NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

NNI Funding

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$54.07	$56.10	$57.10
Computer and Information Science and Engineering	13.89	17.75	14.00
Education and Human Resources	2.50	-	2.50
Engineering	183.22	166.37	174.75
Geosciences	0.85	0.85	0.30
Mathematical and Physical Sciences	209.99	183.16	181.56
Social, Behavioral and Economic Sciences	1.67	1.67	0.60
International and Integrative Activities	0.10	0.10	0.10
Total, NNI	**$466.29**	**$426.00**	**$430.91**

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 are realizing revolutionary advances in areas such as catalysts for industry; individualized pharmaceuticals; new drug delivery systems; order-of-magnitude faster computer chips; more resilient materials and fabrics; and sustainable development for water and energy resources utilization.

FY 2014 NNI Funding

NSF supports nanoscale science and engineering throughout all the research and education directorates as a means to advance discovery and innovation and integrate various fields of research. NNI enables increased interdisciplinarity at atomic and molecular levels for about 5,000 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 nanoscale science and engineering in FY 2014. NSF contributes to the goals and eight program component areas (PCAs) outlined in the NNI Strategic Plan (www.nano.gov). Increases of $1.63 million in the Nanomanufacturing PCA and $1.91 million in the Nanomaterials PCA will be dedicated to research on breakthrough materials and advanced manufacturing as part of the Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) NSF-wide investment, which coordinates and synchronizes activities across four main areas – breakthrough materials, advanced manufacturing, robotics, and smart systems – and allows interdependencies and common research elements to surface. Three Nanosystems Engineering Research Centers (NERC), with a total estimated budget of approximately $55.0 million for five years, were established in September 2012 and started full operation in FY 2013. 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 2014 the agency 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. Overall, NNI funding in the FY 2014 Request will increase by $4.91 million, or 1.2 percent, over the FY 2012 Enacted.

A portion of NSF's FY 2014 NNI funding is for the NNI Signature Initiatives. FY 2014 funding for the Nanoelectronics for 2020 and Beyond Signature Initiative is $42.83 million, which is distributed in the Fundamental Nanoscale Phenomena and Processes, Nanomaterials, and Nanoscale Devices PCAs. These three PCAs also include FY 2014 funding of $31.67 million for the Nanotechnology for Solar Energy Collection and Conversion Signature Initiative. In addition, FY 2014 funding of $23.40 million for Sustainable Nanomanufacturing is contained within the Nanomanufacturing PCA, funding of $7.0 million for Nanotechnology for Sensors and Sensors for Nanotechnology Signature Initiative within Nanoscale Devices and Systems PCA, and funding of $20.0 million for Nanotechnology Knowledge Infrastructure across all PCAs.

In FY 2014, NSF will continue its funding for the Environmental, Health and Safety (EHS) PCA at $28.96 million, representing nearly seven percent of its overall NNI budget. Requests for research are primarily directed at environmental, health, and safety implications and methods for reducing the respective risks of nanotechnology development.

NSF sponsored an international study on long-term research entitled "Nanotechnology Research Directions for Societal Needs in 2020" (NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/). It provides 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 "Nanotechnology Research Directions: A vision for the next decade" (1999), adopted as an official document of the National Science and Technology Council (NSTC).

Fundamental Nanoscale Phenomena and Processes

The FY 2014 Request includes $148.78 million, an increase of $2.49 million over the FY 2012 Enacted, for fundamental research and education. Special emphasis will be on:

- Novel phenomena, quantum control, selfassembling, and basic engineering processes at the nanoscale – to discover and understand phenomena and design processes specific at the nanoscale, including new phenomena in materials, mechanics, chemistry, biology, electronics, and optics. Potential applications include quantum information systems, novel products by multiscale selfassembling, and new devices and sensors for industry and environmental monitoring. A new focus will be on understanding complex and emerging behavior of nanosystems, and creating nanomaterials and nanosystems by computational design.
- Biosystems at the nanoscale – to support study of biologically-based or -inspired systems that exhibit novel properties and potential applications. Potential applications include improved drug delivery; biocompatible nanostructured materials for implantation; exploiting of functions of cellular organelles; devices for research in genomics; proteomics and cell biology; food and plant systems; and nanoscale sensory systems, such as miniature sensors for early detection of cancer. A focus will be on the understanding of structure and function and simulation of cells, tissues, and nervous systems.
- Converging science and engineering at the nanoscale – to support the convergence of nanotechnology with information technology, modern biology, and social sciences – potentially reinvigorating discoveries and innovation in almost all areas of the economy. Examples are the nano-biology interface, the nano-information interface, and nano-neurosciences.

