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National Nanotechnology Investment in the FY 2015 Budget

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INTRODUCTION

The emerging fields of nanoscale science, engineering, and technology — which investigate how to measure and restructure matter at the atomic, molecular, and supramolecular levels to create materials, devices, and systems with fundamentally new properties and functions — are leading to unprecedented understanding and control over the basic building blocks and properties of all natural and man-made things. The fiscal year (FY) 2015 funding request for nanoscale science, engineering, and technology (in brief, *nanotechnology*) research and development (R&D) is **$1.54 billion** (see Table I-8) across 20 participating federal departments, independent agencies and commissions (called in brief participating "agencies"; see Table 1 for names and acronyms), reflecting nanotechnology potential. Known as the National Nanotechnology Initiative (NNI), this investment began in FY 2001, inspired by a long-term vision,[2] and with a budget of $494 million.[3] The 2014 NNI Strategic Plan and 2011 NNI Environmental, Health and Safety Research Strategy are implementation guiding documents.[3]

The NNI vision is a future in which understanding and control of matter at the nanoscale will lead to a revolution in technology and industry that benefits society. The four goals of the NNI are to: advance a world-class nanotechnology research and development program; foster the transfer of

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[2] "Nanotechnology Research Directions" (M.C. Roco, S. Williams, P. Alivisatos, eds.), Springer 1999, adopted as an official document of NSTC in 2000; "Nanotechnology Research Directions for Societal Needs in 2020" (M.C. Roco, C. Mirkin, M. Hersam, eds.), Springer, 2011; http://www.wtec.org/nano2/
[3] See the NNI website at http://www.nano.gov/2014StrategicPlan and .../node/681

new technologies into products for commercial and public benefit; develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and support responsible development of nanotechnology. The NNI engages in strategic collaboration to accelerate the discovery, development, and deployment of nanotechnology. Because of the NNI, federal agencies have engaged in strategic planning and collaboration and have initiated major new nanotechnology R&D activities under a common vision that supports national goals and agency missions. These agencies have established an extensive infrastructure of nanotechnology research and education centers, and they are working together to maximize the effectiveness of their individual and collective investments for societal impacts.

The 21st Century Nanotechnology R&D Act (Public Law 108-153) was signed into law in December 2003 and authorized long-term funding levels for five agencies (NSF, DOE, NASA, NIST, and EPA). New legislation for multi-year reauthorization is currently in preparation in Congress at the time of this writing.

The Global nanotechnology community is partially transitioning its R&D focus from nanoscale components to nanosystems, and from basic research to inventions and innovations that support national priorities such as energy, manufacturing, healthcare, and environmental protection.[4] Spin-off areas of nanotechnology (such as metamaterials, plasmonics, and synthetic biology) and new areas at the intersection between nanotechnology and other technology platforms (such as nanobiomedicine, nanoinformatics, and nano-neuroscience) expand the use of nanoscale science and engineering beyond the initial definition.

SUMMARY OF FY 2015 BUDGET REQUEST FOR NNI

The FY 2015 President's request of $1.54 billion for federal investment in nanotechnology is about the same as the actual FY 2013 budget of $1.55 billion and estimated FY 2014 budget of $1.54 billion, with a decrease in the DOD requested contribution and an increase in the DHS and DOE budget requests. Approximately two-thirds of total NNI funding supports academic research and one-third supports R&D at government laboratories and industry. Additionally, about 6 percent of the $1.7 billion budget is estimated for the Small Business Innovation

[4] "Nanotechnology Research Directions for Societal Needs in 2020" (M.C. Roco, C. Mirkin, M. Hersam, eds.), Springer, 2011; available on http://www.wtec.org/nano2/

Research (SBIR) and Small Business Technology Transfer (STTR) programs, based on average funding levels from the five most recent years with completed data, FY 2008 to FY 2012.

