NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

Total Funding for NNI
(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	$48.80	$48.80	$48.80
Computer and Information Science and Engineering	13.75	13.75	13.75
Education and Human Resources	2.50	2.50	2.50
Engineering	219.95	168.50	168.50
Geosciences	0.30	0.30	0.30
Mathematical and Physical Sciences	203.07	180.62	180.37
Social, Behavioral, and Economic Sciences	1.30	0.53	0.53
Office of International Science and Engineering	0.10	0.10	0.10
Total, NNI	**$489.77**	**$415.10**	**$414.85**

Totals may not add due to rounding.

NSF's contribution to the multiagency National Nanotechnology Initiative (NNI) encompasses the systematic understanding, organization, manipulation, and control of matter at the atomic, molecular, and supramolecular levels in the size range of about 1 to 100 nanometers. Novel materials, devices, and systems – with their building blocks designed on the scale of nanometers – open up new directions in science, engineering, and technology with potentially profound implications for society. With the capacity to control and manipulate matter at this scale, science, engineering, and technology researchers are realizing revolutionary advances in areas such as order-of-magnitude faster computers with less energy consumption; catalysts for industry; molecular medicine; imaging and understanding of the brain; nanosensors to monitor health and the environment; efficient and large-scale nanomanufacturing; more resilient materials and system architectures; and sustainable development for water, energy, and food resource utilization. NSF contributes to the NNI goals and five Program Component Areas (PCAs) outlined in the 2014 NNI Strategic Plan and the NNI Supplement to the President's Budget for Fiscal Year 2017.[1] Funding by PCA is shown at the end of this discussion.

FY 2017 NNI Funding

NSF supports nanoscale science and engineering throughout all the research and education directorates as a means to advance discovery, invention, and innovation and to integrate various fields of research. NNI enables increased interdisciplinarity at atomic and molecular levels for about 6,000 active awards with full or partial contents on nanoscale science and engineering (NSE). Approximately 10,000 students and teachers will be educated and trained in NSE in FY 2017.

Overall, total NNI funding in the FY 2017 Request is $414.85 million, a decrease of $250,000 from the FY 2016 Estimate of $415.10 million.

Several new directions planned for FY 2017 are nanotechnology for brain-like computing, nanobiomanufacturing, food-energy-water processes, nanomodular materials and systems by design including two-dimensional nanoscale materials, and emerging aspects of nanoelectronics, photonics, and neuroscience. NSF sponsors an annual NSE grantee conference to assess the progress in nanotechnology and facilitate identification of new research directions.[2]

[1] www.nano.gov
[2] 2015 Nanoscale Science and Engineering Grantees Conference: www.nsf.gov/nano and www.nseresearch.org/2015

In FY 2017, NSF support will increasingly focus on convergence research and education activities in confluence with other priority areas such as: the National Strategic Computing Initiative (NCSI); Science, Engineering, and Education for Sustainable Chemistry, Engineering and Materials (SusChEM); Research at the Interface of Biological, Mathematical and Physical Sciences, and Engineering (BioMaPS); Designing Materials to Revolutionize and Engineer our Future (DMREF); Materials Genome Initiative; Smart Systems; Quantum Information Science and Engineering; and synthetic biology. Partnerships of new NERCs with small businesses in the areas of nanomanufacturing and commercialization will be strengthened while maintaining about the same level of NSF investment. A new industrial internship in emerging nanotechnology areas is planned with IBM. NSF continues its contributions to translational innovation programs, including Grant Opportunities for Academic Liaison with Industry (GOALI); Industry/University Cooperative Research Centers (I/UCRC); the NSF Innovation Corps (I-Corps™) program; and the two subcomponents of Partnerships for Innovation (PFI): Accelerating Innovation Research (AIR) and Building Innovation Capacity (BIC). The NSF Small Business Innovation Research (SBIR) program has an ongoing nanotechnology topic with subtopics for nanomaterials, nanomanufacturing, nanoelectronics and active nanostructures, nanotechnology for biological and medical applications, and instrumentation for nanotechnology.

NSF sponsored an international study on long-term research entitled *Nanotechnology Research Directions for Societal Needs in 2020.*[3] It provides an assessment of nanotechnology development in the last ten years (2000-2010) and a vision of the field for the next decade (2010-2020). This study evaluates the outcomes recommended by the first report issued in 1999, *Nanotechnology Research Directions: A vision for the next decade*, which was adopted as an official document of the National Science and Technology Council (NSTC). With the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), Office of Naval Research (ONR) and the U.S. Department of Agriculture (USDA), NSF co-sponsored the study entitled *Converging Knowledge, Technology, and Society*[4] evaluating the convergence of nanotechnology with other emerging areas. A follow-up report on *Science and Technology Convergence* will be completed in 2016. A study on *Nanomodular Materials and Systems by Design* to identify international activities and research directions will be completed in 2016.[5] The 2015 workshop "Rebooting the IT Revolution" was conducted in collaboration with the Semiconductor Industry Association (SIA), the Semiconductor Research Corporation (SRC), the National Institute of Standards and Technology (NIST) and the Defense Advanced Research Projects Agency (DARPA). The purpose of this workshop was to define Grand Challenges, one of them being "Brain-like Computing." The report addresses aspects of fundamental research for energy-efficient sensing and computing, data storage, real-time communication ecosystem, multi-level and scalable security, a new fabrication paradigm, and insight computing. [6,7]

