**DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES (MPS)** **$1,345,320,000**
**-$17,110,000 / -1.3%**

**MPS Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Percent |
|---|---|---|---|---|---|
| Astronomical Sciences (AST) | $252.05 | - | $230.69 | -$21.36 | -8.5% |
| Chemistry (CHE) | 246.24 | - | 230.58 | -15.66 | -6.4% |
| Materials Research (DMR) | 314.31 | - | 295.05 | -19.26 | -6.1% |
| Mathematical Sciences (DMS) | 233.54 | - | 218.82 | -14.72 | -6.3% |
| Physics (PHY) | 281.43 | - | 266.73 | -14.70 | -5.2% |
| Office of Multidisciplinary Activities (OMA) | 34.86 | - | 103.45 | 68.59 | 196.8% |
| **Total** | **$1,362.43** | **-** | **$1,345.32** | **-$17.11** | **-1.3%** |

## About MPS

MPS serves the Nation by supporting fundamental discoveries at the forefront of science. These discoveries form a tapestry of knowledge and innovation that transforms the future. Research in the disciplines supported by MPS has led to advances that are used for a wide variety of applications; examples include laser technology, navigation using the Global Positioning System, materials fundamental to integrated circuits, and algorithms used for advanced cybersecurity. The FY 2019 Budget Request for MPS supports a collection of vigorous disciplinary and multidisciplinary research programs that foster discovery and cultivate the technical workforce. Awards funded by MPS provide the foundations of basic research in astronomical sciences, chemistry, materials research, mathematical sciences, and physics that explore the frontiers of science.

The programs in MPS span the range from individual investigator awards to large, multi-user facilities. The science spans an enormous range as well: from the smallest objects and shortest times ever studied to distances and times that are the size and age of the universe. Individual investigators and small teams receive most awards, but centers, institutes, and multi-user facilities are all integral to MPS-funded research. MPS continues to participate in NSF-wide investments and multi-directorate activities, particularly ones that connect to the fundamental research at the heart of its mission. These multi-directorate activities include growing MPS foundational research for several of the Big Ideas that are discussed elsewhere in this document.

Programs in the MPS divisions respond to special intellectual opportunities and reflect careful choices to provide the greatest return on the research investment. Identifying these opportunities involves the community, through the MPS Advisory Committee and through groups chartered to identify prospects, for revolutionary science in particular areas. Input from the National Academies of Sciences, Engineering, and Medicine (the National Academies) is critical for prioritization; two recent examples are New Worlds, New Horizons: A Midterm Assessment (delivered in August 2016) and Frontiers of Materials Research: A Decadal Survey (scheduled for completion in FY 2018).

Facilities that enable unique science that would be impossible without the special resources of a shared, multi-user environment are integral to our mission. Some of these facilities are observatories for photons, neutrinos, or gravitational waves. Others provide unique resources such as the largest controlled magnetic fields in the world or beams of rare isotopes. Stewardship of the MPS facilities portfolio and the balance among the different awards programs are critical issues that also engender extensive community

consultation. MPS continues assessing the future of different facilities and fostering collaborations for those facilities.

In partnership with other research directorates and offices, MPS will participate in building the foundation for the Big Ideas described previously. In particular, FY 2019 investments will advance the work of several of the Research Big Ideas, including Windows on the Universe: The Era of Multi-Messenger Astrophysics (WoU); The Quantum Leap: Leading the Next Quantum Revolution (QL); Harnessing the Data Revolution for 21st-Century Science and Engineering (HDR); Understanding the Rules of Life: Predicting Phenotype (URoL); and The Future of Work at the Human-Technology Frontier (FW-HTF).

In FY 2019, MPS will invest OMA funds to advance QL and WoU Big Ideas. These convergent activities will enable pursuit of fundamental research in quantum enabled sciences and technologies and multi-messenger astrophysics. By exploiting quantum phenomena such as superposition, entanglement, and squeezing, the QL activities will develop the foundations for and enable quantum computing, quantum sensors, quantum communications, quantum simulators, and other inherently quantum technologies, enhancing the social sciences and informing discussions on the social impacts of quantum innovation. The WoU activities will bring together fundamental research in electromagnetic waves, high-energy particles and gravitational waves; advance the study of the universe; and grow the Nation's multi-messenger astrophysics, engineering and data science workforce. While budget management and reporting for these investments will be the responsibility of MPS, the convergent activities will be overseen and managed collaboratively by the multi-directorate/office QL and WoU leadership teams.

MPS provides about 49 percent of the federal funding for basic research at academic institutions in the mathematical and physical sciences.

