NATIONAL HIGH MAGNETIC FIELD LABORATORY (NHMFL) **$35,760,000**
+$12,610,000 / 54.5%

National High Magnetic Field Laboratory Funding[1]
(Dollars in Millions)

FY 2017 Actual	FY 2018 (TBD)	FY 2019 Request	Change over FY 2017 Actual Amount	Percent
$23.15	-	$35.76	$12.61	54.5%

[1] Forward funding in FY 2016 reduced the amount needed in FY 2017 by $12.65 million. Without this action, the FY 2019 change over FY 2017 would be -$400,000, or -0.11 percent.

NHMFL is managed by Florida State University (FSU), and consists of facilities at 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 condensed matter and material physics, materials science and engineering, chemistry, biology, biochemistry, neuroscience, energy, and the environment. It is the world's premier high magnetic field laboratory with a comprehensive collection of high-performing magnet systems and extensive support services. The facilities are available to all qualified scientists and engineers through a peer-reviewed proposal process. There are approximately 1,500 users per year, including faculty and staff at the three host institutions. Stewardship and oversight of NHMFL is provided through the MPS Division of Materials Research (DMR), and the Fourier Transform Ion Cyclotron Resonance (FT-ICR) Laboratory is overseen by the MPS Division of Chemistry (CHE).

The laboratory is an internationally recognized leader in magnet design, development, and construction, including the development of new superconducting materials. Many unique magnet systems have been designed, developed, and built by the Magnet Science and Technology Division of NHMFL. Since 2012, the laboratory has held the world's record for the highest nondestructive, pulsed magnetic field at 100.75 Tesla, a unit of magnetic strength (magnetic flux density). The 45 Tesla magnet currently provides the highest steady-state magnetic fields in the world for user access. This world record has been held for more than a decade. Recently, NHMFL's new 36 Tesla Series-Connected Hybrid (SCH) magnet has reached its performance milestone of no change in magnetic field stability and homogeneity greater than 1 part per million (ppm) across the sampling volume. This stability has enabled the world's first nuclear magnetic resonance spectrum at 1.5 GHz which opens a window for chemists and biologists to probe greater numbers of elements in the periodic table. The field strength of this 36 Tesla magnet design exceeds those of other all-superconducting magnets by 62 percent, and those of all-resistive magnets with similar bore size and uniformity by 44 percent. Both the 45 Tesla and 36 Tesla magnets enable scientists to gain new insights into the electronic structures of novel materials such as graphene, topological insulators, and high temperature superconductors

In 2009, a $15.0 million award funded through CHE enabled the purchase of a 21 Tesla magnet for the construction of a FT-ICR spectrometer. The FT-ICR instrument opened for user operations in October 2015. This 21 Tesla FT-ICR is unprecedented in sensitivity and selectivity, capable of analyzing chemical samples of great complexity, such as biological fluids, biofuels, and raw and weathered petroleum. The system impacts a broad array of research areas, such as chemistry, molecular biology, and earth science.

A major scientific impact from NHMFL is expected from the research on quantum materials conducted by users using the record-setting NHMFL magnets. These magnets allow for the exhibition, identification, and visualization of new and unusual quantum effects that lead to deeper understanding of quantum materials and enables the discovery of new ones. Another example of a potential breakthrough is in new imaging

techniques for studying the brain. Currently, Magnetic Resonance Imaging (MRI) and functional MRI have been based on imaging proton spin density and intrinsic tissue relaxation rates. With higher magnetic field strengths, NHMFL is investigating other nuclei to use that would result in new insights into mapping the brain and neuroscience.

Total Obligations for NHMFL

(Dollars in Millions)

	2017	2018	2019	ESTIMATES[1]				
	Actual	(TBD)	Request	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Operations & Maintenance (DMR)[2]	$23.15	-	$34.03	$35.05	$36.10	$37.18	$37.18	$37.18
Operations & Maintenance (CHE)[3]	-	-	1.73	1.73	1.73	1.73	1.73	1.73
Total	**$23.15**	-	**$35.76**	**$36.78**	**$37.83**	**$38.91**	**$38.91**	**$38.91**

[1] Outyear funding estimates are for planning purposes only. The new cooperative agreement is expected to end in mid-2023.

[2] DMR forward funded $10.73 million in FY 2016, thereby reducing the planned FY 2017 contribution to $23.15 million.

[3] CHE forward funded $1.92 million in FY 2016, thereby reducing the planned FY 2017 contribution to zero.

NHMFL collaborates with more than 60 private sector companies as well as national laboratories. These include those supported by the Department of Energy (DOE), such as Oak Ridge National Laboratory, which hosts the Spallation Neutron Source, and Argonne National Laboratory, which hosts the Advanced Photon Source. Additionally, NHMFL collaborates internationally. NHMFL delivered and commissioned a 26 Tesla SCH magnet to the Helmholtz-Zentrum Berlin for neutron scattering experiments. Collaborations also exist with the International Thermonuclear Experimental Reactor in France, and national magnet labs in France, the Netherlands, Germany, and China.

NHMFL provides a unique interdisciplinary and convergent learning environment. The Center for Integrating Research and Learning at NHMFL conducts education and outreach activities, which include a Research Experience for Undergraduates program, summer programs for teachers, a summer camp for middle school girls, and activities to raise the scientific awareness of the general public.

Management and Oversight

- NSF Structure: NHMFL is supported by DMR, with the DMR program director as the primary contact for most of the laboratory. CHE supports the FT-ICR Laboratory, which is overseen by a CHE program director.
- External Structure: A consortium of FSU, UF, and LANL operates NHMFL under a cooperative agreement. FSU, as the agreement signatory, is responsible for administrative and financial oversight and for ensuring that lab operations are consistent with the cooperative agreement. The principal investigator, the NHMFL director, reports to the FSU Vice President for Research. Four senior faculty members are co-principal investigators. The NHMFL director receives guidance primarily from NHMFL executive committee, NHMFL science council, and NHMFL diversity committee and recommendations from an external advisory committee and the users' executive committee.
- NSF initiated a community study through the National Research Council on opportunities in high magnetic field research. The 2013 report *High Magnetic Field Science and Its Application in the United States*[17] was presented to the National Science Board (NSB) in May 2014. The report continues to inform future plans for investments in this area, including new magnet developments.
- In 2017, NSF held a workshop, *Exploring Quantum Phenomena and quantum Matter in Ultrahigh Magnetic Fields,* to identify the most exciting directions of ultrahigh-field research that could impact the understanding of quantum materials. This workshop was informed by the long-term ultrahigh field

[17] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states

magnet development recommendations from the 2013 NRC report.

- Reviews: NSF monitors annual plans and reports including user metrics and conducts monthly teleconferences with the director. NSF conducts annual external reviews, which assess the 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. In addition to these yearly scientific reviews, NHMFL undergoes periodic business systems review by the NSF Large Facilities Office and the Division of Acquisition and Cooperative Support.
- Recent and upcoming reviews include:
  - Renewal proposal site visit, August 29-31, 2016.
  - NSF program director site visit, September 28, 2017.
  - Renewal of NHMFL approved by NSB, August 2017.
  - Site visit review with external panel of experts, October 2018.

Renewal/Recompetition/Termination

In May 2015, the NSB determined that it was in the best interest of the U.S. science and engineering enterprise to renew rather than re-compete the NHMFL award. A renewal proposal was submitted in May 2016. In August 2017, the NSB authorized an award to FSU for the operation of NHMFL for 60 months starting in mid-2018.

The National High Magnetic Field Laboratory, Tallahassee, Florida site. *Credit: NHMFL*