadership in radio astronomy. AUI has managed NRAO ever since, overseeing its continued growth as the recognized premier radio astronomy observatory in the world.

Over its 56-year history, AUI and NRAO have developed nine major telescopes at four primary sites. Our long-term strategy is to upgrade facilities as possible; to plan, build and operate new facilities driven by developing scientific needs; and to retire facilities that have been made obsolete and superseded. NRAO's capacity for continuing renewal, providing forefront facilities relies on the excellence of its scientific and technical staff, working closely with the astronomy community.

AUI selected Green Bank, West Virginia as the initial site for NRAO. Its remote location, surrounded by the Appalachian Mountains, offers excellent protection from harmful radio interference. Significant early facilities built there include the 85-foot Tatel telescope (1958), the 300-foot transit telescope (1962), and the Green Bank Interferometer (1964). Today's vastly more capable 100-meter GBT, which was completed in 2002, has a precision surface larger than a football field with more than 2 acres of collecting area. Of the telescopes at Green Bank, only the GBT remains supported under the NSF Cooperative Agreement today, although the other facilities are used for various educational and independently-funded projects.

A 36-foot millimeter-wave telescope was completed in 1967 at Kitt Peak, near Tucson, Arizona. Upgraded to the 12-meter in 1984, this facility pioneered the entire field of millimeter-wave astronomy and was a direct precursor to ALMA. NRAO ceased operating this telescope in 2000 when ALMA construction was on the horizon; it continues to be used by the University of Arizona using state and private funds.

The iconic Very Large Array near Socorro, New Mexico was completed in 1980 and consists of 28 antennas, each 25-meters in diameter. Located on the high Plains of San Agustin, the antennas can be reconfigured along 40 miles of railway track to adjust the angular resolution of the telescope, analogously to the zoom lens of a camera. The VLA has recently been upgraded and re-dedicated just two weeks ago as the Jansky Very Large Array, with 10-1000 times the original capability. The original VLA, and the upgraded Jansky VLA project, were both carried out on-time and on-budget.

The Very Long Baseline Array, also controlled from Socorro, was completed in 1993. It consists of 10 antennas distributed across the continental U.S., in St. Croix, U.S. Virgin Islands, and on Mauna Kea, Hawaii. Because of the 5000-mile extent of the array, the VLBA has the highest angular resolution (image sharpness) of any telescope at any wavelength.

ALMA, the newest NRAO facility, shared with partner countries, is being built by an international collaboration among the United States, Canada, Europe, East Asia, and Chile. ALMA, a 66-telescope millimeter/ submillimeter array in the high Atacama Desert of northern Chile, is the largest ground-based astronomy project in the world and has the potential to revolutionize our understanding of the universe. AUI is the North American Executive for ALMA, and oversees NRAO in the construction and operations for the North American portion of ALMA, acting on behalf of the NSF. ALMA began its first science operations in the fall of 2011, and all North American project deliverables will be completed in 2012. A formal inauguration is scheduled for Spring 2013. ALMA will provide for the first time detailed images of stars and planets as they are being formed, of young galaxies being assembled, of the structures around black holes at the centers of active galaxies, and it will open new windows into the cold Universe via a tremendous increase in sensitivity and resolution at millimeter and submillimeter wavelengths.

Other multi-user facilities managed or supported by AUI

In recent years, AUI has responded to research needs in several projects beyond NRAO. These projects represent important tools for astronomy and serve as examples of AUI's readiness to adapt to provide the most benefit to the scientific community.

AUI responded to a high priority need in the astronomy community to provide common access to data from major astronomy archives of both space and ground-based observatories. Several years ago, AUI joined with its sister organization, the Association of Universities for Research in Astronomy (AURA), which operates the National Optical Astronomy Observatory and the Hubble Space Telescope Science Institute, to manage the Virtual Astronomical Observatory (VAO). The VAO links together major astronomy archives to create an integrated, publically accessible tool for astronomical research. VAO is funded by NSF and NASA and is enabling innovative new methods to extract meaning from the massive quantities of data produced by astronomical instruments. This is an example of the type of Big Data Initiative recently announced by NSF and several other agencies. Astronomy is indeed a science where massive data sets are generated, are publicly accessible, and are more useful studied in combination than individually.

CCAT is a 25-meter single dish sub-millimeter telescope that will be built in Chile on top of a peak adjacent to ALMA. It will be a unique facility that allows large scale surveying of the sky to pinpoint targets for ALMA observations and ensure that US users get maximal benefit from its ALMA investment. CCAT is a university-based initiative, being built by a consortium of universities in the United States, Canada, and Germany, along with AUI. AUI is leveraging its experience building ALMA to navigate the issues of construction and operations in Chile. NSF is providing support for the detailed design and expects to contribute to the construction and operations, adding to the funds being supplied by the universities. The universities will benefit by engaging students and faculty in the design and development of instruments, with telescope time available for the broad US astronomical community.

Why Does NSF Fund NRAO and what is the National Return on this Investment?

The NSF is the only US agency dedicated solely to funding fundamental research across the spectrum of disciplines from physics to biology to engineering to social and behavioral sciences, and NSF is the dominant supporter of US ground-based astronomy. It is from the ground, not in space, that almost all state-of-the-art radio astronomy is conducted; this makes radio astronomy highly cost-effective when compared to equally important telescopes that must fly in space.

Astronomers need state-of-the-art tools that are often too big and expensive for single university groups to build, or if they could build them, would be too expensive and wasteful to replicate. NRAO, with funding from NSF, has consistently supplied such radio astronomy facilities to the astronomy community. A focused effort is also required to develop enabling technology, and NRAO maintains the US core competence in radio science technology. These two aspects – building and operating major multi-user instruments, and maintaining the technological underpinnings of the discipline, along with supporting the research community in using these capabilities – are the basic reasons to have a National Facility.

NRAO has a long history of enabling fundamental discoveries in radio astronomy. The entire field of molecular line astronomy, which probes star formation, began using NRAO telescopes. The carbon monoxide molecule, the most ubiquitous molecule of all, was discovered at NRAO, as was formaldehyde, the first of many organic molecules seen in space, providing clues to the origin of life. The powerful radio source at the center of our Galaxy, Sgr A*, now believed to be a massive black hole, was discovered at NRAO. The structure of the Milky Way was mapped and the distances to the spiral arms measured. Recently, astronomers have used pulsars to determine the fundamental nature of nuclear physics and confirm General Relativity in a manner that would never be possible in a man-made laboratory.

Aside from satisfying scientist's curiosity about profound questions in the physical realm, public support for fundamental research -- research not specifically aimed at solving immediate, practical problems -- has consistently resulted in very practical benefits to the nation and its people. Sometimes these benefits derive directly from understanding nature better. For example, studies of the Sun and its then-mysterious source of power aided our development of nuclear power. Sometimes the benefits come in the form of "spinoffs" from technology first developed to probe deeper into nature's secrets; examples include improved technology for cell phones first pioneered in radio astronomy by NRAO. The technology that NRAO has developed to detect chemicals at great distances also has practical applications on Earth.

Even in the realm of "pure" scientific research conducted with radio astronomy, there is often practical value. For example, NRAO's unique ability to map the rotation of Near-Earth Asteroids can help us better understand, and thus prepare plans to counter the threat of, asteroids that could collide catastrophically with our planet.

NRAO also has a distinguished record of technology development that has not only made radio astronomy instruments highly sensitive and capable, but has also found application in other fields. NRAO has been a world leader in the development of cryogenic low noise amplifiers, superconducting detectors for millimeter wave radiometers, and digital correlators. NRAO built the low noise amplifiers for NASA's WMAP mission that measures cosmic background radiation. NRAO scientists and technologists have also pioneered software techniques later adopted for medical imaging, developed algorithms later used in cell-phone operations, and spawned an entire computer language (FORTH) still used in embedded processors.

To maximize the return on the taxpayers' investment, AUI and NRAO engage in an extensive program to bring the benefits of NRAO's research activities to the public, and to broaden the impact of its programs. This includes STEM education, student programs, teacher training, public news dissemination, and informal education. The Green Bank Science Center has a large visitor center with hands-on exhibits, displays, classrooms, and a guided tour of the site. The facility hosts approximately 50,000 visitors per year, including numerous school groups, and several formal programs such as the Governor's School for Math and Science. The JVLA Visitor Center hosts about 20,000 visitors per year. North American ALMA outreach is integrated with NRAO outreach, and has now extended to other countries. In addition, with AUI support, a student and teacher exchange program between the villages of San Pedro de Atacama, Chile and Magdelana, New Mexico was instituted.

NRAO has developed high impact STEM education programs to make use of the unique research opportunities afforded by radio astronomy. In the *Pulsar Search Collaboratory*, an NSF-funded program, high schools students are given raw pulsar survey data from the GBT and are trained to use straightforward software analysis tools to search for pulsars in the data. If a student discovers one, he or she becomes a co-author with professional astronomers on scientific journal papers. They are thus trained in the entire scientific research process, from experimental design to publication. Several high school students in the program have successfully detected pulsars. Surveys of the attitudes of the students before and after joining the program have shown that the female students, in particular, gained substantial confidence in their abilities in math and science as a consequence of their participation. The students participating in the program thus far have been located primarily in West Virginia and a few surrounding states. AUI and NRAO are currently exploring collaborations that would expand the program nationwide. In another program, backed by AUI and coordinated by the international astronomy professional organization IAU, and funded by Chilean industry, US astronomers and students will visit Chile to help train Chilean science teachers, promoting international understanding, providing an important US ally with much-needed capacity, and providing US students a unique educational experience.

AUI and NRAO actively seek new opportunities to expand their outreach programs, not just at NRAO facilities but in collaboration with other programs AUI manages or helps to manage (*e.g.* VAO and CCAT). We are in active talks with NSF and several university partners to investigate potential new programs that use astronomy, its vast data archives, and its engineering-rich operations to enhance science and engineering education programs. Student interns from the New Mexico Institute of Mining and Technology already work at NRAO's Socorro operations, and AUI is currently in discussion with the administrations of West Virginia University and University of Virginia to broaden such programs. AUI is also in discussion with the University of Colorado, to determine how radio astronomy can participate in Colorado's national-impact STEM education programs.

What Steps are taken to ensure the Best Stewardship of NRAO?

AUI takes its role as steward of the facilities it operates very seriously; we feel responsible not only to the NSF, but to the research community and the taxpayers as a whole. NRAO not only builds and operates forefront facilities, but also engages and helps foster the university research community, and implements public outreach programs. NSF in turn takes its oversight role seriously, reviewing AUI and NRAO programmatic, management, and technical performance.

AUI seeks out the best management practices, and helps NRAO implement them. AUI and NRAO engage annually in many levels of internal and external review to ensure a process of continuous improvement. The AUI Board, which includes members of the university research community, senior engineers, administrators and managers, oversees and regularly reviews NRAO performance. The AUI Board has standing Audit and Operations and Administration Committees that monitor and advise AUI and NRAO management on fiscal and administrative matters. AUI also establishes ad hoc committees as necessary, notably including the ALMA Oversight Committee that has advised AUI and overseen its role in the construction of ALMA. It is noteworthy that ALMA, the largest facility ever funded by NSF, has already started early science on schedule and that the North American deliverables will be completed on the schedule and within the budget promised to the National Science Board over six years before.

AUI and NRAO take all steps necessary to ensure that business and financial practices follow best accounting practices and meet all existing NSF and AUI policies. AUI establishes policies and processes and monitors NRAO's adherence to these policies. AUI engages an external audit firm to perform annual A-133 external audits. AUI also conducts internal audits of AUI/NRAO, selecting for examination several major audit areas each year, on a rotating basis. The Board's

Audit Committee oversees all these processes and reports to the full Board. AUI and NRAO have a long record of excellent, unqualified audit reports. Approximately every four years, NSF performs a detailed Business Systems Review. The most recent BSR was completed just a few weeks ago, with no reported concerns. The Defense Contract Audit Agency (DCAA), working under contract with NSF, has also been conducting its own audit for the past two years, and has not reported any significant findings.

To review its science impact, policies, and programs affecting users, NRAO appoints a Users Committee made up of representative members of the community. NRAO evaluates the recommendations of this committee and reports on the status of implementing its recommendations. AUI also appoints a distinguished independent Visiting Committee made up of senior scientists and administrators to review overall NRAO program and organizational effectiveness. This Committee reports to AUI and its Board, and its report and the NRAO Director's response is forwarded to NSF. External ad hoc committees are established from time to time to review and/or advise on particular matters of concern, and to address matters of importance to the broad radio astronomy community.

What Roles do NRAO, AUI & NSF Play in the Scientific, Budget, and Management Components of the Facility?

AUI is responsible to NSF to execute the responsibilities contained in the Cooperative Agreement, but it delegates day-to-day operations to the NRAO Director and his or her staff.

Each year, NRAO drafts an annual Program Operating Plan written to the projected NSF budget allocation, together with a 5-year Long Range Plan written to NSF-supplied projections. These plans integrate community science priorities determined from major reviews such as the National Academies Astronomy and Astrophysics Decadal Survey, input from the NRAO Users Committee, and from NRAO's internal reviews and discussions. NRAO has an internal program prioritization process to ensure that within its budget, funds are spent for the highest priority activities with the greatest impact. Divisions develop internal plans for their activities, the proposed activities are evaluated and ranked by management according to impact. AUI reviews and approves the program plans and the associated budget before submission to NSF.

NSF convenes a formal review panel to evaluate the program plans, as well as the success of the previous year's program. After any necessary revisions based on comments and recommendations, NRAO manages to the revised Program Operating Plan during the fiscal year.

After Congress approves the NSF budget, and the NRAO allocation becomes final, NRAO submits quarterly estimates of cash draw-down requirements within the allocation amount

(Form 1030). In accordance with the cash management requirement of OMB A-110 to minimize time elapsed between the transfer and disbursement of funds, each week our fiscal office draws down the cash required to meet payroll and accounts payable needs for the next business week.

Formal and informal communications between NSF, AUI, and NRAO take place on a continuing basis to ensure good communication and to report progress toward goals. Formal Quarterly Status Updates are prepared by NRAO and submitted by AUI to NSF, with face-to-face presentations by senior NRAO management to NSF's program officers. These updates summarize progress against milestones, financial status, science, technical, and broader impact highlights, as well as any anomalies. AUI's North American ALMA Project Director at NRAO reports monthly to NSF. AUI meets approximately monthly with the NSF program officers to discuss any matters of concern, and NSF is also invited to share perspectives directly with the AUI Board of Trustees several times per year. The AUI Board routinely reviews NRAO progress toward meeting the plan at each Board meeting and AUI informs NSF of any significant events that could represent a departure from the Program Operating Plan.

Planning the Lifecycle of Facility Components

NRAO has built – and retired – multiple generations of facilities. NRAO's mission is to enable forefront research at radio wavelengths; this requires forefront facilities. Ground-based radio telescopes are typically constructed with a 20-30 year design lifetime, and may undergo one or more major upgrades or renovations that extend their productive lifetime. NRAO has never attempted to "hang on" to facilities that are past their prime, but rather has developed, built, or upgraded facilities so that they are state-of-the-art and the best in the world at what they do. All components of NRAO's current suite of telescopes: JVLA, GBT, VLBA, and ALMA, fit this description. Furthermore, the technology is freely shared with the university community and, in some cases, university groups actively collaborate in building NRAO instruments.

None of NRAO's first generation telescopes are still operational under the NSF Cooperative Agreement for NRAO, although some have found extended useful life with other organizations or external funding. For example, the Green Bank 140-foot telescope has been used under an Air Force contract with MIT / Lincoln Labs for radar studies, and other facilities at Green Bank have been used for dedicated educational purposes, solar monitoring, time keeping, and other non-research activities. The Kitt Peak 12-meter continues observations under the aegis of University of Arizona.

In all previous cases in which NRAO telescopes have been retired, a new and more capable facility has been on the horizon. NRAO has always conducted discussions with the NSF and the astronomical community about the proper time for closure and then proceeded.

Due to current tight budgets, NRAO may, for the first time in its history, be forced to close or drastically reduce operations of a telescope while it is still operating as a forefront facility with no near-term successor. Either or both the GBT or VLBA are presently vulnerable, and external funding is being actively sought.

Recompetition History

NSF's Cooperative Agreement with AUI for NRAO operations has had a typical term of five years. NSF has in the past conducted mid-term management reviews that have been asked to recommend whether the Cooperative Agreement should be competed. AUI has demonstrated an outstanding record of stewardship of NRAO over the years and has received high marks from all evaluations of its management, both recently and historically. Each time, AUI has been renewed without recompetition. However, given the National Science Board's (NSB) emerging policy of promoting recompetition for all facilities regardless of current management performance, AUI's Cooperative Agreement for both NRAO and ALMA operations will be recompeted next year. NSF recently convened a committee to recommend best practices for NSF's competitions.

The Cooperative Agreements for both NRAO and ALMA Operations expire in 2015. NSB issued a resolution that, "urges the use of a recompetition plan that ensures that the recompetition of the management and operation of ALMA is separated from the recompetition of the management and operation of NRAO." NRAO and AUI believe that separating ALMA and NRAO management would have a seriously negative impact on science in the U.S. The scientific, engineering, and administrative staffs supporting these instruments are highly integrated, which produces cost efficiencies and helps ensure that US researchers reap the scientific benefits of the US investment in ALMA. Splitting them apart would result in an enormous loss of efficiency and expertise that would cause the US research community and all Observatory components to suffer and increase the costs of operations to the US taxpayer. AUI and NRAO have urged NSF to keep NRAO and ALMA operations under a single Cooperative Agreement.

External Partnerships

Throughout their history, NRAO and AUI have engaged in collaborations with external partners, including both US and international institutions. These collaborations have increased scientific productivity, aided university researchers, supported other US government agencies, expanded the funding base for NRAO, and resulted in the development of cutting-edge technology. Foreign collaborations in particular depend on stable long-standing relationships, good will and, and often legal agreements or MOUs.

The most notable example is the international partnership to build ALMA, which due to its sheer scale and expense would likely never have been built without a joint effort. The VLA upgrade also utilized a construction partnership among the U.S., Canada, and Mexico, which expanded the funding base for the project and procured a critical technical component.

University collaborations have included the development of instruments for the GBT. Several university groups have built receivers which not only supply needed capabilities for the GBT but also give students the much-needed opportunity for training in instrument building and software development. Foreign research groups (*e.g.* Max Plank Institute) have also contributed instruments to NRAO that become available to all users. This open exchange of scientific instrumentation has benefited the entire research enterprise.

NRAO has also on occasion provided critical mission support to NASA using the VLA, GBT, and the VLBA both for tracking spacecraft and for receiving telemetry from planetary flybys and landers. In addition, the U.S. Naval Observatory (USNO) has provided operational support for the VLBA in return for observations in support of their precision timekeeping mission. NSF's 2006 Senior Review recommended that in times of constrained budgets, NRAO should seek outside funding for the VLBA, which USNO provides.

Major Challenges Faced by NRAO

NRAO has been a pioneer of radio astronomy for 56 years, building world-leading telescopes and enabling forefront research throughout its history. The Observatory has blazed many trails technically, scientifically, and organizationally, and overcome many challenges.

The greatest technological and managerial challenge in recent years has been the construction of ALMA, due to its unprecedented technical complexity and size, its remote location in the desert of northern Chile, the need to manage a supply chain with contributions from around the world, and the need to coordinate with an international team of equal partners. Despite these difficulties, ALMA has been on time and on budget since a 2006 rebaselining.

NRAO has overcome other technical challenges, including the successful resolution of a GBT azimuth track problem. The track, which bears over 16 million pounds of moving weight – the GBT is the largest moving land-based structure – began to fail within the first year of operation. The contractor's design was faulty, and not only did NRAO, with added expertise from the AUI Board, convene engineering experts from around the world to develop a replacement design that has worked superbly since, but AUI oversaw a hard-negotiated warranty settlement with the contractor that helped fund the corrective actions.

The current major challenge facing NRAO is maintaining its status as the world's forefront radio observatory under an extremely constrained budget, which may force the closure of one or more world-leading telescopes. In addition, US leadership and its core competence in radio astronomy are threatened by the potential split of domestic NRAO facilities from ALMA, the world's newest and transformational radio facility. AUI sees its role as ensuring that US researchers reap the benefits of the large US investment in ALMA, and the advantages of a unified national facility, and not put the US at a disadvantage in using this ALMA as compared with European astronomers interacting with ALMA via ESO.

The rest of the world is working hard to surpass the US in radio astronomy leadership. Europe, Asia, and Africa are actively engaged in planning for the next generation radio astronomy instrument, the *Square Kilometer Array*. The US must continue to invest in forefront radio astronomy research and facilities to continue unlocking the secrets of the universe and keep its leadership role in a key scientific discipline.

Key Points:

- Radio astronomy is an important tool for understanding the universe, and NRAO has consistently provided the research community the best radio astronomy capabilities.
- NRAO is the pre-eminent radio astronomy organization in the world, with major instruments in all relevant wavebands, and major facilities in Virginia, West Virginia, New Mexico and Chile.
- AUI created NRAO and continues to successfully and closely manage it via its active governance structure, regular technical, programmatic, and fiscal review and oversight, and close communication with both the research community and NSF.
- AUI has a long history of success, and in addition to managing NRAO, it is flexible in responding to research community needs, and representing radio interests in the broader astronomical community. It helps manage the Virtual Astronomical Observatory and is helping the university community build a new forefront observatory in Chile.
- AUI and NRAO actively work to leverage radio astronomy investments to promote STEM education through proven outreach and dissemination activities across the country.
- The current fiscal environment presents unique challenges; a major issue facing AUI is maintaining NRAO's status as the world's forefront radio observatory in an extremely constrained fiscal environment. One or more forefront facilities may face closure.
- AUI sees its role as ensuring that US researchers reap the benefits of the large US investment in ALMA. Recompetition of NRAO is approaching, and an issue of particular concern is the possible separation of ALMA from NRAO. US leadership and its core competence in radio astronomy are threatened by this potential split of domestic NRAO facilities from ALMA, the world's newest and transformational radio facility. We assert that the best use of taxpayer dollars is to continue the long association of NRAO and ALMA.
- Our long successful history indicates we know what we're doing. The experience gained in building and operating the world's leading radio facilities is guiding our way forward in these difficult times. We perceive that certain initiatives, like separating ALMA from NRAO, appear to greatly increase the complexity and risk of these successful programs, and we look forward to working with NSF and Congress to consider the options.

Chairman BROOKS. Thank you, Dr. Schreier.

The Chair now recognizes Dr. Smith for his five minutes.