**Major Investments**

**MPS Major Investments**
(Dollars in Millions)

| Area of Investment | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| CAREER | $90.32 | - | $70.94 | -$19.38 | -21.5% |
| INFEWS[1] | 8.78 | - | - | -8.78 | -100.0% |
| NSF I-Corps™ | 1.69 | - | 1.70 | 0.01 | 0.6% |
| NSF Research Traineeship[2] | 4.54 | - | - | -4.54 | -100.0% |
| SaTC | 1.03 | - | 1.00 | -0.03 | -2.9% |
| UtB | 25.46 | - | 13.30 | -12.16 | -47.8% |
| *BRAIN Initiative* | *25.46* | - | *13.30* | *-12.16* | *-47.8%* |
| NSF's Big Ideas | | | | | |
| *NSF INCLUDES[3]* | *2.22* | - | - | *-2.22* | *-100.0%* |
| *Quantum Leap* | - | - | *30.00* | *30.00* | *N/A* |
| *Windows on the Universe* | - | - | *30.00* | *30.00* | *N/A* |

Major investments may have funding overlap and thus should not be summed.

[1]In FY 2019, INFEWS funding declined due to other priorities.

[2]In FY 2019, NRT funding is provided through CISE and EHR.

[3]In FY 2019, NSF INCLUDES funding is provided through the EHR account.

## MPS Funding for Centers Programs and Facilities

**MPS Funding for Centers Programs**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$97.50** | **-** | **$91.00** | **-$6.50** | **-6.7%** |
| Centers for Analysis & Synthesis (DMS) | 0.20 | - | - | -0.20 | -100.0% |
| Centers for Chemical Innovation (CHE) | 20.87 | - | 20.00 | -0.87 | -4.2% |
| Materials Research Science & Engineering Centers (DMR)[1] | 62.13 | - | 56.00 | -6.13 | -9.9% |
| Nanoscale Science & Engineering Centers (CHE, DMR) | 0.50 | - | - | -0.50 | -100.0% |
| STC: Center for Integrated Quantum Materials (DMR) | 4.20 | - | 5.00 | 0.80 | 19.0% |
| STC: STC for Real-Time Functional Imaging (DMR) | 5.00 | - | 5.00 | - | - |
| STC: Center for Bright Beams (PHY) | 4.60 | - | 5.00 | 0.40 | 8.7% |

[1]Includes forward funding of $6.13 million in FY 2017.

For detailed information on individual centers programs, see the NSF-Wide Investments chapter.

**MPS Funding for Facilities**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$289.17** | **-** | **$298.37** | **$9.20** | **3.2%** |
| Arecibo Observatory | 3.90 | - | 3.05 | -0.85 | -21.8% |
| Atacama Large Millimeter Array (ALMA) | 44.98 | - | 40.28 | -4.70 | -10.4% |
| Cornell High Energy Synchrotron (CHESS)[1] | 16.20 | - | 10.00 | -6.20 | -38.3% |
| Daniel K. Inouye Solar Telescope (DKIST)[2] | 13.50 | - | 18.50 | 5.00 | 37.0% |
| Gemini Observatory | 24.24 | - | 21.66 | -2.58 | -10.6% |
| IceCube Neutrino Observatory (IceCube) | 3.50 | - | 3.50 | - | - |
| Large Hadron Collider (LHC)[3] | 16.00 | - | 16.00 | - | - |
| Large Synoptic Survey Telescope (LSST) | - | - | 0.50 | 0.50 | N/A |
| Laser Interferometer Gravitational Wave Observatory (LIGO)[4] | 41.93 | - | 45.00 | 3.07 | 7.3% |
| National High-Magnetic Field Laboratory (NHMFL)[5] | 23.15 | - | 35.76 | 12.61 | 54.5% |
| National Nanotechnology Coordinated Infrastructure (NNCI) | 2.88 | - | 2.50 | -0.38 | -13.2% |
| National Optical Astronomy Observatories (NOAO) | 22.99 | - | 20.13 | -2.86 | -12.4% |
| National Radio Astronomy Observatories (NRAO) | 31.67 | - | 38.85 | 7.18 | 22.7% |
| National Solar Observatory (NSO)[6] | 6.00 | - | 4.00 | -2.00 | -33.3% |
| National Superconducting Cyclotron Laboratory (NSCL) | 24.00 | - | 24.00 | - | - |
| Other MPS Facilities: | 14.23 | - | 14.64 | 0.41 | 2.9% |
| Center for High Resolution Neutron Scattering (CHRNS) | 2.78 | - | 2.79 | 0.01 | 0.4% |
| Other Astronomical Facilities (LBO, GBO) | 11.45 | - | 11.85 | 0.40 | 3.5% |

[1]Includes forward funding of $8.20 million in FY 2017.

[2]Includes $2.0 million per year for cultural mitigation activities as required by the compliance process.

[3]Excludes $5.71 million in FY 2017 and $6.30 million in FY 2019 for High-Lumosity LHC Upgrade planning.

[4]Includes one-time supplemental funding of $2.50 million in FY 2017 for a critical vacuum repair.