NNI-sponsored R&D is reported in **five Program Component Areas** (PCAs) in FY 2015 Request:

(1) Nanotechnology Signature Initiatives (NSIs), $291.3 million, representing about 19 percent of the budget;
(2) Foundational Research, $530.4 million, about 35 percent;
(3) Nanoscale-Enabled Applications, Devices, and Systems, $363.0 million, about 24 percent;
(4) Research Infrastructure and Instrumentation, $239.8 million; about 15 percent;
(5) Environment, Health, and Safety, $112.4 million, about 7 percent.

The NSIs[5] are designed to accelerate innovation in areas of national priority through enhanced interagency coordination and focused investment:

(1a) **Nanotechnology for Solar Energy Collection and Conversion: Contributing to Energy Solutions for the Future**, $69.2 million, with participation from DOD, DOE, IC/DNI, NASA, NIST, NSF, and USDA/NIFA. The primary aim of this initiative is to use nanotechnology to improve photovoltaic solar electricity generation, solar thermal energy generation and conversion, and solar-to-fuel conversions.

(1b) **Sustainable Nanomanufacturing: Creating the Industries of the Future**, $36.2 million, with participation from DOD, DOE, IC/DNI, NASA, NIOSH, NIST, NSF, OSHA, and USDA/FS. It has two areas of focus: design of scalable and sustainable nanomaterials, components, devices, and processes; and nanomanufacturing measurement technologies.

(1c) **Nanoelectronics for 2020 and Beyond**, $71.5 million, with participation from DOD, DOE, IC/DNI, NASA, NIST and NSF. The initiative aims to explore new or alternative "state variables" for computing; merge nanophotonics with nanoelectronics; explore carbon-based nanoelectronics; exploit nanoscale processes and phenomena for quantum information science; and augment the national nanoelectronics research and manufacturing infrastructure network (university-based infrastructure).

[5] http://www.nano.gov/signatureinitiatives

(1d) **Nanotechnology Knowledge Infrastructure: Enabling National Leadership in Sustainable Design**, $26.2 million, with participation from CPSC, DOD, EPA, FDA, NASA, NIH, NIOSH, NIST, NSF, and OSHA. The initiative aims to create a community-based, solutions-oriented knowledge infrastructure, including informatics and modeling and simulations, to accelerate nanotechnology discovery and innovation.

(1e) **Nanotechnology for Sensors and Sensors for Nanotechnology: Improving and Protecting Health, Safety, and the Environment**, $88.2 million, with participation from CPSC, DOD/DTRA, EPA, FDA, NASA, NIH, NIOSH, NIST, NSF, and USDA/NIFA. The initiative aims to provide new solutions in physical, chemical, and biological sensing that enable increased detection sensitivity, specificity, and multifunction in portable devices for a variety of health, safety, and environmental assessments.

The five agencies with the largest FY 2015 investments are described below: HHS/NIH, NSF, DOE, DOD and DOC/NIST (see Table I-8). The Department of Homeland Security requests the largest increase, 35 percent, from $24 million estimated in FY 2014 to $32 million in FY 2015.

The Department of Health and Human Services (HHS) would support nanotechnology R&D at $469.6 million, about the same as FY 2014 and slightly lower than the $485.4 million in FY 2013. This funding is distributed between the National Institutes of Health (NIH: $441.5, flat from FY 2014), the Food and Drug Administration (FDA: $17 million, flat from FY 2014) and the National Institute for Occupational Safety and Health (NIOSH: $11.1 million, a $0.1 million increase) (see Table I-8). NIH has the largest request among all agencies in FY 2015, to address nanotechnology-based biomedical research at the intersection of the life and physical sciences. Research on emerging technologies, projected for 2015, will focus on the translation of nanoscience discoveries into new biomedical technologies. In addition to research on using nanotechnology to deliver new therapies, several of NIH's institutes are focused on advancing nanotechnology-based techniques, including clinical lab tests and assays, and tools and devices, for early disease diagnosis; and *in vivo* imaging techniques. The four major NIH nanotechnology programs [the NIH Common Fund Nanomedicine Initiative, NCI's Alliance for Nanotechnology in Cancer, the National Heart, Lung and Blood Institute's (NHLBI) Program of Excellence in Nanotechnology, and the National Institute of Environmental Health