STATEMENT OF DR. WILLIAM S. SMITH, JR., ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY

Dr. SMITH. Thank you, Chairman Brooks, Mr. Lipinski and other Members of the Committee. It is a privilege to be able to testify to this Committee that plays such an important role in looking at the balance of investments within the NSF, so this is a very useful hearing for you to have called.

I will use acronyms if you permit. Association of Universities for Research and Astronomy, or AURA, is a consortium of universities, and we manage the optical telescopes which are different from the radio telescopes. They look different. They are placed in different locations. But many of the things that Dr. Schreier said also apply to the telescopes that we manage. Our facilities are open to all researchers on a peer-review basis.

The NSF and AURA partnered in the late 1950s to provide an alternative to what was then only privately operated telescopes, and they did this to ensure broad community participation and access. This decision was extremely important and has been fundamental to the development of astronomy in the United States since that time. Ours and I would also say Dr. Schreier's are the publicly funded and publicly available telescopes, and in the optical area, they are the only ones, so they are extremely important in serving the role. The nurturing of strong national organizations that can support the NSF mission and that of the science community to fulfill its potential is a mutual goal both of the NSF and the AURA, and we work very closely together in partnership to do that.

So you are in this hearing paying attention to the facilities that precede the future construction, that feed in, in many cases, to future construction projects. We have really worked with the NSF a very long time on trying to develop a policy that works well to make that transition. Our observatories, like many others in the NSF that are in this pot of money called research infrastructure, have declined in budget over the last couple of years. So I know today is not one that you want to dwell on the budget but it is true that the declining percentage of the NSF budget and research infrastructure is a concern. Earlier this week, NOAO was forced to terminate about ten percent of its workforce because of the belt tightening, and we will have to do for Gemini in the future. I expect other observatories will go through the same issue.

But I do want to address some of the policy issues that you mentioned. First, the issue of recompetition. I would start by saying the primary goal that the NSF should have is building strong, effective national organizations that work with the community and fulfill the NSF mission. Recompetition is one tool to effect that, but I wouldn't say it was the only tool or even the most important one, but if you start from that first premise, what we need to do to make AUI or AURA a very effective leader in developing the community, recompetition comes into play and so we do acknowledge the value of this but there are many circumstances in which you would make a different decision other than recompete the contract, and this was certainly the issue that Dr. Schreier mentioned with ALMA and NRAO. So there are other features of this overall goal that I think should be examined before the decision to recompete is actually made.

The second issue was one of decommissioning facilities, and again, this is an extremely important issue for us. The NSF has a very sound and well-developed policy for beginning construction projects, operating projects. For decommissioning facilities, there isn't a clear approach yet, and I illustrate one such example in my testimony. We would like to shut down our facilities in Sac Peak but just in terms of relative budgets, it costs about a million dollars a year to operate but it may take $7 million or $8 million to decommission. When you sit in Indian tribal lands or Forest Service lands and have to return those to their natural state, this can be a very substantial cost. And so decommissioning doesn't come for free, and my testimony recommends that some addressing of this be put in the NSF budget just as construction projects were.

You asked about international collaborations. I am almost out of time. It is very important for the U.S. community to fulfill its goals through such collaborations, so they are very important.

I will just end by acknowledging the second half of the title of this hearing, ensuring fiscal responsibility and accountability, and that is a prerequisite to everything else we do. We all know that. We work very hard, take it very seriously to get it right. I would say that it is a continuous process. The NSF has a very robust way of looking at what we do, our accounting processes. That is very appropriate. I would say that our systems are in constant change as we engage in this dialog with the NSF, but I think that we have a system that fulfills your mandate to ensure this fiscal responsibility.

[The prepared statement of Dr. Smith follows:]

AURA

Association of Universities for Research in Astronomy

Management of Astronomical Observatories
A Partnership between the National Science Foundation and AURA

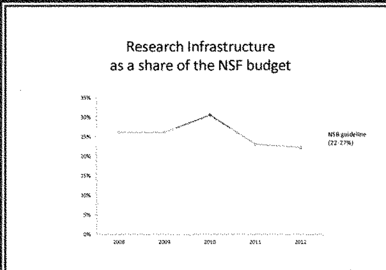
The Association of Universities for Research in Astronomy (AURA) is a consortium of universities that manage the National Optical Astronomy Observatory (NOAO), the National Solar Observatory (NSO), the Gemini Observatory, and the Large Synoptic Survey Telescope (LSST) project. AURA has managed and nurtured such public observatories from their original formation, some going back 50 years. This statement lays out why the NSF provides funding for AURA managed observatories, the return on this investment, and how AURA assures that taxpayer dollars are spent effectively.

Also addressed, are specific issues faced by AURA as well as other managing organizations.

- The goal of building effective national organizations should be the highest level objective by the NSF. Other administrative goals such as recompetition, are a means, but not the only means, to achieving this central goal. A wide range of factors should be considered in making a decision to recompete.
- Decommissioning is an essential element of the evolution of scientific facilities but costs should be included in an NSF-wide budget such as MREFC.
- International collaborations and other forms of partnership in many cases call for governance structures that could be complex. It is crucial that the US community perceive that scientific return and management control are commensurate with the US investment.

Introduction

The Association of Universities for Research in Astronomy (AURA) is a consortium of universities and educational institutions that operates world-class astronomical observatories on behalf of the National Science Foundation (NSF). Our aim is to act on behalf of the science communities that are served by these facilities, and as trustees and advocates for their missions. AURA was founded in 1957, with the encouragement of the National Science Foundation, by a group of U.S. universities with a common interest to create astronomical observing facilities that would be available for use by all qualified researchers from U.S. institutions and universities on the basis of scientific merit. Today, there are 37 U.S. Member Institutions and 7 International Affiliate Members which comprise the Member Institutions of AURA. AURA's mission is "*To promote excellence in astronomical research by providing access to state-of-the-art facilities.*"



Facility Plan Presentation, Feb 2012 NSB Meeting

In its organic act, Congress restricted the NSF from directly managing facilities[1]. Thus, from the outset, the NSF has contracted with managing organizations such as AURA. All of AURA's awards take the form of a cooperative agreement in which AURA is expected to provide a service to the scientific community on behalf of the NSF[2].

Major, multi-user facilities, operated on a competitive peer review basis, has emerged as a major tool for advancing the state of knowledge in astronomy and astrophysics. Just as important, these facilities have been the training ground for students at all levels, providing early career research experiences, and enabling research for PhD students at academic institutions across the US and indeed across the world.

Research infrastructure funding within the NSF, which includes all AURA operated facilities, has declined since 2010. Although the National Science Board has recommended that this portion of the overall NSF budget be between 22-27%, it is now at the bottom of that range. AURA operated facilities have followed this trend. Significant reductions in personnel and functional roles are now being planned in response to fiscal limitations.

[1] 42 USC 1873(b), which states "The Foundation shall not, itself, operate any laboratories or pilot plants"

[2] This differs from the award vehicle for AURA's management of the Space Telescope Science Institute. That contract is based on the presumption that AURA provides a service to the Government.

Although precise, specific correlations are not possible, research infrastructure is a fundamental part of the nation's R&D portfolio, which stimulates innovation, and ultimately economic growth. Astronomy has played a major part in this overall picture because advances in this field are largely driven by improvements in technology. The effort to compete scientifically has inspired technological breakthroughs in detector development, cyber-infrastructure, optics, and a host of other frontier applications.

AURA applauds the efforts of the Committee to examine the general area of facility management by the NSF and its managing organizations. This has been a valuable and evolving partnership. The nurturing of strong national organizations that can support the NSF mission and enable the scientific community to fulfill its potential is a mutual goal of the NSF and its managing organizations.

How AURA Manages

AURA's fundamental structure includes two major parts: first the employee-based management structures for our observatories; and, second, the community-based governance structures that oversee and guide our activities. AURA employs nearly 900 staff. Of these, between 120 and 130 are scientists. AURA provides tenure to those scientists on tenure track in a manner comparable to academia.

Direct community involvement is achieved through governance. Although AURA does not purport to **represent** the community, AURA is **representative** of the community and its interests. At the core of AURA governance are the 44 Member Institutions, but community involvement goes far beyond this. Over the past five years, in excess of 200 individuals drawn from the community have been involved in AURA related activities including standing oversight committees and special purpose committees and groups.

AURA's traditional governance philosophy includes:

- Maintaining strong links to the community: AURA has sought to maintain active links to its Member Institutions and, through the member representatives, an active link to the broader community. Membership on all AURA bodies is elective and rooted in the most democratic and inclusive process possible.
- Heavy reliance on oversight: AURA provides its own community-based oversight and relies on this as a part of its management approach. AURA evaluates the performance of its own staff, establishes metrics for its observatories, and includes feedback as an integral part of its

process. In addition, oversight mechanisms put in place by the NSF have served as an external check[3].

A crucial component of management for AURA, as well as other NSF funded facilities, is the conduct of independent reviews. The following represents some reviews that are now in place:

AURA Management Oversight Councils—as stated above, AURA has established an oversight committee for each major observatory. The members of these councils are drawn from the community and elected by the AURA member institutional representatives. These councils meet at least twice per year and examine every aspect of the observatory.

Visiting Committees—AURA requires periodic independent reviews of the performance of the staff and facilities by visiting committees. Visits are conducted about every two to three years for NOAO and NSO. For Gemini, the Gemini Board itself charters the visiting committee.

Program Review Panel—for NOAO, the NSF has established a special Program Review Panel that meets at least once per year and reports its findings to the NSF. The primary purpose is to review NOAO's annual program plans and to make independent recommendations to the NSF.

NSF Management Reviews—NSF conducts mid-term management reviews of all observatories including NOAO, NSO, and Gemini. These Review Panels report to the NSF on the progress and performance under the cooperative agreements.

Business Systems Review—the NSF Large Facilities Office conducts periodic reviews of the financial management systems and policies for all observatories.

Other NSF Reviews—the Astronomy Division within the NSF conducts major community based reviews of its portfolio in order to align its overall budget and priorities and balance of investments. These have included Senior Reviews and Portfolio Allocation Reviews. A Portfolio Review is now under way.

AURA Managed Observatories

Our facilities serve as the primary observational facilities used by the general astronomical community for ground-based, solar astronomy and for night-time optical and infrared (O/IR) astronomy. Comparable managing organizations are similarly responsible for radio-astronomy.

In the fields of O/IR and solar astronomy in the US, there has also been a healthy development of privately and State funded and operated telescopes. These usually serve specific communities--normally the faculty of the home institutions.

NSF and AURA partnered in the late 1950s to provide an alternative to privately operated facilities to ensure broad community participation and access. This decision and the result have been fundamental to the development of astronomy in the US. The NSF funds these observatories because they provide the primary access to observing facilities for most of the community. They are the only publicly funded publicly available telescopes.

Public observatories, with access determined on a pure merit basis, have been responsible for many of the major scientific breakthroughs over the past several decades. These include:

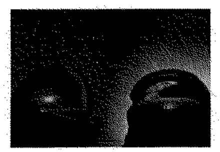
- The discovery of "dark matter" that is responsible for the rotation of observable galaxies, and dominates the dynamics of the universe (NOAO)
- The discovery of the accelerating universe that has recently been recognized for a Nobel Prize (NOAO)
- The detection of black holes at the center of galaxies and their effect on galaxy evolution (NOAO)
- The first reported spectra of arcs caused by gravitational lensing (NOAO)
- The detection and measurement of solar oscillations (sound waves below the surface of the sun) that lead directly to sunspot activity. (NSO)
- Discovery of the solar filigree (small bright points associated with strong magnetic fields). These measurements were the first showing that features existed at much smaller scales than the granulation and that they were associated with strong magnetic fields. (NSO)
- The development of the first adaptive optics for low contrast, extended objects, for the Advanced Technology Solar Telescope. This has practical uses in retina imaging, satellite identification and a whole host of applications. (NSO)
- First direct images of extra-solar planets; the multiple-planetary system around HR 8799 (Gemini)
- Observation and measurement of the most distant gamma ray bursts, providing evidence for the formation of the first stars following the Big Bang (Gemini)
- Measurement of super-massive black hole growth and the linkage to the chemical enrichment of the early universe (Gemini)

The return on investment for the NSF has been substantial. In 2011, a typical year, 965 US investigators were awarded observing time on NOAO and Gemini telescopes. This represented 180 academic institutions in the US from 41 states. Of these, 80 PhD students and 106 non-thesis students were awarded time.

For National Solar Observatory facilities, typically researchers from 30 to 40 academic institutions per year conduct observing programs studying the Sun. Two to three PhD students are in residence at any given time.

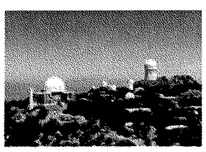
Because NSF telescopes are operated on an "open skies" basis (i.e. our facilities also open to non-US users), a substantial number of non-US observers and students were also awarded time. Maintaining leadership through open access to the best minds, wherever they are, has been a hallmark of NSF funded facilities.

The appendix to this statement provides a description for each AURA managed observtory, its management structure and a historical summary. Present facilities managed by AURA on behalf of the NSF are as follows:



Gemini Observatory is an international partnership to operate twin 8.1-meter telescopes, one on Hawaii's Mauna Kea and the other on Chile's Cerro Pachon. The partners include the United States, United Kingdom, Canada, Chile, Australia, Brazil, and Argentina. AURA manages Gemini under the auspices of the International Gemini Board and the U.S. National Science Foundation as its executive agency.

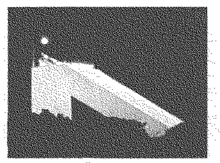
Today, Gemini has over 200 staff. However, due to the recent withdrawal of the UK from the Gemini partnership, staffing will be reduced to less than 170 by 2015. The present contribution from all Gemini partners is about $37M of which $19 M is from the US.



National Optical Astronomy Observatory (NOAO) - NOAO operates telescopes for night-time astronomy. These telescopes are located on Kitt Peak in Arizona and Cerro Tololo and Cerro Pachon in Chile, and are used by approximately one thousand professional astronomers and students each year. NOAO is also designated as a Federally Funded Research and Development Center. This provides a substantial advantage in long term planning and commitments.

NOAO is comprised of about 350 staff distributed between its two sites and the Directorate in Tucson, Arizona. Although past funding levels have been over $29M, the present request is $25.5 M, necessitating a reduction of about 30 staff over the next year. NOAO serves over 1300 users from 350 institutions world-wide.

National Solar Observatory (NSO) - The mission of the National Solar Observatory is to



advance our understanding of the Sun in its astrophysical context as a star, as the driver of conditions in interplanetary space, in its influence on the terrestrial atmosphere, and in its role in long-term climate change. NSO provides observing facilities for use by the nation's solar and solar-terrestrial physics community. NSO conducts research at Sacramento Peak in New Mexico and at Kitt Peak in Arizona. Its current major initiative is the Advanced Technology Solar Telescope (ATST).

Currently, NSO has about 100 staff members and receives about $9 M per year from the NSF. When the ATST begins operations, however, the budget and staffing will increase. Presently operated NSO facilities in Kitt Peak and Sac Peak serve about 100 users per year[4].

Large Synoptic Survey Telescope (LSST) - The LSST is a public-private partnership to operate an 8.4-meter telescope on Chile's Cerro Pachon. The partnership includes NSF and DOE, private foundations, LSST Member Institutions, and international collaborators. The LSST is a wide-field telescope facility that will add a qualitatively new capability in astronomy. For the first time, the LSST will provide time-lapse digital imaging of faint astronomical objects across the entire sky. It will make fundamental contributions to the understanding of dark energy, dark matter, Earth crossing asteroids and other high priority topics. The LSST emerged as the highest priority in the most recent astronomy and astrophysics Decadal Survey.

LSST is presently in its final design and development phase. It is anticipated that a new construction start can be established as early as FY14. It is anticipated that LSST will begin operations in 2021.

Issues Addressed by Managing Organizations

Recompetition

The February 7, 2008 resolution by the National Science Board stated that the Board "*..endorsed strongly the principle that all expiring awards are to be recompeted, because rarely will it be in the best interest of U.S. science and engineering research and education not to do so*." This position was based on the conviction that peer-reviewed competition is the process most likely to assure the best use of NSF funds for supporting research and education. This premise has been further examined by the NSF in community-based workshops, in particular whether there are other factors in the interest of research and education that should also be considered.

[4] Solar and night-time observations differ substantially. A night-time observation may take one to three nights, a solar observation typically requires several weeks.

For AURA operated facilities, the following cooperative agreement expirations will occur:

Gemini: 9/30/2015
NOAO: 3/31/2014
NSO: 3/31/2014

AURA recognizes that a recompetiton can have a positive effect in reinvigorating the management of NSF facilities. This can be accomplished either by selecting a different managing organization who can manage more effectively or by effecting changes in the incumbent managing organization by virtue of the competitive process. In the period 2000-2002, the NSF undertook a recompetition of the National Optical Astronomy Observatory and the National Solar Observatory[5]. This recompetition was based on the concern that NOAO, under AURA management, should become a more effective national organization and extend its mission beyond the operation of its own telescopes at Kitt Peak, and in Chile. AURA strongly internalized this criticism and undertook a fundamental redefinition of the mission and purpose of NOAO. AURA also undertook an effort to separate NSO as a stand-alone organization so that it could pursue the development a new generation of ground-based solar telescopes more efficiently.

The result was that the AURA proposal, which included a vision of NOAO as a national leader promoting a "system" of US observing capabilities, was successful and has been pursued since 2003 as the mission of NOAO. This expanded mission includes a mandate to achieve access to private and independent telescopes. It is clear that this recompetition was an effective exercise for the NSF and for AURA in re-focusing the NOAO mission.

Although the recompetition in context was successful, AURA recommends that the primary emphasis be placed on building effective national organizations and enabling the community to conduct transformative science. A recompetition is one tool for accomplishing this, but there are others that must also be available. Some examples of alternatives to recompetition include the following:

- Recently a major redirection in the Gemini Observatory has been carried out through a close working collaboration between AURA, the managing organization, the Gemini Observatory management, and the Gemini Board and NSF. This redirection was made necessary by the withdrawal of the UK from the international partnership and the resulting dramatic decrease in financial contributions. It is doubtful that this change, which includes more efficient observing modes and staffing strategies, could have been accomplished through a recompetition. It required the development of a strong consensus among all of the

[5] Up until that time NSO was a division of NOAO.

stakeholders. The National Science Board recognized these circumstances and agreed to extend AURA's cooperative agreement to allow this transition to proceed smoothly.

- The US Decadal Survey for Astronomy and Astrophysics, *New Worlds, New Horizons*, has recommended that a common management structure be considered for NOAO and Gemini in order to achieve cost savings and to put in place a stronger US national observatory. However, such a merger would strongly affect the conduct of recompetitions for NOAO and for Gemini as separate organizations. The Decadal Survey recommended that the benefits of building such a strong consolidated organization should be the primary consideration by the NSF. However, it is clear that the entanglement of NOAO and Gemini would be an impediment to recompetition. Thus, currently the NSF is not considering any such structural changes that would complicate a recompetition. AURA accepts the NSF position at this time but clearly this deserves further examination in the future.
- For Gemini, regardless of whether any major consolidation with NOAO takes place, the Gemini Partners have strongly suggested that their continuing participation in Gemini should be predicated on a governance change of some sort in 2015 when the present International Agreement expires, which overlaps the expiration of the cooperative agreement. Such a governance change would in turn strongly affect the role of the managing organization and hence the guidelines for a recompetition. It is unlikely that a mutually agreeable governance change for the Gemini partnership will be in place at that time.
- The National Solar Observatory represents a case that is common within the NSF. NSO, under AURA management, undertook a strong community leadership role to define and promote the Advanced Technology Solar Telescope which achieved a new start within the NSF. It is crucial to continue this management arrangement throughout construction. Major procurements and agreements exist between AURA and the vendors that would be extremely difficult to novate or re-negotiate. The National Science Board has recognized that the policy should be transparent to the research community such that after construction of major facilities is completed, an appropriate time period to bring the facility to sustainable operations will be needed before a full and open competition. Thus a recompetition in 2014 would be highly disruptive for AURA and for the community.
- All AURA observatories have established strong scientific collaborations in order to enhance and leverage their scientific programs. These collaborations have required nurturing over many years, and in many cases formal agreements. Collaborating partners have made significant commitments on their own part, such as matching funds and, in the case of NSO, faculty lines. A recompetition could have a severe detrimental effect on science itself if these factors are not considered.

Unlike DOE facilities, many of which are Government owned/Contractor Operated, NSF facilities have a more complex ownership, many times involving the contractor itself. Astronomical facilities are unique in that they must be sited in locations that are remote and in many cases only accessible to not-for-profit organizations like AURA. AURA owns the land in Chile on which NOAO and Gemini telescopes sit. Other sites include tribal lands, and lands managed by other Federal agencies such as the Forest Service. The transfer of ownership or operating authority to another organization as a result of recompetition is not straightforward.

Furthermore, some of the most advanced telescopes in operation today are the result of many years of strong advocacy and technical development by the managing organizations themselves. Gemini, for example, was created as a result of decades of work by AURA itself.

Each facility recompetition may involve factors that are unique to that community and how it interacts with that facility. A recompetition is justified when the managing organization is inefficient, not performing in an effective manner, when it is not responsive to the community, or when it is unable to evolve to respond to changing needs. The community itself should have a role in making this judgment.

However, the timing of a recompetition may not be best aligned with the expiration of a cooperative agreement if larger changes within the landscape are taking place. AURA advocates a process that considers community input in the decision to recompete. The community is well able to judge the more subtle factors that need to be weighed.

AURA recommends that NSF Management Reviews include as part of their charge an explicit requirement to make recommendations on whether it is appropriate to recompete in specific expiring cooperative agreements. Although the NSF is free to make a different decision, it is crucial that the user communities be fully engaged as a part of this process, and clear benefits of recompetition should be evident.

Lifecycle Planning

Lifecycle Planning should include the costs of construction, instrumentation and operation, and decommissioning. Currently the NSF has clear policies and mechanisms for construction planning in the MREFC budget, and instrumentation and operations in the base budgets of the facilities. However, decommissioning costs are not as well addressed.

Ideally, life cycle planning should anticipate the decommissioning of facilities as they become obsolete or when resources must be freed up to allow new facilities to come on line. For many astronomical facilities, their scientific utility and competitiveness are dominated much more by the instrumentation rather than the telescope itself. Thus it is clear that telescopes such as the 4 meter Mayall and Blanco telescopes operated by NOAO can remain among the most competitive in the world for many decades even as 8 meter and 30 meter class telescopes emerge.

However, there is no question that a process must be in place to make major transitions to new facilities when transformative science can be done. Some challenges in making such transitions include the following.