[5]CHE and DMR forward funded NHMFL by $1.92 million and $10.73 million respectively in FY 2016. This reduced the FY 2017 total needed by $12.65 million.

[6]Excludes $11.50 million in FY 2017 and $16.50 million in FY 2019 for operations and maintenance support for the DKIST construction project. This funding is included in the DKIST total presented above.

For detailed information on individual facilities, please see the Facilities and the Major Research Equipment and Facilities Construction chapters.

## Funding Profile

**MPS Funding Profile**

| | FY 2017 Actual Estimate | FY 2018 (TBD) | FY 2019 Estimate |
|---|---|---|---|
| **Statistics for Competitive Awards:** | | | |
| Number of Proposals | 8,849 | - | 9,000 |
| Number of New Awards | 2,335 | - | 2,300 |
| Funding Rate | 26% | - | 26% |
| **Statistics for Research Grants:** | | | |
| Number of Research Grant Proposals | 7,754 | - | 8,000 |
| Number of Research Grants | 1,853 | - | 1,800 |
| Funding Rate | 24% | - | 23% |
| Median Annualized Award Size | $120,000 | - | $120,000 |
| Average Annualized Award Size | $139,127 | - | $140,000 |
| Average Award Duration, in years | 3.2 | - | 3.2 |

## People Involved in MPS Activities

**Number of People Involved in MPS Activities**

| | FY 2017 Actual Estimate | FY 2018 (TBD) | FY 2019 Estimate |
|---|---|---|---|
| Senior Researchers | 8,102 | - | 7,900 |
| Other Professionals | 3,271 | - | 3,100 |
| Postdoctoral Associates | 2,059 | - | 2,000 |
| Graduate Students | 8,828 | - | 8,600 |
| Undergraduate Students | 6,121 | - | 5,900 |
| K-12 Teachers | - | - | - |
| K-12 Students | - | - | - |
| **Total Number of People** | **28,381** | **-** | **27,500** |

## Program Monitoring and Evaluation

External Program Evaluations and Studies:

- The Astronomy and Astrophysics Advisory Committee (AAAC) completed its report[1] on interagency activities by NSF, the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA) in March 2017. Findings and recommendations of this annual report help guide AST decision making and prioritization until superseded by a subsequent report. The AAAC held three meetings in early FY 2018 that will lead up to their next annual report, expected in March.
- AST, together with the NASA Astrophysics Division and the High Energy Physics Branch of the DOE Office of Science, commissioned a study (*Review of Progress Toward the Decadal Survey Vision in New Worlds, New Horizons in Astronomy and Astrophysics*) of the mid-term status of agency responses to the 2010 decadal survey in astronomy and astrophysics, through the NRC Space Studies Board. The resulting NRC mid-term review committee report was published in August 2016.[2] Findings and recommendations of this "mid-decadal" report will guide AST decision making and prioritization until

[1]www.nsf.gov/mps/ast/aaac.jsp
[2]http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_161177

superseded by the next "decadal" report, expected in the early part of the 2020s.

- Pursuant to the National Environmental Policy Act of 1969, AST has prepared or is in the process of preparing Environmental Impact Statements (EIS) for three AST facilities: Arecibo Observatory, Sacramento Peak Observatory, and Green Bank Observatory.[3] These statements are intended to study and evaluate the potential environmental effects of proposed operational changes to these facilities due to funding constraints. Prior to finalization, the general public has several opportunities to review draft documents and provide external, independent formal input into the formulation of the final EIS. For two of these facilities, Sacramento Peak and Green Bank Observatories, the process is on-going. For Arecibo Observatory, a final EIS was published in July 2017. In November 2017, NSF signed a Record of Decision for Arecibo Observatory, which concluded the agency's decision-making process with respect to the general path forward for Arecibo Observatory.[4]
- The CCI program is being assessed through an evaluation. Final results are expected in FY 2019.
- DMR co-sponsored with the DOE Office of Basic Energy Sciences (BES) a National Academies Decadal Survey entitled *Frontiers of Materials Research*. This important study will identify future needs and important emerging research areas of materials research in the context of U.S. and international efforts.[5] A report, anticipated in June 2018, will inform DMR of future directions.
- In FY 2019, PHY plans to charge the National Academies with a Decadal Survey of Atomic, Molecular, and Optical Physics, together with DOE BES.
- In FY 2019, PHY plans to charge the MPS Advisory Committee to study the implementation of its Physics Frontiers Centers Program.

