DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES (MPS)

$1,436,450,000
+$87,300,000 / 6.5%

MPS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Astronomical Sciences (AST)	$245.23	$246.73	$262.61	$15.88	6.4%
Chemistry (CHE)	246.29	246.31	262.16	15.85	6.4%
Materials Research (DMR)	337.62	310.03	329.71	19.68	6.3%
Mathematical Sciences (DMS)	235.43	234.05	249.17	15.12	6.5%
Physics (PHY)	276.10	277.03	295.26	18.23	6.6%
Office of Multidisciplinary Activities (OMA)	35.65	35.00	37.54	2.54	7.3%
Total, MPS	**$1,376.32**	**$1,349.15**	**$1,436.45**	**$87.30**	**6.5%**

Totals may not add due to rounding.

The FY 2017 Budget Request for MPS is $1,436.45 million, of which $1,355.06 million is discretionary funding and $81.39 is new mandatory funding. The major focus of the mandatory funding is support for core activities, with special emphasis on supporting investigators in the early parts of their careers. These early career investigators bring innovative research ideas that often draw on new possibilities in computational- and data-intensive techniques.

Examples of research areas in which MPS has particular opportunities to support early career scientists and advance computational- and data-intensive research are:

- Quantum Information Science
- Optics and Photonics
- Clean Energy

Each of these areas provides tremendous intellectual opportunities for early career scientists.

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. The FY 2017 Request for MPS supports a collection of vigorous disciplinary and multidisciplinary research programs that foster discovery and cultivate the technical workforce. The research programs in MPS provide the foundation of basic research in astronomical sciences (AST), chemistry (CHE), materials research (DMR), mathematical sciences (DMS), and physics (PHY) that explore the frontiers of science.

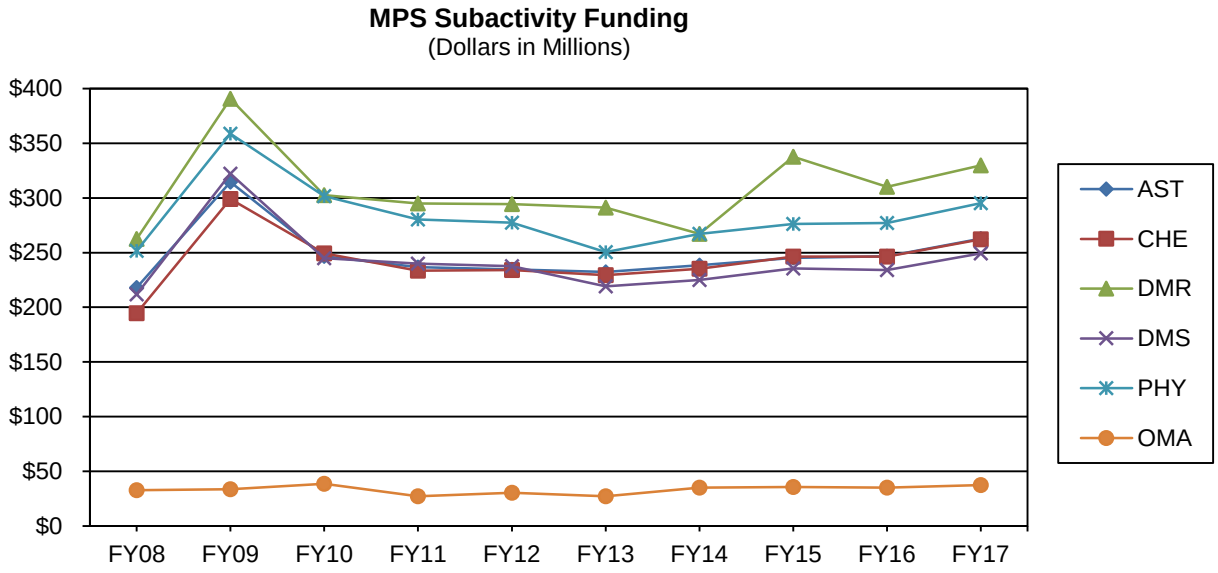
The collection of programs in MPS spans the range from individual investigator awards to large, multi-user facilities. The science spans an enormous range as well: from the smallest objects and shortest times ever studied to distances and times that are the size and age of the universe. Individual investigators and small teams receive the majority of awards, but centers, institutes, and multi-user facilities are all integral to MPS-funded research. The relatively new MPS midscale research infrastructure program is meeting a critical research need, and the FY 2017 Request continues to sustain that effort. MPS is also growing research in optics and photonics, a promising area with well-articulated and exciting possibilities, and in the related area of quantum information science, an activity that links in part to the National Strategic Computing Initiative (NSCI).

Programs in the MPS divisions respond to special intellectual opportunities and reflect careful choices about directions in order 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. The Particle Physics Project Planning Panel (P5) Report and the Long Range Plan from the Nuclear Science Advisory Committee are just two recent examples. These and other thoughtful reports inform the choices made in MPS, and the advice the directorate receives often emphasizes our declining support of unsolicited proposals, a source that many regard as the origin of the most vibrant ideas. Thus, supporting unsolicited proposals that address topics central to MPS research is one of our primary goals.

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 partnerships for those facilities.

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. The MPS program in optics and photonics is a partnership with the Directorates for Engineering (ENG) and Computer and Information Science and Engineering (CISE). Investments continue in NSF-wide investments such as Research at the Interface of the Biological, Mathematical, and Physical Sciences (BioMaPS); Understanding the Brain (UtB); Cyber-Enabled Materials Manufacturing and Smart Systems (CEMMSS), which includes both advanced manufacturing and Designing Materials to Revolutionize and Engineer the Future (DMREF); Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21); Secure and Trustworthy Cyberspace (SaTC); and NSF Innovation Corps (I-Corps™). Core research funds also contribute to research in clean energy technology and support the program of Research Experiences for Undergraduates (REU). The Sustainable Chemistry, Engineering, and Materials (SusChEM) program is also part of this Request and will continue to evolve even as the NSF-wide investment in Science, Engineering, and Education for Sustainability (SEES) concludes at the end of FY 2017.

MPS provides about 43 percent of the federal funding for basic research at academic institutions in the mathematical and physical disciplines covered by MPS.



FY 2009 funding reflects both the FY 2009 omnibus appropriation and funding provided through the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

FY 2017 Summary by Division

- AST's FY 2017 Request will support individual investigator awards and astronomical observatories, as well as investment in CIF21 and the major MPS priority of midscale research infrastructure. Funding for individual investigator research is balanced against funding for facilities. Among facilities, support for the Daniel K. Inouye Solar Telescope (DKIST) increases.

- CHE's FY 2017 Request provides enhanced support for core research programs and augments the focus on Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) as a research driver. CHE will continue its commitment to research in clean energy technologies, advanced manufacturing, and CIF21. CHE also strongly supports research at the interfaces of biology and chemical science, within both experimental and theoretical/computational frameworks, including the major cross-Foundation effort, UtB.

- DMR's FY 2017 Request provides continued support for its portfolio of individual investigators, small teams, and centers, especially in areas where advanced materials are essential for areas such as advanced manufacturing, CEMMSS (through DMREF), clean energy technologies, sustainability, and UtB. DMR will continue to support its facilities, including the newly launched Materials Innovation Platforms (MIP) program as investment in mid-scale research infrastructure.

- DMS's FY 2017 Request focuses on enhancing support for frontier research, training a diverse group of researchers in mathematical and statistical sciences with computational skills, investing in mathematical sciences institutes, and providing support through efficient mechanisms to foster multidisciplinary research activities in, but not limited to CIF21, Risk and Resilience, BioMaPS, CEMMSS, SaTC, and UtB.

- PHY's FY 2017 Request includes continued support for individual investigator awards, particularly those in NSF-wide priorities such as CIF21, BioMaPS, and UtB. PHY also requests increased funding for investigators using its major facilities, and for operations and maintenance of these facilities. In

FY 2017, PHY will maintain its program in accelerator science and its commitment to the MPS priority of midscale research infrastructure.