- Economics: In most cases, the one-time cost of decommissioning a major facility vastly exceeds the annual operating cost of that facility. Thus, it is frequently more affordable in the short term to continue its operation. For example, the National Solar Observatory plans to divest the current operation of its facilities in Sac Peak, New Mexico as the Advanced Technology Solar Telescope (ATST) comes on line in 2017. Clearly ATST will offer transformative scientific capabilities over what is presently available. The cost of operating existing facilities at Sac Peak is about $1 M per year[6]. However, the range of costs associated with decommissioning and shutting down those facilities is at least $7 M and possibly up to $30 M. Thus, it is implausible to finance the decommissioning through savings from the operations budget alone.
- User Impacts: Many long term astronomical facilities have developed strong, dedicated user communities which depend on these facilities for their science. Most scenarios for decommissioning imply a disruption or discontinuity in science unless other facilities are readily available. Such a disruption can have a devastating effect on a community as those researchers shift their scientific focus to other areas[7].

Both of these issues suggest that mechanisms must be found for lifecycle planning that can fit the NSF budget structure, and minimize impacts on the community. For example, it is possible to plan for decommissioning costs within the MREFC budget. The logic that led to the establishment of the MREFC budget—that construction costs were too large to be accommodated within an operating budget line—apply equally to decommissioning. This would help in overall budget planning and would minimize the disruption to the community.

For the present, AURA has surveyed the community to ascertain potential academic institutions and other entities that may desire to take over the operation of these facilities for their own purposes. Some of these, such as the Sac Peak facility, can be refurbished to provide for education and training, and even dedicated research for those institutions. It is unclear at this point whether this would be attractive to such institutions.

<u>International Collaboration and Other Forms of Partnership</u>

It is clear that the US community can achieve some of its more ambitious visions only through cost sharing with other international partners and other forms of partnership. In addition, it is

[6] The labor related costs of operating Sac Peak are an additional $2.8 M, however these personnel will be required for ATST.
[7] A well known case is the NASA decision to decommission the Kuiper airborne infrared observatory in order to create a funding wedge for the SOFIA observatory which would take its place. The two decade long interval between the two is widely believed to have adversely impacted the field of infrared astronomy.

AURA's experience that such collaboration enriches the scientific potential of shared facilities. It is important, however, that the US community perceives that its influence and role within an international project, as well as the scientific return to the community is commensurate with its investment.

The standard model for NSF facility management—that is, a managing organization working directly with the NSF through a cooperative agreement—does not fit the emerging complex partnerships which involve private entities, international partners, and other Federal Agencies.

There are many models for international collaboration and associated governance structures. Each has their advantages and disadvantages.

- Gemini Model—AURA manages the Gemini Observatory on behalf of the Gemini International Partnership. The NSF is both a partner and the "Executive Agent" for the partnership as a whole which operate through the Gemini Board. The governance is established and controlled by a Government to Government International Agreement. All partner funding flows through the NSF.

  Because AURA operates under a cooperative agreement, all guidance and direction come through the NSF. Although this provides NSF with direct oversight and control, it requires the other partners to subject their own investments to the policies and practices unique to NSF and the National Science Board. In many cases these are different than their own national practices. For example, the requirement to recompete the cooperative agreement for Gemini in 2015 limits the ability of the partners to examine other governance models.

- SOAR Model—AURA is a partner in the Southern Observatory for Astronomical Research (SOAR) located in Chile. This observatory is a partnership between NOAO, Brazil, the University of North Carolina, and Michigan State University. It is managed through an independent corporation and a managing Board. All partners provide resources and participate in decision making. This model and others like it, have proven to be very flexible in accommodating the needs of the partners. However there is no Government-to-Government agreement, nor a specific cooperative agreement. It is likely that for large scale projects this lack of a direct NSF involvement would not be acceptable.

Although cost-sharing is accepted as a highly desirable feature of any major new facility, it is not straightforward that all funding should flow through the NSF and that an NSF administered cooperative agreement will be appropriate in accommodating partner needs.

In the future, the ATST and LSST will involve international partners in some way. However, the form of the governance is not established. Although for Gemini, the NSF was directly involved at the outset in soliciting partnerships, and a substantial amount of work went into building these Government-to-Government relationships, ATST and LSST are proceeding now only at the project level in developing the international roles.

Managing Tax Payer Dollars Effectively

It is a major objective of all NSF facility operators to maximize the return on investment in terms of science per dollar. AURA, like many other NSF managing organizations, is a not-for-profit entity that operates on a very low overhead. Of AURA's current award total, only about 0.6% can be attributed to a management fee. The bulk of the awards are used for operating the facilities themselves.

AURA, like other managing organizations, has an obligation to proactively seek out waste, fraud, and abuse, and any wasteful practice. AURA has put in place a number of mechanisms to ensure a high level of fiduciary responsibility and integrity. Some of these include:

- Maintaining a standing Audit Committee appointed by the AURA Board;
- The appointment of an external independent audit firm, presently Clifton Larson Allen;
- The establishment of an independent corporate internal auditor;
- Participation in NSF organized Business Systems Reviews (BSR);
- Strong Fraud and Ethics Practices policies; and
- Whistle blower protection policies, and in the near future a whistle blower "hotline."

In addition, AURA is audited by the Defense Contracts Audit Agency on a regular basis. Because Federal policies and guidelines for grant holders are constantly evolving, the BSRs are particularly important in identifying needed changes in policy and improvements in accounting standards and financial systems.

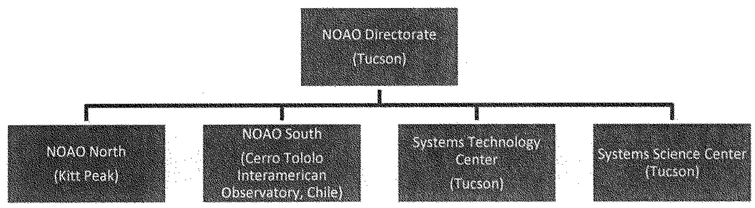
Conclusion

AURA has acted as a partner with the NSF and as steward of the preeminent public observatories that have influenced the development of astronomy within the US. Our observatories are among the most competitive and productive in the world. The return on investment for the NSF and the taxpayer has been substantial.

AURA looks forward to working with the Committee to strengthen NSF's research infrastructure to maximize the ability of our observatories to serve the community.

Appendix

National Optical Astronomy Observatory



NOAO is located at two sites, in Tucson Arizona and nearby Kitt Peak, and at the AURA site in Chile near La Serena. In Chile, AURA operates the Cerro Tololo Interamerican Observatory (CTIO) near La Serena. (AURA also operates the Gemini Observatory and the SOAR telescopes on Cerro Pachon, and soon will operate the LSST there.)

NOAO divisions include NOAO North for Kitt Peak, NOAO South for CTIO, a Systems Technology Center in Tucson for instrumentation development, and a Systems Science Center which provides access to other telescopes including Gemini.

NOAO was established as AURA's initial public observatory. Prior to the 1950s, research astronomers only had access to the scientific facilities available through the particular institution with which they were affiliated. Therefore, a faculty member teaching at a major university might be able work with a more powerful, better equipped telescope than a colleague at a smaller school. There was no equal access to the best research facilities.

Following World War II, the United States entered the Cold War with the Soviet Union. The successful launching of the first satellite, Sputnik, in 1957, by the Soviets, was a major catalyst for the formation of a national space program, and its obvious partner, astronomy research.

At that time, numerous astronomers petitioned the federal government for funds to build a research center available to the entire astronomy community, a National Observatory.

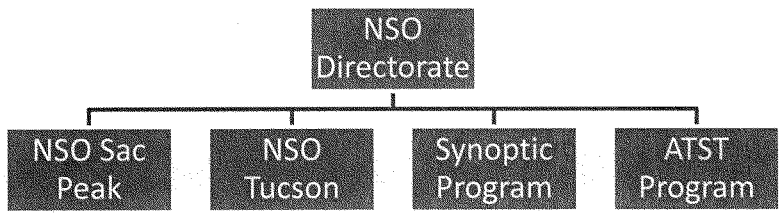
Over 100 mountains in the western portion of the nation were surveyed. From the narrowed list of eleven sites in California, Arizona and New Mexico, Kitt Peak was determined to have the greatest number of positive attributes. A comparable search took place in the southern hemisphere to provide US astronomers with full sky access.

For Kitt Peak, the National Science Foundation secured a lease from the Tohono O'odham Nation to use the chosen mountain on their ancestral homeland for the sole purpose of astronomy research.

By the early 1960s, the building of roads and such early telescopes as the 0.9-meter (36-inch) and 2.1-meter (84-inch) had begun across Kitt Peak, as well as the current Tucson-based headquarters of the National Optical Astronomy Observatories.

For its operations in Chile, AURA secured special legislation from the Chilean government that provided AURA with special juridical privileges and exemption from Chilean taxes. AURA has nurtured good relations with the Chilean government from the 1960s through turbulent times up to the present.

National Solar Observatory



The National Solar Observatory facilities are currently located at Sac Peak New Mexico and Kitt Peak Arizona. The Director spends his time between the two sites. NSO also operates a synoptic program consisting of the Global Oscillations Network Group (GONG) and the Synoptic Optical Long-term Investigation of the Sun (SOLIS) located in Tucson. The Advanced Technology Solar Telescope Program is primarily made up of personnel now located at Sac Peak who will transition to Maui Hawaii as ATST moves into construction and operations.

Some of the first facilities on Kitt Peak were solar telescopes. Until recently, NSO existed as a division of NOAO and it evolved along with NOAO. In the 1970s, the Air Force asked the NSF to take over the operation of their facilities at Sac Peak, and the NSF subsumed these into the NOAO management structure. At that time AURA initiated actions to separate out NSO as a stand-alone organization. By 2009, a separate cooperative agreement was awarded to AURA to operate NSO separately from NOAO.

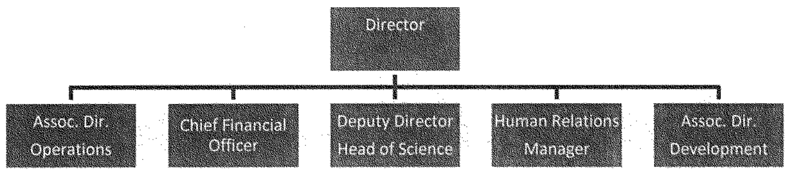
Some of the major NSO facilities include the following:

The 76-cm Dunn Solar Telescope, located on Sacramento Peak at an altitude of 2804 meters, is the premier facility for high-resolution solar physics. The evacuated light path eliminates the loss of image clarity due to distortions from the air. NSO has pioneered solar adaptive optics and high-resolution, ground-based solar physics as a necessary prelude to ATST.

The McMath-Pierce Solar Telescope on Kitt Peak, at an altitude of 2096 meters, is currently the largest unobstructed-aperture optical telescope in the world, with a diameter of 1.6 meters. Thus, it is uniquely capable of panchromatic, flux-limiting studies of the Sun. In particular, it is the only solar telescope in the world on which investigations in the relatively unexplored infrared domain beyond 2.5 microns are routinely accomplished.

The Global Oscillation Network Group (GONG) studies the internal structure and dynamics of the Sun by means of helioseismology - the measurement of acoustic waves that penetrate throughout the solar interior - using a six-station, world-circling network that provides nearly continuous observations of the Sun's "five-minute oscillations."

Gemini Observatory



Gemini telescopes are located on Mauna Kea, Hawaii, and on the AURA site near La Serena Chile. Gemini is operated as a single observatory located at two sites. This operating philosophy reduces operations costs.

The Gemini Observatory organization was restructured during 2011. One significant change was to consolidate all of operations activities, including engineering and science, into a single division. Within Operations, there is a Head of Science Operations for each site, and a Head of Engineering Operations for each site, all of whom report to the AD for Operations.

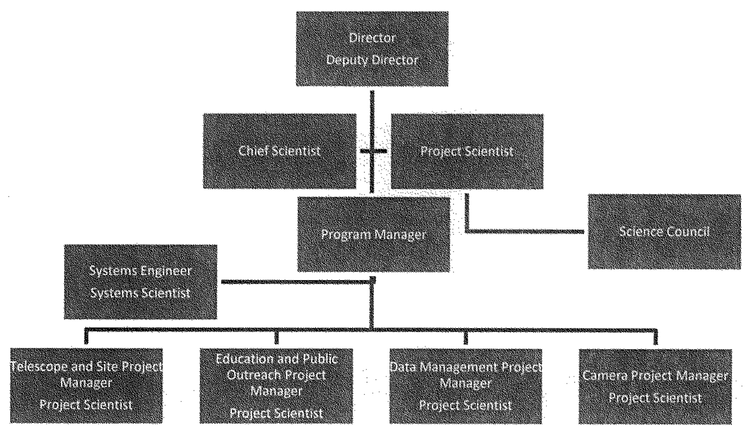
The Deputy Director provides leadership for the science staff and also heads the Public Information and Outreach activities.

The Development branch is organized largely according to key projects, each of which is led by a project manager. The Systems Engineering Group and Adaptive Optics are also part of this division.

The management structure also provides for independent direct reporting by the Human Relations Manager and Chief Financial Officer.

The Gemini Observatory was the NSF's entry into large aperture telescope astronomy. Recommended in the 1990 Decadal Survey, the NSF took the initiative to create an international collaboration including Great Britain, Canada, Australia, Brazil, Argentina, and Chile. Great Britain announced that it intended to withdraw from the partnership in 2012. Presently the US share of Gemini is about 65%.

LSST Program Office



The LSST Project Office is located in Tucson. It consists of a Director and Deputy Director, a Chief Scientist and Project Scientist, and a Program Manager who has purview of four major work packages. The work packages consist of a telescope and site manager in Tucson, an Education and Public Outreach manager, a Data Management Project manager and a Camera Project Manager located at the Stanford Linear Accelerator Laboratory.

The LSST was recommended in the 2010 Decadal Survey as the highest priority ground-based initiative. The LSST is a wide-field deep imaging facility that will add a qualitatively new capability in astronomy: *Wide-Fast-Deep.* LSST's field of view is 3100 times larger than the Hubble Space Telescope's wide-field Advanced Camera for Surveys. The final catalog will include twenty trillion measurements for 10 billion stars and 10 billion galaxies.

For the first time, the LSST will provide time-lapse digital imaging of faint astronomical objects across the entire sky. LSST's unique ability to go *Wide-Fast-Deep* will expand our window on the dynamical universe by a thousand-fold: from bursts of light caused by the extreme physics of rare objects, to unknown dark objects closer to Earth. The LSST will provide digital imaging of faint astronomical objects across the entire sky, night after night.

If construction for LSST begins in FY2014, it is anticipated that it will be fully operational in 2021.

Chairman BROOKS. Thank you, Dr. Smith, for your insight.
At this time the Chair recognizes Dr. Divins for five minutes.

STATEMENT OF DR.DAVID DIVINS, VICE PRESIDENT AND DIRECTOR, OCEAN DRILLING PROGRAMS, CONSORTIUM FOR OCEAN LEADER, INC.

Dr. DIVINS. Thank you, Mr. Chairman and distinguished Members of the Committee for the opportunity to testify this morning.

The Consortium for Ocean Leadership is a consortium of academic institutions involved in ocean sciences. We have been through our predecessor organization, Joint Oceanographic Institutions, managing the drilling program, scientific drilling programs for NSF for close to 40 years now. The U.S.-support scientific drilling programs are probably one of the earth sciences longest-running and most successful international collaborations that we have and we are continuing to open new doors, for example, with nonprofit organizations such as the Moore Foundation to participate in the scientific advancement for our program and for our community through funding, observatory instrumentation and other areas to supplement the NSF funding.

Ocean drilling has been very successful in itself in terms of the science, contributing significantly to a broad range of accomplishments within the earth science disciplines. It has advanced our understanding of solid earth cycles, revealed the flow of fluid in microbe ecosystems beneath the sea floor, and has gathered extensive information on earth's climate history. The Integrated Ocean Drilling Program, or IODP, is the current phase of scientific ocean drilling, and IODP builds on the successes of earlier programs, the Deep Sea Drilling Project and the Ocean Drilling Program, to expand our view of earth history and global processes through ocean basin exploration, and the ocean basins are the place to go and do this because they are untouched by human interaction and so we have millions of years of earth system changes that are recorded in the sediments and the rocks below the sea floor, providing a unique baseline that we can then measure past and future planetary changes against.

IODP is different from the other two drilling programs that have come before it in that it is a multi-platform program. It is an international program. There are three drilling platforms that are involved. The United States brings to the table the JOIDES Resolution, which is again, that is our facility. The Japanese contribute their ship, which is the Chikyu, and the Europeans bring a mission-specific platform, which is a unique platform tailored to a specific expedition. The JOIDES Resolution, or the JR, is the riserless platform, which is the technology used for the drilling, and it is the U.S. contribution, as I said.

After 20 years of service in the ocean drilling program, the JR was modernized and retrofitted with funds provided by the MREFC account. The JR underwent a $150 million two-year renovation and returned to service in 2009, and this comprehensive refit, which extended the facility's life by 20 years, included a replacement of all structures forward of the derrick, which is basically the front half of the ship. A new multi-floor laboratory was incorporated into the structure of the hull and incorporated into the ship itself with the majority of the science systems either being renovated or completely replaced. The ship now holds state-of-the-art analytical equipment for on-board core descriptions and equipment for a wide variety of microbiological, geotechnology and analytical chemical investigations.

Now, the concern is, Dr. Smith was talking about the changing availability of funding for these large facilities becoming an increasing issue. When the JR came out of the shipyard back in 2009, the prices of oil, as you can remember, were skyrocketing and are still continuing to increase. That has had a serious impact on the operation and maintenance budget that we have available for the JR. The result was a decrease in operational days from 12 months, basically 365 days a year operations, to only 8 months of operations. This has a serious effect, possibly jeopardizing our international contributions to participate in future programs where the facility is not operated at its peak level, and the reality really is that for a small 20 percent increase, you could get 40 percent more science and deliver much more groundbreaking and fundamental science.

The other thing I would like to say is the Ocean Drilling Program is nearing its—its current contract ends at the end of fiscal year 2013 and we will be—there is a program at the National Science Board to extend the program for one more year with a contract extension which then would be followed by a five-year cooperative agreement with a complete recompete is the process here, and for us, the recompetition—we don't own the facility, NSF does not own the facility. It is a leased facility. You put in jeopardy—by having these recompetitions, you put in jeopardy that contract that is in place that the costs may become prohibitive or out of reach for NSF, given the funding levels that we have.

And so thank you very much.

[The prepared statement of Dr. Divins follows:]

18 April 2012

Written Testimony of Dr. David Divins, Program Director, Integrated Ocean Drilling Program – United States Implementing Organization (IODP-USIO)
Vice President and Director Ocean Drilling Programs, Consortium for Ocean Leadership

UNITED STATES HOUSE OF REPRESENTATIVES
Subcommittee on Research and Science Education

NSF Major Multi-User Reasearch Facilities Management: Ensuring Fiscal Responsibility and Accountability

Chairman Brooks, Ranking member Lipinski, and distinguished members of the Subcommittee, thank you for the opportunity to testify about the management and and operations of multi-user research facilities. My name is David Divins, I am the Program Director and Principal Investigator of the System Integration Contract for the Integrated Ocean Drilling Program (IODP–USIO). I also serve as Vice President and Director of Ocean Drilling Programs within the Consortium for Ocean Leadership.

I will begin with an overview of the Integrated Ocean Drilling Program (IODP) from its inception to operations today and a brief introduction of the facility, the JOIDES Resolution, which I am responsible for. My testimony also will address the questions posed to me by the committee.

Overview – Integrated Ocean Drilling Program

Scientific ocean drilling represents one of Earth sciences' longest running and most successful international collaborations.

The first phrase of scientific ocean drilling, the Deep Sea Drilling Project (DSDP), began in 1968 and operated using the D/V Glomar Challenger. This was the first NSF Multi-user facility for scientific ocean drilling. DSDP sampled the global seafloor by deep ocean coring and downhole logging, and its accomplishments were striking. Research based on the samples strongly supported the hypotheses of seafloor spreading—the relationship of crustal age to the record of Earth's magnetic reversals—and plate tectonics.

In 1985, JOIDES Resolution replaced the Glomar Challenger at the start of a new program, the Ocean Drilling Program (ODP). ODP was truly an international cooperative effort to explore and study the composition and structure of the Earth's subseafloors. During ODP, the JOIDES Resolution, a larger and more advanced drilling ship, was used to conduct 110 expeditions with 2000 holes from major geological features located throughout the ocean basins of the world.

Integrated Ocean Drilling Program (IODP) builds upon earlier successes of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) to revolutionize our view of Earth history and global processes through ocean basin exploration. The program, begun in 2003 and scheduled to run through 2013, distinguishes itself from its legacy programs by employing multiple drilling platforms, *JOIDES* Resolution (US), Chikyu (Japan) and Mission-Specific-Platforms (Europe) and collaborating with 25 worldwide nations.

IODP's mission is to advance the scientific understanding of the Earth by monitoring, drilling, sampling, and analyzing subseafloor environments. IODP draws samples of rock, sediment, living organisms, and fluids from beneath the seafloor to study the interdependence of geological, physical, chemical, and biological processes in the Earth system. IODP research focuses on factors controlling climate change, the vast circulation of fluids within Earth's crust, the nature of life on and within Earth, and the dynamics of the formation of the Earth. Most IODP research, therefore, takes place in the fields of geology, geochemistry, plate tectonics, paleoclimatology, and chemical oceanography.

Scientific ocean drilling's long history of discovery continues with IODP. For more than 40 years, stretching over hundreds of scientific expeditions, and involving thousands of researchers, the outcomes of scientific ocean drilling have significantly advanced our understanding of the Earth. Reliable information about how our planet works—and has worked in the past—is recorded in great clarity in the sediments and rocks that form the global ocean floor. The pristine samples of subseafloor sediments and rocks, brought to the surface by scientific ocean drilling, are indispensable to scientists expanding mankind's knowledge of environmental change, earthquake genesis, volcanic processes, the evolution of life on earth, and more.

JOIDES Resolution Overview

The *JOIDES* Resolution serves as the riserless drilling research platform for the science community as well as the United States' contribution to support the scientific mission of the IODP. After 20 years of service, the *JOIDES* Resolution, the pioneering scientific ocean drilling vessel that allowed scientists to retrieve samples of the Earth's crust and sediments from deep beneath the ocean, was modernized and retrofitted with funding provided by the NSF Major Research Equipment and Facilities Construction (MREFC) Account.