Workshops and Reports:

- In October 2016, a CHE-sponsored workshop titled *Measuring the Brain: From the Synapse to Thought* brought together the chemical and neuroscience communities to identify challenges in brain research and how chemical probes, sensors, and instrumentation could address challenges in understanding brain functioning. The report is now available.[6]
- CHE sponsored two 2016 workshops on midscale investment opportunities. The first resulted in *Mid-Scale Instrumentation: Regional Facilities to Address Grand Challenges in Chemistry.*[7] This report focuses on six "grand challenges" for regional facilities in the chemical community (e.g., structure and dynamics at interfaces, highly parallel chemical synthesis and characterization, structure-function relationships in disordered and/or heterogeneous systems, etc.). The second 2017 report, *Workshop on Midscale Instrumentation Development for the Chemical Sciences*,[8] focuses on instrument development that could impact the chemical community and closely associated industries in the U.S. and globally (e.g., fuels, energy, commodity chemicals and materials, and medicine).
- The CHE workshop *Quantum Information and Computation for Chemistry* was held in November 2016, with representatives attending from the chemical community, the National Academies, multiple federal agencies, and industries involved in quantum sciences. The workshop explored the boundaries between classical and quantum computation, quantum machine learning, quantum optical tools for chemistry, and sensing and communication applications. A report is available.[9]
- The CHE workshop *Framing the Role of Big Data and Modern Data Science in Chemistry* was held in April 2017 and focused on big data research and the use of modern data science in chemistry. The workshop addressed the needs of the chemical research and data science communities to fully develop

[3]www.nsf.gov/news/news_summ.jsp?cntn_id=139158&org=AST
[4]www.nsf.gov/mps/ast/env_impact_reviews/arecibo/arecibo_rod.jsp
[5]http://sites.nationalacademies.org/DEPS/materials-decadal/index.htm
[6]www.nsf.gov/mps/che/measuring_the_brain_from_synapse_to_thought_10_2016.pdf
[7]www.nsf.gov/mps/che/workshops/msiegionalcenters_workshopreport_5_1_17.pdf
[8]www.nsf.gov/mps/che/workshops/mid-scale_instrument_development_for_the_chemical_sciences_workshop_september_2016.pdf
[9]www.nsf.gov/mps/che/workshops/che_qis_workshop_november_2016.pdf

sharing, searching, and repurposing for data mining, machine learning, and data analytics. The report will be available in FY 2018.

- DMR sponsored several workshops in FY 2017 and FY 2018 aimed at building the materials research community,[10,11] preparing the community to better respond to the NSF QL Big Idea,[12,13,14] and developing critical skills in the use of data-driven research.[15,16] In addition, DMR sponsored a study from The Minerals, Metals & Materials Society (TMS) titled *Building a Materials Data Infrastructure: Opening New Pathways to Discovery and Innovation in Science and Engineering* which recommends potential methods of effectively storing and maintaining data, the value of data by enabling its reuse, and creating incentives that encourage data sharing.[17]
- DMR will sponsor several workshops throughout FY 2018 and FY 2019 that will focus on condensed matter science, quantum materials,[18] solid state materials chemistry, metals, and the application of data-driven science and machine learning to accelerated materials discovery,[19] and best practices in managing shared research instrumentation Facilities.
- In October 2017, DMS and the CISE Division of Computing and Communication Foundations sponsored a Kickoff Principle Investigator (PI) meeting for the joint Transdisciplinary Research in Principles of Data Science (TRIPODS) program that supported the development of small collaborative institutes bringing together mathematicians, statisticians, and theoretical computer scientists. All 12 TRIPODS groups that received awards in the summer of 2017 participated, presented their planned activities, and discussed opportunities for future collaborations with domain sciences and industry.
- In September 2017, DMS and the National Geospatial Intelligence Agency sponsored a PI meeting for the joint program on Algorithms for Threat Detection. The program focuses on research to develop the next generation of mathematical and statistical algorithms for analysis of large spatiotemporal datasets with application to quantitative models of human dynamics.[20]
- In collaboration with the National Institutes of Health (NIH), DMS supported a Data Science Innovation Lab workshop in June 2017. The goal of the workshop was to foster new interdisciplinary collaborations to support the development of innovative approaches for visualization, modeling, and analysis of microbiome big data. The activity brought together researchers in quantitative and biomedical sciences with a goal of developing new research teams to address data science challenges in furthering our understanding of the microbiome. Prior Innovation Labs have focused on Precision Medicine (2015) and Mobile Health (2016).
- DMS co-sponsored (with CISE, EHR, SBE) a National Academies study "Envisioning the Data Science Discipline: The Undergraduate Perspective" with the goal of understanding the "core underlying principles, intellectual content, and pedagogical issues specific to data science, including core concepts that distinguish it from neighboring disciplines." A workshop in May 2017 brought together stakeholders from different disciplines and types of institutions. Following the workshop, the committee issued an interim report[21] and organized webinars to obtain feedback from the community. A follow-up workshop was held in December 2017; the final report is expected in 2018.