- OMA will continue its role of providing support for multidisciplinary research and activities in education and broadening participation. OMA will emphasize research relevant to NSF priorities such as CIF21, BioMaPS, UtB, and CEMMSS. OMA will coordinate MPS activities related to I-Corps™, NSF Research Traineeship (NRT), and NSF-wide Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES). Also OMA will support responsible decisions regarding portfolio composition, including studies of possible environmental issues, stewardship transition costs, or partnership start-up costs; in FY 2017, the focus will be on implementing the recommendations of the AST portfolio review.

Major Investments

MPS Major Investments
(Dollars in Millions)

Area of Investment	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
BioMaPS	$17.94	$13.00	$13.00	-	-
CAREER	79.07	67.53	68.45	0.92	1.4%
CEMMSS	65.07	49.84	47.14	-2.70	-5.4%
Advanced Manufacturing	*65.07*	*49.84*	*47.14*	*-2.70*	*-5.4%*
Clean Energy Technology	123.23	143.34	195.36	52.02	36.3%
CIF21	34.89	11.50	16.15	4.65	40.4%
NSF I-Corps™	1.30	1.70	1.70	-	-
NSF INCLUDES	-	2.74	2.60	-0.14	-5.1%
INFEWS	-	2.40	6.40	4.00	166.7%
NRT[1]	5.04	4.47	4.54	0.07	1.6%
Risk and Resilience	-	0.50	0.50	-	-
SaTC	1.86	2.00	2.00	-	-
SEES	50.85	16.00	13.00	-3.00	-18.8%
Understanding the Brain	15.44	19.49	18.70	-0.79	-4.1%
BRAIN Initiative	15.44	19.49	18.70	-0.79	-4.1%

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

[1] Outyear cmmitments for Integrative Graduate Education and Research Traineeship (IGERT) are included in the NRT line and are $2.80 million in FY 2015 and $220,000 in FY 2016.

- BioMaPS (equal to the FY 2016 Estimate at $13.0 million): This continues to be an exciting research area, the focus of which is the partnership with BIO that will emphasize research towards Understanding the Brain (UtB) and other emerging areas of multidisciplinary science.

- CAREER (+$920,000, to a total of $68.45 million): This program remains a top priority for the directorate, ensuring that top young scientists in all of the MPS disciplines are funded at a healthy level. The CAREER program is an important element in the growth and maturity of young scientists.

- Cyber-Enabled Materials Manufacturing and Smart Systems (CEMMSS) (-$2.70 million below the FY 2016 Estimate): MPS' contribution includes both Advanced Manufacturing and Designing Materials to Revolutionize and Engineer the Future (DMREF). DMREF is the MPS response to the Administration's Materials Genome Initiative and has received strong interest from MPS communities. MPS will continue to support highly meritorious proposals to advance materials discovery by closely

linking theory, modeling, and experiment, an approach critical to solving related research challenges in areas such as optics and photonics, clean energy, and the brain.

- Clean Energy Technology (+$52.02 million, to a total of $195.36 million): Research in this area remains strong in MPS core programs.

- MPS's Computational and Data-Enabled Science and Engineering (CDS&E) program, which is part of CIF21, supports development of fundamental insights in materials and physics that will carry computation beyond the limits of current technology as well as creating algorithms and software for new approaches to computation and data analytics. An increase of $4.65 million in FY 2017 (to a total of $16.15 million) will support the evolution of these efforts as CIF21 concludes as planned. Funding will also support activities at the heart of the new federal government-wide National Strategic Computing Initiative (NSCI), which MPS and the Directorate for Computer and Information Science and Engineering (CISE) will lead within NSF.

- I-Corps™ (level with FY 2016 Estimate at $1.70 million): MPS support in this area continues, primarily through I-Corps™ teams. Investments are directed to an assessment of the commercial viability of the scientific discoveries in MPS disciplines through the individual investigator award program.

- NSF INCLUDES (-$140,000 to $2.60 million): MPS continues to support the program, an NSF-wide broadening participation activity.

- INFEWS (+$4.0 million, to a total of $6.40 million): This funding provides for cross directorate cooperation and further development of research communities to address sustainability issues.

- NRT: Funding increases (+$290,000, to a total of $4.54 million) while final commitments within the Integrative Graduate Education and Research (IGERT) program (-$220,000 to zero) were completed in FY 2016.

- Risk and Resilience (level at $500,000): MPS will join CISE, ENG, GEO, and SBE in continuing to fund programs within this portfolio. Scientific research supported by MPS will improve predictive and risk-assessment capabilities, increasing resilience to reduce the impact on civilization of extreme events. Work on fundamental scientific issues, such as understanding the dynamic processes that produce extreme events, will advance knowledge and help to create tools for increased resilience of societal infrastructure to natural and anthropogenic hazards.

- SaTC (level at $2.0 million): Funding supports questions surrounding securing information networks against hostile intrusion and ensuring individual privacy in anonymized data sets present crucial challenges for society. Research supported by DMS through SaTC will provide a fresh look at such current cybersecurity challenges from the viewpoint of the mathematical sciences.

- SEES (-$3.0 million, to a total of $13.0 million): Support for SEES concludes at the end of FY 2017 as planned. Much of the remaining funding in MPS will focus on Sustainable Chemistry, Engineering, and Materials (SusChEM) research.

MPS Funding for Centers Programs and Facilities

MPS Funding for Centers Programs
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, Centers Programs	**$123.66**	**$88.89**	**$90.40**	**$1.51**	**1.7%**
Centers for Analysis & Synthesis (DMS)	0.20	0.20	0.20	-	-
Centers for Chemical Innovation (CHE)	36.66	28.10	29.50	1.40	5.0%
Materials Centers (DMR)[1]	79.66	56.00	56.00	-	-
Nanoscale Science & Engineering Centers (CHE, DMR)	0.50	0.50	0.50	-	-
Science & Techology Centers (DMR)	6.64	4.09	4.20	0.11	2.7%

Totals may not add due to rounding.

[1] Due to delayed awards processing, funding for FY 2015 includes $27.74 million carried over from FY 2014 and obligated in early FY 2015.

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

- Centers for Chemical Innovation (CCI) (+$1.40 million, to a total of $29.50 million): Funding is expected to support nine Phase II centers and up to three Phase I awards selected in a new competition planned for FY 2017. Total funding required for these centers is $41.40 million, depending on final number of awards made. Of this total, $29.50 million is provided in this Request. The remaining amount is expected to be provided via forward funding from prior fiscal years, co-funding by MPS/OMA, and support from the National Aeronautics and Space Administration (NASA) through an ongoing interagency agreement.

- Materials Research Science and Engineering Centers (MRSEC) ($56.0 million, no change from the FY 2016 Estimate): Funding will support approximately 20 MRSECs, with the precise number depending on the outcome of the next MRSEC competition in FY 2017.

- Nanoscale Science and Engineering Centers (level at $500,000): MPS continues to provide limited support to nanoscale-related centers as this centers program winds down as planned across NSF.

- Science and Technology Center (STC) Center for Integrated Quantum Materials (+$110,000, to a total of $4.20 million): DMR support will ramp up as planned for this STC from the FY 2013 cohort.