Program Component Areas (PCAs) are the major subject areas of relevance to the NNI agencies, where progress is critical to achieving the NNI's goals and to realizing its vision.[8] NSF supports funding in all five PCAs.

PCA 1: Nanotechnology Signature Initiatives (NSIs)
The first PCA, which encompasses the five Nanotechnology Signature Initiatives (NSIs), will increase by $2.0 million to a total of $92.52 million. The changes are in the Sustainable Nanomanufacturing NSI with an increase of $2.0 million for research on manufacturing for nanosystems and nanomodular materials. The Nanotechnology for Solar Energy Collection and Conversion NSI graduated in FY 2015, and there are plans for a new NSI on Nanotechnology for Water. Special emphasis will be on:

[3] NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/
[4] NSF/WTEC 2013, Springer, available on www.nsf/gov/nano and www.wtec.org/NBIC2-Report/
[5] http://www.wtec.org/nmsd/
[6] http://1.usa.gov/1Fg90Dw
[7] https://src.org/newsroom/rebooting-the-it-revolution.pdf
[8] http://www.nano.gov/nni-pca

- Sustainable Nanomanufacturing ($28.40 million) – Establishing manufacturing technologies for economical and sustainable integration of nanoscale building blocks into complex, large-scale systems by supporting product, tool, and process design informed by and adhering to the overall constraints of safety, sustainability, and scalability. This signature initiative specifically focuses on high-performance structural carbon-based nanomaterials, optical metamaterials, and cellulosic nanomaterials. This initiative will establish manufacturing technologies for economical and sustainable integration of nanoscale building blocks into complex, large-scale systems. A program solicitation on Scalable Nanomanufacturing will be announced in FY 2016 and another is planned for FY 2017. Engineering biology at the nanoscale for advanced manufacturing activities in the Directorates for Biological Sciences (BIO) and Engineering (ENG) are being organized for 2016 and 2017.
- Nanoelectronics for 2020 and Beyond ($37.50 million) – Discovery and use of novel nanoscale fabrication processes and innovative concepts to produce revolutionary materials, devices, systems, and architectures to advance the field of nanoelectronics. This initiative is aimed at discovering and using novel nanoscale fabrication processes and innovative concepts to produce revolutionary materials, devices, systems, and architectures to advance the field of electronics. Collaboration in the Nanoelectronics Research Initiative with SRC and NIST is planned to continue in FY 2017. Research will address the NNI Grand Challenge "Brain-like Computing." Two examples of active centers are the Science and Technology Center (STC) on Quantum Materials and Devices at Harvard University and the MRSEC on Quantum and Spin Phenomena in Nanomagnetic Structures at the University of Nebraska, Lincoln.
- Nanotechnology Knowledge Infrastructure ($19.12 million) – Activities surrounding the fundamental, interconnected elements of collaborative modeling, a cyber-toolbox, and data infrastructure for nanotechnology, leveraging and extending existing and emerging resources, programs, and technologies to create an infrastructure to accelerate the vetting of new knowledge and to enable effective data utilization. This initiative aims to provide a community-based, solution-oriented knowledge infrastructure for discovery, innovation, and nanoinformatics of research, education and regulatory interest to NNI agencies. The Network for Computational Nanotechnology (NCN) conducts key activities in support to this NSI and is planned to be re-competed in 2017.
- Nanotechnology for Sensors and Sensors for Nanotechnology ($7.50 million) – Use of nanotechnology and nanoscale materials to build more sensitive, specific, and adaptable sensors and the development of new sensors to detect engineered nanomaterials across their life-cycles to assess their potential impacts. This initiative supports materials and technologies that enable new sensing of biological, chemical, and nanoscale materials, including sensors for nano environment, health, and safety (nano-EHS). A dedicated program on nanobiosensors in the Chemical, Bioengineering, Environmental, and Transport Systems (CBET) division in ENG will support this effort.

PCA 2: Foundational Research

The FY 2017 Request includes $210.47 million for the discovery and development of fundamental knowledge pertaining to new phenomena in the physical, biological, and engineering sciences that occur at the nanoscale. Also included is funding for research aiming to understand scientific and engineering principles related to nanoscale systems, structures, processes, and mechanisms; research on the discovery and synthesis of novel nanoscale and nanostructured materials including biomaterials and modular structures; and research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, ethical, and legal implications. About 60 percent of the MRSECs pursue NSE-related fundamental research.

