

NATIONAL HIGH MAGNETIC FIELD LABORATORY (NHMFL)**\$36,780,000**
-\$17,380,000 / -32.1%**National High Magnetic Field Laboratory Funding**

(Dollars in Millions)

FY 2018 Actual ¹	FY 2019 (TBD)	FY 20 Request	Change over	
			FY 2018 Actual Amount	Percent
\$54.16	-	\$36.78	-\$17.38	-32.1%

¹ The FY 2018 Actual includes \$10.08 million in additional FY 2018 one-time funding above the requested amount and \$9.34 million to fund part of FY 2019 costs.

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. The laboratory is managed by Florida State University (FSU), and consists of facilities at FSU, the University of Florida (UF), and Los Alamos National Laboratory (LANL). 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 1,700 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) facility within NHMFL 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 almost two decades. In April 2017, NHMFL's new 36 Tesla Series-Connected Hybrid (SCH) magnet reached its performance milestone of no change in magnetic field stability and homogeneity greater than one 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. Prior to this milestone, the previous record was set at 1.0 GHz. The one-year commissioning period for the SCH magnet ended in Fall 2017 and the magnet was added to the user program in January 2018. 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.

The 21 Tesla FT-ICR spectrometer opened for user operations in October 2015. This instrument 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 researchers 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 enable the discovery of new ones. Another example of an area of great potential is new imaging techniques for studying the brain. Magnetic resonance imaging and functional magnetic

resonance imaging are currently 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.

NHMFL collaborates with more than 60 private sector companies as well as a number of national laboratories. These include those supported by the Department of Energy, 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. The laboratory 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 laboratories in several other countries, including France, the Netherlands, and Germany.

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.

Total Obligations for NHMFL

(Dollars in Millions)

	FY 2018	FY 2019	FY 2020	ESTIMATES ¹				
	Actual	(TBD)	Request	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance (DMR) ²	\$42.33	-	\$35.05	\$36.10	\$37.18	\$37.18	\$37.18	\$37.18
Operations & Maintenance (CHE)	1.73	-	1.73	1.73	1.73	1.73	1.73	1.73
Facility Upgrades ³	10.08	-	-	-	-	-	-	-
Total	\$54.14	-	\$36.78	\$37.83	\$38.91	\$38.91	\$38.91	\$38.91

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2022.

² The FY 2018 Actual for DMR includes \$9.34 million to fund part of FY 2019 costs.

³ The FY 2018 Actual includes \$10.08 million in additional FY 2018 one-time funding above the requested amount.

Facility Upgrades: In FY 2018, NSF awarded \$10.08 million via two supplements: (1) to support the purchase of major equipment in need of refurbishment or replacement (\$5.88 million), and (2) to support the first phase of advanced research and development towards the construction of a novel 40 Tesla All-Superconducting Magnet (\$4.20 million). The second supplement was provided to address one of the magnet goals recommended by the 2013 report by the National Academies of Science, Engineering, and Medicine (the National Academies) on opportunities in high magnetic field research¹ (see Management and Oversight section).

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 Facility, which is overseen by a CHE program director. The Division of Acquisition and Cooperative Support (DACS) and the Large Facilities Office (LFO) in BFA provide financial and administrative support and the MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.
- 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 the

¹ www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states

Major Multi-User Research Facilities

NHMFL executive committee, the NHMFL science council, and the NHMFL diversity committee together with recommendations from an external advisory committee and the users' executive committee.

- NSF initiated a community study through the National Academies on opportunities in high magnetic field research. The resulting report titled *High Magnetic Field Science and Its Application in the United States* was released in 2013 and presented to the 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



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

impact the understanding of quantum materials. This workshop was informed by the long-term ultrahigh field magnet development recommendations from the 2013 National Academies report.

Reviews

NSF monitors annual plans and reports including user metrics and conducts monthly teleconferences with the NHMFL director. NSF conducts annual external reviews to assess the user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, as well as 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 reviews by LFO and DACS.

Recent and upcoming reviews include:

- Renewal of NHMFL operations award approved by the NSB, August 2017.
- External Safety Review at all three sites of the NHMFL (July and September 2018)
- Site visit review with external panel of experts, November 2018.
- Site visit review with external panel of experts, October 2019.

Renewal/Recompetition/Termination

In May 2015, NSF 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 2018. The current award for the operation of the NHMFL started in January 2018 and will end in December 2022.