MPS Funding for Facilities

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, Facilities	**$279.42**	**$269.50**	**$294.58**	**$25.08**	**9.3%**
Arecibo Observatory	4.01	4.10	4.20	0.10	2.4%
Atacama Large Millimeter Array (ALMA)	40.17	40.35	43.25	2.90	7.2%
Cornell High Energy Synchrotron Source (CHESS)[1]	11.97	8.03	10.00	1.97	24.5%
Daniel K. Inouye Solar Telescope (DKIST)	7.00	11.00	16.00	5.00	45.5%
Gemini Observatory	20.61	19.88	20.42	0.54	2.7%
IceCube Neutrino Observatory (IceCube)	3.45	3.45	3.50	0.05	1.4%
Large Hadron Collider (LHC)	18.00	18.00	20.50	2.50	13.9%
Laser-Interferometer Gravitational Wave Observatory (LIGO)	33.00	39.43	39.43	-	-
National High Magnetic Field Laboratory (NHMFL)[2]	35.92	22.78	35.78	13.00	57.1%
National Nanotechnology Coordinated Infrastructure (NNCI)	2.88	2.88	2.88	-	-
National Optical Astronomy Observatories (NOAO)	25.50	21.60	21.83	0.23	1.1%
National Radio Astronomy Observatories (NRAO)[3]	43.14	41.73	32.00	-9.73	-23.3%
National Solar Observatory (NSO)[4]	8.00	9.50	6.00	-3.50	-36.8%
National Superconducting Cyclotron Laboratory (NSCL)	23.00	24.00	24.50	0.50	2.1%
Center for High Resolution Neutron Scattering (CHRNS)	2.77	2.77	2.79	0.02	0.7%
Other Astronomical Facilities[3]	-	-	11.50	11.50	N/A

Totals may not add due to rounding.

[1] Forward funding of $1.97 million in FY 2015 reduced the amount required in FY 2016.

[2] Forward funding of $11.88 million ($10.0 million from DMR and $1.88 million from CHE) in FY 2015 reduced the amount required in FY 2016.

[3] The decrease in NRAO support is due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMA; this funding is now under the "Other Astronomical Facilities" line in this table.

[4] Totals presented do not include $5.0 million in FY 2015, $9.0 million in FY 2016, and $11.50 million in FY 2017 for operations and maintenance support for the DKIST facility construction project. That funding is captured as part of the total presented in the DKIST line above.

For detailed information on individual facilities, please see the Facilities chapter.

MPS sustains or increases operations and maintenance budget levels for most of its large user facilities:

- Arecibo Observatory (+$100,000, to a total of $4.20 million): This increase covers added operating costs due to inflation. This value may change in FY 2016 depending on discussions with NSF/GEO and NASA as well as a baseline environmental survey.

- Atacama Large Millimeter Array (ALMA) (+$2.90 million, to a total of $43.25 million): Funding includes an increase of the annual contribution to the ALMA Development Fund agreed to by the international partners.

- Cornell High Energy Synchrotron Source (CHESS) (+$1.97 million, to a total of $10.0 million): MPS funding will support this national user facility of high-energy X rays, which serves researchers in fields of biology, engineering, and materials. In FY 2015, DMR forward funded CHESS by $1.97 million, reducing the amount required in FY 2016. The FY 2017 Request is consistent with the current cooperative agreement. (ENG and BIO contributions remain level at $5.0 million each.)

- Daniel K. Inouye Solar Telescope (DKIST) (+$5.0 million, to a total of $16.0 million): This increase

supports the continued ramp-up of DKIST operations within NSO from $9.0 million to $11.50 million, plus the DKIST cultural mitigation award held steady at $2.0 million. Of the $16.0 million total, $2.50 million will be used to support the construction of the Remote Operations Building. See the Major Research Equipment and Facilities Construction chapter for more detail.

- Gemini Observatory (+$540,000, to a total of $20.42 million): This level accounts for slight increases in operations and maintenance and in the instrument development fund as agreed to by the international Gemini Board.

- Large Hadron Collider (LHC) (+$2.50 million, to a total of $20.5 million): This level includes $18.0 million for operations and maintenance and $2.50 million for planning a potential Phase II LHC upgrade.

- National High Magnetic Field Laboratory (+$13.0 million, to a total of $35.78 million): This unique facility, using extremely high magnetic fields, enables transformative research in fields ranging from biology and chemistry, to materials and condensed matter physics. Forward funding of $11.88 million ($10.0 million from DMR and $1.88 million from CHE) in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request is consistent with the current cooperative agreement.

- National Optical Astronomy Observatory (NOAO) (+$230,000, to a total of $21.83 million): This change includes an increase in the NOAO base (+$530,000 to a total of $18.03 million) and a decrease for special projects in partnership with NASA and Department of Energy (DOE) (-$300,000 to a total of $3.80 million).

- National Radio Astronomy Observatories (-$9.73 million, to a total of $32.0 million): This decrease is due to the removal of the Green Bank Observatory (GBO) and the Very Long Baseline Array (VLBA) from the new NRAO cooperative agreement, expected in early FY 2017. GBO and VLBA funding is now captured under Other Astronomical Facilities line described below.

- National Solar Observatory (-$3.50 million, to a total of $6.0 million): Of the total change, most (-$2.50 million to zero) is due to the end of a one-time activity to make NSO Space Weather infrastructure more robust, and the rest (-$1.0 million, to a total of $6.0 million) is a decrease in NSO base support as emphasis shifts to DKIST operations.

- National Superconducting Cyclotron Laboratory (+$500,000, to a total of $24.50 million): Increased funding is pursuant to recent external site reviews that provided updated guidance on management and operations costs for the laboratory.

- Center for High Resolution Neutron Scattering (CHRNS) (+$20,000, to a total of $2.79 million): This small increase will support small (less than three percent) cost of living salary adjustments for CHRNS staff, postdocs, and technicians.

- Other Astronomical Facilities (+$11.50 million, to a total of $11.50 million): This funding is due to the removal of GBO and VLBA from the new NRAO cooperative agreement. See the NRAO bullet above.

Summary and Funding Profile

MPS supports core research, education, and research infrastructure. MPS will invest heavily in areas such as INFEWS, advanced manufacturing, CIF21, clean energy, and UtB, while increasing support for core research areas as well. Midscale instrumentation in several MPS divisions will be maintained in response to community needs.

In FY 2017, the number of research grant proposals to MPS is expected to increase relative to FY 2016, with research grant award funding rates expected to rise as a function of higher budgets.

In FY 2017, MPS will invest $90.40 million for Centers, about 6.3 percent of the FY 2017 Request. This ratio is similar to the FY 2016 Estimate. Centers are an important modality for MPS sciences as research in many MPS-supported disciplines, especially CHE and DMR, has evolved to be more collaborative and interdisciplinary.

Operations and maintenance funding for MPS-supported user facilities comprises almost 21 percent of the FY 2017 Request. Funding is maintained for most facilities in order to keep operational capacity current.

MPS Funding Profile

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Statistics for Competitive Awards:			
Number of Proposals	9,133	9,200	9,300
Number of New Awards	2,593	2,600	2,800
Funding Rate	28%	28%	30%
Statistics for Research Grants:			
Number of Research Grant Proposals	8,061	8,100	8,200
Number of Research Grants	2,050	2,100	2,300
Funding Rate	25%	26%	28%
Median Annualized Award Size	$124,932	$125,000	$150,000
Average Annualized Award Size	$148,606	$149,000	$149,100
Average Award Duration, in years	3.1	3.1	3.1

Program Monitoring and Evaluation

External Program Evaluations and Studies

- The MPS Advisory Committee (MPSAC) released a report in 2015, *Response to strategic plan for the Particle Physics Project Prioritization Panel*"[1] which provided a review of existing programs and suggested recommendations for balanced future plans for investments in particle physics.
- The Astronomy and Astrophysics Advisory Committee (AAAC) completed their annual report[2] on interagency activities by DOE, NASA, and NSF in March 2015. The next annual report is expected in March 2016.
- The National Research Council (NRC) of the National Academy of Sciences was commissioned to carry out a study of *A Strategy to Optimize the U.S. Optical/Infrared System in the Era of the Large*

[1] www.nsf.gov/mps/advisory/mpsac_other_reports_chron.jsp
[2] www.nsf.gov/mps/ast/aaac.jsp

Synoptic Survey Telescope.[3] Under the auspices of the NRC Committee on Astronomy and Astrophysics, the study was completed in May 2015. AST delivered an initial public response, including its proposed actions, in Dear Colleague Letter NSF 15-115[4] released in September 2015. Further details on the status of the response were reported to the American Astronomical Society at its January 2016 meeting. NSF continues to work with its awardee for NOAO and the Large Synoptic Survey Telescope (LSST) to refine and update the responses, which will be reported to the community at a variety of forums.