PCA 3: Nanotechnology-Enabled Applications, Devices, and Systems

The FY 2017 Request includes $44.56 million for research that applies the principles of nanoscale science and engineering to create novel devices and systems, or to improve existing ones. This includes the incorporation of nanoscale or nanostructured materials and the processes required to achieve improved performance or new functionality, including metrology, scale up, manufacturing technology, and nanoscale

reference materials and standards. The NERC for Nanotechnology-Enabled Water Treatment at Rice University investigates distributed water filtration methods.

PCA 4: Research Infrastructure and Instrumentation

The FY 2017 Request includes $45.66 million for the establishment and operation of user facilities and networks, acquisition of major instrumentation, workforce development, and other activities that develop, support, or enhance the Nation's physical or human infrastructure for nanoscale science, engineering, and technology. This PCA includes research pertaining to the tools needed to advance nanotechnology research and commercialization, including next-generation instrumentation for characterization, measurement, synthesis, and design of materials, structures, devices, and systems. While student support to perform research is captured in other categories, dedicated educational and workforce efforts, ranging from curriculum development to advanced training, are included here as resources supporting the human infrastructure of the NNI. In FY 2015, NSF awarded the National Nanotechnology Coordinated Infrastructure (NNCI) sites, whose national coordination office will be added in FY 2016. NNCI, which replaces the National Nanotechnology Infrastructure Network (NNIN), has an annual budget estimated at $16 million. One new NERC was awarded in FY 2015, and a new ERC competition will be completed in FY 2017 which could include additional NERCs. NSF continues to sponsor nanotechnology education and related activities, such as the FY 2016 video series with NBC Learn, "Nanotechnology: super small science," and student competition "Generation Nano".[9]

PCA 5: Environment, Health, and Safety

In FY 2017, NSF will continue its funding for the Environment, Health, and Safety (EHS) PCA at $21.64 million, representing roughly 5.2 percent of its overall NNI budget. Requests for research are primarily directed at understanding nano-bio phenomena and processes, as well as environment, health, and safety implications and methods for reducing the respective risks of nanotechnology development. NSF continues to sponsor two Centers for Environmental Implications of Nanotechnology at the University of California, Los Angeles (UCLA) and Duke University.

Coordination with Other Agencies

The NSF NNI program is coordinated with 20 departments and agencies through the NSTC subcommittee on Nanoscale Science, Engineering and Technology (NSET). These agencies also partner with NSF to sponsor joint workshops on nanotechnology research directions and send representatives to participate in grantees conferences. Some specific coordination efforts are:

- Sustainable Nanomanufacturing – NSF with NIST, Department of Energy (DOE), EPA, NIH, National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), USDA/Food Safety (FS);
- Two-Dimensional Atomic-layer Research and Engineering (2-DARE) program (4-year awards begun in FY 2014 and FY 2015) – NSF and Department of Defense (DOD)/Air Force Office of Scientific Research (AFOSR);
- Nanoelectronics – NIST, DOD, DOE, Intelligence Community (IC)/Director of National Intelligence (DNI), NASA;
- Environmental issues, including the planned competition for a "Consumer Products nano Center" – EPA, USDA/National Institute of Food and Agriculture (NIFA), Consumer Product Safety Commission (CPSC);
- NSECs, NNIN, and NCN centers and networks – NSF with DOD, NASA, DOE, NIH;
- Nanosensors – NSF, NIH, and USDA;
- Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) program – NSF and USDA/NIFA joint solicitation; and

[9] www.nsf.gov/news/special_reports/gennano/index.jsp

- Organization for Economic Cooperation and Development (OECD) (Working Group on Bio, Nano, and other Converging Technologies) and other international forum activities – participation by NSF in collaboration with State Department and other NNI agencies.

NNI Funding by Program Component Area

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
1. Nanotechnology Signature Initiatives	$158.58	$90.52	$92.52
Nanotechnology for Solar Energy	*24.91*	-	-
Sustainable Nanomanufacturing	*34.11*	*26.40*	*28.40*
Nanoelectronics for 2020 and Beyond	*60.75*	*37.50*	*37.50*
Nanotechnology Knowledge Infrastructure	*23.81*	*19.12*	*19.12*
Nanotechnology for Sensors	*15.01*	*7.50*	*7.50*
2. Foundational Research	210.85	212.72	210.47
3. Nanotechnology-Enabled Applications, Devices, and Systems	54.77	44.56	44.56
4. Research Infrastructure and Instrumentation	40.48	45.66	45.66
5. Environment, Health, and Safety	25.09	21.64	21.64
Total, NNI	**$489.77**	**$415.10**	**$414.85**

Totals may not add due to rounding.