[10]http://reg.conferences.dce.ufl.edu/Physics/1202
[11]https://sites.cns.utexas.edu/epm_nsf_workshop
[12]https://scholar.princeton.edu/nsfcmp/home
[13]http://qs3.mit.edu/images/pdf/2017-QS3-Detailed-Schedule.pdf
[14]https://nsfhighfield.princeton.edu/
[15]https://mrsec.uchicago.edu/mat_summit
[16]www.mri.psu.edu/2d-crystal-consortium/nsf-efri-2daredmref-2dmip-grantees-meeting
[17]www.tms.org/mdistudy
[18]http://qs3.mit.edu/index.php/summer-school-program
[19]https://matdat18.wordpress.ncsu.edu/
[20]https://atd2017.soe.ucsc.edu/home
[21]www.nap.edu/catalog/24886/envisioning-the-data-science-discipline-the-undergraduate-perspective-interim-report

Committees of Visitors (COV):

- In FY 2019, COVs will review AST, DMR, and PHY.
- In FY 2020, COVs will review CHE and DMS.

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

**DIVISION OF ASTRONOMICAL SCIENCES (AST)** **$230,690,000**
**-$21,360,000 / -8.5%**

**AST Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$252.05** | **-** | **$230.69** | **-$21.36** | **-8.5%** |
| **Research** | **60.43** | **-** | **55.17** | **-5.26** | **-8.7%** |
| CAREER | 4.83 | - | 4.90 | 0.07 | 1.4% |
| **Education** | **4.24** | **-** | **5.70** | **1.46** | **34.4%** |
| **Infrastructure** | **187.38** | **-** | **169.82** | **-17.56** | **-9.4%** |
| Arecibo Observatory | 3.90 | - | 3.05 | -0.85 | -21.8% |
| Atacama Large Mm/SubMm Array (ALMA) | 44.98 | - | 40.28 | -4.70 | -10.4% |
| Daniel K. Inouye Solar Telescope (DKIST)[1] | 13.50 | - | 18.50 | 5.00 | 37.0% |
| Gemini Obervatory[2] | 24.24 | - | 21.66 | -2.58 | -10.6% |
| Large Synoptic Survey Telescope (LSST) | - | - | 0.50 | 0.50 | N/A |
| National Optical Astronomy Obervatory (NOAO) | 22.99 | - | 20.13 | -2.86 | -12.4% |
| National Radio Astronomy Obervatory (NRAO) | 31.67 | - | 38.85 | 7.18 | 22.7% |
| National Solar Observatory (NSO)[3] | 6.00 | - | 4.00 | -2.00 | -33.3% |
| Other Astronomical Obervatories (LBO, GBO) | 11.45 | - | 11.85 | 0.40 | 3.5% |
| Mid-Scale Innovations Program (MSIP) | 20.67 | - | 1.00 | -19.67 | -95.2% |
| Research Resources | 7.98 | - | 10.00 | 2.02 | 25.3% |

[1]Includes $2.0 million per year for cultural mitigation activities as required by the compliance process.

[2]Includes a technical reobligation of $3.74 million in FY 2017 at the end of an expiring coop. support

[3]Excludes $11.50 million in FY 2017 and $16.50 million in FY 2019 for operations and maintenance support for the DKIST construction project. This funding is included within the DKIST line above.

**AST Summary**

AST is the federal steward for ground-based astronomy in the U.S., funding research awards to individual investigators and small research groups and cooperative agreements for the operation of large telescope facilities. These facilities provide world-leading, one-of-a-kind observational capabilities on a competitive basis to thousands of astronomers each year. These facilities enable scientific advances by making archived data products available to researchers. AST also supports the development of advanced technologies and instrumentation and manages the electromagnetic spectrum for scientific use by the entire NSF community.

AST supports research to understand the origins and characteristics of planets, stars, and galaxies, as well as the structure that has evolved in the universe since its origin more than 13 billion years ago. The results of this research will lead to a better understanding of the cosmos, of the possibility of life existing on planets circling other stars, and of the nature of the mysterious dark matter and dark energy that comprise more than 95 percent of the mass-energy of the universe.

AST contributes to WoU with investments in facilities that support ground-based electromagnetic follow-up as well as projects that employ pulsars as an alternative gravitational wave detection method.

In general, about 19 percent of the AST portfolio is available for new research grants. About 72 percent of AST's budget supports the forefront instrumentation and facilities needed for progress at the frontiers of observational astronomy, while almost 24 percent supports the research of individual investigators. Through the MREFC Account, AST also oversees the construction of LSST and DKIST.