- AST continues to respond to the 2010 decadal survey in astronomy and astrophysics carried out under the auspices of the National Research Council. A recent update on the status of this response was published as Dear Colleague Letter NSF 15-044[5] in March 2015. This letter also included the status of the AST response to the AST Portfolio Review that was carried out by a subcommittee of the Advisory Committee for MPS in 2011-2012.
- AST, together with the NASA Astrophysics Division and the High Energy Physics Branch of the DOE Office of Science, has commissioned study 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 will meet three times in early FY 2016 with a final report expected in May 2016.
- In FY 2017, CHE will initiate an evaluation of the Centers for Chemical Innovation (CCI) program. Results are expected to be used to inform the design of future solicitations and center oversight. Final results are expected in FY 2019.
- DMS implemented recommendations of the 2013 report *The Mathematical Sciences in 2025*[6] by the Board on Mathematical Sciences and their Applications of the National Research Council. In response, DMS instituted the new Mathematical Sciences Innovation Incubator (MSII) activity.[7]
- NSF and DOE received a report[8] in October 2015 from the Nuclear Science Advisory Committee (NSAC) that provides a strategic plan for nuclear physics covering the next 10 years.
- NSF and DOE received a report[9] in October 2015 from a subcommittee of NSAC that was charged with providing additional guidance toward a next-generation detector of neutrino-less nuclear double beta decay.

Workshops and Reports

- To identify opportunities for chemical sciences to contribute to solving grand challenges at the nexus of food-energy-water systems, CHE sponsored the following series of workshops:
  - *Enabling Resiliency in Energy Water and Food Systems for Society: Addressing the Scientific, Technological and Societal Challenges of the Energy, Water and Food Nexus*, was held in April of 2015. The final report was published in 2015.[10]
  - *Closing the Human Phosphorous Cycle Workshop* covered chemical advances necessary for efficient use and recovery of the element, phosphorous. The workshop was held in June 2015 and the final report published.[11]
  - *FEWS: Food-Energy-Water Systems Challenging Chemists in the 21st Century* examined grand challenges related to water chemistry at the food-energy-water nexus. Co-sponsored with ENG/CBET, this workshop was held in October of 2015 and a report is forthcoming.

[3] http://sites.nationalacademies.org/BPA/BPA_087934
[4] www.nsf.gov/pubs/2015/nsf15115/nsf15115.jsp
[5] www.nsf.gov/pubs/2015/nsf15044/nsf15044.jsp
[6] www.nap.edu/catalog/15269/the-mathematical-sciences-in-2025
[7] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505044
[8] http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf
[9] http://science.energy.gov/~/media/np/nsac/pdf/docs/2016/NLDBD_Report_2015_Final_Nov18.pdf
[10] www.nsf.gov/mps/che/workshops/uarizona_few_nexus_workshop_report_final.pdf
[11] www.nsf.gov/mps/che/workshops/phosphorus_cycle_report_final.pdf

  - *Feeding the World in the 21st Century: Grand Challenges in the Nitrogen Cycle* covered chemical advances necessary for the efficient synthesis and use of nitrogen compounds for food production. Co-sponsored with ENG/CBET, this workshop was held in November of 2015 and the final report is forthcoming.
- The CCI program in CHE sponsored a CCI Diversity Forum, *Evidence-Based Practices for Broadening Participation in the Chemical Sciences* in May of 2015. The focus was drawing upon evidence-based practices from other programs and disciplines to develop strategic actions to broaden participation of the researchers in chemical sciences - racial and ethnic minorities, women, people with disabilities and veterans. The final report was submitted in 2015.[12]
- CHE supported a workshop on *Accelerating our Understanding of Supramolecular Chemistry in Aqueous Solutions* to identify multidisciplinary approaches for creating and understanding molecular assemblies in water. The workshop was held on May 31-June 4, 2015, and the final report is pending.
- DMR and CHE, together with the DOE Office of Basic Energy Sciences (BES) and the National Institute of Health (NIH), co-sponsored a workshop on *Ultrahigh Field NMR and MRI: Science at Crossroads* in November 2015. The workshop is a response to recommendations from the 2013 NRC report on *High Magnetic Field Science and its Applications in the United States: Current Status and Future Directions*.[13] The workshop's aim was to catalyze the development of a long-term ultrahigh field magnetic resonance science program in the U.S. The workshop report has been published.[14]
- DMR and the DOE/BES co-sponsored joint DOE/NSF Materials Genome Initiative (MGI) Principal Investigators' Meetings in January 2015 and January 2016. Bringing together investigators from NSF's DMREF program and the DOE's Predictive Theory and Modeling Program, the meetings are a venue for scientists to present and exchange information about their research, to foster new ideas and establish collaborations, and to discuss future research directions. They also help NSF and DOE in assessing the needs of this research community and in charting future directions.
- DMR, ENG's Division of Civil, Mechanical, and Manufacturing Innovation, and CISE's Division of Advanced Computational Infrastructure sponsored a workshop on Rise of Data in Materials Research in June 2015. The workshop provided an opportunity to discuss themes related to the rising importance of data in materials science with the aim of identifying high priority issues and work toward a concrete way forward to facilitate the emerging data revolution while fostering scientific excellence.
- DMR sponsored the *Condensed Matter Physics Broader Impacts Workshop* in January 2015. The workshop provided PI's with a venue to interact with each other and with program officers and to learn best practices for broader impacts. DMR also sponsored a workshop and a Webinar in 2015 for assistant professors seeking CAREER awards. PHY and DMR have been supporting Professional Skills Development Workshops for assistant professors organized by the American Physical Society for many years.
- DMR sponsored several workshops in 2015 that targeted a particular area of research or topic. Several workshops in 2016 will focus on ceramic science, polymer science, and soft condensed matter science.
- In response to the 2013 report of the project *Investing in the Next Generation through Innovative and Outstanding Strategies for Mathematics and Statistics* (INGenIOuS), DMS designed and implemented a new program in FY 2015, *Enriched Doctoral Training in the Mathematical Sciences* (EDT).[15] EDT, through research training, prepares Ph.D. students to recognize and find solutions to mathematical challenges arising in other fields and in areas outside today's academic setting. Following internal assessment of the first competitions of EDT, DMS convened a 2015 workshop at the Institute for Pure and Applied Mathematics that gathered input from representatives of business, industry, government, and academia on community needs, challenges, and opportunities in providing non-academic internship

[12] http://csp.umn.edu/wp-content/uploads/2015/07/Final-Report-CCI-Diversity-Forum.pdf
[13] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states
[14] https://sites.udel.edu/uhf-nmr-workshop/files/2015/08/UHF_workshop_report-176ncoq.pdf
[15] www.nsf.gov/funding/pgm_summ.jsp?pims_id=505083

experiences for mathematical sciences Ph.D. students.

- DMS sponsored a 2015 community workshop on *Mathematical Sciences Challenges in Quantum Information*. The workshop report highlights the centrality and importance of mathematical tools in the field, assesses outstanding theoretical quantum information challenges, and identifies new areas.[16]
- In collaboration with NIH, DMS supported an Innovations Lab held at the Statistical and Applied Mathematical Sciences Institute in FY 2015 on Interdisciplinary Approaches to Biomedical Data Science Challenges. The activity fostered the formation of new interdisciplinary collaborations among mathematicians, statisticians, and biomedical science researchers. A Dear Colleague Letter, *Unsolicited Proposals for Quantitative Approaches to Biomedical Big Data (QuBBD)*[17] was issued to encourage proposals for collaborative research planning grants in this topic area, and ten planning grants were issued. A second Innovations Lab will be held in FY 2016.

Committees of Visitors (COV)

- In FY 2015, COVs reviewed AST, DMR, and PHY.[18]
- In FY 2016, COVs will review DMS and CHE.