During its history, the *JOIDES* Resolution has been adapted and upgraded with minor modifications several times. But the scale of the latest conversion was beyond any past upgrades. The *JOIDES* Resolution, also known as the JR, is renowned for its global capability, versatility and operational flexibility. The JR can operate in water depths from 75 to 8,200 meters, with as much as 2 kilometers of subseafloor penetration. After 133 scientific drilling expeditions, the JR underwent a $115 million renovation supported by the NSF and came back into service in 2009. This comprehensive renovation, which extended the JR's life by 20 years, included the replacement of all structures forward of the derrick as well as the upgrade or replacement of all major drilling and downhole logging systems. A new multifloor laboratory was installed, and the majority of the science systems were renovated or replaced. The ship now holds state-of-the-art analytical equipment for onboard core descriptions and equipment for a wide variety of microbiological, geotechnical and analytical chemistry investigations.

In the three years since its return to operations, the JR has shown its versatility, with global operations that include high-resolution paleoceanographic expeditions, investigations into the evolution and formation of a large igneous province, mantle dynamics, global sea-level change, Antarctic glaciation history, subseafloor hydrogeology and microbiology. Its new drilling capabilities have directly led to scientific coring penetration records, including the deepest scientific ocean sediment hole drilled to 1,928 meters. On each expedition, a staff of about 55 scientists and technicians process the core and completely characterize the recovered material by conducting detailed chemical, geotechnical and microbiological analyses.

The new and improved JR enables IODP to continue to expand the boundaries of ocean drilling research by collecting unique subseafloor samples and data that would otherwise remain inaccessible to researchers.

IODP United States Implementing Organization

The Consortium for Ocean Leadership and its partners, the Lamont-Doherty Earth Observatory (LDEO) of Columbia University and Texas A&M University (TAMU), were selected by NSF to be the IODP United States Implementing Organization (IODP-USIO), providing the *JOIDES* Resolution to IODP. Ocean Leadership, the USIO Systems Integration Contractor, is responsible to NSF and IODP Management International (IODP-MI) for the overall program leadership, education and outreach, technical, operational, and financial management, and delivery of services. USIO Science Services, TAMU, under subcontract to Ocean Leadership, is responsible for providing a full array of science services, ranging from vessel and drilling operations to ship- and shore-based science laboratories, core repositories, and publication. USIO Science Services, LDEO, under subcontract to Ocean Leadership, is responsible for logging-related shipboard and shore-based science services and for leading an international logging consortium to participate in scientific ocean drilling operations. The objectives of the USIO are to provide leadership regarding the U.S. interests in IODP as the challenges and demands of a multiplatform drilling program present themselves. The USIO also seeks to ensure that services are provided in a cost-effective and responsive manner to facilitate comprehensive, integrated, and flexible management that involves a broad array of stakeholders.

IODP science planning is supported by the Science Advisory Structure (SAS), an independent structure that involves approximately 100 scientists and engineers on five standing committees and panels. IODP-MI, formally hosting SAS, supports the SAS by managing the submission and review of drilling proposals, assisting SAS committee chairs, and organizing and maintaining public records of SAS activities. The IODP-MI-hosted Operations Task Force (OTF) assists in the SAS process, and has representatives from the SAS, the Implementing Organizations and IODP-MI. OTF's primary function is to define fiscally and operationally feasible drilling plans, based on SAS scientific priorities, and present its findings for final inclusion in the annual science plan.

All IODP science is motivated by community input in the form of proposals that are reviewed and prioritized by the IODP SAS. All proposal submissions are reviewed by the Proposal Evaluation Panel (PEP), which in turn will receive program-external peer-review of mature proposals before being considered for implementation by OTF. Science plans approved by SAS need funding agency approval before actually being carried out.

Why does the federal government contribute funding for IODP?

As Earth's population expands, changing climate conditions, increasing demand for resources, and the risks of geohazards such as earthquakes and tsunami demonstrate the need for better understanding of the close connection between the Earth system and daily human life. Millions of years of Earth system change—devoid of human influence—are recorded in the sediments and rocks located beneath the seafloor, providing a baseline record against which we can compare current and future planetary change. The seafloor itself contains potentially valuable new resources and hosts novel microbial communities that live at the limits of habitability. The flows of mass and energy from Earth's deep interior to the surface create new crust, build volcanoes and islands, and generate earthquakes and landslides. Scientific ocean drilling provides the only means to access valuable historical information, collect samples and data, conduct experiments, and monitor conditions and active processes as they occur in remote marine environments. Scientific ocean drilling addresses the fundamental questions about Earth's climate, deep life, geodynamics, and geohazards, and facilitates a long-term, global perspective on some of today's most pressing environmental issues.

What is the return on investment from the facility or equipment for the U.S. taxpayer?

Without scientific ocean drilling we would not understand how our planet is forming and our climate history as well as we do today. It is difficult to put a price tag on the knowledge gained through scientific ocean drilling.

While the science of IODP is priceless, we could be getting more. As mentioned earlier, NSF invested $115 million to renovate and upgrade the *JOIDES* Resolution. The "new" JR is a state of the art floating university with laboratory capabilities not found at most U.S. universities. However the global economic situation took a change for the worse during the time the JR was in the shipyard with oil prices sky rocketing. The impact of the ever increasing oil prices on the fuel and lubricants the JR needs, and also on shipping and other related costs has been devastating, reducing our ability to operate the facility at an optimal level. At the time the JR was returning to operations, within NSF there appeared to be a shift in the way facilities were funded and all operations and maintenance costs for new facilities (like the JR) were to be accounted for within existing divisional budgets. The result on the facility was a decrease in operations from 12 months to 8 months per year. The reality is that for a 20% increase in funding we could deliver 40% more fundamental and groundbreaking science and be operating our facility at an optimal level.

Please describe how and why foreign entities, non-profit organizations, industry, or other organizations are involved in the facility, including financial support.

IODP's initial 10-year life span is supported by seven funding entities, including the U.S. National Science Foundation and Japan's Ministry of Education, Culture, Sports, Science, and Technology (the Lead Agencies), the European Consortium for Ocean Research Drilling (Contributing Member), and the following Associate Members: the People's Republic of China

(MOST), the Interim Asian Consortium (Korea), The India Ministry of Earth Science (MoES), and the Australia-New Zealand IODP Consortium (ANZIC). Platform Operation Costs are supplied directly to the Implementing Organizations by the national agencies that support them. Co- mingled funds from these sources are used for the Science Operation Costs of all IODP program activities.

Lead Agencies

IODP is primarily supported by the two Lead Agencies (NSF and MEXT). Each Agency has equal membership rights and responsibilities, contribute core capabilities to the IODP, determine total program costs, and contribute equally to the total program costs. The Lead Agencies provide budget guidance to the Central Management Office (IODP Management International) and review and approve the annual IODP Program Plan prior to implementation.

Members

IODP members are expected to make appropriate annual payments to the National Science Foundation. The annual payments are then co-mingled and turned over to the Central Management Office for distribution in support of science-operating costs. Annual payment must be at least equal to one full "participation unit". The amount of a participation unit is adjusted annually to meet the demands of specific program objectives (the amount is about $5.6 million). To attain membership in IODP, a minimum annual contribution amount equal to one participation unit is required. A member's expected level of participation in the IODP is proportional to the number of participation units represented by that member's contribution to the IODP.

One participation unit entitles an IODP member to the right to (1) have two of its scientists participate in each drilling cruise; (2) be represented on all planning and advisory panels; (3) have access to all data, samples, scientific and technical results, all engineering plans, data or other information produced under contracts supported as program costs; (4) have access to all data from geophysical and other site surveys performed in support of the program which are used for drilling planning; (5) submit proposals to the Science Advisory Structure for drilling or engineering developments in support of IODP science; and (6) be represented on the IODP Council.

The European Consortium for Ocean Research Drilling (ECORD) Managing Agency is currently a member of IODP (in addition to the Lead Agencies). The consortium represents 17 European nations and Canada. The European Consortium provides the IODP scientific community with access to mission-specific platforms, in the form of funding and implementation, in addition to the participation unit(s) contributed for science-operating costs.

Associate Members

Associate IODP members are those that contribute an amount less than one participation unit and equivalent to at least 1/6 participation unit. Associate IODP members may elect to have scientific participation and representation on Science Advisory Structure service committees, panels, or working groups in proportion to their contributions. However, associate members do not have representation on the Science Advisory Structure Executive Authority. Participation in drilling operations is prorated based on the fraction of participation unit contributed by an associate member (one full participation unit corresponds to inclusion of two scientists in all drilling operations).

Non-Profit

Recently the Gordon and Betty Moore Foundation provided funding for the instrumentation and partial infrastructure for the seafloor observatories installed on an IODP expedition. Third party support, especially non-profit organization is a means of increasing the scientific return on NSF's investment in ocean drilling. The instrumentation needed for IODP's seafloor observatories is becoming increasingly difficult to fund through NSF program dollars. Foundation, like the Moore Foundation can make a major contribution to ocean drilling and our understanding of the longterm processes in the subseafloor.

The Consortium for Ocean Leadership, the prime contractor for IODP is a non-profit organization and represents more than 100 universities, consortia, and government and private entities.

Industry

Historically the role of industry in IODP has been as members of the Science Advisory Structure and members of scientific expedition parties. IODP is looking to industry for cost saving opportunities. Industry use of the JOIDES Resolution would save NSF day rate and other costs, freeing funds to be used to add operational days or seafloor observatories.

What steps are being taken to ensure the best stewardship of American tax dollars at IODP? How do you ensure federal funding is properly spent, managed and accounted for?

The IODP-USIO has a hierarchical structure, with the Consortium for Ocean Leadership (a non-profit) as the 'prime' and each partner as a 'subawardee.' A Contract between Ocean Leadership (OL) and the NSF establishes a set of terms and conditions for the project, which flow down to each subawardee. The IODP-USIO Program Management Office at Ocean Leadership is responsible for project compliance to those terms and conditions, including reporting of financial status and technical progress against milestones. On a functional basis, the program management office monitors and coordinates the work within the expedition-driven project schedule through daily interactions between Ocean Leadership and each major subawardee. Several teleconferences are conducted each week by the Program Management Office to facilitate communications across the geographically-distributed team.

Discussions and meetings occur with NSF frequently. The development and submission of quarterly reports by the Program Management Office to the NSF also serves as an important management tool for the Program Management Office.

What role do you play in the scientific, budget, and management components of IODP, including monitoring and evaluating the facility or equipment and/or work conducted through IODP? What role does NSF play?

I serve as the IODP-USIO Director, coordinating leadership actions with the senior staff at each partner organization, and communicating on a regular basis with the NSF. I report to the CEO of the Consortium for Ocean Leadership. The IODP-UISO Senior Management Team, composed of myself with the Directors at our partner organizations, Texas A&M University and Lamont Doherty Earth Observatory of Columbia University, has responsibility for overall project management and implementation of the operational schedule. I have ultimate budget responsibility and work closely with the senior management team to set budgets and spending priorities.

Under the Contract, IODP-USIO has specific reporting and procurement compliance responsibilities to the NSF. In addition, prudent project management dictates that the IODP-USIO maintains open channels of communication with the NSF about all project activities. We therefore have frequent interaction and information exchange. This level of interaction has been extremely beneficial.

I also work closely with the IODP Science Advisory Structure (SAS) to implement the highest priority science identified by the ocean drilling community. The IODP-USIO actively participates in all SAS meetings to make sure that the facility delivers what the scientific community requires within the limits of the resources at our disposal. I visit the facility on a regular basis to meet with IODP-USIO staff as well as the onboard science participates to listen to and collect feedback about their experience on the JR. These informal meetings prove to be the most effect means to ascertain the effectiveness of the IODP-USIO.

Regular communication and collaboration with NSF is essential to maintain our effectiveness, our flexibility, and our level of service to our scientific community.

How do you plan for the life-cycle of the facility or equipment, including possible ramp-down? How is NSF involved in the planning? Please describe the recompete history of IODP and the current status of the contract.

At the beginning of IODP, as part of the IODP Systems Integration Contract, a new scientific ocean drilling vessel was planned. As described above, the JR was completely modified for use by the IODP science community. The expected lifetime of the new JR is 20 years, that includes the 10 years of IODP and a potential program renewal of 10 additional years. The initial contract for use of the JR is 10 year contract (2004-2013) with a series of 10 one year extensions possible for a future drilling program. The option to exercise the one-year options is the IODP-USIO and NSF's.

As part of our annual planning process in collaboration with NSF, we perform routine replacement and upgrade of laboratory and drilling equipment within the budget guidance for a given fiscal year. Unfortunately, given a flat funding scenario, we are not able to update our systems as frequently as we believe they should be. However, the safe operation of the facility is our number one priority.

Currently we are in the 9th year of a 10 year contract. NSF is in the process of seeking National Science Board Approval for a new phase of scientific ocean drilling. Initially they are seeking approval for a one year contract extension. It is envisioned that following the one year extension, NSF will ask for a competition for a 5 year cooperative agreement for the management of the IODP systems Integration functions. Historically, the program management and vessel operation functions have been carried through a series of competed 10 year contracts.

What major obstacles or challenges has IODP faced, and how have the problems been resolved?

IODP and its successor programs have been and continue to be very successful scientific programs. The biggest challenges faced have all be related to funding. During IODP the conversion and modernization of the JR was hampered by increased costs at global shipyards and a fixed MREFC budget. The IODP-USIO, with NSF redefined the scope of the conversion to deliver the a "new" vessel within the existing hull.

The soaring prices of oil have dramatically raised the costs associated with operating the IODP facility while NSF funding has remained essentially flat. Working with NSF and the international community, the IODP-USIO reduced its service levels to pre-IODP levels and reduced the number of operational months from 12 to 8. The struggle to continue to deliver 8 months of operations continues to loom large. IODP-USIO, NSF, and the international IODP science community continue to work on efficiencies and planning activities that allow the JR to be operated as cost effective as possible while delivering the maximum science possible for the funding received.

Major Accomplishments of IODP

At the request of the National Science Foundation, the National Research Council appointed an expert committee to review the scientific accomplishments of U.S.-supported scientific ocean drilling: Deep Sea Drilling Project, Ocean Drilling Program, and Integrated Ocean Drilling Program. They also assessed the potential for future transformative scientific discoveries from Illuminating Earth's Past, Present, and Future: The International Ocean Discovery Program Science Plan for 2013-2023.

The committee identified Deep Sea Drilling Project, Ocean Drilling Program, and Integrated Ocean Drilling Program scientific accomplishments and analyzed their significance. Their list of accomplishments is summarized in the table to the left. They also examined the fields of inquiry that were enabled due to scientific ocean drilling capabilities. The committee then considered the scientific ocean drilling programs' contributions to capacity building, science education, and outreach activities.

U.S.-supported scientific ocean drilling programs have been very successful, contributing significantly to a broad range of scientific accomplishments in a number of earth science disciplines. Scientific ocean drilling has advanced understanding of solid Earth cycles, revealed the flow of fluid and microbe ecosystems within the seafloor, and gathered extensive information on Earth's climate history. In addition, scientific ocean drilling has spurred technological innovations that have strongly influenced further advancements in both the research community and the private sector.

Some of the major accomplishments of scientific ocean drilling include:

Solid Earth Cycles

- Verification of the seafloor spreading hypothesis and plate tectonic theory
- Development of an accurate geological time scale for the past 150 million years
- Confirmation that the structure of oceanic lithosphere is related to spreading rate
- Exploration of the emplacement history of submarine large igneous provinces
- Contributed to a new paradigm for continental breakup due to studies of rifted margins
- Confirmation that subduction erosion as well as accretion occurs in subduction zone forearcs

Fluids, Flow, and Life in the Subseafloor

- In situ investigation of fluid flow processes, permeability, and porosity in ocean sediments and basement rocks
- Characterization of the sediment- and rock-hosted subseafloor microbial biosphere
- Study of subseafloor water-rock interactions and the formation of seafloor massive sulfide deposits in active hydrothermal systems
- Examination of the distribution and dynamics of gas hydrates in ocean sediments

Earth's Climate History

- Reconstruction of global climate history for the past 65 million years, based on ocean sediments
- Development and refinement of the Astronomical Geomagnetic Polarity Timescale
- Documentation of the pervasive nature of orbital forcing on global climate variability
- Recognition of past geological analogues (for example, thePaleocene-Eocene Thermal Maximum) for Earth's response to increases in atmospheric carbon dioxide
- Discovery of the history of polar ice sheet initiation, growth and variability, and their influence on fluctuations in global sea level

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Mr. Chairman and members of the Subcommittee, I wish to thank you for this opportunity to answer questions about Major Multi-User Reasearch Facilities Management processes and the Integrated Ocean Drilling Program. I would be happy to discuss any of these topics with you during the hearing.

Chairman BROOKS. Thank you, Dr. Divins, for your testimony and insight.

Dr. Boebinger, you now have five minutes.

STATEMENT OF GREGORY S. BOEBINGER, DIRECTOR, NATIONAL HIGH MAGNETIC FIELD LABORATORY, AND PROFESSOR OF PHYSICS, FLORIDA STATE UNIVERSITY AND UNIVERSITY OF FLORIDA

Dr. BOEBINGER. Thank you, Mr. Chairman and Members of the Subcommittee. My name is Greg Boebinger. I am the Director of the National High Magnetic Field Laboratory and a Physics Professor at Florida State University and the University of Florida.

The MagLab is a multi-user research facility that is supported by a partnership of the NSF and the State of Florida. It is a fine example of the benefits of a federal-state partnership. Since its founding in 1990, in fact, the MagLab has received roughly $500 million from the NSF and $350 million from the State of Florida. 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 MRI rely on the knowledge gained from magnetic-field research.

The scope of work currently underway at the MagLab is vast. It includes the study of new superconductors, batteries and fuel cells with the potential to revolutionize energy delivery and storage. It also includes the search for new medicines and a crucial analysis of petroleum and biofuels that could lead to better fuel production. The MagLab has campuses at Florida State University, the University of Florida and Los Alamos National Laboratory. Every year, MagLab facilities are used by 1,200 scientists from more than 100 institutions across the United States. Access is through a peer review of proposals submitted by users, whose work spans material physics, magnetic engineering, chemistry, biology and biomedicine.

Funding for the MagLab comes in three competitive 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 competition to win the right to establish and operate the Nation's magnet lab.

The second stage of competition is our five-year renewal proposal process. Each renewal proposal includes the development of a new and updated scientific vision as well as a new zero baseline budget for the facility. Renewal proposals are peer reviewed by both anonymous referees and an expert NSF site visit committee. It takes 2–1/2 years to complete each five-year renewal proposal process.

The third stage of competition determines the MagLab's funding on an annual basis when the NSF budget decisions are made. These decisions weigh competing demands on limited resources and take into account the annual evaluation of the laboratory's performance by the MagLab's user committee and the NSF site visit committee. Competitive review is therefore already built into the NSF oversight of its multi-user research facilities. As such, consideration of a full recompetition should begin with a formal process to determine whether a winner-take-all recompetition is in the best interest of the Nation and the science. The process should analyze whether the present facility is underperforming or failing to provide the infrastructure and support needed for world-leading research. The process should also assess the cost of a full recompetition and the impact of a winner-take-all recompetition on future funding by partners who have already invested significantly in the facility. Future NSF recompetition policy must be flexible because every multi-user research facility is different. Each facility here today represents a unique funding portfolio, a complex infrastructure and an equally complex relationship with its user community and its managing institutions. Each of the MagLab's three partner institutions contributes valuable infrastructure and expertise including professors serving in management roles and research scientists providing support for user research. The MagLab's buildings, infrastructure and equipment are not federally owned. As such, a full recompetition of the MagLab is a decision whether to relocate the Nation's high magnetic-field facility and build it somewhere else.

As MagLab Director, I want to emphasize that I welcome the ongoing challenge of competitive review by both our users and our sponsors. It ensures its scarce resources are used to support the best science and the best management of important national assets. At the same time, given the complexity and costs involved in a winner-take-all recompetition, a flexible recompete policy is necessary.

I thank you very much for this opportunity to testify, and I would be pleased to answer any questions.

[The prepared statement of Dr. Boebinger follows:]

THE FLORIDA STATE UNIVERSITY

Statement of Gregory Boebinger
Director, National High Magnetic Field Laboratory
Florida State University
Before the
Research and Science Education Subcommittee
Committee on Science, Space, and Technology
House of Representatives
Washington, D.C.
April 18, 2012

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.

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.

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

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.*

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

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

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.*

Chairman BROOKS. Thank you, Dr. Boebinger.

At this point the Chair recognizes Dr. Gruner for five minutes.

STATEMENT OF DR. SOL MICHAEL GRUNER, DIRECTOR, CORNELL HIGH ENERGY SYNCHROTRON SOURCE, AND THE JOHN L. WETHERILL PROFESSOR OF PHYSICS, CORNELL UNIVERSITY

Dr. GRUNER. Thank you, Chairman Brooks, Ranking Member Lipinski and distinguished Members of the Subcommittee. Thank you for the opportunity to testify today.

My name is Sol Gruner and I am the Director and Principal Investigator of the Cornell High Energy Synchrotron Source, CHESS. CHESS provides X-ray resources essential to users working in physics, chemistry, material science, geology, biology, biomedicine, engineering, environmental science and even art restoration archaeology. The X-ray beams are generated by an accelerator machine a half mile in circumference in a tunnel underneath the central Cornell University campus. The machine uses both matter and antimatter particles passing through magnets to generate X-ray beams millions of times more brilliant than possible with conventional X-ray machines.

The NSF-funded facility was built in under two years and started operations in 1979. It has since been repeatedly upgraded during competing renewals, which occur roughly every five years, to maintain world-class capabilities. These, by the way, are existential competing. NSF annual support for CHESS is about $20 million with an additional roughly $15 million from Cornell, the National Institutes of Health and related grants. The facility staff of about 150 people hosts between 600 and 1,000 user visits a year by students, scientists and engineers from 38 states and territories and 24 countries who use the X-ray beam for an extraordinary variety of purposes. The result is about one scientific publication per day of X-ray operations.

The American taxpayer supports CHESS to fulfill three missions. The first one, of course, is world-class science, the second one is new technology development, and the third one is student training. Repeated NSF external reviews have confirmed that CHESS is extremely successful at all three missions. Examples of scientific results including fundamental work on fluid jets underpinning fluid injection in engines, basic pharmaceutical and biomedical science, discovery of new polymer ceramic composite materials, studies of materials at center of earth pressures, studies of famous paintings, etc. Our users have won many awards including Nobel Prizes.

The facility is a world leader in developing synchrotron technology. Synchrotrons are tools enabling much science and industry, and for this reason, there is a fierce international competition for technological supremacy in the field. Many of the technologies that have enabled the field, many of those which now are operating, for example, at DOE laboratories, were developed at our facility. We are world leaders in superconducting acceleration, X-ray detectors, optic simulators and many more areas.

