NATIONAL HIGH MAGNETIC FIELD LABORATORY (NHMFL) **$37,740,000**
-$2,880,000 / -7.1%

National High Magnetic Field Laboratory Funding
(Dollars in Millions)

FY 2019 Actual[1]	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual	
			Amount	Percent
$40.62	-	$37.74	-$2.88	-7.1%

[1] Includes $14.20 million for continuity of operations into FY 2020 and excludes $9.34 million of FY 2019 O&M costs obligated in FY 2018.

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 2,000 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 the NHMFL. The NHMFL holds numerous records for high magnetic fields, such as the highest field for a continuous-field magnet (45 Tesla), highest-field magnet for Nuclear Magnetic Resonance (36 Tesla), highest-field superconducting magnet for FT-ICR mass spectrometry (21 Tesla), and highest-field for a magnetic resonance imagining study of a living animal.

These unique facilities are available to thousands of users each year and help define and advance science frontiers in many disciplines through measurements with state-of-the-art resolution and accuracy enabled by the high magnetic fields.

Over the last several years, the NHMFL has contributed to major scientific accomplishments in the budding field of topological materials, an entirely new class of quantum materials prominently distinguished by the 2016 Nobel Prize in Physics. Two recent prominent results from the NHMFL include the first confirmation of the existence of a three-dimensional topological insulator state, and the first evidence of a long-sought-for quantum phenomenon known as chiral anomaly in a quantum material.

The record-high magnetic fields made available to scientists at the NHMFL enabled an unprecedented and confounding discovery, a phenomenon called re-entrant superconductivity that only exists for magnetic fields above 40 Tesla. A superconducting state arises, breaks down, and then re-emerges in a material under the application of an extremely strong magnetic field. This phenomenon violates current understanding and is likely to reveal unknown facets of superconductivity.

NHMFL's MRI at high magnetic fields (21.1 Tesla) has enabled in vivo imaging of brain function and cancer research in rats. In April 2017, NHMFL's new 36 Tesla Hybrid magnet reached a performance milestone of ultrahigh stability and homogeneity across the sampling volume. This stability has enabled the world's first nuclear magnetic resonance spectrum at 1.5 GHz, which opens new probing capabilities for chemists and biologists.

In 2016, the NHMFL opened its 21 Tesla Ion Cyclotron Resonance (ICR) magnet for user access, allowing enhanced resolution of complex chemical mixtures, such as intact proteins and petroleum crude oil, which have been heretofore intractable for rapid analysis. The ICR magnet impacts a broad array of research areas, such as chemistry, molecular biology, and earth science.

A major scientific impact is expected from the research on quantum materials conducted by researchers using the 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 a potential area for advancement by NHFML 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.

Partnerships and Other Funding Sources: 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 series connected hybrid 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 countries, including 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 2019[1]	FY 2020	FY 2021	ESTIMATES[2]				
	Actual	(TBD)	Request	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026
Operations & Maintenance (DMR)	$38.89	-	$36.01	$37.18	$36.09	$36.09	$36.09	$36.09
Operations & Maintenance (CHE)	1.73	-	1.73	1.73	1.73	1.73	1.73	1.73
Total	**$40.62**	**-**	**$37.74**	**$38.91**	**$37.82**	**$37.82**	**$37.82**	**$37.82**

[1] Includes $14.20 million in DMR funding for continuity of operations into FY 2020 and excludes $9.34 million of FY 2019 O&M obligated in FY 2018.

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

For information on continuity of operations funding, see the opening narrative of this chapter.

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 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.

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, 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 reviews by LFO and DACS.

Recent 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, September 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. During 2020, MPS and DMR will assess the status and performance of NHMFL as well as the evolution of high-magnetic-field science to determine the path forward after 2022.

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