**DIVISION OF CHEMISTRY (CHE)** **$230,580,000**
**-$15,660,000 /-6.4%**

**CHE Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$246.24** | **-** | **$230.58** | **-$15.66** | **-6.4%** |
| **Research** | **232.61** | **-** | **216.75** | **-15.86** | **-6.8%** |
| CAREER | 35.19 | - | 22.71 | -12.48 | -35.5% |
| Centers Funding (total) | 21.12 | - | 20.00 | -1.12 | -5.3% |
| Centers for Chemical Innovation | 20.87 | - | 20.00 | -0.87 | -4.2% |
| Nanoscale Science & Engineering Centers | 0.25 | - | - | -0.25 | -100.0% |
| **Education** | **6.06** | **-** | **5.10** | **-0.96** | **-15.8%** |
| **Infrastructure** | **7.57** | **-** | **8.73** | **1.16** | **15.3%** |
| National Nanotechnology Coordinated Infrastructure (NNCI) | 0.30 | - | - | -0.30 | -100.0% |
| National High Magnetic Field Laboratory (NHMFL)[1] | - | - | 1.73 | 1.73 | N/A |
| Research Resources | 7.27 | - | 7.00 | -0.27 | -3.7% |

[1]Forward funding of $1.92 million in FY 2016 reduced the planned FY 2017 increment to zero. Without this action, the change from FY 2017 Actual would be -$190,000, or -9.9 percent.

**CHE Summary**

The chemical industry is one of the largest and most important industries worldwide both in terms of impact on the economy and employment. It includes sectors in energy, pharmaceuticals and medical applications, electronics, agriculture, textiles, building products, and numerous other commercial and consumer products. CHE leads the discovery, invention, innovation, and development of a skilled workforce capable of fundamental and foundational research that ultimately supports commercial manufacturing in the chemical industries. Specifically, CHE enables research on the synthesis and characterization of new molecules, surfaces, and nanostructures (by both theoretical and experimental methods) that lead to usable products beneficial to society.

CHE contributes to building the foundation for several of NSF's Big Ideas including: HDR by promoting data discovery sciences to effectively and efficiently mine extensive volumes and varieties of chemical data in order to advance discovery and innovation; QL by contributing to the production of next generation technologies at the quantum level by observing, manipulating, and controlling the behavior of matter and energy in nanometer dimensions; and URoL by increasing knowledge of the structure-function relationships in biological systems leading to important advances in understanding the human body and improving health.

CHE is also involved in the development of new mid-scale instrumentation to examine and solve complex chemical problems including the synergistic combinations of multiple types of measurement (including remote access and cyber-enabled tools) and the development of novel, new instruments. Such tool development is essential for continuing progress in fields as diverse as understanding the brain, sensing for agriculture and forensics applications, and improving the sustainable and responsible advanced manufacturing of chemical feedstocks as they transition from the lab bench to commercial scales.

About 67 percent of the CHE portfolio is available to support new research grants. The remaining 33 percent supports research grants made in prior years and the research infrastructure needed by this community.

**DIVISION OF MATERIALS RESEARCH (DMR)** **$295,050,000**
**-$19,260,000 / -6.1%**

**DMR Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 Request | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$314.31** | **-** | **$295.05** | **-$19.26** | **-6.1%** |
| **Research** | **248.95** | **-** | **234.84** | **-14.11** | **-5.7%** |
| CAREER | 26.38 | - | 24.03 | -2.35 | -8.9% |
| Centers Funding (total) | 71.58 | - | 66.00 | -5.58 | -7.8% |
| Materials Research Science & Engineering Centers[1] | 62.13 | - | 56.00 | -6.13 | -9.9% |
| Nanoscale Science & Engineering Centers | 0.25 | - | - | -0.25 | -100.0% |
| STC: Center for Integrated Quantum Materials | 4.20 | - | 5.00 | 0.80 | 19.0% |
| STC: Science and Technology Center on Real-Time Functional Imaging | 5.00 | - | 5.00 | - | - |
| **Education** | **4.83** | **-** | **2.13** | **-2.70** | **-55.9%** |
| **Infrastructure** | **60.53** | **-** | **58.08** | **-2.45** | **-4.0%** |
| Cornell High Energy Synchrotron Source (CHESS)[2] | 16.20 | - | 10.00 | -6.20 | -38.3% |
| National High Magnetic Field Laboratory (NHMFL)[3] | 23.15 | - | 34.03 | 10.88 | 47.0% |
| Center for High Resolution Neutron Scattering (CHRNS) | 2.79 | - | 2.79 | - | - |
| National Nanotechnology Coordinated Infrastructure (NNCI) | 2.58 | - | 2.50 | -0.08 | -3.1% |
| Mid-scale Research Infrastructure[4] | 12.86 | - | 6.31 | -6.55 | -50.9% |
| Research Resources | 2.95 | - | 2.45 | -0.50 | -16.9% |

[1]Includes forward funding of $6.13 million in FY 2017. Without this action, FY 2019 would be level with FY 2017.

[2]Includes forward funding of $8.20 million for DMR's increment in FY 2017. Without this action, the change from FY 2017 Actual would be $2.0 million, or 25.0 percent.