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.

Number of People Involved in MPS Activities

	FY 2015 Actual Estimate	FY 2016 Estimate	FY 2017 Estimate
Senior Researchers	7,847	8,000	8,600
Other Professionals	3,232	3,100	3,300
Postdoctoral Associates	2,032	2,000	2,200
Graduate Students	9,022	8,700	9,400
Undergraduate Students	5,832	5,400	5,800
Total Number of People	**27,965**	**27,200**	**29,300**

[16] https://sites.google.com/site/mathqinfo2015/report.pdf
[17] www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf15093
[18] www.nsf.gov/mps/advisory/cov.jsp

DIVISION OF ASTRONOMICAL SCIENCES (AST) $262,610,000
+$15,880,000 / 6.4%

AST Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, AST	**$245.23**	**$246.73**	**$262.61**	**$15.88**	**6.4%**
Research	**67.65**	**62.32**	**73.16**	**10.84**	**17.4%**
CAREER	4.84	4.89	4.90	0.01	0.2%
Education	**5.49**	**6.50**	**6.00**	**-0.50**	**-7.7%**
Infrastructure	**172.09**	**177.91**	**183.45**	**5.54**	**3.1%**
Arecibo Observatory	4.01	4.10	4.20	0.10	2.4%
Atacama Large Millimeter Array (ALMA)	40.17	40.35	43.25	2.90	7.2%
Daniel K. Inouye Solar Telescope (DKIST)	7.00	11.00	16.00	5.00	45.5%
Gemini Observatory	20.61	19.88	20.42	0.54	2.7%
National Optical Astronomy Observatory (NOAO)	25.50	21.60	21.83	0.23	1.1%
National Radio Astronomy Observatory (NRAO)[1]	43.14	41.73	32.00	-9.73	-23.3%
National Solar Observatory (NSO)[2]	8.00	9.50	6.00	-3.50	-36.8%
Other Astronomical Facilities[1]	-	-	11.50	11.50	N/A
Mid-Scale Innovations Program (MSIP)	12.95	19.25	18.00	-1.25	-6.5%
Research Resources	10.71	10.50	10.25	-0.25	-2.4%

Totals may not add due to rounding.

[1] The decrease in NRAO support in FY 2017 is due to the separation of the Green Bank Observatory and the Very Long Baseline Array from NRAO and ALMA; this funding is now included under the "Other Astronomical Facilities" line in this table.

[2] The totals presented do not include $5.0 million in FY 2015, $9.0 million in FY 2016, and $14.0 million in FY 2017 for operations and maintenance support for the DKIST facility construction project. That funding is captured as part of the total presented in the DKIST line above.

The FY 2017 Budget Request for AST is $262.61 million, of which $247.73 million is discretionary funding and $14.88 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

AST is the federal steward for ground-based astronomy in the U.S., funding research with awards to individual investigators and small research groups and via cooperative agreements for the operation of large telescope facilities. These telescope facilities provide world-leading, one-of-a-kind observational capabilities on a competitive basis to thousands of astronomers each year. These facilities also 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.

In general, 24 percent of the AST portfolio is available for new research grants and 76 percent is available for continuing grants. About 70 percent of AST's budget supports the forefront instrumentation and

facilities needed for progress at the frontiers of observational astronomy, while almost 28 percent supports the research of individual investigators. Through the MREFC appropriation, AST also oversees the construction of LSST and DKIST.

In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics,*[19] the NRC committee recommended that "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." In response to this recommendation, the Division of Astronomical Sciences (AST) conducted a community-based review of its portfolio. The resulting Portfolio Review Committee (PRC) report, *Advancing Astronomy in the Coming Decade: Opportunities and Challenges*[20] was released in August 2012 and included recommendations about all of the major AST telescope facilities.

In FY 2012 and FY 2013, AST began actively to engage in facility partnership discussions with other federal agencies and university-based groups. In FY 2014 and FY 2015, AST continued those talks, and NSF brought a general engineering contractor on-board for all its engineering and environmental reviews. In the first half of FY 2016, the contractor will deliver final feasibility reports for divestment alternatives, which will provide the results of baseline engineering and environmental surveys of a number of individual telescopes and observatories. Once NSF has identified viable options for divestment, it will embark on formal reviews in FY 2016 and FY 2017 to evaluate environmental impacts of these options, including partnership opportunities that could have impacts to the environment. Details for individual facilities are described in the Facilities chapter of this Budget Request.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$10,000, to a total of $4.90 million): This continues AST's commitment to early-career investigators.
- Disciplinary and interdisciplinary research programs (+$10.15 million, to a total of $63.60 million): Support for fundamental research is a major focus. This increase will allow additional support to the Astronomy and Astrophysics (AAG) research program with a particular emphasis on cross-agency activities in
  - Optics and Photonics (-$500,000, to a total of $1.50 million): Decrease is due to low proposal pressure and higher priority needs in core research funding
  - CIF21 (+$1.45 million, to a total of $3.30 million): Funding supports LSST development and other CIF21 activities.
  - Networking and Information Technology Research and Development (NITRD) program (level at $7.67 million).
- Enhancing Access to the Radio Spectrum (EARS) (-$1.0 million to zero): AST is not funding this program in FY 2017 due to relatively low community demand.

[19] www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics
[20] www.nsf.gov/mps/ast/ast_portfolio_review.jsp

Education

- Partnerships in Astronomy and Astrophysics Research and Education (PAARE) (-$500,000, to a total of $1.50 million): Reduced proposal demand for PAARE in FY 2016 has resulted in a shift in the funding balance between PAARE and other workforce development and early-career programs.

Infrastructure

- ALMA (+$2.90 million, to a total of $43.25 million): Funding includes an increase of the annual contribution to the ALMA Development Fund agreed to by the international partners.
- Arecibo Observatory (+$100,000, to a total of $4.20 million): The increase covers added operating costs due to inflation.
- DKIST (+$5.0 million, to a total of $16.0 million): This increase supports the continued ramp-up of DKIST operations within NSO from $9.0 million to $11.50 million, plus the DKIST cultural mitigation award held steady at $2.0 million. Of the $16.0 million total, $2.50 million will be used to support the construction of the Remote Operations Building. See the Major Research Equipment and Facilities Construction chapter for more detail.
- Gemini Observatory (+$540,000, to a total of $20.42 million): This level accounts for slight increases in operations and maintenance and in the instrument development fund as agreed to by the international Gemini Board.
- NOAO (+$230,000, to a total of $21.83 million): This change includes an increase in the NOAO base (+$530,000 to a total of $18.03 million) and a decrease for special projects in partnership with NASA and DOE (-$300,000, to a total of $3.80 million).
- NRAO (-$9.73 million, to a total of $32.0 million): This decrease is due to the removal of the Green Bank Observatory (GBO) and the Very Long Baseline Array (VLBA) from the NRAO base budget in FY 2017. Funding for GBO and VLBA is captured in the Other Astronomical Facilities line as discussed below.
- NSO (-$3.50 million, to a total of $6.0 million): Of the total change, most (-$2.50 million to zero) is due to the end of a one-time activity to make NSO Space Weather infrastructure more robust, and the rest (-$1.0 million to a total of $6.0 million) is due to a decrease in NSO base support as emphasis shifts to DKIST operations.
- Other Astronomical Facilities (+$11.50 million, to a total of $11.50 million): This line captures operational support for GBO and VLBA, which were moved from the NRAO base budget as noted in the NRAO bullet above.
- Mid-Scale Innovations Program (MSIP) (-$1.25 million, to a total of $18.0 million): This change is due to re-balancing MSIP with core individual investigator programs for which funding also decreases.
- Research Resources (-$250,000, to a total of $10.25 million): This decrease, to a total of $250,000, constitutes the final increment of a five-year planning award for the Giant Segmented Mirror Telescope that is scheduled to end in FY 2017. Funding for other activities on this line, the Advanced Technologies and Innovation program and Dark Energy Survey Data Management, remain constant at about $8.0 million and $2.0 million, respectively.