Perhaps our most important function, however, is student training. Student training is closely linked to innovation. Our graduate students develop new ideas from concept through to implementation. They are in the control room and behind the shielding wall, meaning that the build the facility and learn how to make it better. This type of access is consistent with the university mission and is essential to training the innovators of tomorrow and the key to winning in the highly competitive synchrotron radiation field. In addition to receiving technological training, our students are immersed in frontier science working with users from across the world and across the country, thereby equipping them for future leadership roles.

A cooperative agreement with the NSF details numerous specific steps to ensure that government funds are spent accountably and responsibly. These include metrics, regular written reports, audits and external reviews.

I would like to close with the challenge that I believe threatens the very existence of major NSF interdisciplinary facilities, especially at universities. As you know, the NSF is divided into divisions, each devoted to a discipline such as chemistry or physics or biology. Now, consider the work of one of our users, Dr. Rod MacKinnon from Rockefeller University, who used our accelerator, which was designed for physics, and the CHESS facility, which is funded by the material science division. His work depended on apparatus we custom-built using methods from astronomy and engineering, allowing Dr. MacKinnon to resolve a seminal biological problem of biomedical importance, for which he won the Nobel Prize in chemistry. Now, I ask you, what division owns that research? It is a quandary. And perhaps it won't surprise you that each NSF division seems to feel that some other division should steward the costs. The path of least resistance, the path that I fear the agency is on, is to simply terminate broadly interdisciplinary facilities, especially at universities where student involvement mixes the disciplines. The temptation to do this is especially pronounced during tight fiscal times when the easiest way to increase the number of grants that a division can offer is to decrease large-facility obligations. I respectfully submit that this issue deserves your attention.

Thank you, and I would be pleased to answer questions.

[The prepared statement of Dr. Gruner follows:]

Testimony of Dr. Sol M. Gruner

Director and Principal Investigator,
Cornell High Energy Synchrotron Source/Cornell Electron Storage Ring
The John Wetherill Professor of Physics
Cornell University

Before the

UNITED STATES HOUSE OF REPRESENTATIVES
Committee on Science, Space & Technology
Subcommittee on Research & Science Education

Hearing on

"NSF Major Research Equipment and Facilities Management:
Ensuring Fiscal Responsibility and Accountability"

April 18, 2012

Chairman Brooks, Ranking member Lipinski, and distinguished members of the Subcommittee, thank you for the opportunity to testify today. My name is Sol Gruner and I am the director and principal investigator of the Cornell High Energy Synchrotron Source/Cornell Electron Storage Ring (CHESS/CESR), a major multi-user NSF-supported facility. My testimony provides an overview of the facility from inception to the present day, with background pertaining to the changing relationship between the NSF and universities over stewardship of major interdisciplinary facilities. The challenges of this relationship will be described toward the end of my testimony.

1. Overview of the CHESS/CESR facility from inception to the present day

Historical Overview

Cornell University was an early leader in accelerator and synchrotron radiation research, having built the second cyclotron accelerator in the world in the 1930s and the world's first synchrotron radiation beamline in the early 1950s. In 1977, the NSF Physics Division awarded Cornell $22 million to build a colliding beam storage ring nearly a half mile in circumference in a pre-existing tunnel underneath the central Cornell campus. This machine, called the Cornell Electron Storage Ring (CESR), collided electron and positron beams for high-energy physics (HEP) studies. CESR was built in just 18 months, on budget, and was operational in 1979. Because storage rings also produce intense beams of x-rays through the synchrotron radiation process, the NSF Division of Materials Research (DMR) awarded Cornell the funds in 1978 to build the Cornell High Energy Synchrotron Source (CHESS) to utilize the x-ray beams produced by CESR. CHESS also became operational in 1979.

From the beginning, CESR was designed to be so flexible that advances in technology could easily be incorporated as they were developed. The HEP experiment at CESR was a collaboration between 22 universities and national laboratories. It was one of the most productive and longest running experiments in the history of high-energy physics, resulting in more than 500 publications in peer-reviewed journals. In 2008, after nearly 30 years of operation, the NSF Physics Division and Cornell scientists ended HEP data collection at CESR. At that time, DMR became the primary steward and funding source for both the CHESS x-ray user facility and the CESR machine needed to generate the x-rays (collectively, CHESS/CESR). The flexibility of CESR, however, makes it ideal for accelerator physics studies that cannot be performed anywhere else in the world. The NSF Physics Division (and, to a lesser extent, the Department of Energy) continues to support advanced accelerator physics research and development on CESR when the machine is not being used for x-ray production.

CHESS is a multidisciplinary user synchrotron radiation facility for research in physics, chemistry, biology and biomedical science, geology, engineering, and environmental and materials sciences, and objects of art and antiquity. CHESS serves experimental groups from universities, national laboratories, and industry from around the world with many unique, state-of-the-art capabilities. Each year, between 600 and 1000 research scientists, graduate, and undergraduate students use CHESS to develop experiments, receive advanced training, and collect data. Demand for CHESS beam time greatly exceeds capacity. At present, CHESS is able to serve only about one-third of the demand for time on its beamlines. Furthermore, the facility is highly productive: CHESS data results in about one publication for each day of user operations.

CHESS and CESR have both been upgraded multiple times to maintain world-class capabilities. In 1979, CHESS had three beamlines and five experimental stations. It expanded in the late 1980s and again in 2000. Over time, both CHESS and CESR have developed and implemented new technologies that have been adopted at other synchrotron radiation and electron storage facilities around the world. This process is on-going: Cornell is currently planning to upgrade CHESS with novel undulators that would provide much needed high-energy x-ray capabilities that are in very short supply in the United States.

Management

Cornell University has decades of experience using the Research Laboratory structure to operate large NSF-supported national facilities – including the Arecibo Radio telescope, CHESS/CESR, and the Cornell Nanofabrication Facility – flexibly and cost effectively. The Cornell Laboratory for Accelerator-based ScienceS and Education (CLASSE) is the umbrella Research Laboratory for CHESS/CESR. The Director of CLASSE reports to Cornell's Senior Vice-Provost for Research. A Directorate consisting of the directors for x-ray science, particle physics, accelerator science, technical operations, and administration makes CLASSE decisions.

Accelerator laboratories are complex enterprises, and rely on experts in radio-frequency engineering, accelerator physics, x-ray optics, high vacuum, cryogenics, and other technical disciplines to operate successfully. CLASSE maintains the necessary skill set to operate CHESS/CESR through a matrixed organization, whereby skills are shared and costs are allocated to projects by the amount of service provided. The advantage of this organization is that it reduces redundancy and lowers the operating costs of our research laboratory. CLASSE also draws upon the skills of about a dozen faculty members for whom the CLASSE facilities are their primary research tools, and several dozen additional faculty members who make extensive use of the facilities. These faculty members represent a university contribution to CHESS/CESR worth millions of dollars annually. Overall, CLASSE has an annual budget of about $35 million per year, not counting faculty costs. The NSF CHESS/CESR award – about $20 million in FY 2012 – makes up the majority of this budget with the rest paid for by a combination of other grants and Cornell University.

Competing CHESS/CESR renewals, typically every five years (see question 5 for elaboration) define the proposed program and the resulting detailed year-by-year preliminary budgets. Every six to twelve months, the NSF informs us of adjustments to the preliminary budget for the period, and Cornell's Office of Sponsored Programs submits a revised budget for the period. Every time a new budget is accepted, the NSF generates a notice of Grant Award to Cornell specifying the sum of allowed expenditures for each category for the budget period.

CLASSE has a Business Office to check expenditures against allowable expenses in each budget category. Cornell's Sponsored Financial Services Office handles the billing to the NSF. Cornell is reimbursed for its actual expenditures though weekly or bi-monthly requests for payment to NSF's Fastlane system for recent expenses. A few days after the request is made, the funds are deposited into Cornell's bank account.

CHESS/CESR is managed through a series of cooperative agreements and memoranda of understanding, partnerships, and line management arrangements that ensure accountability and open communication between all parties. The primary accelerator facility awards are managed under the terms of carefully negotiated Cooperative Agreements between the NSF and Cornell University. The Cooperative Agreements provides for the basic infrastructure of the accelerator facilities at Cornell. The major biomedical component of CHESS – the MacCHESS program – is a National Institutes of Health (NIH) Biomedical Biotechnology Research Center award, and managed under terms of that NIH grant. Specific experimental programs are managed through individual memoranda of understanding between CHESS/CESR and organizations such as the DOE-funded Energy Materials Center at Cornell, the Air Force Office of Scientific Research, the NSF-funded Materials Research Science and Engineering Center at Cornell, and the King Abdullah University of Science and Technology, which provide resources to CHESS/CESR through their grants. The terms of these individual agreements require these resources are owned by CHESS/CESR and are available to all CHESS/CESR users. More information on management is given in the answers to questions below.

2. Justification for the CHESS/CESR facility and return on the taxpayer investment
CHESS/CESR has a different character from light sources operated by the Department of Energy (DOE) that is immediately apparent to visitors familiar with both types of facilities. In addition to serving as a user facility, it has two unique and intertwined functions: it advances light source technology by training the young scientists who develop the new techniques and improved x-ray beams of the future. Both of these roles stem directly from the location of CHESS at a university, and they reflect the NSF's twin goals of innovation and education.

Student training is closely linked to innovation – our graduate students develop the new ideas from concept through implementation. As we like to say, they are in the control room and behind the shielding wall, meaning that they make the beams, and make them better. The mission of the DOE's large-scale user facilities is inconsistent with this type of access. However, it is essential to training the workforce, and innovators, of tomorrow. Moreover, it is the key to maintaining progress in the highly competitive synchrotron radiation field. In addition to receiving technological training, our students are immersed in frontier science, thereby equipping them for future leadership roles.

The importance of Cornell's synchrotron activities is demonstrated by our global impact. From the world's first synchrotron radiation beamline to CHESS/CESR today, Cornell has been a source of much of the accelerator and synchrotron radiation technology that enables modern synchrotron light source facilities. These facilities are recognized as necessary tools for much modern technology. For this reason, global capital investment in synchrotron light sources exceeds ten billion dollars, with global user communities numbering in the tens of thousands. The global competition for supremacy in the synchrotron light area is fierce because of the scientific and economic impact of this research, and as a result there is a global shortage of the requisite highly trained personnel. CHESS/CESR continues to be one of the world's major training grounds for these personnel, who develop new technology in the course of their training.

3. Steps to ensure best stewardship of taxpayer dollars and that money is spent appropriately and wisely
The CHESS/CESR cooperative agreement with the NSF details procedures to assure best stewardship practices. Required, regularly reported performance metrics for the CHESS/CESR facility operation ensure that American taxpayers continue to get high value for their investment. A list of recent NSF oversight and review of CHESS/CESR operations is included in **Box 1** and the answer to question 4.

BOX 1

- In 2010 the NSF performed a thorough Business Services review of the CHESS/CESR facility. An NSF team spent nearly a week at Cornell examining our financial, human resource, safety, accounting and other practices to assure that they were satisfactory.
- Cornell accounts are frequently subject to random audits by an independent firm chosen by the government. As one of the largest Cornell awards, CHESS/CESR is almost always chosen for audit.
- The NSF requires a detailed written annual report on the facility. The NSF also requires annual reporting of GPRA metrics of deliverables specified in the Cooperative Agreement, and projected budgets and financial reports.
- Milestones for the R&D programs set out in the original proposals and cooperative agreements ensure that they are performing at a high level.
- Matrix managed technical staff uses a commercial computer system to track and charge time to appropriate projects. The Cornell Administration units (e.g., Human Resources, Purchasing, Accounting, Office of Sponsored Programs) oversee and check financial and human resource transactions of the facility.
- The NSF performs a comprehensive annual external scientific review to assure that the facility is performing well.

BOX 2

Cornell's responsibilities, as summarized from the cooperative agreement

- Cornell assumes primary responsibility for planning, operation, safety and management of the facility, in accordance with the competing renewal proposal won for continued operation of the facility and the awarded budget.
- Maintenance, management, and operation of the facility equipment and human infrastructure.
- Operation of competitive, peer-reviewed proposal process for user access to the facility resources, and assistance to all users to help them succeed in their experiments.
- Upgrading of the facility, within budgetary constraints.
- Research and development of unique or desirable experimental capabilities, as specified in the renewal proposal.
- Continual assessment of national needs and adjustments to operations and the facility to meet these needs, and to remain at the forefront of synchrotron radiation-based research.
- Maintenance of an external advisory board, which also reviews all aspects of the facility, including the proposal process for access to the facility.
- Maintenance of a Committee of Users to advise on needs of the user community.
- Human resource development, including seeking a diversified staff, and involvement of students at all levels of the facility.
- Specific deliverables of x-ray beam time.
- Education in the broadest sense. This includes graduate student and post-doc trainees at the facility, as well as robust outreach program to the public to develop the national STEM workforce. The latter involves the public, K-12 students, and undergraduates at other institutions.

Joint Cornell/NSF roles, as summarized from the cooperative agreement

- Involvement in NSF-organized facility meetings and functions.
- Contribution to national scientific, engineering, and educational goals in synchrotron radiation research and capabilities.
- An annual site-visit review of all aspects of the facility.
- A periodic business service review.

4. Role of the Principal Investigator (PI)/Director and role of the NSF
The cooperative agreement signed between Cornell and the NSF specifies the respective roles and responsibilities of each party. Cornell has chosen me to be Principal Investigator and Director; in this role, I am responsible for ensuring that the facility meets the goals and obligations set out in the cooperative agreement. I also serve as the main interface to the NSF on this project. The work and roles in the cooperative agreement are briefly summarized in **Box 2**. These duties involve frequent communication and coordination, often several times per week, with our program officer at the NSF.

Broadly put, my role is to guide the facility, staff, and associated Cornell faculty to maximize the scientific and educational output of the facility, ensure that the facility is accessible to users, and to help users succeed in their science. I am charged with managing the facility responsibly, according to NSF and Cornell expectations. I also identify and foster the unique roles – education and innovation – of an NSF-stewarded facility. As mentioned above, the major distinction between CHESS/CESR and the synchrotron facilities in DOE laboratories is fulfillment of the NSF mission of education and training through the performance of research and development. Toward this end, Cornell expects me to facilitate involvement of the larger Cornell community to fulfill NSF and national goals.

5. Describe the life-cycle planning for the facility, including Cornell and NSF roles, and the competitive renewal process.
Each NSF-supported multi-user facility has distinct objectives. Some, like telescopes, serve well-defined disciplinary roles. Others, such as synchrotron x-ray sources, are interdisciplinary tools that provide capabilities that are otherwise unavailable, and that serve many users doing many different types of unrelated experiments. CHESS/CESR provides x-ray beams and capabilities to users from across the science and engineering disciplines, including physicists, chemists, materials scientists, biologists, biomedical scientists, environmental scientists, geological scientists, engineers, archaeologists, paleontologists, art historians, and cultural preservationists. A multidisciplinary multi-user facility reaches the end of its life cycle when it no longer serves a vibrant user community, usually because users have alternative means or places to acquire their data. In other words, users vote with their feet.

This is not the case with CHESS/CESR – as mentioned previously, the facility is greatly oversubscribed and can fulfill only about a third of the demand for its resources. In addition to the demand, CHESS/CESR serves an important national mission. As described above, CHESS/CESR is a unique national training ground for accelerator physicists and x-ray beam-line scientists. CHESS/CESR also enables the lengthy process of developing new synchrotron experiments and technologies. Furthermore, CESR – which also receives funding through the NSF's Division of Physics – is uniquely suited for accelerator physics studies and relies on the infrastructure currently provided by the CHESS/CESR facility. This combination of functions cannot be replicated elsewhere, except at great cost.

With respect to recompeting major facilities, the National Science Board stated in 2008, that "...after construction is completed and an appropriate time period is implemented to bring the facility to sustainable operations, full and open competition of the operations award will be required." The NSB was clearly referring to the free-standing facilities that comprise the great majority of the NSF major facilities portfolio. Recompetition for operations of CHESS/CESR must be considered in a different class, since the facility is physically embedded in the central Cornell campus and Cornell owns all the equipment. Instead, NSF requires an existential competitive renewal proposal every three to five years that is a much higher bar than recompeting the operation of a free standing facility. When facility operations are recompeted, the facility operators may change, but the facility and its staff remain. By contrast, if a university-owned facility such as CHESS/CESR fails to make a convincing case during a competitive renewal, the facility is terminated and the operators and the staff are dismissed. The threat of termination focuses the minds of all facility personnel on the compelling and important aspects of renewal.

During the recompetition process, reviewers are charged to evaluate uniqueness as well as the importance and quality of the proposed program. NSF reviewers have repeatedly and strongly endorsed the renewal of CHESS/CESR. Prior to signing the current cooperative agreement in 2010, the Mathematical and Physical Sciences Directorate additionally appointed a national panel of experts to evaluate whether the NSF should steward synchrotron light sources. The panel made a strong statement that the NSF has a unique role in the national framework of synchrotron sources and that it should steward light source facilities. The panel explicitly stated the national importance of the Cornell program. The NSF also performed reviews in 2010 and 2011, again charging the review panels to evaluate the uniqueness, importance, and effectiveness of the program. Both reviews strongly endorsed CHESS/CESR.

6. Describe the involvement of foreign entities, non-profit organizations, industry and other organizations with the facility.

NSF provides the primary support for CHESS/CESR. Additional support, amounting to about 10 percent of the overall costs, comes from the NIH for the MacCHESS program in structural biology. MacCHESS has been competitively renewed every three to five years since 1983, and the current award ends in mid-2013. CHESS also receives about $400,000 from a program at the NIH National Institute of General Medical Sciences to support macromolecular biology experiments.

As stipulated in the CHESS/CESR cooperative agreement, users gain access to the facility by competitive peer-reviewed proposal, without regard to their geographical location. Users wishing to obtain proprietary data must pay full cost recovery. In the last five years, CHESS has served users from 38 states, Washington D.C. and U.S. territories, as well as 24 foreign countries. We maintain a healthy reciprocity involved with foreign CHESS users – most of who are engaged in scientific collaborations with U.S. users, and many U.S. users utilize facilities in the foreign countries. In addition, users from 31 industrial organizations also used the facilities.

CHESS/CESR scientists are routinely involved in collaborations and exchanges, and serve as technical advisors for many counties, including Canada, Denmark, Japan, Taiwan, China, the United Kingdom, Saudi Arabia, Germany, and France. CHESS staff members routinely serve as technical advisors for almost all the DOE national synchrotron light, nuclear, and high-energy physics accelerator laboratories, as well as at many comparable international facilities.

Our scientists frequently collaborate with other national entities. Currently, we are working with the Air Force Laboratory at Wright Patterson Air Force base to build a special high-energy x-ray capability at Cornell to study the failure of aircraft alloys and materials. CHESS staff members played a leading role in designing the x-ray detectors operating at the x-ray free-electron laser in DOE's SLAC Accelerator Laboratory in California. CHESS/CESR staff members invented and developed the new helical undulator currently being installed on the Linac Coherent Light Source at SLAC. CHESS staff members are collaborating with DOE's Advanced Photon Source to test novel pixel-array detectors on their beamlines.

In addition to serving industrial users, CHESS/CESR staff members have been involved in sourcing technology to a number of independent companies. Many of the world's recent synchrotron light sources are powered by superconducting RF cavities developed for CESR and outsourced to industry. They are all tested at Cornell before being shipped to the end-user. A very large fraction of the world's protein structural data has been acquired on detectors sold by Area Detector Systems Corporation (ADSC) in Poway, California. This technology was first demonstrated at CHESS and transferred to ADSC. Advanced Design Consulting in Lansing, New York is major supplier of instrumentation to accelerators and synchrotron light sources. The company, started by a former CHESS employee, routinely uses CHESS as a test bed for new products developed by the company.

7. Describe major accomplishments of the facility?

CHESS and CESR have played key roles in the development of high-energy physics, particle accelerators, and x-ray sciences. At the same time, many of the hundreds of students and early career scientists who trained at CHESS and CESR have gone on to build and operate major research facilities around the world. Although CHESS and CESR have had profound impacts in many areas of sciences, due to the limited space available, we will mention only a few highlights in x-ray, particle, and accelerator sciences.

Many of the pioneering x-ray experiments done at CHESS opened up new areas of research and motivated and justified the development of third generation light sources. Examples include the discovery of resonant magnetic x-ray scattering by Dennis McWhan and Doon Gibbs, both of Brookhaven National Lab, scattering too weak to be seen by other means, and the first nanosecond time-resolved x-ray scattering and laser melting experiment by Ben Larson of the Oak Ridge National Lab and his coworkers.

Michael Rossmann of Purdue University, used CHESS to collect protein crystallography data while solving the structure of the human rhinovirus, the first large-scale macro-molecular structure determination that proved to skeptical biologists that synchrotron facilities had revolutionary capabilities to solve their problems. That seminal work helped usher in the field of synchrotron structural biology, driving the burgeoning need in the 1990s that justified building new light source capabilities around the country. Our users have won many prizes. Fore example, the work by Ada Yonath of the Weitzmann Institute in Israel on ribosomes and the work by Rod MacKinnon of Rockefeller University on the potassium channel were both awarded Nobel Prizes in Chemistry within the last decade.

The work described above would not have been possible without a long string of developments in x-ray optics and technology. Major breakthroughs include the invention or discovery of:

- The idea for cryogenically cooled x-ray optics, which make brilliant third generation undulator beamlines possible;
- X-ray standing-wave techniques that find impurities in crystals, on atomically clean surfaces, and in thin films;
- Diamond-anvil specimen cell methods that let scientists study materials at high-pressure and high-temperatures;
- Tapered glass-capillary optics that focus x-ray beams to micron-scale;
- Nanofabricated confocal optics that create x-ray fluorescence analyzers with micron-scale depth resolution;
- High-pressure cryofreezing apparatus techniques that freeze small crystals without using cryoprotectants; and
- CCD and pixel-array area detectors, which have transformed x-ray data collection strategies.

In addition, CESR was the test bed for the prototype of the undulator used at the Advanced Photon Source at the Argonne National Laboratory. Building on this work, scientists have recently invented a new type of very inexpensive permanent magnet undulator that will power helically polarized x-ray beams at the x-ray free electron laser at the SLAC Accelerator Lab in Stanford, California.

Inventions and firsts in accelerator technologies at Cornell go back to the first characterization of the synchrotron-radiation spectrum. CESR is the first storage ring and collider exclusively powered by Superconducting Radio-Frequency (SRF) cavities. It was the test bed for the superconducting cavities that are the basis of the Thomas Jefferson National Accelerator Facility in Newport News, VA. It owns the record for the lowest vertical emittance in a positron storage ring and was the first storage ring to use superconducting wigglers to dominate emittance control and radiation damping. Cornell was the first organization to commercialize an SRF cryomodule by technology transfer to industry.