- Multi-scale, multi-phenomena theory, modeling, and simulation at the nanoscale – to support theory, modeling, large-scale computer simulation and new design tools, and infrastructure in order to understand, control, and accelerate development in new nanoscale regimes and systems. A special focus will be on simulations with atomic precision, time resolution of chemical reactions, and for domains of engineering and biological relevance.
- NNI Signature Initiatives – to support the NNI Signature Initiatives, as well as planning for nanotechnology for regenerating the human body and nanostructured catalysts for green manufacturing.
- Advanced Manufacturing Technologies – to support research in the Directorate for Engineering (ENG) and the Directorate for Computer and Information Science and Engineering (CISE) on advanced manufacturing technologies. A portion of this funding supports CISE's participation in the Nanoelectronics for 2020 and Beyond Signature Initiative.

Nanomaterials
The FY 2014 Request includes $80.71 million, an increase of $1.91 million over the FY 2012 Enacted level, for discovery of novel nanoscale and nanostructured materials, and improving the comprehensive understanding of the properties of nanomaterials (ranging across length scales and including interface interactions). A special focus will be design and synthesis, in a controlled manner, of nanostructured materials with targeted properties. Research on the discovery, understanding, and control of materials at the nanoscale will be critical to the development and success of innovative technologies, including advances in electronics in science and engineering beyond Moore's Law, catalysts, energy, healthcare, and manufacturing.

Nanoscale Devices and Systems
The FY 2014 Request includes $51.08 million, a decrease of $1.35 million from the FY 2012 Enacted level, for R&D that applies the principles of nanoscale science and engineering to create novel, or to improve existing, devices and systems. A research focus will be on the architecture and emerging behavior of nanosystems, and on nanomanufacturing of active nanostructures and nanosystems. Nanoelectronics beyond silicon nanotechnology and complementary metal-oxide superconductors (CMOS) research will explore the ultimate limits to scaling of features and alternative physical principles for devices employed in sensing, storage, communication, and computation. The research activity in this area will help develop innovative technologies, including replacing electron charge as information carrier, bottom-up device assembly technologies at the atomic and molecular levels, and new system architectures using nanoscale components. Another focus will be on building biosystems and to regenerate the human body. An additional area of emphasis will be nano-informatics for better communication and nanosystem design.

Instrumentation Research, Metrology, and Standards for Nanotechnology
The FY 2014 Request includes $11.98 million for R&D to create new tools needed to advance nanotechnology research and commercialization. Special challenges are developing tools for measuring and restructuring matter with atomic precision, for time resolution of chemical reactions, and for domains of biological and engineering relevance. Another focus is on developing on-line process instrumentation for nanoscale characteristics.

Nanomanufacturing
The FY 2014 Request includes an increase of $1.63 million above the FY 2012 Enacted level, to $49.40 million, to support new concepts for high-rate synthesis and processing of nanostructures, nanostructured catalysts, nanobiotechnology methods, fabrication methods for devices, and assembling them into nanosystems and then into larger scale structures of relevance to industry and to the medical field. R&D is aimed at enabling scaled-up, reliable, cost effective manufacturing of nanoscale materials, structures, devices, and systems. Advanced semiconductor and optical device design, fabrication and processing, for

application in biomedical, alternative energy, communications, computing and sensing systems, will be pursued both through support of the centers and the core programs. The NNI Signature Initiative on Sustainable Nanomanufacturing will support processes and techniques for continuous and scalable nanomanufacturing with a focus on three classes of sustainable materials—high-performance structural carbon-based nanomaterials, optical metamaterials, and cellulosic nanomaterials. CISE will support fabrication of new reconfigurable, evolvable, adaptive hardware architectures and the use of heterogeneous systems that can dynamically change via software mechanisms and architectures capable of combating error-prone devices at the nanoscale. The Foundation will continue to support four NSECs (Nanoscale Science and Engineering Centers) that focus on manufacturing at the nanoscale. Those centers and the National Nanotechnology Infrastructure Network (NNIN) have strong partnerships with industry, national laboratories, and international centers of excellence, which puts in place the necessary elements to bring discoveries in the laboratory to real-world, marketable innovations and technologies. The NSECs with a focus on nanomanufacturing are: the Center for Hierarchical Manufacturing (CHM), the Center for Scalable and Integrated Nanomanufacturing (SINAM), the Center for High-rate Nanomanufacturing (CHN), and the Center for Nano-Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS). NSF also supports the National Nanomanufacturing Network (NNN), which includes the NSF NSECs and non-NSF centers in collaboration with the Department of Defense (DOD), National Institute of Standards and Technology (NIST), and industry partners in an alliance to advance nanomanufacturing strength in the U.S. The FY 2014 Request increase is primarily associated with an additional funding for research on sustainable nanomanufacturing.