[3]DMR forward funded its increment by $10.73 million in FY 2016, reducing the planned FY 2017 increment. Without this action, the change from FY 2017 Actual would be +$150,000 or +0.4 percent.

[4]Includes forward funding of $6.09 million in FY 2017. Without this action, the change over FY 2017 Actual would be -$460,000, or -6.8 percent.

## DMR Summary

DMR invests in the discovery of new materials and the explanation of materials phenomena. Materials are ubiquitous and pervasive, serving as the critical building blocks to modern technology and innovation. DMR accomplishes this through support of basic experimental and theoretical materials research via programs focused on condensed matter physics, solid-state and materials chemistry, and the science of materials that are ceramic, metallic, polymeric, nano-structured, biological, electronic, photonic, and multifunctional. The discovery and deployment of new materials have shaped our understanding of our world and enabled significant advances in electronics, communications, transportation, and health. This enterprise is dependent on investments across scales; from single investigators to teams and centers; to singularly focused research versus that requiring interdisciplinarity; and small instruments to large facilities.

DMR contributes to building the foundations for several Big Ideas, including QL with investments in high-risk/high-impact projects in topical materials research programs, and HDR via awards that focus on using and exploiting digital data to advance materials research.

In general, within the core programs (topical materials research programs) 34 percent of the DMR portfolio is available for new research grants and 66 percent is available for continuing grants.

**DIVISION OF MATHEMATICAL SCIENCES (DMS)** **$218,820,000**
**-$14,720,000 / -6.3%**

**DMS Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$233.54** | **-** | **$218.82** | **-$14.72** | **-6.3%** |
| **Research** | **220.72** | **-** | **207.20** | **-13.52** | **-6.1%** |
| CAREER | 13.57 | - | 12.00 | -1.57 | -11.6% |
| Centers Funding (total) | 0.20 | - | - | -0.20 | -100.0% |
| Centers for Analysis & Synthesis | 0.20 | - | - | -0.20 | -100.0% |
| **Education** | **12.82** | **-** | **11.62** | **-1.20** | **-9.4%** |

**DMS Summary**

DMS provides U.S. federal support of basic research at the frontiers of discovery in the mathematical sciences. Modern communication, transportation, medicine, manufacturing, security, and finance all depend on developments in the mathematical sciences. DMS investments catalyze research at the frontiers of fundamental, applied, and computational mathematics and statistics and enable discovery and innovation in other fields of science and engineering linked to key national priorities. In turn, advances in science and engineering inspire development of ever more sophisticated mathematical and statistical methodologies, theories, and tools. DMS investments underpin these developments as well as the training of future researchers in the mathematical sciences.

In addition to supporting a vibrant research community through core programs in mathematics and statistics, DMS supports the Mathematical Sciences Research Institutes program that advances research, increases the impact of the mathematical sciences, responds to national needs, and expands the U.S. talent base engaged in mathematical and statistical research. Through partnerships with other divisions in NSF, other government agencies, and a private foundation, DMS is able to support foundational research related to several of the NSF Big Ideas, including HDR, URoL, FW-HTF, and QL. Partnerships include: joint activities in biosciences with the National Institutes of Health, a joint program with the National Geospatial Intelligence Agency to develop the next generation of mathematical and statistical algorithms for analysis of large spatiotemporal datasets, and a joint program on Algorithms for Modern Power Systems with DOE. Other examples include a joint program with CISE to support the development of small collaborative institutes called the Transdisciplinary Research in Principles of Data Science (TRIPODS) program, as well as a joint program with BIO and the Simons Foundation to support research centers on the Mathematics of Complex Biological Systems.

In general, 47 percent of the DMS portfolio is available for new research grants and 53 percent goes to continuing grants.

**DIVISION OF PHYSICS (PHY)** **$266,730,000**
**-$14,700,000 / -5.2%**

**PHY Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change Over FY 2017 Actual Amount | Change Over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$281.43** | **-** | **$266.73** | **-$14.70** | **-5.2%** |
| **Research** | **178.57** | **-** | **159.01** | **-19.56** | **-11.0%** |
| CAREER | 10.04 | - | 7.30 | -2.74 | -27.3% |
| Centers Funding (total) | 4.60 | - | 5.00 | 0.40 | 8.7% |
| STC: Center for Bright Beams | 4.60 | - | 5.00 | 0.40 | 8.7% |
| **Education** | **5.87** | **-** | **4.92** | **-0.95** | **-16.2%** |
| **Infrastructure** | **96.99** | **-** | **102.80** | **5.81** | **6.0%** |
| IceCube Neutrino Observatory (IceCube) | 3.50 | - | 3.50 | - | 0.0% |
| Large Hadron Collider (LHC) | 16.00 | - | 16.00 | - | 0.0% |
| Laser Interferometer Gravitational Wave Observatory (LIGO)[1] | 41.93 | - | 45.00 | 3.07 | 7.3% |
| National Superconoducting Cyclotron Laboratory (NSCL) | 24.00 | - | 24.00 | - | 0.0% |
| Midscale Research Infrastructure | 5.85 | - | 8.00 | 2.15 | 36.8% |
| Pre-construction Planning: | | | | | |
| High-Luminosity LHC Upgrade Planning | 5.71 | - | 6.30 | 0.59 | 10.3% |

[1]FY 2017 includes one-time supplemental funding of $2.50 million for a critical vacuum repair.