Sciences (NIEHS) Centers for EHS], initiated prior to 2014, will continue to receive support to develop new treatments, diagnostics, and interventions for disease management and patient care related to nanotechnology. An increased focus will be on building partnerships with the private sector and other NNI agencies. NIOSH will continue to investigate the potential human health hazards of engineered nanomaterials by exploring their biologic mechanisms. There will also be increased emphasis on measuring worker exposures and developing effective control and risk-management methods, along with developing guidance on medical surveillance.[6]

The National Science Foundation (NSF) would continue to support research and education in all disciplines of nanoscale science and engineering with a budget of $412.4 million in FY 2015. Under the request, NSF would support about 5,000 active awards with full or partial contents on nanoscale science and engineering, and about 10,000 students and teachers will be educated and trained. NSF has established a set of three "Nanosystems Engineering Research Centers," with a total budget of $11.0 million per year. The FY 2015 NSF request includes about $115.6 million for the five Signature Initiatives, an increase of $2.7 million over FY 2014 estimates. The EHS research would be $22.3 million, about 5.5% of the total NNI funding at NSF. Support will be provided to increase research supporting new generations of nanotechnology products. Converging science and engineering at the nanoscale supports the convergence of nanotechnology with information technology, modern biology, and the social sciences, potentially reinvigorating discoveries and innovation in almost all areas of the economy. NSF co-sponsored with five other NNI agencies the study entitled "Converging Knowledge, Technology and Society"[7] evaluating the convergence of nanotechnology with other emerging areas.

The focus on energy is reflected in the **Department of Energy (DOE)'s** request of $343.1 million in FY 2015, a 13.1 percent increase. The Department of Energy includes the Office of Science, the Advanced Research Project Agency-Energy (ARPA-E), and the Office of Energy Efficiency and Renewable Energy (EERE). Its focus is on fundamental and applied nanotechnology research providing a basis for new and improved energy technologies. DOE's Office of Science will continue to

[6] See the 2013-2016 NIOSH Nanotechnology Research Strategic Plan (www.cdc.gov/niosh/docs/2014-106

[7] M.C. Roco, W.S. Bainbridge, T. Bruce and G. Whitesides 2013, Springer, available on www.nsf/gov/nano and www.wtec.org/NBIC2-Report/

support full operation of the five DOE Nanoscale Science Research Center (NSRC) user facilities and the Energy Frontier Research Centers. The Office of Science will also continue support for the Energy Innovation Hub focusing on batteries and energy storage and Joint Center for Artificial Photosynthesis. The SunShot program within EERE will support a variety of projects that use nanotechnology to drive down the cost of solar power installations. DOE plans to merge three Electron-7 Beam Microcharacterization Centers (EBMCs) with the five NSRCs. DOE has requested an approximately 5% increase in the NSRC budgets for 2015 to allow for improved operational levels.

The Department of Defense (DOD) funding request is $144.0 for FY 2015, which is $31.9 million below the FY 2014 estimated budget of $175.9 million and more than 50 percent below the FY 2012 budget. This reflects the maturation and completion of certain projects, especially at DARPA, and broadly reduced estimates associated with budget uncertainties and ongoing competitions, which cannot be counted until awards are made. The nanotechnology investment will continue with approximately 50 percent for fundamental research, 40 percent applied research, and 10 percent advanced technology development. DOD's focus is on nanoscale science and engineering research advancing defense and dual-use capabilities. Parts of the investment in nanotechnology are done through the Army Engineer Research and Development Center, the Office of Naval Research's Multidisciplinary University Research Initiative, the Air Force Office of Scientific Research's individual awards, the collaborative Focus Center Research Program at DARPA, the Defense Threat Reduction Agency, the Chemical and Biological Defense Program, and SBIR/STTR programs. An example of basic research includes tailoring the electronic bandgap of graphene using techniques such as catalytic nanolithography, scanning probe and directed e-beam nanolithography, and chemical functionalization. The Navy is exploring extraordinarily lightweight materials with outstanding mechanical properties. The Defense Production Act Title III Program is establishing the infrastructure for the world's first manufacturing production facility for carbon nanotube yarn and sheet material. Another example is the development of electrochemical techniques for patterning metals to produce nanoscale features for antennas, sensors, metamaterials, and catalysts. Because the DOD nanotechnology investment is driven by mission needs and opportunities, changes in investment during the year are to be expected.

