NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

Total Funding for NNI
(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request
Biological Sciences	$50.28	$48.80	$48.80
Computer and Information Science and Engineering	13.23	13.66	14.14
Education and Human Resources	2.50	2.50	2.50
Engineering	204.76	166.00	168.50
Geosciences	0.30	0.30	0.30
Mathematical and Physical Sciences	191.70	180.62	180.62
Social, Behavioral, and Economic Sciences	1.67	1.40	1.40
Office of International Science and Engineering	0.10	0.10	0.10
Total, NNI	**$464.54**	**$413.38**	**$416.36**

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; nanosensors to monitor health and environment; efficient and large scale nanomanufacturing of nanotechnology-based products; more resilient materials and system architectures; and sustainable development for water, energy, and food resources 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 2016.[1] Funding by PCA is shown at the end of this chapter.

FY 2016 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). About 10,000 students and teachers will be educated and trained in NSE in FY 2016.

Overall, total NNI funding in the FY 2016 Request of $416.36 million is $2.98 million over the FY 2015 Estimate of $413.38 million and a decrease of $48.18 million from the FY 2014 Actual of $464.54 million. The decrease is caused in part by the results of the peer review process of unsolicited proposals that resulted in a larger number of highly-ranked nanotechnology projects funded in FY 2014 as compared to what initially was planned.

Several new directions planned for FY 2016 are nanotechnology for water-energy-food processes, nanomodular materials and systems by design including two-dimensional nanoscale materials, and

[1] www.nano.gov

emerging aspects of nanoelectronics and photonics. NSF sponsors an annual NSE grantee conference to assess the progress in nanotechnology and facilitate identification of new research directions.

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. In FY 2016, 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). An increased focus is on support of convergence research and education activities in confluence with other priority areas such as: Science, Engineering, and Education for Sustainability/Sustainable Chemistry, Engineering and Materials (SusChEM); Research at the Interface of Biological, Mathematical and Physical Sciences, and Engineering (BioMaPS); and Smart Systems. 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*.[2] It provides an assessment of nanotechnology development in the last ten years (2000-2010) and a long-term vision of the field in the next decade (2010-2020). This study evaluates the outcomes as recommended by the first report issued in 1999, *Nanotechnology Research Directions: A vision for the next decade*, adopted as an official document of the National Science and Technology Council (NSTC). NSF co-sponsored, with five other NNI agencies, the study entitled *Converging Knowledge, Technology, and Society*[3] evaluating the convergence of nanotechnology with other emerging areas. A study on *Nanomodular Materials and Systems by Design* to identify international activities and research directions will be completed in 2015-2016.[4]

Nanotechnology Signature Initiatives (NSIs)

The first PCA, which encompasses the five Nanotechnology Signature Initiatives (NSIs), will increase by $3.50 million, as compared to the FY 2015 Estimate, to $118.07 million. The changes are in the Sustainable Nanomanufacturing NSI with an increase of $3.0 million for research on breakthrough materials and advanced manufacturing, and in the Nanotechnology for Knowledge Infrastructure NSI, with an increase of $500,000 for nanoinformatics in core programs, dedicated networks, and as part of the Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) NSF-wide investment. Three Nanosystems Engineering Research Centers (NERC) are being supported, with a total estimated budget of approximately $55.0 million for five years 2012-2017. Special emphasis will be on:

- Nanotechnology for Solar Energy Collection and Conversion ($27.67 million) – Enhancing understanding of energy conversion and storage phenomena at the nanoscale, and utilization of the unique physical phenomena that occur on the nanoscale to help overcome current performance barriers and substantially improve the collection and conversion of solar energy. This initiative is aimed at using nanotechnology to help overcome current performance barriers and substantially improve the collection and conversion of solar energy.
- Sustainable Nanomanufacturing ($26.40 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

[2] NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/
[3] NSF/WTEC 2013, Springer, available on www.nsf/gov/nano and www.wtec.org/NBIC2-Report/
[4] www.wtec.org/nmsd

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 2015 and FY 2016.