DIVISION OF CHEMISTRY (CHE) $262,160,000
+$15,850,000 / 6.4%

CHE Funding

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, CHE	**$246.29**	**$246.31**	**$262.16**	**$15.85**	**6.4%**
Research	**232.65**	**235.15**	**249.88**	**14.73**	**6.3%**
CAREER	28.10	23.91	24.18	0.27	1.1%
Centers Funding (total)	34.91	28.35	29.75	1.40	4.9%
Centers for Chemical Innovation	34.66	28.10	29.50	1.40	5.0%
Nanoscale Science & Engineering Centers	0.25	0.25	0.25	-	-
Education	**6.34**	**5.85**	**5.05**	**-0.80**	**-13.7%**
Infrastructure	**7.30**	**5.31**	**7.23**	**1.92**	**36.2%**
National High Magnetic Field Laboratory (NHMFL)[1]	1.88	-	1.92	1.92	N/A
National Nanotechnology Coordinated Infrastructure (NNCI)	0.20	0.30	0.30	-	-
Research Resources	5.22	5.01	5.01	-	-

Totals may not add due to rounding.

[1] Forward funding of $1.88 million in FY 2015 reduced to zero the amount required in FY 2016.

The FY 2017 Budget Request for CHE is $262.16 million, of which $247.31 million is discretionary funding and $14.85 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

CHE supports a large and vibrant research community engaged in fundamental molecular and nano-science research linked to key national priorities. CHE will enable research in sustainability and clean energy, providing new molecules and tools that are essential to our economy and well-being. Through the development of new methodologies in chemical synthesis and catalysis, CHE is a natural contributor to advanced manufacturing technology. CHE strongly supports research at the interfaces with biology and materials science, within both experimental and theoretical/computational frameworks. CHE-supported research will also enable new solutions to problems at the nexus of food, energy and water systems. CHE's programs invite research in catalysis for energy capture and storage as well as for the formation of new chemical bonds, appreciation of, and insight into, the chemistry of life processes, new nano-structured materials that will revolutionize electronics and photonics, and better awareness of how nano-size aerosols and particles impact our environment. In addition, CHE supports curiosity-driven research that leads to increased understanding of molecules and their chemical transformation, as well as the development of new instrumentation to study and detect molecules.

In general, 63 percent of the CHE portfolio is available for new research grants, and the remaining 37 percent is used primarily to fund continuing grants made in the previous years. Almost 86 percent of CHE's budget is used to support individuals and small groups of researchers, while over 14 percent of the budget supports centers and facilities.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$270,000, to a total of $24.18 million): CHE continues its commitment to young investigators; this investment level scales with the divisional budget.
- Disciplinary and Interdisciplinary Research (+$12.42 million, to a total of $191.32 million): Support for fundamental research is a major focus. This increase will allow added funding for research awards with a particular emphasis on activities below:
  - Advanced Manufacturing (-$5.20 million, to a total of $14.54 million) continues to be important for CHE, with projects supported both through unsolicited individual investigator awards and through the Centers for Chemical Innovation program. Reductions in funding are due to competing priorities within the individual investigator portfolio.
  - BioMaPS (no change at $3.24 million): Research at the chemistry-biology interface is an important area of the chemical sciences. Funding will strengthen research programs in advanced spectroscopic and imaging techniques for biomolecules and biosystems, metal speciation, coordination and function, chemical studies of enzyme and ribozyme catalysis, and other studies at the chemistry-biology frontier.
  - CIF21 (+$800,000, to a total of $2.65 million): CHE will accelerate research by investing in new functional capabilities in computational methods, algorithms, tools and data core methods, and technologies.
  - Clean Energy (+$21.31 million, to a total of $90.0 million): Additional research in the CHE clean energy portfolio includes hydrogen, fuel cells, biomass, solar energy, hydrocarbon conversion, the capture and use of CO_2, and energy storage.
  - INFEWS (+$1.0 million, to a total $3.0 million): Increased support of research will occur in this NSF-wide program via joint solicitations, Dear Colleague Letters, and unsolicited proposals to divisional programs.
  - UtB (-$1.08 million, to a total $3.80 million): CHE continues support for this cross-NSF activity. The reduction brings the commitment in line with the FY 2015 level and reflects competing priorities within the individual investigator portfolio.
- Centers for Chemical Innovation (+$1.40 million, to a total of $29.50 million): Funding is expected to support nine Phase II centers and up to three Phase I awards selected in a new competition planned for FY 2017. An evaluation of this program is anticipated to begin in FY 2017.

Education

- Research Experiences for Undergraduates (REU) (level at $5.05 million): CHE maintains a commitment to REU Sites and REU Supplements activities.

Infrastructure

- NHMFL (+$1.92 million, to a total of $1.92 million): CHE funding supports the maintenance and operation of the 21-Tesla magnet at the Ion Cyclotron Resonance (ICR) facility. Forward funding of $1.88 million in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request level is consistent with the commitment in the current cooperative agreement.
- Research Resources (no change at $5.01 million): This includes support for the Chemistry and Materials Consortium for Advanced Radiation Sources (ChemMatCARS) at Argonne National Laboratory and for highly meritorious Major Research Instrumentation (MRI) program proposals.

DIVISION OF MATERIALS RESEARCH (DMR) $329,710,000
+$19,680,000 / 6.3%

DMR Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, DMR[1]	**$337.62**	**$310.03**	**$329.71**	**$19.68**	**6.3%**
Research	**273.69**	**250.65**	**261.05**	**10.40**	**4.1%**
CAREER	23.28	21.53	21.78	0.25	1.2%
Centers Funding (total)	86.55	60.34	60.45	0.11	0.2%
Materials Research Science & Engineering Centers[1]	79.66	56.00	56.00	-	-
Nanoscale Science & Engineering Centers	0.25	0.25	0.25	-	-
STC1: Center for Layered Polymeric Materials	2.66	-	-	-	N/A
STC2: Center for Integrated Quantum Materials	3.98	4.09	4.20	0.11	2.7%
Education	**11.14**	**5.60**	**5.60**	**-**	**-**
Infrastructure	**52.79**	**53.78**	**63.06**	**9.28**	**17.3%**
Cornell High Energy Synchrotron Source (CHESS)[2]	11.97	8.03	10.00	1.97	24.5%
National High Magnetic Field Laboratory (NHMFL)[3]	34.04	22.78	33.86	11.08	48.6%
National Nanotechnology Coordinated Infrastructure (NNCI)	2.68	2.58	2.58	-	-
Mid-scale Research Infrastructure	-	16.29	12.50	-3.79	-23.3%
Research Resources	1.33	1.33	1.33	-	-
Center for High Resolution Neutron Scattering (CHRNS)	2.77	2.77	2.79	0.02	0.7%

Totals may not add due to rounding.

[1] Due to delayed awards processing, funding for FY 2015 includes $27.74 million carried over from FY 2014 and obligated in early FY 2015.

[2] Forward funding of $1.97 million in FY 2015 reduced the amount required in FY 2016.

[3] Forward funding of $10.0 million in FY 2015 reduced the amount required in FY 2016.

The FY 2017 Budget Request for DMR is $329.71 million, of which $311.03 million is discretionary funding and $18.68 million is new mandatory funding. The mandatory funding is within the Research line in the above table**.**

DMR research looks at advancing materials discovery, design, synthesis, and characterization. Programs focus 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. DMR awards enable understanding of the electronic, atomic, and molecular mechanisms and processes that govern macroscale to nanoscale properties, manipulation and control of these properties, discovery of emerging phenomena, and creation of novel design, synthesis, and processing strategies that lead to new materials with unique characteristics.