The technical accomplishments enabled a string of firsts in high-energy particle physics, including discoveries of B-meson decay channels; the discovery of the Ds, Y(1D), and 11 charmed baryons; the first observation of $J/\psi \rightarrow \gamma\gamma\gamma$ decays; and absolute measurements of D branching fractions.

Work at Cornell also led to the idea of energy recovery using superconducting RF cavities. This idea that has spawned a world-leading, decade-long research and development effort to design and prototype a high-energy Energy Recovery Linac (ERL) coherent x-ray source. This is a next generation light source, and a significant leap forward from current technology. Major accomplishments of the ERL research and development program include a laser-driven DC photocathode electron source with world record currents, and a prototype injector that can produce sufficiently small emittances to meet ERL design requirements.

8. What obstacles and challenges does the facility face?

Despite highly successful service to the nation, university-based interdisciplinary facilities face a daunting structural challenge because NSF's discipline-based organizational structure does not lend itself easily to support of truly interdisciplinary facilities. This challenge has national policy implications and would benefit from the attention of the Congress.

As the Subcommittee knows, the NSF is organized into Directorates such as the Directorate for Mathematical and Physical Sciences (MPS) and the Directorate for Biological Sciences (BIO). Each Directorate, in turn, consists of several Divisions. MPS, for example, includes divisions devoted to physics, chemistry, materials research, astronomy, and mathematics. NSF's major facilities are usually stewarded by a single division, which works well for facilities with users primarily from a single discipline. Thus, the astronomy division is a natural steward for telescopes.

The disciplinary model, however, is not well suited for facilities that serve broad interdisciplinary communities. **Figure 1** shows the NSF directorates that fund the principal investigators on CHESS proposals (see caption for details). As the figure illustrates, no single Directorate, much less a Division within a Directorate represents a majority. This should be the definition of a broadly successful interdisciplinary research facility. Moreover, many of the complex problems studied at CHESS do not divide neatly along simple disciplinary lines, which is one reason why so many "firsts" have resulted from work at the facility.

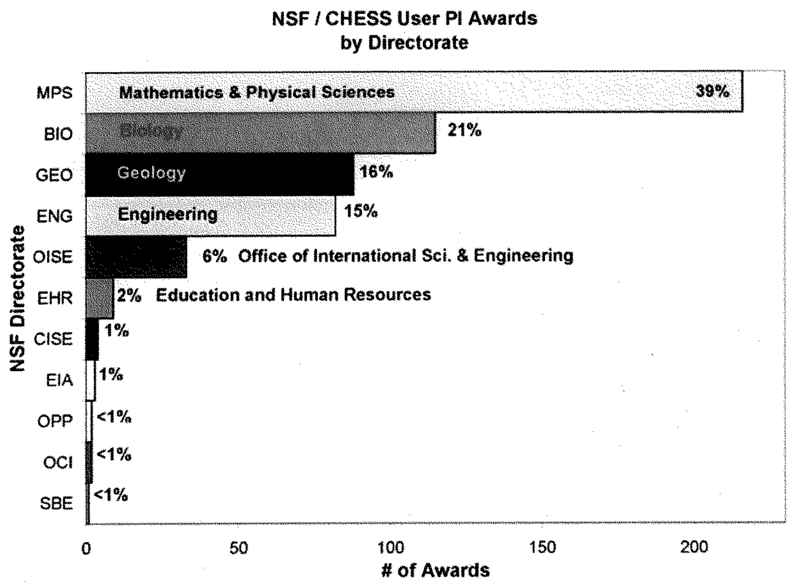

Figure 1. Distribution of NSF grants, by awarding Directorate, to principal investigators (PIs) who had active CHESS beam time proposals during 2003-2007. Many PIs of CHESS proposals are funded by other agencies and not the NSF, and are not represented here. If they were included the interdisciplinary spread would be even larger.

An excellent example is the work of Rod MacKinnon of Rockefeller University, who won the 2003 Nobel Prize in chemistry for research done primarily at CHESS. He determined the atomic structure of potassium ion channels, a class of proteins that are the essential engines that generate nerve impulses. Researchers had been trying to solve this problem for nearly a half century. Professor MacKinnon's research used a machine – CESR – built to do high-energy physics and a facility – CHESS – motivated by materials research. The critical data were taken using a novel detector, which we built utilizing techniques from astronomy and engineering. These data solved a seminal biological and biomedical problem that won a Nobel Prize in chemistry. What, then, is the relevant discipline: Physics? Materials? Astronomy? Engineering? Biology? Chemistry? A non-NSF focus, such as biomedicine? The answer, of course, is all of the above.

NSF's Divisions are under great pressure from their constituencies to use their resources to support their own discipline's grantees. The NSF is aware of this and recently launched the Integrated NSF Support Promoting Interdisciplinary Research and

Education (INSPIRE) program in an attempt to address the issue. The INSPIRE program, however, is aimed at research and education grants rather than facilities. Divisions know that supporting a major facility requires a large, long-term obligation, and are reluctant to provide support unless the science is "owned" by their discipline. Referring back to Figure 1, each NSF division notes that it is a minority player and concludes that the funding burden should lie elsewhere. The unintended result is that the discipline-based divisions are reluctant to support interdisciplinary facilities, even though their investigators rely on these facilities to do their work.

The NSF's discipline-based organizational structure also has consequences on the allocations between different types of awards in a division's portfolio. The Divisions are always under pressure to increase the number of awards they make. By definition, major facilities have large budget lines and are tempting targets for Division Directors seeking additional funding to increase the total number of awards they make. Unlike smaller awards, major facilities require initial investments of hundreds of millions of dollars and take many years to go from conception to full operation. The rate-limiting step is the time required to develop the highly trained and specialized human infrastructure to operate a facility. With even a short break in support, this human infrastructure disperses when the highly skilled staff – who are in great demand around the world – find other jobs. Such a team cannot be easily or quickly reassembled. Thus, major facility funding decisions must be considered in a long-term context, a task made especially difficult by the NSF's rotator system where the directors of divisions and directorates change every few years.

NSF has guidelines for the appropriate distribution of funds in divisional funding portfolios. Ten years ago, the National Science Board released a study (NSB 02-190) that considered the balance between the NSF investment in tools and facilities and other types of awards. The NSB found that 22 percent of portfolio going towards tools and facilities – the amount at the time of the study – was too low and advised increasing the level to 27 percent.

The NSF has not made much progress towards the NSB's recommendations, however, on the funding of facilities. As an example, the Division of Materials Research, which is one of the NSF's largest, devoted less than 20 percent of its base budget to tools and facilities in FY 2011. This is of special concern, because DMR's facility portfolio consisted primarily of major university-based interdisciplinary facilities. These included the Synchrotron Radiation Center, a low-energy x-ray facility at the University of Wisconsin for which funding was recently dropped; CHESS/CESR at Cornell; and the National High Field Magnet Lab in Tallahassee, Florida. DMR also provides support for smaller-scale facilities at universities, such as the National Nanotechnology Infrastructure Network. As noted above, the NSF's current discipline-based structure makes it more likely that multi-disciplinary university-based facilities will be the first casualties of a declining budget. Without some explicit direction from Congress, the nation is at risk of losing some of the key tools of innovation in the NSF's budget stovepipes.

In conclusion, I am most concerned for the future of NSF-supported interdisciplinary facilities at universities. As the Subcommittee knows, education is one of the most important parts of the NSF mission. As exemplified by CHESS/CESR, universities are ideally suited to incorporate student training into facility operation. At Cornell, we are quick to point out that CHESS/CESR is a proven incubator to develop the leaders of the future needed to sustain national synchrotron and accelerator, as well as other types of science. Moreover, universities deploy faculty and other resources to enhance the performance of the facility at no cost to the NSF. For decades, the NSF has stewarded facilities at universities that serve the nation by fostering innovation and educating young scientists. The NSF must decide how to reshape itself to support the multidisciplinary facilities of the future. Otherwise, it will remain static and lose those facilities, along with untold opportunity, innovation, and discovery. For the sake of the country's technical and economic strength and leadership, I urge you to make certain that the NSF chooses the path of adaptation and innovation.

Mr. Chairman, this concludes my written statement. Again, I thank you for the opportunity to testify at this important hearing. I would be pleased to answer any questions you or members of the Subcommittee may have.

Chairman BROOKS. Thank you, Dr. Gruner.

I thank the witnesses, each of them, for their valuable testimony and the Members for their upcoming questions. At this point I recognize myself for questioning for five minutes. The Chair will then recognize other Members for five minutes.

The first question I have is for all witnesses. What perceived or anticipated benefits, detriments or vulnerabilities could the research conducted at your facilities or the communities you serve face by regular recompetition of multi-user facility operating awards? Whoever wishes to go first. If not, I will start on the right with Dr. Gruner, but if someone else wants to go first, jump at it.

Dr. GRUNER. We have been recompeted every five years for as far back as I can remember. Because the facility is physically embedded in Cornell University, because all the equipment is owned by Cornell University, there doesn't seem to be too much in the way of choices. So we deal with every recompetition as existential. Either they are going to fund us and we will continue, or they will not fund us and we will simply go out of business. This is considerably different than a freestanding facility where you can recompete the operators and the staff stays. In our case, if we fail the recompetition, not only do the operators leave but, of course, the staff are dismissed. This helps focus the mind.

Chairman BROOKS. Dr. Boebinger?

Dr. BOEBINGER. Yeah, I agree with everything my colleague, Dr. Gruner, said. In addition, for the magnet lab at least, because we have such a large involvement from the State of Florida, it is difficult to see how and why the State of Florida would be putting up 35 percent of the funding if they felt that every five years there was a winner-take-all competition. Of course, it is a double-edged sword. It could be that it gets everyone's attention. The primary point that I would make is that as my colleague said, every five years these renewal proposals are not a case of showing up and asking for one's allowance. It starts with a zero-balance budget and it ends up with a decision that really does determine the existence of the user facility at the university for the next 5 years.

Chairman BROOKS. Dr. Divins?

Dr. DIVINS. Again, I would like to agree with what has been said. Our case is a little different than the rest of the panel in that the facility in question is not actually owned by the National Science Foundation or by Ocean Leadership, for example. It is a contracted vessel that we receive. We work out, in this case, a ten-year contract with the owner of that vessel. Having regular competition could have a pros and cons in that model. If the economic situation is such that the vessels are not in demand, we could negotiate a nice lower rate on the facility. If the economic conditions are such that, you know, oil is booming, they want to use the ship for other purposes, then we risk losing the facility due to making the cost of having the contract might be prohibitively expensive. So there is a balance there in terms of doing that as an annual competition, but the other part, in addition to the actual ship is that we do have facilities that are contributed to IODP through our academic partners. For example, Texas A&M University and Lamont Doherty Earth Observatory of Columbia, they provide in kind buildings and overhead and other activities that if you were to do this as a constant winner-take-all procedure, you know, you could potentially be having to either build new buildings, hire new staff on a regular basis. So it really is a delicate balance between where are the pros and where are the cons to make an annual recompete process.

Chairman BROOKS. Dr. Smith?

Dr. SMITH. Thank you. You asked the question from the community standpoint, which is appropriate, and I think really the community should be heard when the agency is making a decision to recompete. I will go back to something that I said earlier, and that is, if the first question is, is this organization serving the community in the best possible way, you start from that and then ask how can it be better, and I think there is one issue that I illustrate in my testimony, and that is, if recompetition precludes organizations from consolidating, which can certainly offer cost benefits and efficiencies to the community, then the recompetition is not in the best interests of the community, and that certainly can be—that is an issue that we face. Dr. Schreier mentioned the same one from his standpoint. It is a common issue. And so in our case, we are willing to compete. I think we will compete strongly. But there ought to be other avenues to allow us to restructure to be more effective, and when recompetition impedes those, then there should be some process for looking at the alternatives.

The other issue I wanted to point out is that in many cases, for example, with our work with the National Solar Observatory, we are in the process of heading into the advanced—a major facility advanced technology solar telescope, which means that I am signing very large contracts and making very large commitments. It is inconceivable to me that you would have a process where I am unplugged and somebody else steps in to sign the same contracts. I don't know how that process will work. Again, we will compete strongly but there is a large uncertainty just in pure legal and logistical terms how you make that transition, and I have to say, it is very, very daunting.

Chairman BROOKS. Dr. Schreier?

Dr. SCHREIER. Thank you. I agree with many of the previous comments, especially Dr. Smith's. One point I could add is that in the case I was discussing, there are many complex international agreements involved in running these facilities. Some are government-to-government but many are the legal responsibility of the parties who do the work like my organization. We have agreements with Chile. We are subject to Chilean labor laws. For example, if ALMA is recompeted, if a new organization takes over ALMA, all the 300 staff in Chile have to be fired, given severance pay and rehired by a new organization. The labor laws are very strict there. There are relationships with our foreign partners in terms of ALMA being a joint project. It is a very expensive project. We pay less money because other countries are participating but we also have to negotiate from a position of strength with, for example, Europe and with Japan in terms of how we support our scientific communities. The European organization is extremely strong. It represents 13 European countries. We have developed relations with them through the years, and we know how to maneuver this situation. A new organization will have to start from scratch, figure out how to negotiate, how to work together. These are very important factors that can't be ignored in a recompetition.

Chairman BROOKS. Thank you, Dr. Schreier and the other witnesses.

At this point the Chair recognizes Mr. Lipinski of Illinois for five minutes.

Mr. LIPINSKI. Thank you, Mr. Chairman.

I appreciated the witnesses' comments on the recompetition. One thing I just want to follow up, hopefully very quickly, Dr. Smith. I think you had mentioned a couple times when we were talking about recompetition that there would be alternatives. Is there anything more that you can say on that? What are you talking about?

Dr. SMITH. Yeah. I thank you for asking me to be specific. There was something on my mind. The Astronomy and Astrophysics Decadal Survey a couple of years ago recommended that the NSF consider ways of consolidating the National Optical Astronomy Observatory, NOAO, and Gemini. They sit on similar sites. They serve the same community but they are separate programs now. We thought that was a serious recommendation and we certainly wanted to examine all aspects of that, but the National Science Board's decision was that when you take two organizations that are under separate cooperative agreements and somehow entangle them or merge them, then that impedes recompetition because of the coupling and so we're not now considering consolidating those two organizations, notwithstanding the recommendation of the decadal survey. There may be or may not be, we just haven't had a chance to examine it, a tremendous cost savings. There certainly would be advantages for the U.S. community. It would be very difficult, of course, to accommodate all the international partners but it is a situation which because the recompetition itself became the highest principle, the more important matters of just building a stronger, more responsive organization are things that are off the table. We can't examine that.

Mr. LIPINSKI. Dr. Schreier?

Dr. SCHREIER. I would like to add to that. I think that is a very important point that Dr. Smith made. I can tell you from the mirror image standpoint, we are currently operating ALMA and NRAO together. We have been asked by NSF because of the National Science Board's recommendation to assess the cost of splitting them, and we have done that. We submitted this information to NSF and they are analyzing it. But the first year of the spilt would cost approximately $27 million more to separate these facilities, you know, firing people, rehiring them, creating new infrastructure, and there would be a steady state increase of about $6 million a year. So we are talking about a steady state increase in cost of maybe five percent or so with the budget and a first-time cost that is much higher.

The second point that Dr. Smith made, which I would like to emphasize, is that by being associated, by having the forefront facilities like Gemini and the National Optical Astronomy Observatory, and ALMA and the radio facilities is one way we maintain our technology expertise, by working on the forefront instrumentation, and that is essential. If you are relegated to separating these facilities and just maintaining things at the odd facilities and not the new facilities, then you lose your expertise. It goes somewhere else, and that is something I think the United States wouldn't want to do.

Mr. LIPINSKI. I want to move on to the issue of decommissioning plans and costs, and Dr. Smith has recommended that NSF considering allowing for decommissioning costs within the MREFC budget, and I just want to open up to the rest of the panel, do you agree with this recommendation? Do you have any additional suggestions regarding de commissioning that we should consider?

Dr. SMITH. Can I just maybe offer one clarification?

Mr. LIPINSKI. Yes.

Dr. SMITH. I would really like to see decommissioning because it is a large one-time cost relative to your operating budget be handled in some agency-wide budget like MREFC, if not MREFC, but there could be some other agency-wide pool of money that you could use to address that.

Mr. LIPINSKI. Thank you for that clarification.

Does anyone else have any comments? Dr. Boebinger?

Dr. BOEBINGER. Yes. For the magnet lab, the issue of decommissioning I think is very different than for some of my colleagues on the panel. We have a sufficiently large suite of magnets that typically for us decommissioning is getting funding for the next higher performing magnet, and so then we take the old one offline. It was similar to the graph that was shown for telescopes but it is a much smaller financial scale, and so I don't see a need at least for us to have a formal process for decommissioning. In fact, this upgrading of equipment is one way that we get involvement by NIH and Department of Energy as we propose new magnets. So at least for the magnet lab, I don't think it is a budgetary issue.

Mr. LIPINSKI. Anyone else? Dr. Schreier?

Dr. SCHREIER. I can add an example to what was just said. The Very Large Array in New Mexico, which is 27 antennas spread across the plains of San Agustin, was the forefront facility dedicated in 1980. It was the best radio telescope in the world. In the 1990s, the National Science Board approved an upgrade and for something less than, significantly less than $100 million, that same telescope was just rededicated two weeks ago as the Jansky Very Large Array and is between ten and 1,000 times more powerful just by virtue of replacing the electronics. So this has become a brand-new telescope that is now a half-billion-dollar-class telescope developed not by decommissioning, but by just replacing 1970s vintage electronics and correlators and receivers with 2000 vintage equipment. This is a very powerful way to proceed and it doesn't happen automatically, but it is a very cost-effective way to get new capabilities.

Mr. LIPINSKI. Dr. Divins?

Dr. DIVINS. I would like to second that. I mean, that is exactly what has happened with our facility over the years, that as the existing infrastructure becomes dated, the MREFC program was the way to—you know, we didn't have to decommission, we just reinstituted a new program and a new facility and we got the latest state-of-the-art technology. It didn't have to be the same ship in our case. It was an open competition for any vessel but it would have given us a new facility, and what we ended up with was much better than what we had and we didn't have to actually shut down any facility. We just transitioned to the new one. It was, I think, a very cost-effective way to handle it.

Mr. LIPINSKI. Dr. Gruner?

Dr. GRUNER. I would like to add to that. There doesn't seem to be a very effective process to consider the costs of decommissioning versus the costs of upgrading or replacing the facility if the need for that facility continues to exist. It would be very helpful in fact if that were to occur.

Mr. LIPINSKI. Thank you. Obviously, each situation, each facility is very different in these considerations, and that has to be taken into account, so I appreciate hearing all the different perspectives, and I yield back.

Chairman BROOKS. Thank you, Mr. Lipinski.

The Chair next recognizes Mr. Tonko of New York.

Mr. TONKO. Thank you, Mr. Chair.

Dr. Gruner, from your testimony, it appears clear that there is a high demand for the use of the Cornell facility. Does the concept of recompeting this facility really apply in this case?

Dr. GRUNER. I don't think it applies in the same sense that it would apply to recompeting the operation of a standalone facility. And, as I had mentioned, because demand continues to be high and because we either continue or go out of existence as a facility, the decision really is not whether we want to transfer operations to another operator but whether there is enough service going on to the Nation to justify the continued expenditure. So in that sense, a competing renewal makes a great deal of sense. A recompetition of the operation of the facility does not.

Mr. TONKO. And I think you are responding to that in that hypothetically if Cornell were to lose, you would lose too. There is probably no other facility that would show interest or——

Dr. GRUNER. I am not quite sure. It is worth noting that the history of the Cornell facility has been complex because it started out actually as two facilities, one of which dealt with high-energy physics. It was arguably the most productive high-energy physics experiment in the world. It went on for 30 years. And eventually that physics played out and the NSF and Cornell University terminated that activity. We then looked at what can be done with the physical apparatus because ultimately that represents a huge taxpayer investment, and it was clear that there is a tremendous demand, continued demand, for the X-ray resources which also been going on over that entire period of time. That is what we would like to leverage on, where we feel we can best serve the American taxpayer.

Mr. TONKO. And in your testimony, you described the process for reapplying to NSF for the operating support, I believe?

Dr. GRUNER. Yes.

Mr. TONKO. Is this a rigorous review?

Dr. GRUNER. Oh, absolutely. The review typically consists of a proposal which encompasses what you want to do in the way of upgrading the facility, what the new research focuses will be, why it is justified to continue in a unique fashion certain activities or to create new activities that uniquely serve the country. These reviews are then sent out, or rather this proposal is sent out for written reviews. The written reviews come back and a national panel is assembled by the NSF to do a site review. They address both the concerns that might have occurred with the written review and things that they might have seen at the site review, and make a recommendation to the NSF as to whether the facility should be renewed at all.

Mr. TONKO. So I am hearing that this type of review ensures that NSF funds are well spent on their given facilities based on information that they gather through the review?

Dr. GRUNER. I believe that is the case.

Mr. TONKO. Can you think of any other interaction that NSF could do to strengthen the outcomes of the effectiveness or the efficiency of the funds?

Dr. GRUNER. Well, I think at this point the NSF has been struggling with the issue of what recompetition means for its broad portfolio of different kinds of facilities. I think it is very clear from where we sit at this table that no one size is going to fit all. The portfolio of facilities NSF operates are sufficiently diverse in terms of their ownership, the way they are run, who they serve, and the collaborations that they have, that some flexibility and common sense has to be applied in order to make the system work.

Mr. TONKO. And if that facility at Cornell were to close, are there alternate sites for doing the work?

Dr. GRUNER. There are facilities operated by the Department of Energy, which of course are also light sources. But the system that has evolved in the United States is that our facility serves a very particular function. It complements what goes on in the DOE laboratories. If you go to every single one of the DOE laboratories, you will find that many of the people who lead those facilities or operate the accelerator or run their beam lines were trained at ours, because that is our function. We are an educational institution. We are able to train people by taking them behind the shielding wall where they can learn how to make these things work. It is not something that you can learn in a classroom. You actually have to have hands-on operation. That is largely incompatible with the mission of a facility that has to be operating all the time to get the maximum number of users through.

Mr. TONKO. And you mentioned a wide array of disciplines that the facility is applying—is offering. Can you give us a few examples of research outside of high-energy physics that are being pursued?

Dr. GRUNER. Right now, high-energy physics is not being done on the machine. All the disciplines that I mentioned, chemistry, biology and so on are being done on the machine. So we have a very large base of people who are doing work on protein structure. These are the proteins that are basis of much of modern biotechnology. We have a very large contingent of people who are doing materials research on new kinds of polymeric materials. We are now engaged with the Air Force in trying to build a capability to help them understand how metals fail when they are repeatedly stressed. As you know, you have to change the skin of aircraft regularly because there really isn't a good understanding of the failure mechanisms. We have a very vibrant community that uses diamond anvil cells. These are diamonds where you crush materials to try to make new kinds of materials that would then be metastable; the ultimate goal is to make something stronger than diamond. The list goes on. It is very diverse. We had a group of people who are analyzing paintings. In the last few years we have discovered a new Brueghel the Younger painting. We revealed a painting that was covered over by N.C. Wyeth. It is just a very vibrant place in that regard.