- 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 Semiconductor Research Corporation and the National Institute of Standards and Technology (NIST) is planned to continue in FY 2016.
- Nanotechnology Knowledge Infrastructure ($19.0 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 (with NNI agencies). The Network for Computational Nanotechnology (NCN) conducts key activities in support to this NSI.
- 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 development of new sensors to detect engineered nanomaterials across their life cycles in order 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-EHS. A dedicated program on Nanobiosensors in the Chemical, Bioengineering, Environmental and Transport Systems (CBET) division in the Directorate for Engineering will support this effort.

Foundational Research

The FY 2016 Request includes $187.00 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. The request also includes funding for research aiming to understand scientific and engineering principles related to nanoscale structures, processes, and mechanisms. Research is also supported that is aimed at discovery and synthesis of novel nanoscale and nanostructured materials. Research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, ethical, and legal implications is also supported. About 60 percent of the Materials Research Science and Engineering Centers (MRSECs) pursue NSE-related fundamental research.

Nanotechnology-Enabled Applications, Devices, and Systems

The FY 2016 Request includes $44.21 million for research and development 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.

Research Infrastructure and Instrumentation

The FY 2016 Request includes $44.60 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. NSF has under competition in FY 2015 the National Nanotechnology Coordinated Infrastructure (NNCI), with an annual budget estimated at $16 million that will be in operation in FY 2016, replacing the National Nanotechnology Infrastructure Network (NNIN). Additional Nanosystems Engineering Research Centers (NERCs) are under competition in FY 2015 and will be in operation in FY 2016.

Environment, Health, and Safety

In FY 2016, NSF will continue its funding for the Environmental, Health, and Safety (EHS) PCA at $22.48 million, representing nearly 5.4 percent of its overall NNI budget. Requests for research are primarily directed at understanding nano-bio phenomena and processes, as well as environmental, health, and safety implications and methods for reducing the respective risks of nanotechnology development.

Coordination with Other Agencies

The NSF NNI program is coordinated with 20 departments and agencies through the NSTCs subcommittee on Nanoscale Science, Engineering and Technology (NSET). Some specific coordination efforts are:

- Sustainable Nanomanufacturing (National Institute of Standards and Technology (NIST), Department of Energy (DOE), Environmental Protection Agency (EPA), National Institutes of Health (NIH), National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), U.S. Department of Agriculture/Food Safety (USDA/FS));
- NSF and Department of Defense (DOD)/Air Force Office of Scientific Research (AFOSR) collaborate on the Two-Dimensional Atomic-layer Research and Engineering (2-DARE) program that has a competition in 2015 for four-year group awards;
- Nanoelectronics (NIST, DOD, DOE, Intelligence Community (IC)/Director of National Intelligence (DNI), National Aeronautics and Space Administration (NASA));
- Environmental issues (EPA, USDA/National Institute of Food and Agriculture (NIFA), Consumer Product Safety Commission (CPSC));
- Solar energy conversion (DOE, IC/DNI, NASA, NIST, USDA/NIFA);
- NSECs, NNIN, and NCN centers and networks (DOD, NASA, DOE, NIH); and
- Nanosensors (NIH, and USDA).

These agencies also partner with NSF to sponsor joint workshops on nanotechnology research directions, and representatives from agencies involved in NNI activities participate in grantees conferences.

NNI Funding by Program Component Area

(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request
1. Nanotechnology Signature Initiatives	$122.49	$114.57	$118.07
Nanotechnology for Solar Energy	*29.50*	*27.67*	*27.67*
Sustainable Nanomanufacturing	*30.66*	*23.40*	*26.40*
Nanoelectronics for 2020 and Beyond	*34.44*	*37.00*	*37.50*
Nanotechnology Knowledge Infrastructure	*11.33*	*19.00*	*19.00*
Nanotechnology for Sensors	*16.56*	*7.50*	*7.50*
2. Foundational Research	212.22	186.80	187.00
3. Nanotechnology-Enabled Applications, Devices, and Systems	54.85	45.00	44.21
4. Research Infrastructure and Instrumentation	53.53	44.54	44.60
5. Environment, Health, and Safety	21.45	22.47	22.48
Total, NNI	**$464.54**	**$413.38**	**$416.36**

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