These discoveries transcend traditional scientific and engineering disciplines. They enable new technologies that meet societal needs. DMR-supported research is essential for the development of future technologies and industries. A critical enabler to these scientific advances is the investment in the materials workforce, cyberinfrastructure, materials centers, and next generation instruments and facilities, including support for mid-scale user facilities called Materials Innovation Platforms (MIP). A MIP, in addition to providing access to new instrumentation, conducts research on a materials challenge by integrating

synthesis, characterization, and materials theory or modeling. It aligns with goals of Advanced Manufacturing as well as the national Materials Genome Initiative. Finally, conveying the exciting science and the societal benefit enabled by materials research to students and to the general public remains an important aspect of the division's mission.

In general, about 33 percent of the DMR portfolio is available for new research grants and 67 percent goes to continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$250,000, to a total of $21.78 million): DMR places high priority on these grants in order to develop a pipeline of new faculty who will help form the community of the future.
- Disciplinary and Interdisciplinary Research (+$9.24 million, to a total of $172.97 million): Support for fundamental research is a major focus. This increase will allow added funding for research awards with a particular emphasis on activities below:
  - CEMMSS: DMR participates in the CEMMSS and Advanced Manufacturing initiatives (both level at $23.67 million) through DMREF (+$1.65 million, to $13.90 million), MIP (described below under Research Infrastructure), the Scalable Nanomanufacturing program, and through MRSECs and other core program investments. DMREF and MIP (described below under Research Infrastructure) are major efforts to accelerate the discovery and deployment of new materials with a specific and desired function or property through synergistic integration of theory and computation, experiments, and systematic use of materials data. These latter activities are well aligned with the Materials Genome Initiative.
  - CIF21 (level at $2.65 million): Support continues for research in the cyberinfrastructure needed for CEMMSS/DMREF and MIP, by investing in new functional capabilities in computational methods, algorithms, tools and data core methods, and technologies.
  - Clean Energy (+$13.24 million, to a total of $83.36 million): Funding supports fundamental materials research that enables advances in hydrogen production, fuel cells, biomass, solar energy, hydrocarbon conversion, the capture and use of CO_2, and energy storage
  - SEES (level at $3.0 million): Support for SEES comes through the Sustainable Chemistry, Engineering and Materials (SusChEM) program, with a focus on fundamental materials research. As SEES sunsets as planned in FY 2017, DMR will begin investments in sustainable materials through INFEWS at $3.0 million.
  - UtB (-$1.08 million, to a total of $3.80 million): DMR increased support in this agency-wide focus in FY 2016. The FY 2017 Request returns to the FY 2015 level. Some of the DMR investment in UtB are connected to activities supported by BioMaPS.
- MRSECs (level at $56.0 million): MRSECs support interdisciplinary materials research and education of the highest quality while addressing fundamental problems in materials science of a scope and complexity requiring the scale and synergy provided by a center.
- STCs (+$109,000, to a total of $4.20 million): The materials community has been very active in seeking STC funding. A ramp up in support for the Center on Integrated Quantum Materials from the 2013 cohort is consistent with the current cooperative agreement. Funding for the Center for Layered Polymeric Systems from the 2005 cohort ended as planned in FY 2015 after ten successful years.

Education[21]

- REU (level at $5.17 million): DMR's education portfolio maintains commitments to this program that supports active participation in scientific research by undergraduate students in meaningful ways.

Infrastructure

- CHESS (+$1.97 million, to a total of $10.0 million): Funding will support this national user facility of high-energy X-rays, which serves researchers in fields of biology, engineering, and materials. Forward funding of $1.97 million in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request is consistent with the current cooperative agreement. (ENG and BIO contributions remain level at $5.0 million each.)
- NHMFL (+$11.08 million, to a total of $33.86 million): This unique facility, using extremely high magnetic fields, enables transformative research in fields ranging from biology, chemistry, to materials and condensed matter physics. Forward funding of $10.0 million in FY 2015 reduced the amount required in FY 2016. The FY 2017 Request is consistent with the commitment in the current cooperative agreement.
- Mid-scale Research Infrastructure (-$3.79 million, to a total of $12.50 million): Launch of the Materials Innovation Platforms (MIP), originally planned for FY 2015, was delayed to FY 2016. The two MIPs in the inaugural class embrace the goals set forth by the Materials Genome Initiative and include closed-loop efforts in materials synthesis, characterization, theory, modeling and/or simulation. They are designed to help enabling Advanced Manufacturing capability in the U.S. through support of bulk crystal growth, as well as fabrication of novel materials. The decrease in the FY 2017 Request reflects a planned ramp down of equipment purchases in the second year. MIP competitions are planned triennially. The next competition is currently scheduled for FY 2018.
- Research Resources (level at $1.33 million): This funding supports the Chemistry and Materials Consortium for Advanced Radiation Sources (ChemMatCARS) and instrumentation for materials research.
- Center for High Resolution Neutron Scattering (CHRNS) (level at $2.77 million): Funding is held level for this effort.

[21] FY 2015 Actual funding under Education includes education activities, such as REU awards, via the MRSECs. FY 2016 Estimate and FY 2017 Request funding captures these activities on the MRSEC line under Research.

DIVISION OF MATHEMATICAL SCIENCES (DMS) $249,170,000
+$15,120,000 / 6.5%

DMS Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, DMS	**$235.43**	**$234.05**	**$249.17**	**$15.12**	**6.5%**
Research	**223.27**	**226.56**	**241.68**	**15.12**	**6.7%**
CAREER	13.05	9.65	9.85	0.20	2.1%
Centers Funding (total)	0.20	0.20	0.20	-	-
Centers for Analysis & Synthesis	0.20	0.20	0.20	-	-
Education	**12.16**	**7.49**	**7.49**	**-**	**-**

Totals may not add due to rounding.

The FY 2017 Budget Request for PHY is $249.17 million, of which $235.05 million is discretionary funding and $14.12 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

DMS plays a critical role in providing more than 60 percent of all U.S. federal support of basic research at the frontiers of discovery in the mathematical sciences.

The influence of mathematical sciences on daily life is fundamental and pervasive; for example, every secure commercial transaction on the internet is an application of research in number theory and algebraic geometry, and similarly many of the modern smart materials used in advanced manufacturing are the result of mathematical analysis and simulation. 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 research programs in mathematics and statistics, DMS supports a range of other investments that advance research, increase the impact of the mathematical sciences, respond to national needs, and expand the U.S. talent base engaged in mathematical and statistical research. These include mathematical sciences research institutes, multi-agency programs such as a joint activity in biosciences with the National Institute of General Medical Sciences, as well as initiatives in data science. A newer DMS activity, the Mathematical Sciences Innovation Incubator, supports the involvement of the mathematical sciences community in collaborative research projects that address national priorities, including the National Strategic Computing Initiative (SCI), climate science research, and clean energy research. The DMS workforce program offers funding opportunities that support efforts to increase the number of well-prepared students who pursue careers in the mathematical sciences in all sectors. These investments in mathematical sciences discovery, connections, and community are essential components of the innovation engine that drives the nation's economy in the 21st century.