Mr. TONKO. I understand that. It is in upstate New York. So we thank you for the contributions you make to the country.

Dr. GRUNER. Thank you.

Mr. TONKO. Thank you, Mr. Chair.

Chairman BROOKS. Thank you, Mr. Tonko.

At this point the Chair recognizes Ms. Bonamici of Oregon for questions.

Ms. BONAMICI. Thank you so much, Mr. Chairman.

I wanted to ask each of you a bit about what your facilities do to inspire students with regard to STEM education. I know, Dr. Schreier, you gave an example about pulsars and that you have interns, and you talked about AUI promoting STEM education but I would like to hear a little bit from each of you about whether you have outreach efforts and to any particular groups and how you bring students in and inspire them to pursue careers or to further their efforts in STEM education. Thank you.

Dr. SMITH. Yes. Thank you. This is an extremely high priority for us, and I think that AURA facilities, as the others here, offer a research experience for students, and so as they progress through their careers, whether they enter into the sciences or a STEM field or not, it is still extremely important that they see the working environment in which science gets done and that they see how scientists work and they learn to think critically. Again, it matters less whether they become scientists but they certainly need to understand, you know, how the STEM—how the sciences work and so we do have a very active program of bringing in students. There is a program, research experience for undergraduates. We are very active participants in that, which is an NSF program. It is very successful, and I would say that although it is very competitive, the diversity of the students coming in is absolutely impressive. I think we all know that the future challenge in the sciences is to make them more diverse, to bring in more women and minorities because that—we don't look very diverse today but we know that we have to achieve a much higher level of diversity in the future. So we are all working on that pipeline. Our facilities, I have some numbers in here but I will just tell you that we take it very seriously. It is a major—one of our major priorities.

Ms. BONAMICI. Thank you.

And others? Yes, Doctor.

Dr. BOEBINGER. Yes, I agree with what Dr. Smith said. The magnet lab has a Center for Integrating Research and Learning, so this is a team of professional educators who bring together the scientists at the magnet lab with the K–12 programs and the undergraduate research programs. So that group makes face-to-face contact with 10,000 K–12 students every year. We also have an open house annually at the magnet lab. We get 5,000 people from the general public coming through. We have about 100 hands-on exhibits. So there are programs that reach out to a broad audience. We also have programs where we are seeking to identify individuals to, if you will, get them networked and get that leg up. Among those programs is the Research Opportunities for Undergraduates program that brings undergraduates in for the summer to work in a laboratory. We also have a Research Experience for Teachers program for K–12 teachers, and in particular we try to attract teachers and the majority of those teachers come from Title I schools. We also have a workforce initiative program where our scientists go out to HBCUs, women's institutes, and they give lectures. They talk about the research at the magnet lab. They have some funding that is made available that they can invite students to the summer programs and we found that that is a way to really form relationships that bring undergraduates and grad students into the larger network of research in the United States.

Ms. BONAMICI. Terrific. Any others?

Dr. SCHREIER. I wouldn't mind adding to what I said before. I gave you only one example. We have several—we also participate in the Research Opportunities for Undergraduates. It is an interesting thing. One of the members of my board, who happens to be a professor at Cornell University and a member of the National Academy of Sciences, was a summer student at Green Bank in West Virginia in the 1970s while she was a student, and she became a scientist. We have visitor centers at both New Mexico and West Virginia. The Green Bank Telescope in West Virginia is in one of the poorest counties east of the Mississippi and has a very advanced science center courtesy of our existence there. We have programs for high school students there. We have been expanding this to Chile. We have had a sister cities program between San Pedro de Atacama in Chile and Magdalena, New Mexico. We have two interesting indigenous, not very advanced towns next to world-leading telescopes, and we set up a program whereby teachers and students were exchanged between the two. So people learn how these different cultures work, and also get interested in science, which they do. We have recently been—I have recently been personally talking with the University of Colorado, which has one of the better STEM education programs in the country teaching current teachers and first-year college students how to get more involved with science and mathematics to see how we can leverage the local programs we have in radio astronomy to a national level to improve STEM education.

Ms. BONAMICI. Thank you very much. My time is expired. Thank you.

Chairman BROOKS. The Chair is willing to entertain a second round of questions from the Members if any so desire. Seeing none, I would like to thank our witnesses for their valuable testimony and the Members for their questions. The Members of the Subcommittee may have additional questions for the witnesses, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments from Members.

The witnesses are excused and this hearing is adjourned.

[Whereupon, at 11:13 a.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Ethan J. Schreier

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
Hearing on *NSF Major Multi-User Research Facilities Management: Ensuring Fiscal Responsibility and Accountability*
April 18, 2012

QUESTIONS FOR THE RECORD FOR DR. ETHAN J. SCHREIER, ASSOCIATED UNIVERSITIES, INC.
May 24, 2012

QUESTIONS FOR THE RECORD FROM THE HONORABLE MO BROOKS, CHAIRMAN:

1. Have any of the Associated Universities, Incorporated (AUI) facilities experienced a year when the projected budget allocation set forth in the cooperative agreement cannot be met due to fiscal constraints? What happens in this case? How are obligations met?

For every year of its 56 year history, AUI's NRAO facility has balanced its budget to the NSF allocation. The allocation has sometimes been below AUI/NRAO's optimal program requirements, and the plan to achieve balance thus required prioritization and some reductions in planned scope. The FY 2013 Presidential Request Level budget is an example of this. The FY 2013 NRAO Operations and Maintenance allocation is $2.0 million below the FY 2012 estimate and $3.3 million below the prior year forecast for FY 2013. To meet this budget, AUI has developed a science-based prioritization plan, based on community input. The plan ensures that the highest priority objectives, such as the successful operation of the new Atacama Large Millimeter/Submillimeter Array and the Jansky Very Large Array, are met first. Because of several prior years of continuing tight budgets, the new reductions will negatively impact some elements of the core program for instrumentation development and science delivery to the community. Operations of the Green Bank Telescope and the Very Long Baseline Array, which continue to be world-leading facilities, will see the greatest impacts. We anticipate staffing cuts may be necessary in the near future to address these operations funding shortfalls.

2. What are the key elements NSF and the National Science Board should be assessing to create a beneficial recompetition policy? How can both ensure science is the priority in its recompetition policies and procedures? How can NSF ensure it is implementing a recompetition policy rigorously?

In our opinion, the primary goals for the recompetition and renewal process should be to ensure that NSF's national centers maintain and enhance US science and national competitiveness. AUI's National Radio Astronomy Observatory facilities are the leading radio telescopes in the world in essentially all categories: the Atacama Large Millimeter/Submillimeter Array (ALMA) and the Jansky VLA are the transformational millimeter/submillimeter and the centimeter wavelength arrays, respectively; the GBT is the world's leading large single dish telescope, and the VLBA is the world's highest resolution interferometer. While a recompetition may offer an opportunity to improve further the operation of these facilities or introduce new partners or resources, we believe there can also be unintended consequences and risks, including possibly irreparable damage to unique national resources. To avoid this, we suggest the NSF and NSB clearly identify their objectives in any recompetition, specifically including the scientific and technology values they wish to preserve or enhance. To the extent that an existing management agreement or operational arrangement is working well and serving the needs of the research community, unconstrained changes as part of the recompetition exercise may well create unnecessary risks and waste taxpayer dollars. For example, the possibility that ALMA could be separated from the rest of NRAO as part of a recompetition is widely regarded as introducing great risk of damaging a scientifically-effective ALMA over ten years in the making, and increasing the cost of operations.

ALMA is presently integrated into NRAO and the efficiency of operations and the scientific delivery to the community benefit greatly from the expertise and experience shared by the entire NRAO staff. NRAO is the national center for radio astronomy in the US, and investments made in ALMA are leveraging as well as fostering advances in NRAO and other US domestic facilities. For example, the data processing system for ALMA (CASA) is shared with the Jansky VLA. Similarly, the data archiving system developed for ALMA (NGAS) has been adopted as the NRAO standard. The commercial software helpdesk system purchased for use by ALMA has also been adopted NRAO-wide. The ALMA development program is specifically designed to involve US community groups and NRAO in research and development activities to maintain the best performance of ALMA in the coming years, both stimulating and taking advantage of the technical capabilities of the domestic groups and facilities. These are examples where ALMA techniques and infrastructure have been leveraged for the benefit of NRAO domestic operations; conversely, NRAO intellectual capital has greatly contributed to the success of ALMA. This shows the strength of the AUI/NRAO enterprise.

3. One of the goals for multi-user facilities is to provide training to scientists. Why is this role, as a training ground, important? What do researchers and scientists do next with the knowledge gained from AUI facilities?

AUI/NRAO has always held student training as one of its most important contributions to the national research and technology endeavor. As has been pointed out in numerous studies, the number of U.S. students pursuing careers in sciences and engineering has steadily declined and poses a long-term risk to the economy and security of the country. AUI/NRAO is working hand-in-hand with the university community to address this issue. The AUI/NRAO operates the nation's forefront research instruments in radio astronomy. These facilities are on a scale of operational complexity that is beyond that which individual universities can operate. Students training for research careers in the physical sciences receive the best preparation and perform the most competitive research when they work with state-of-the-art instrumentation. By having Ph.D. students perform their work on AUI/NRAO facilities, they receive the best possible training for competition in a world-wide market. AUI/NRAO sponsor a number of graduate student and pre-doctoral support programs to assist students. About 16% of all observing proposals are from Ph.D. students. In addition to observing time, AUI/NRAO supports a number of collaborative instrumentation development projects. In these projects, instruments are built at university labs using student labor, with support from NRAO, and then placed on NRAO telescopes such as the GBT as observing instruments for unique scientific research.

The knowledge gained from scientific research at AUI facilities is typically used to answer fundamental questions about the universe. Quite often, the cosmos provides us with laboratories for studying fundamental physics or chemistry in a way that is not accessible to earth-bound laboratories. Radio astronomers typically receive a very broad training in physics, computer science, and basic engineering, and emerge from their degree training with skills that are applicable to a broad range of careers. Many astronomers find employment in firms ranging from aerospace companies to Wall Street.

AUI/NRAO has also maintained the country's core competence in technology related to radio astronomy. We have designed antennas and produced receivers and receiver components that are used around the world.

4. How do you ensure the science conducted through AUI facilities is unique and not duplicative or redundant of other science? How can we ensure that multi-user facilities complement one another and are not necessarily competing? Or does the U.S. need competitive facilities and science?

Many astronomical phenomena are only observable at radio wavelengths. Radio astronomy has opened new vistas into the Universe, uncovering birthplaces of stars and planets, studying super-massive black holes, neutron stars, gravitational waves, and the remnant heat of the Big Bang. NRAO has built and operated the world's most advanced radio telescopes, developed state-of-the-art technology to provide transformational scientific capabilities in radio astronomy that are not duplicative of the science, the facilities or techniques available at other wavelengths. AUI/NRAO has also ensured that all of its facilities are scientifically complementary among themselves. The Jansky VLA and ALMA cover different but complementary regions of the electromagnetic spectrum, and taken together seamlessly cover the meter/centimeter and millimeter / submillimeter wavelength ranges. The GBT adds rapid and sensitive wide-field imaging and high sensitivity, and the VLBA offers the highest angular resolution of any astronomical telescope. Mainitaining competitive facilities and science is key to attracting and retaining the best minds in scientific research and technical development in the US, in order to maintain US competitiveness in global astronomy. The status of NRAO's facilities as world-leading is further demonstrated by the fact that so many foreign astronomers use them, and in some cases even contribute to their operation or technical enhancement.

5. In your testimony, you stated that AUI "informs NSF of any significant events that could represent a departure from the Program Operating Plan?" What is the definition of "significant" for these purposes? How often does a significant event take place? What is your procedure for communicating with NSF in the case of these types of events? Has NSF ever challenged the need for changes to the Program Operating Plan?

AUI/NRAO maintains good communication with the NSF, and regularly reports routine program milestones as well as any extraordinary or anomalous events as they occur. AUI reports budgetary departures of more than a few percent that may arise, for example, from unexpected maintenance requirements. Significant events can include unusual damage by storms or major power outages that can negatively affect routine operations or science productivity. Opportunities for new projects, partnerships, or proposals frequently arise in between annual Program Operating Plan submissions. A mechanism is specified in the Cooperative Agreement for describing the impact of such activities and for seeking NSF's approval for participation. The NSF has approved such requests in nearly every case.

QUESTIONS FOR THE RECORD FROM THE HONORABLE RANDY HULTGREN:

1. At the National Science Foundation and across agencies, the Federal government is building ground-breaking facilities as part of international partnerships. I am most familiar with big scientific projects and the importance of international collaborations from the Fermi National Accelerator Laboratory (Fermilab) in Illinois. The U.S. physics community has been a leader and major contributor to high energy and particle physics for decades running the Tevatron accelerator. U.S. physicists are major partners in the Large Hadron Collider in Switzerland, and as Fermilab begins its next major project,

the Long Baseline Neutrino Experiment, it is seeking international collaborators to be part of this new frontier. You mentioned several examples in your testimony, such as the Atacama Large Millimeter Array in Chile. How are you ensuring that these investments both leverage and contribute to our critical domestic science facilities?

The Atacama Large Millimeter/Submillimeter Array (ALMA) is fully integrated within NRAO, the national center for radio astronomy in the US, and investments made in ALMA are leveraging as well as fostering advances in NRAO and other US domestic facilities. For example, the data processing system for ALMA (CASA), is shared with the Jansky VLA of the NRAO. Similarly, the data archiving system developed for ALMA (NGAS) has been adopted as the NRAO standard. The commercial software helpdesk system purchased for use by ALMA has also been adopted NRAO-wide. The ALMA development program is specifically designed to involve the US community groups and the NRAO in research and development to maintain the best performance of ALMA continually in the coming years, both simulating and taking advantage of the technical capabilities of the domestic groups and facilities. There have been a number of examples in which ALMA techniques and infrastructure have been leveraged for the benefit of NRAO domestic operations. Conversely, NRAO intellectual capital has greatly contributed to success of ALMA, which represents the strength of the AUI/NRAO enterprise. While ALMA is being assembled in Chile, many of its components are built in the United States. Twenty five antennas have been built in Texas, software is being developed in New Mexico; receiver components are built in NRAO laboratories in Virginia, West Virginia and New Mexico.

2. I understand from your testimony that scientific facilities can last for decades. The U.S. physics community has consolidated projects, closed projects early (B-Factory), shut down its major experiment at the Tevatron, last year, and has squeezed existing budgets to redirect funding to new, exciting, never-before-done science. How do you plan for the full life cycle of a facility and are current fiscal conditions or policies impacting this process? How have AUI and NRAO kept its facilities at the forefront of radio astronomy?

AUI/NRAO tries to achieve the best science impact with its facilities and to make the best use of the taxpayers' money over the long term. Most of the AUI/NRAO facilities are large capital investments with potential 20-30 year operating lifetimes, during which it is assumed that there will be major upgrades. In its 56 years of history, several NRAO telescopes became obsolete scientifically and were removed from active service, including the Green Bank Interferometer, the 92 Meter, 43 Meter, and the 12 Meter telescopes. While upgrades may extend their scientific lifetimes, in some cases these facilities are turned over to schools for teaching, or refurbished for special purposes not funded by NSF. The VLA, the most productive ground-based telescope ever built, has just been upgraded as the Jansky VLA with 10-1000 times improvement in the various capabilities of the original array; it remains the world's leading radio interferometer. Imaging cameras are being designed for the GBT, which will increase its observing speed by a factor of 100 or more. Such upgrades can be made at a fraction of the original construction cost, yet have increased the scientific capabilities by orders of magnitude, and driven technology research.

A $5 million/year development program is budgeted for ALMA, which will ensure that the facility will remain at the state-of-the-art throughout its 50-year lifetime. NRAO has always been mindful of the reality that ultimately telescopes do reach the end of their lifetime and are superseded by more capable facilities.

Responses by Dr. William S. Smith

Question for Dr. William Smith:

1. **Have any of the Association of Universities for Research in Astronomy (AURA) facilities experienced a year when the projected budget allocation set forth in the cooperative agreement cannot be met due to fiscal constraints? What happens in this case? How are obligations met?**

   Cooperative Agreements for facility operations are typically 5 years in duration, and the National Science Board authorizes an upper limit to the aggregate five year spending. This upper limit assumes, in many cases, an annual growth that is not met in the year to year budgeting process. Thus, AURA must structure its obligations based on the presumption that annual shortfalls may occur. Obligations are incurred for payroll, for external contracts and for long term scientific collaborations.

   The NSF budgeting process for major facilities takes place in the following steps:

   - Each facility is invited to make a presentation in the spring in anticipation of the agency budget preparation in the fall. Various funding level options and consequences are laid out.
   - Initial planning for labor and non-labor adjustments is initiated when the President's budget is released in February and a range of options is developed throughout the remainder of the year as the appropriations process clarifies.
   - Beginning in October of the fiscal year, a number of management options are developed to cope with what is often an anticipated budget shortfall from the President's request. Personnel reductions in force are particularly critical since typical severance for non-voluntary separation is about 6 month's salary.
   - Following the final appropriations action, and approval of the NSF program plan, final funding levels are determined. Often this occurs mid-year or late in the year.

   AURA often encounters difficulty when the final funding levels do not become known until mid or late in the fiscal year. At that point, reductions in force are an ineffective means of reducing that year's budget (since six month's severance must be paid in any event). In such cases, adjustments in that year are only possible by reducing non-labor (external contracts, hardware purchase, scientific collaborations, etc.) Thus, obligations for payroll are an especially difficult problem because closure on the budget process may take up half of the fiscal year.

Over the past decade, shortfalls from the initial planning state, the President's budget request, have occurred in most years.

2. **What are the key elements NSF and the National Science Board should be assessing to create a beneficial recompetition policy? How can both ensure science is the priority in its recompetition policies and procedures? How can NSF ensure it is implementing a recompetition policy rigorously?**

Recompetition is one, but by no means the only, nor even the most important tool in ensuring the maximum dollar return from investments in NSF facilities. Federally Funded Research and Development Centers such as NOAO are expected to be long-term. FAR 34.017 states *"Long-term relationships between the Government and FFRDC's are encouraged in order to provide the continuity that will attract high-quality personnel to the FFRDC. This relationship should be of a type to encourage the FFRDC to maintain currency in its field(s) of expertise, maintain its objectivity and independence, preserve its familiarity with the needs of its sponsor(s), and provide a quick response capability."*

Moreover, the strengthening of the science potential for a facility may depend on actions that might be inconsistent with a recompetition decision. For example, the U.S. Decadal Survey for Astronomy and Astrophysics in recommended that a common management framework be examined for Gemini and NOAO[1]. A possible consolidation of these two organizations was envisioned to save costs and enhance science. However, the current NSB policy strongly discourages such consolidation because it would lead to entanglements that would make their individual recompetitions implausible. To date, the NSF has been unable to fully evaluate or implement the Decadal Survey recommendation due to the existence of the NSB mandate.

There is no single policy that can address all of the individual features of each facility and the effects of a recompetition. The NSF should rely on a case-by-case evaluation and recommendation by community based independent reviews. Each such review should structure the questions and issues that can allow the NSF to make a decision.

The assertion that all facilities should be recompeted *"..because rarely will it be in the best interest of U.S. science and engineering research and education not to do so.."* may not be correct. Such cases may arise often.

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[1] New Worlds, New Horizons, National Academy Press, p. 179. **"To exploit the opportunity for improved partnership between federal, private, and international components of the optical and infrared system, NSF should explore the feasibility of restructuring the management and operations of Gemini and acquiring an increased share of the observing time. It should consider consolidating the National Optical Astronomy Observatory and Gemini under a single operational structure, both to maximize cost-effectiveness and to be more responsive to the needs of the U.S. astronomical community."**

3. **One of the goals for multi-user facilities is to provide training to scientists. Why is this role, as a training ground, important? What do researchers and scientists do next with the knowledge gained from AURA facilities?**

   It is now well established that a research experience is a vital part of STEM education. Whether this occurs in a university laboratory or a national facility, it is essential that students gain a first-hand experience in implementing their scientific training. National facilities such as NOAO, NSO, and Gemini also provide students and young scientists direct experiences in how major organizations function. Thus, in addition, it exposes these individuals to STEM fields as long term careers.

   Even if an individual does not choose to pursue a STEM career, an experience in a national facility provides a deeper understanding of the role of science and technology in our society and why it underpins further economic growth.

4. **How do you ensure the science conducted through AURA facilities is unique and not duplicative or redundant of other science? How can we ensure that multi-user facilities complement one another and are not necessarily competing? Or does the U.S. need competitive facilities and science?**

   For all AURA operated facilities, their missions are unique and generally not duplicated by other facilities. Each such facility, however, actively engages the broader scientific community to ensure that its role is enabling and not competitive with the community.

   As was suggested in question 2, the community itself is in the best position to make a judgment as to whether a particular facility has maintained its usefulness, whether other avenues for accomplishing the research are available, and whether there are options for narrowing, or broadening the mission of a particular facility to better respond to community and scientific needs. Periodic independent reviews are the best means for assuring this.

5. **Have the AURA facilities experienced a "significant" change from the Program Operating Plan? What is your procedure for communicating with NSF in the case of these types of events? Has NSF ever challenged the need for changes to the Program Operating Plan?**

   From time to time, changes do occur from the Program Plan which necessitate NSF approval. For example, for the Gemini Observatory, prior NSF approval is required for

- Proposed changes in the research objectives or facility activities that differ qualitatively from that described in the Program Plan.
- Changes in the aggregate budgeted level of salary and wages in excess of 10% or $200,000 whichever is greater.
- The reprogramming of funds on any budget line, that exceed either a cumulative total of 10% of the funds budgeted for that line in the approved Program Plan, or $100,000, whichever is greater.
- Any change in the total planned expenditures in the Development Funds amounting to greater than 5%.

Changes to the Program Plan are usually negotiated with the NSF. There is no known case of a dispute requiring extraordinary resolution.

Responses by Dr. David Divins

Q1: Has your facility experienced a year when the projected budget allocation set forth in the contract cannot be met due to fiscal constraints? What happens in this case? How are obligations met?