**PHY Summary**

PHY supports fundamental research addressing frontier areas of physics that lead to the understanding of the make-up of the Universe, from the formation of stars and galaxies to the principles of life processes on Earth. This research covers a range of physics subfields: atomic, molecular, optical and plasma physics, elementary particle physics, gravitational physics, nuclear physics, particle and nuclear astrophysics, physics of living systems, physics at the information frontier, and theoretical physics.

PHY is the primary supporter of all research in the U.S. in gravitational physics and the leading supporter of fundamental research in atomic, molecular, and optical physics in the United States. PHY is a major partner with DOE in support of elementary particle physics, nuclear physics, and plasma physics. PHY also has the only U.S. program designed for the support of physics research in living systems. The development of the most advanced cutting-edge computational resources, innovative technology, and new instrumentation is a key part of physics research, and tools developed by the physics community continuously have major impact in other scientific and engineering fields. As a result, the division contributes to building the foundation for several of NSF's Big Ideas including WoU, QL, URoL, and HDR.

Approximately 18 percent of the PHY portfolio is available for new research grants. The remaining 82 percent is used primarily to fund continuing grants made in previous years (47 percent) and to support operations and maintenance for four facilities that are a key part of the division portfolio (36 percent).

**OFFICE OF MULTIDISCIPLINARY ACTIVITIES (OMA)** **$103,450,000**
**+$68,590,000 / 196.8%**

**OMA Funding**
(Dollars in Millions)

| | FY 2017 Actual | FY 2018 (TBD) | FY 2019 Request | Change over FY 2017 Actual Amount | Change over FY 2017 Actual Percent |
|---|---|---|---|---|---|
| **Total** | **$34.86** | **-** | **$103.45** | **$68.59** | **196.8%** |
| **Research** | **25.55** | **-** | **96.71** | **71.16** | **278.5%** |
| Big Idea: Quantum Leap | - | - | 30.00 | 30.00 | N/A |
| Big Idea: Windows on the Universe | - | - | 30.00 | 30.00 | N/A |
| CAREER | 0.31 | - | - | -0.31 | -100.0% |
| **Education** | **9.22** | **-** | **-** | **-9.22** | **-100.0%** |
| **Infrastructure** | **0.09** | **-** | **6.74** | **6.65** | **7388.9%** |
| Portfolio Analysis[1] | 0.09 | - | 6.74 | 6.65 | 7388.9% |

[1]FY 2017 actions were unexpectedly low due, in part, to the timing of contracts and the phases of operation of various research facilities under review.

**OMA Summary**

OMA co-funds research that is relevant to the broad swath of scientific disciplines represented in the five disciplinary divisions of MPS. OMA enables and facilitates MPS support of novel, challenging, or complex projects of varying scale, in both research and education, which are not readily accommodated by traditional organizational structures and procedures. This is done primarily in partnership with MPS disciplinary divisions and is especially directed at activities undertaken by multi-investigator, multidisciplinary teams, as well as cross-NSF and interagency activities.

In FY 2019, MPS, in partnership with NSF research directorates and offices, will invest OMA funds to advance the QL and the WoU Big Ideas. These convergent activities will enable pursuit of fundamental research in quantum enabled sciences and technologies and multi-messenger astrophysics. By exploiting quantum phenomena such as superposition, entanglement, and squeezing, the QL activities will develop the foundations for and enable quantum computing, quantum sensors, quantum communications, quantum simulators, and other inherently quantum technologies, enhancing the social sciences and informing discussions on the social impacts of quantum innovation. The Windows activities will bring together fundamental research in electromagnetic waves, high-energy particles and gravitational waves, advance the study of the universe and grow the nation's multi-messenger astrophysics, engineering and data science workforce.

While budget management and reporting for these investments will be the responsibility of MPS, the convergent activities will be overseen and managed collaboratively by the multi-directorate/office QL and WoU leadership teams. OMA will also support division investments in HDR, URoL, and FW-HTF.

OMA's practice is to commit funds using only the current fiscal year budget and to limit commitments to outyear support. For this reason, nearly 48 percent of the OMA portfolio is available to support new research grants. Approximately 39 percent of the OMA portfolio is used to support multidisciplinary research grants within MPS, with the remaining 61 percent being used to support research and education activities of interest to MPS but led by non-MPS directorates.