Major Research Facilities and Instrumentation Acquisition

The FY 2014 Request includes $28.69 million for user facilities, acquisition of major instrumentation, and other activities that develop, support, or enhance the scientific infrastructure required for the conduct of nanoscale science, engineering, and technology research and development. It also supports ongoing operations of the National Nanotechnology Infrastructure Network (NNIN), the Network for Computational Nanotechnology (NCN), NNN, and the National High Magnetic Field Laboratory (NHMFL). The networks had about 190,000 users in FY 2012. The investment will support facilities for ongoing NSECs. In addition, the FY 2014 Request will support planned growth supplements to the first class of three new NERCs funded in FY 2012.

Environmental, Health, and Safety

The FY 2014 Estimate includes $28.96 million for research primarily directed at environmental, health, and safety (EHS) implications and methods for reducing the prospective risks of nanotechnology development. NSF, the Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and the European Union (EU) will continue collaboration on development of a joint solicitation for nanotechnology EHS. A focus will be on implications of the next generation of nanotechnology products and productive processes, as well as public participation in nanotechnology-related activities. Research on both implications and applications of nanotechnology will address the sources of nanoparticles and nanostructured materials in the environment (in air, water, soil, biosystems, and working environments), as well as the non-clinical biological implications. Research on the safety of manufacturing nanoparticles is included in seven NSECs and NNIN. Environmental implications of nanotechnology, including development of new measurement methods for nanoparticle characterization and toxicity of nanomaterials will be investigated in two dedicated multidisciplinary centers (Centers for Environmental Implications of Nanotechnology at UCLA and Duke University). These centers aim to conduct fundamental research on the interactions between nano-particles and -materials and the living world at all scales. An essential element of this will be research on methods and instrumentation for nano-particle detection, characterization, and monitoring, including interactions of nano-materials with cellular constituents, metabolic networks and living tissues, bioaccumulation and its effects on living systems, and the impacts of nanostructures dispersed in the environment.

Education and Societal Dimensions

The FY 2014 Request includes $31.31 million for research and other activities that address the broad implications of nanotechnology for society, including education and social aspects, such as:

- Education-related activities, such as development of materials for schools, curriculum development for nanoscience and engineering, development of new teaching tools, undergraduate programs, technical training, and public outreach ($27.06 million). Two networks for nanotechnology education with national outreach will be supported.
- Research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, workforce, educational, ethical, and legal implications ($4.25 million). The application of nanoscale technologies will stimulate far-reaching changes in the design, production, and use of many goods and services. NSF also supports a project to embed humanists and social scientists for greater collaboration in nanoscience around the world, providing a model for future integration of ethicists and social scientists into nanotechnology R & D laboratories.

Coordination with Other Agencies

The NSF program is coordinated with 25 departments and agencies through the NSTCs subcommittee on Nanoscale Science, Engineering and Technology (NSET). Examples of specific coordination efforts are: Sustainable Nanomanufacturing (with NIST, Department of Energy (DOE), EPA, Intelligence Community (IC), National Institutes of Health (NIH), National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), U.S. Department of Agriculture USDA/FS); Nanoelectronics (with NIST, DOD, DOE, IC/DNI, NASA) Environmental issues (with EPA, USDA/NIFA, Consumer Product Safety Commission (CPSC)); Solar energy conversion (with DOE, , IC/DNI, National Aeronautics and Space Administration (NASA), NIST, NSF, USDA/NIFA); NSECs, NNIN and NCN centers and networks (DOD, NASA, DOE, NIH); nano-sensors (with NIH, and USDA) simulations in nanoelectronics (DOD/NASA); research and training activities (DOD/NIH); NSF awards supplements for student participation in the Sandia National Lab "National Institute for Nano-Engineering" Summer Scholars Program. Joint workshops are sponsored on nanotechnology research directions and grantees conferences with all NNI agencies.

NNI by Program Component Area

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
1. Fundamental Nanoscale Phenomena & Processes	$167.59	$146.29	$148.78
2. Nanomaterials	78.83	78.80	80.71
3. Nanoscale Devices & Systems	62.63	52.43	51.08
4. Instr. Research, Metrology, & Standards for Nanotech	13.06	12.05	11.98
5. Nanomanufacturing	44.37	47.77	49.40
6. Major Research Facilities & Instrumentation Acquisition	38.78	28.53	28.69
7. Environmental Health & Safety	24.20	30.01	28.96
8a. Education	31.43	24.79	27.06
8b. Societal Dimensions (ELSI)	5.40	5.33	4.25
Total, NNI	**$466.29**	**$426.00**	**$430.91**

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