In general, 52 percent of the DMS portfolio is available for new research grants and 48 percent goes to continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- CAREER (+$200,000, to a total of $9.85 million): Support for early-career researchers is a division priority. This increase allows DMS to support larger CAREER awards.
- Disciplinary and Interdisciplinary Research (+$14.30 million, to a total of $226.51 million): Support for fundamental research is a major focus. This increase will allow added funding for research awards with a particular emphasis on activities below:
  - BioMaPS (level at $3.26 million): DMS invests in this area in a comprehensive approach to acquire insight into and inspiration from the living world.
  - CEMMSS (+$3.50 million, to a total of $5.60 million): Funding will accelerate fundamental discoveries in materials science and Advanced Manufacturing by investing in new capabilities for mathematical modeling, computational simulation, numerical algorithms, and data analysis and management.
  - CIF21 (+$1.60 million, to a total of $4.90 million): Increased investment will promote the creation and development of the next generation of mathematical and statistical theories and tools that address the challenges presented to the scientific and engineering communities by the ever-expanding role of computational modeling and simulation on the one hand, and the explosion in production of digital and observational data on the other.
  - INFEWS (level at $400,000) and Risk and Resilience (level at $500,000): Research on fundamental scientific issues, such as understanding the dynamical processes that produce extreme events, will advance knowledge and help to create tools for increased resilience of societal infrastructure to natural and anthropogenic hazards.
  - Optics and Photonics (+$2.0 million, to a total of $3.50 million): Investment here reflects increased community interest. DMS leads MPS participation in this multidisciplinary, NSF-wide activity, which is key to enabling technologies in a multitude of application. DMS coordinates the crosscutting Optics and Photonics Working Group that manages co-review of multidisciplinary proposals in collaboration with other participating directorates. The activity will be highlighted through community workshops and the development of a program solicitation.
  - SaTC (level at $2.0 million): Funding reflects continued national need for fundamental cybersecurity research, which investigates questions surrounding securing information networks against hostile intrusion and ensuring individual privacy in anonymized data sets.
  - UtB (+$425,000, to a total of $5.30 million): DMS support increases scientific understanding of the full complexity of the brain, in action and in context, through targeted, cross-disciplinary investments.
  - Mathematical Sciences Research Institutes (-$2.0 million, to a total of $25.20 million): Seven DMS-supported institutes will continue to catalyze frontier research through an array of scientific programs.

Education

- REU (level at $3.39 million): Funding commitments continue to these research experiences for undergraduate students.
- Mathematical Sciences Postdoctoral Research Fellowships (level at $4.10 million). Investments continue in a number of education and diversity activities through the program.

DIVISION OF PHYSICS (PHY)

$295,260,000
+$18,230,000 / 6.6%

PHY Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, PHY	**$276.10**	**$277.03**	**$295.26**	**$18.23**	**6.6%**
Research	**169.33**	**174.51**	**189.69**	**15.18**	**8.7%**
CAREER	8.83	7.55	7.74	0.19	2.5%
Education	**5.60**	**5.16**	**5.16**	**-**	**-**
Infrastructure	**101.17**	**97.36**	**100.41**	**3.05**	**3.1%**
IceCube	3.45	3.45	3.50	0.05	1.4%
Large Hadron Collider (LHC)	18.00	18.00	20.50	2.50	13.9%
Laser Interferometer Grav. Wave Obs. (LIGO)	33.00	39.43	39.43	-	-
Nat'l Superconoducting Cyclotron Lab. (NSCL)	23.00	24.00	24.50	0.50	2.1%
Midscale Research Infrastructure	23.72	12.48	12.48	-	-

Totals may not add due to rounding.

The FY 2017 Budget Request for PHY is $295.26 million, of which $278.53 million is discretionary funding and $16.73 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

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.

In general, about 21 percent of the PHY portfolio is available for new research grants. The remaining 79 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 (32 percent).

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate level.

Research

- CAREER (+$190,000, to a total of $7.74 million): This modest increase continues PHY's commitment to early-career researchers.
- Disciplinary and Interdisciplinary Research (+$14.28 million, to a total of $176.82 million): Support

for fundamental research is a major focus. Funding will allow added emphasis on NSF-wide investments such as these:

- BioMaPS (flat at $3.26 million): This initiative provides for programs that support research at the interface between the mathematical and physical sciences and the life sciences.
- CEMMSS (-$1.0 million, to a total of $3.33 million): Decreased support reflects other division priorities.
- CIF21 (+$800,000, to a total of $2.65 million): Increased support is due to continued strong community interest in this area.
- UtB (+$930,000 to $5.80 million): This provides support for physics-based research that enables scientific understanding of the full complexity of the brain, in action and in context.

Education

- REU (level at $5.06 million): Funding is level in this research experiences program for undergraduates.
- Additionally, $650,000 will support efforts to broaden participation by groups traditionally underrepresented in the physical sciences. Support will be made through internal co-funding.

Infrastructure

- IceCube (+$50,000, to a total of $3.50 million): Funding reflects a slight increase in operations per the cooperative agreement.
- LHC (+$2.50 million, to a total of $20.50 million): This supports operations of the ATLAS and CMS detectors at LHC. The additional funding during enables research and development and planning that could possibly lead to a major construction upgrade beginning in FY 2020.
- LIGO (level at $39.43 million): This supports operations of LIGO and commissioning of its upgraded interferometer following completion of the Advanced LIGO construction project in FY 2014.
- NSCL (+$500,000, to a total of $24.50 million): This supports operations of the NSCL at Michigan State University. Added funding enables support for full operations of NSCL, including the recently commissioned reacceleration facility (ReA3). Recent external site reviews provided updated guidance on management and operations costs for the laboratory.
- Midscale Research Infrastructure (level at $12.48 million): Support will continue for midscale level instrumentation support. (The large number in FY 2015 is due to forward funding from FY 2014 of existing commitments.)

OFFICE OF MULTIDISCIPLINARY ACTIVITIES (OMA) $37,540,000
+$2,540,000 / 7.3%

OMA Funding
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request	Change Over FY 2016 Estimate Amount	Change Over FY 2016 Estimate Percent
Total, OMA	**$35.65**	**$35.00**	**$37.54**	**$2.54**	**7.3%**
Research	**29.78**	**27.39**	**30.00**	**2.61**	**9.5%**
CAREER	0.96	-	-	-	N/A
Education	**5.87**	**7.61**	**7.54**	**-0.07**	**-0.9%**

Totals may not add due to rounding.

The FY 2017 Budget Request for OMA is $37.54 million, of which $35.41 million is discretionary funding and $2.13 million is new mandatory funding. The mandatory funding is within the Research line in the above table.

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 by multi-investigator, multidisciplinary teams, as well as cross-NSF and interagency activities.

In FY 2017, OMA will focus on multidisciplinary research (chiefly through award co-funding) that emphasizes the mathematical and physical scientific foundations of sustainability. This includes issues affecting the nexus of food, energy, and water; fundamental science critical to the discovery, understanding, and development of new materials; fundamental scientific advancements that are enabled by investments in midscale infrastructure, basic research at the interface between the mathematical and physical sciences and the life sciences that will lead to new insights into the molecular basis of life processes and to a better understanding of the healthy human brain and that of model animal species; multidisciplinary explorations in optics and photonics, including light-matter interaction at the nanoscale that encompass materials, devices, and systems; the understanding, control, and manipulation of the behavior of quantum matter and the limitations of quantum information processing, including the roles of spintronics and topological insulators; and team efforts aimed at the development of next-generation instrumentation to enable fundamental advances across a wide spectrum of disciplines. OMA also will provide leadership and support for I-Corps™ activities within MPS.

In general, about 54 percent of the OMA portfolio is available for new research grants and 46 percent is available for continuing grants.

FY 2017 Summary

All funding decreases/increases represent change over the FY 2016 Estimate.

Research

- Disciplinary and Interdisciplinary Research (+$5.57 million, to a total of $20.80 million): In FY 2017, OMA will focus on multidisciplinary research that addresses the key MPS and NSF-wide investments such as Optics and Photonics, INFEWS, CIF21, CEMMSS, BioMaPS, Clean Energy, UtB, and I-Corps™.

- I-Corps™ (level at $1.70 million): Investments are directed to an assessment of the commercial viability of the scientific discoveries in MPS disciplines through the individual investigator award program.
- INSPIRE (-$3.0 million to zero): Through a planned phase-out the OMA investment decreases to zero.

Education

- Career Life Balance (level at $400,000): OMA will coordinate these award supplements for the directorate.
- NRT: Funding for NRT increases (+$290,000, to a total of $4.54 million) while final commitments within the Integrative Graduate Education and Research program (-$220,000 to zero) were completed in FY 2016. OMA will contribute the entire amount of NRT funding for MPS.

Facilities

- Portfolio analysis (no change, for a total up to $7.0 million): OMA will support responsible decision making regarding implementation of portfolio analysis recommendations. This investment will support studies of possible environmental issues, stewardship transition costs, or partnership program start-up costs.