The current contract to operate the IODP facility, the JOIDES Resolution (JR), runs from FY2004-FY2013. The facility, as part of our contract, underwent a significant overhaul during FY2007 and FY2008. When the JR returned to operations in FY2009 the operational costs far exceeded the estimate in the original contract. This was due to the global political climate which saw the price of oil skyrocket. The cost of ship operations are intricately tied to oil prices. As a result when we resumed operations we resumed at a 70% level. In other words, instead of using the facility to collect scientific data and information for 12 months a year, we were only able to operate for 8 months a year. We continue to operate at the 70% level. This translates into 4 expeditions per year compared to 6 expeditions. We continue to deliver the contractual services for those 4 expeditions.

Q2: What are the key elements NSF and the National Science Board should be assessing to create a beneficial recompetition policy? How can both ensure science is the priority in its recompetition policies and procedures? How can NSF ensure it is implementing a recompetition policy rigorously?

Recompetition is not only necessary, it is essential to assuring that the NSF Major Multi-User Research Facilities provide and deliver the services and scientific priorities that our users need and request. The frequency of major re-competes is the big question. A significant amount of time and effort goes into preparing a response to a major recompetition solicitation, time and effort that is not being directed towards the management and operations of the facility. A five year cycle of recompetition is unnecessary. What is more helpful as an evaluation tool are extensive periodic reviews (every 2-3 years) of the scientific outcomes and management and operations of the facility. If a facility does poorly on the reviews then a recompetition is in order. If they do well on the reviews then a recompetition is not needed.

NSF could form a Major Multi-User Research Facilities Evaluation Board that assesses the scientific results accomplished through the use of a major facility, the scientific community's input on the performance of the facility, and the overall management of the facility. Each facility would need its own evaluation board, as one size will not fit all. However, asking each facility to respond to similar requirements and scrutiny should add rigor and consistency to the recompetition and evaluation process.

Q3: One of the goals for multi-user facilities is to provide training to scientists. Why is this role,as a training ground, important? What do researchers and scientists do next with the knowledge gained from your facility?

The JOIDES Resolution (JR) is often referred to as a floating university. Every expedition brings together 25-30 scientists of varying levels of experience, of different nationalities, and of assorted scientific disciplines. We mix graduate students with very accomplished researchers to form a common science party where everyone is a peer.

Training the next generation of scientists is something we take very seriously. The scientific program on any JR expedition is multifaceted and the best way to fully understand how the components fit together is by participating on an expedition. This holds for the graduate student as well as the seasoned researcher. Developing the next generation of scientists and scientific ideas that can only be addressed by the JR has resulted in many new and exciting discoveries over the years that ocean drilling has been conducted.

The researchers and scientists upon leaving an expedition typically take with them samples collected during the expedition and return to their home institutions to further analyze and describe those samples and that information is incorporated with the shipboard data collected during the expedition. If a sample is taken, the researcher has a requirement to publish their findings in a peer-reviewed journal. All data collected during the expedition are under a one year moratorium period before it becomes available to the public. This gives the researchers an opportunity to perform their research and submit a publication before the data are open to the public.

Q4: How do you ensure the science conducted through your facility is unique and not duplicative or redundant of other science? How can we ensure that multi-user facilities complement one another and are not necessarily competing? Or does the U.S. need competitive facilities and science?

The science conducted onboard the JOIDES Resolution (JR) is unique in that there are only to facilities like it the world and both are currently part of the Integrated Ocean Drilling Program (IODP). The NSF provides the JR to IODP while Japan provides the Chikyu. Expeditions conducted on the JR are proposal driven. The IODP Science Advisory Structure (SAS) reviews all proposals before recommending them for scheduling on a facility (ship). The JR conducts specific research that can only be accomplished by that facility and therefore it is not in competition with other facilities. The best way to ensure that facilities are not duplicating each other and that the compliment each other is by carefully examining the capabilities of the facilities and the science that is resulting from them. Large multi-user facilities are expensive to maintain and build therefore it is essential that they do not duplicate capabilities unless there is significant proposal pressure from the scientific community to warrant duplicate capabilities and/or facilities.

Q5: Has your facility experienced a "significant" change from the Program Operating Plan? What is your procedure for communicating with NSF in the case of these types of events? Has NSF ever challenged the need for changes to the Program Operating Plan?

The JOIDES Resolution (JR) operates under an Annual Program Plan (APP) which is developed in consultation with NSF and based on fiscal and programmatic guidance provided by NSF. In case where the programmatic guidance cannot be carried out within the fiscal guidance, options are presented to and discussed with NSF. NSF then provides revised guidance to implement the agreed to option. We are very fortunate in that we have a very collaborative relationship with NSF.

Responses by Dr. Gregory S. Boebinger

THE FLORIDA STATE UNIVERSITY

Response to Followup Questions for the Record
by Gregory Boebinger
Director, National High Magnetic Field Laboratory
Florida State University
in response to questions from the
Research and Science Education Subcommittee
Committee on Science, Space, and Technology
House of Representatives
Washington, D.C.
Original hearing date: April 18, 2012
Date of this response: May 23, 2012

NSF Major Multi-user Research Facilities Management:
Ensuring Fiscal Responsibility and Accountability

1. Has your facility experienced a year when the projected budget allocation set forth in the cooperative agreement cannot be met due to fiscal constraints? What happens in this case? How are obligations met?

Annual budgets for the National High Magnetic Field Laboratory (MagLab) under the CY 2008-2012 cooperative agreement have often been lower than the not-to-exceed funding levels established by the National Science Board (NSB) and set forth in the Cooperative Agreement:

Year	NSB Level	Actual
2008	$29.5 M	$27.75 M
2009	$31.5 M	$31.50 M
2010	$33.0 M	$32.00 M
2011	$34.0 M	$32.70 M
2012	$34.0 M	$32.80 M
Total	**$162.0 M**	**$156.75 M**

Reduced funding occurs because the multi-user research facilities are competing every year against other well-reviewed research proposals at a time of intense NSF budgetary constraints.

As a multi-user research facility, the MagLab's highest priority is uninterrupted research by the 1200 scientists from 110 US institutions who rely on our facility each year; however, reduced budget allocations typically require deferment of longer-term magnet research and development, deferred maintenance of facilities and instrumentation, and deferred replacement of scientific staff who provided support for user research but leave the MagLab occasionally to pursue their own career paths.

Examples of projects deferred for at least a year since 2008 – but since resumed – include:

- high-strength materials research that develops new materials for use in construction of the next-generation higher-magnetic-field magnets;
- a scale-back of superconductor and superconducting test coil projects that underpin the development of high-temperature superconducting magnets that will revolutionize the generation of high magnetic fields for both research and energy and medical applications.
- the one-year slow-down of the MagLab's 100T magnet project. This magnet was commissioned for user research in March 2012 and is the only magnet to ever generate magnetic fields of 100 teslas (2 million times the Earth's magnetic field) nondestructively; and
- the three-year deferment of the MagLab's unique Split Magnet. This magnet was finally commissioned for user research in Spring 2011;

The reduced budget in 2008 further required the institution of shortened hours of magnet access for users of our DC magnets in order to reduce electrical power consumption in the face of reduced budgets and record high electric power rates. In effect, we squeezed users' magnet time in order to keep intact the highly skilled workforce of technicians, engineers and scientists without whom those same users could not perform their research.

Under reduced budget scenarios, the NSF is kept informed of the impact of actual funding levels when they fall below the NSB level in the Cooperative Agreement. These informal communications work very well to keep mutual expectations and priorities in line with actual funding levels and the MagLab's core mission. As an example, in 2008 the NSF originally announced a funding level of $26.5M, three million less than in the Cooperative Agreement. When informed that the impact would necessarily include a total shut-down of the DC magnets for several months late in the year, the NSF made available an additional $1.25M to keep the DC magnets operating. Occasionally, original NSF obligations for magnet and maintenance projects have been mitigated by successful appeals for Florida State University and State of Florida funds. This illustrates one of the many benefits of the Federal-State partnership at the MagLab.

2. A. What are the key elements NSF and the National Science Board should be assessing to create a beneficial recompetition policy? B. How can both ensure science is the priority in its recompetition policies and procedures? C. How can NSF ensure it is implementing a recompetition policy rigorously?

A. What are the key elements NSF and the National Science Board should be assessing to create a beneficial recompetition policy?

A "winner-take-all" recompetition is not the only competitive mechanism for determining the most effective and efficient investment of limited resources for scientific research. The renewal proposal process is itself a stringent two-year-long review of user satisfaction, scientific vision, lab management, and facility infrastructure. The primary decision whether to invite a renewal proposal or recompete the entire facility should be based on a thorough review of the value of the facility to (a) advance fundamental or applied scientific knowledge, and (b) foster innovation and broader impacts on research, education and society at large. A system in which existing renewal processes can be rolled into evaluating the necessity of recompetition could avoid the duplication of effort and reportage, as well as the considerable costs associated with each process.

B. How can both [the NSF and NSB] ensure science is the priority in its recompetition policies and procedures?

The decision process to decide whether to conduct a standard renewal or to recompete a facility must be a deliberative, inclusive and transparent process that seeks to optimize science rather than to recompete for the sake of recompetition. Compelling reasons to launch a recompetition include:

- dissatisfaction with the existing facility capabilities or operations by the user community,
- a stagnant user community that is unresponsive to critical review of facility operations, and
- significant inefficiencies or other exigencies that adversely affect operating costs associated with the facility's research program.

The keys to keeping science at the forefront of the recompetition process are frequent and meaningful user involvement as well as regular input from experts who understand the facility's place in the international research landscape. The value, merits and shortcomings of the facility should be outlined by experts in the scientific fields served by the facility, by experienced users of the facility, and by other stakeholders who can provide an objective evaluation of the significance of research undertaken at the facility. A study of the future, broad directions of scientific and engineering disciplines relevant to the facility - perhaps convened by the National Academy of Sciences - should be undertaken prior to a "winner-take-all" recompetition. The NSF's decision whether to launch a recompetition should also consider the value of the existing facility relative to the merits of other potential facilities and/or research programs that might be proposed to replace the existing facility.

C. How can NSF ensure it is implementing a recompetition policy rigorously?

Rigorous implementation of a recompetition policy must address the following questions in a transparent manner such that all interested parties can compete fairly:

- Has the NSF clearly defined its goals for recompetition? Until and unless NSF can clearly articulate what it hopes to accomplish via a recompetition, it should not embark on one. Once the goals of a recompetition are publicly stated, these goals must be reflected in the request for proposals, and in the criteria to be used to evaluate the proposals.
- Has the NSF developed and published its criteria to determine whether it is feasible to recompete a given facility (i.e., to change the awardee)? Notwithstanding the potential benefits of an open competition, there are situations where it would be extremely difficult, costly or scientifically disastrous to change the awardee.
- Has the NSF evaluated the past performance of the incumbent facility operator in the specific context of whether to launch a "winner-take-all" recompetition? This evaluation should include user input, review visits and site audits of greater duration and depth than the ordinary competitive renewal proposal.
- Has the NSF assessed the optimum timing for a recompetition? This question should be

addressed by the same review described in the previous bullet point. Factors relevant to the timing of a recompetition include: the budget cycles for local and state government support for a facility (e.g., matching financial or in-kind support for operations) for which an NSF recompetition might trigger renegotiations, and; the degree to which the success of large multi-year research projects and/or major upgrades to a facility would be put in jeopardy by an impending recompetition. Such cases would not preclude recompetition, but could influence its optimal timing.

- Upon deciding to hold a recompetition, has the NSF worked with the present facility operator to mitigate any encumbrances that may create significant obstacles to closing the existing facility and constructing a new facility should the award be granted to a competing proposal? Some encumbrances may be sufficiently significant to preclude effective recompetition of the facility until they are mitigated or removed. Examples include: international agreements related to land rights; co-ownership of real estate and other property, including infrastructure and instrumentation; intellectual property that belongs to the current operator; and investments by state and/or local governments or other entities that would be impacted by a relocation of the facility.
- Has the NSF, to the extent possible, a reasonable confidence that there will be two or more serious competitors who will submit viable proposals? The NSF should strive to make the recompetition attractive and fair by minimizing factors that would dissuade potential competitors from participating. This assessment could include the anonymous submission of preproposals in response to an NSF Invitation to Compete for the future facility. The preproposals should be reviewed by an external review committee with representatives from the National Academy of Sciences study (i.e. scientific experts who have recently completed the relevant NAS report) and from other user facilities (i.e. successful user facility managers who know the existing facility but do not have a conflict of interest).

As the National Science Board continues to develop its policy on recompetition, the NSF should be afforded the flexibility to address these issues in its implementation of this policy.

3. One of the goals for multi-user facilities is to provide training to scientists. Why is this role, as a training ground, important? What do researchers and scientists do next with the knowledge gained from your facility?

Training and education in Science, Technology, Engineering, and Mathematics (STEM) fields are a leading driver of U.S. economic growth. It provides economic mobility for our nations' most talented young people and STEM training is particularly vital as the U.S. faces challenges to its international research prominence. Multi-user research facilities like the MagLab exist to provide STEM training to a community of students and early-career researchers who visit the facility from more than 100 institutions across the nation:

- The MagLab facility provides hands-on training every year for more than five hundred undergraduate students, graduate students, postdoctoral researchers and even high school students who work with world-class equipment, infrastructure and experienced, prominent researchers not available anywhere else in the country.
- Between 2006 and 2010, at least 310 Ph.D. and 70 M.S. degrees were awarded for which the research thesis contained MagLab data. Most of these advanced academic degrees were in Physics, Engineering, Chemistry and Biology.

Year after year, students and early-career scientists have used the training and knowledge gained from the MagLab to:

- start their own research groups at universities and government laboratories
- join industry to advance applications of research in areas ranging from microelectronics, lasers, medicine, MRI and pharmaceuticals.
- start entrepreneurial ventures, particularly in the development of new materials for industrial applications and magnet technologies for biomedical and energy applications.
- begin teaching careers in STEM disciplines to teach the next generation of students.

4. How do you ensure the science conducted through your facility is unique and not duplicative or redundant of other science? How can we ensure that multi-user facilities complement one another and are not necessarily competing? Or does the U.S. need competitive facilities and science?

Proposals for research at the MagLab are reviewed by both internal and external reviewers for scientific merit. These reviewers are well-versed experts in the fields they represent. Duplicative, redundant, and low-quality proposals are denied magnet time. Prospective users are encouraged to draw on the expertise of the MagLab's scientists to develop the most exciting proposals for experiments that have never been performed. Groups who propose very similar, high-quality experiments occasionally collaborate with each other in order to make a single, stronger research proposal. *That said, cutting-edge research most often benefits when the best researchers perform similar experiments yet develop competing ideas to address complex research questions.* Multiple experimental approaches to answering important research questions usually provide unanticipated scientific insights. As such, high-quality proposals that address a common scientific question are encouraged, especially if they will use different experimental techniques.

The MagLab is the only high-magnetic-field research facility in the United States, so our competition is with magnet laboratories overseas. The MagLab's range of experiments and degree of user access lead the world in most areas of magnet technology and research techniques. Roughly five magnet labs worldwide provide facilities similar to the MagLab. The advantages, disadvantages, and experimental niches of each magnet lab are known to the research community. Each facility strives to have instrumentation and infrastructure that enables its users to produce the best science. Whereas this world-wide scientific competition is both healthy and spirited, the laboratories themselves are often more collaborative in sharing information on magnet technologies. This is because it can significantly reduce the cost and risk of providing next-generation magnets to the benefit of the entire international scientific user community.

5. Has your facility experienced a "significant" change from the Program Operating Plan? What is your procedure for communicating with NSF in the case of these types of events? Has NSF ever challenged the need for changes to the Program Operating Plan?

This item is addressed under Question 1. Any changes from the Program Operating Plan (POP) result from reduced budget allocations. The annual request for funding includes a budget justification and identifies the programmatic impact of reduced funding. Under the facility stewardship model, NSF and the Principal Investigator discuss the prioritization of the budget allocation and the consequences of reduced funding.

Responses by Dr. Sol Michael Gruner

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Responses to Follow-up Questions for the Record
by Sol M. Gruner
Director, Cornell High Energy Synchrotron Source
in response to questions from the
Research and Science Education Subcommittee
Committee on Science, Space, and Technology
House of Representatives
Washington, D.C.
Original hearing date: April 18, 2012

*NSF Major Multi-user Research Facilities Management:
Ensuring Fiscal Responsibility and Accountability*

Question 1: Has your facility experienced a year when the projected budget allocation set forth in the cooperative agreement cannot be met due to financial constraints? What happens in this case? How are obligations met?

Answer: We have experienced restricted budgets several times. Our response, in consultation with our NSF program officer, has been to descope and reduce expenditures as necessary. This involved reduction of operating hours, deferring upgrades, deferring maintenance, depleting spare equipment, reductions in students that were supported, deferring replacing staff who moved/retired and, as a last resort, lay-offs. We have had to take all of these steps at times within the last 5 years.

Question 2: What are the key elements NSF and the National Science Board should be assessing to create a beneficial recompetition policy? How can both ensure science is the priority in its recompetition policies and procedures? How can the NSF ensure it is implementing a recompetition policy rigorously?

Answer: The word "recompetition" is ill-defined, leading to a great deal of confusion both inside and outside the NSF. "Recompetition" is variously used to mean competing the management of a facility, the need for the facility, and the specific proposed program of the facility for the next grant cycle.

We assume that the intention of recompetition policies is to ensure that the facility serves important scientific needs for the country in the most cost-effective manner. In this case, recompetition policies should assess the importance of the needs the facility is supposed to serve, whether the facility is meeting those needs effectively, and whether some alternative facility or facility operator can meet the needs better at lower overall cost. Given the diversity of ownership and management models within the NSF facility portfolio, no "one size fits all" approach will succeed. Flexibility, guided by policy goals, will be needed. So, for example, for a stand-alone facility, recompetition of the management may be practical. However, for a facility owned and imbedded within a university, such as CHESS, recompetition must be focused on whether CHESS fills an important science need and if so, whether an alternatively located facility can be built to deliver better science more cost-effectively.

Recompetition policies must be realistic about the facts that pertain to major facilities: Major facilities may take 10 - 20 years to plan, staff, and build to capacity. Frequently, this involves major private, state, or international partners who contribute significantly to the cost of the facility. It would be very expensive and unwise if recompetition policies significantly reduced incentives for participation by financial partners. Recompetition policies must also assess the frequency with which management or replacement facility recompetitions occur, given that such competitions are costly and disruptive, and stability allows effective planning and attracting and retaining a high quality staff.

Question 3: One of the goals for multi-user facilities is to provide training to scientists. Why is this role, as a training ground, important? What do researchers and scientists do next with the knowledge gained from your facility?

Answer 3: Accelerators and synchrotron x-ray facilities are essential tools used by scientists in many fields, including, physics, chemistry, materials science, geology, biology, biomedicine, engineering, environmental science and even art restoration and archaeology. Student scientists and engineers must be trained on how to use and build these complex tools effectively. As a university-based facility, CHESS has the dual mission of (1) training students who are the end users of synchrotron x-ray tools, and (2) training the students who will develop and operate other accelerator and synchrotron facilities. Hands-on training at a synchrotron facility is essential. An analogy is provided by the training of surgeons: Class room training is insufficient to teach young doctors how to do surgery. They actually have to practice hands-on surgery to learn the skill.

Training end users: With the exception of CHESS, the other national hard x-ray synchrotron light sources in the U.S. are operated by the Department of Energy (DOE). Many of our experienced users who are faculty members in universities tell us that they send their students to CHESS to learn how to do synchrotron x-ray experiments, and then once this skill is learned, send them to the DOE synchrotrons to quickly acquire the data that they use in their work. These students continue to apply the x-ray skills they learned after they graduate and enter the professional work force as practicing scientists and engineers.

The Cornell facility plays a special role in training the developers and operators of other accelerator and synchrotron facilities. The number of scientists who know how to design, build and operate synchrotron facilities is very small; at the same time, the demand for these accelerators is large, and steadily increasing. The training of accelerator and beamline scientists is a critical need. Cornell is now one of the few universities in the country equipped to train such scientists, and its training program is enormously effective. Accelerator and x-ray beamline scientists trained at Cornell populate all the DOE accelerator laboratories, very often in leadership roles. This role is not restricted to training people who work in the United States. Accelerator and synchrotron leaders trained at Cornell are found in facilities around the world.

Question 4: How do you ensure the science conducted through you facility is unique and not duplicative or redundant of other science? How can we ensure that multi-user facilities complement one another and are not necessarily competing? Or does the U.S. need competitive facilities and science?

Answer 4: The NSF uses peer review to evaluate our competing renewal proposals for programmatic importance and uniqueness. This occurs typically every five years. Given that the Department of Energy operates the other hard x-ray national synchrotron x-ray facilities, CHESS carefully chooses its proposed program so as to be synergistic and complementary to the DOE facility programs. In preparing competing renewal proposals, we propose activities that "will make a difference" in terms of national scientific accomplishments. In doing so, we seek advice from the CHESS Policy and Advisory Board, which includes leaders from the DOE facilities, as well as from colleagues, including CHESS staff, who serve on the scientific advisory committees for the DOE facilities and are therefore aware of their activities. Unique aspects of the CHESS program flow naturally from its being university-based facility, e.g., student training, synchrotron technology R&D, and development of new kinds of synchrotron experiments. These support the NSF missions of training and innovation.

Synchrotron radiation facility science is internationally very competitive. The synergistic complementarity between CHESS and the DOE synchrotron facilities helps the U.S. compete effectively in the work arena. There is also an important element of natural competition within the country between CHESS and the DOE facilities, e.g., each facility wants to have significant, prize-winning scientific work done at their facility. This is healthy and keeps the staff focused on working to have the maximum national impact.

Question 5: Has your facility experiences a "significant" change from the Program Operating Plan? What is your procedure for communicating with NSF in case of these types of events? Has NSF ever challenged the need for changes in the Program Operating Plan?

Answer 5: It is useful to first describe how Program Operating Plans are drafted for CHESS. CHESS undergoes competing renewals, typically every 5 years. The renewal starts with a proposal from CHESS for a plan for the facility for the next grant period, both in terms of upgrades and operations. The proposal is then reviewed and evaluated by the NSF, based on external peer review, for national needs, effectiveness in meeting those needs, and cost. If (and only if) the reviews strongly endorse the program will the proposal be funded, often with suggested modifications to the proposed plan based on the reviews and expected NSF budgets. A

Cooperative Agreement is then drafted between Cornell University and the NSF; this Cooperative Agreement is the Program Operating Plan for the next grant period.

We have not experienced "significant" changes from the Cooperative Agreement in terms of overall goals or governance of the facility, and indeed we are careful that all of our activities are within the scope of the Cooperative Agreement. There have been reductions in scope, however, arising from unavailability of expected financial resources from the NSF. When this occurs, we discuss and come to agreement with the NSF program officer as to the reduced program that can be accomplished within the envelope of available resources (see the answer to Question 1).