The National Institute of Standards and Technology (DOC/NIST) would increase research support in the intramural laboratories and user facilities for nanomanufacturing, major research facilities and instrumentation acquisition, and nano-EHS aspects of nanotechnology. The FY 2015 budget request is for $82.6 million, a decrease from the current FY 2014 estimate of $97.8 million. The Center for Nanoscale Science and Technology user facility maintains the capabilities needed to effectively support industrial innovation. NIST will support instrumentation and metrology in all five signature initiatives. Examples of projects include developing the quantitative atom probe, advanced electron and scanning probe microscopy, and optical nanocalorimetry measurement instrumentation needed to advance technologies ranging from semiconductors and data storage to biotechnology and optoelectronics. NIST is transitioning its activities toward advanced nanomanufacturing investments including precision measurements and advanced materials design and discovery.

The FY 2015 budget would also continue to maintain a comprehensive infrastructure. A list of R&D centers, user facilities, and networks as of March 2014 is given in Table 2 on the following pages.

Many of the NNI participating agencies and programs are also actively participating in and contributing to complementary and synergistic U.S. R&D priorities, including the Networking and Information Technology (NITRD) initiative, the United States Global Change Research Program (USGCRP), the Materials Genome Initiative, Advanced Manufacturing, and the new Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative.

Table 1. NNI members (20 federal departments and independent agencies and commisssions)

Federal Agencies Participating in the NNI (March 2010)
Federal departments, independent agencies and commissions (11) with budgets dedicated to nanotechnology research and development
Consumer Product Safety Commission (CPSC) (*)
Department of Commerce (DOC)
National Institute of Standards and Technology (NIST)
Department of Defense (DOD)
Department of Energy (DOE)
Department of Health and Human Services (HHS)
Food and Drug Administration (FDA)
National Institutes of Health (NIH)
National Institute for Occupational Safety and Health (NIOSH)
Department of Homeland Security (DHS)
Department of Transportation (DOT)
Federal Highway Administration (FHWA)
National Aeronautics and Space Administration (NASA)
National Science Foundation (NSF)
U.S. Department of Agriculture (USDA)
Agricultural Research Service (ARS)
Forest Service (FS)
National Institute of Food and Agriculture (NIFA)
Other participating agencies (9)
Department of Commerce
Bureau of Industry and Security (BIS)
Economic Development Administration (EDA)
U.S. Patent and Trademark Office (USPTO)
Department of Education (DOEd)
Department of Interior (DOI)
U.S. Geological Survey (USGS)
Department of Justice (DOJ)
Department of Labor (DOL)
Occupational Safety and Health Administration (OSHA)
Department of State (DOS)
Department of the Treasury (DOTreas)
Director of National Intelligence (DNI)
Nuclear Regulatory Commission (NRC)
U.S. International Trade Commission (USITC)

(*) Denotes an independent commissions that is represented on NSET but is non-voting

Table 2. NNI R&D centers, user facilities, and networks (March 2014).

Name	Institution(s)
NSF – Ten Networks	
National Nanofabrication Infrastructure Network (NNIN) – 15 nodes (user facilities)	Cornell University – main node (under recompetition in 2013-2014)
Network for Computational Nanotechnology (NCN)	Purdue University – main node
National Nanomanufacturing Network (NNN)	University of Massachusetts, Amherst – main node
Nanotechnology in Society Network (NCN)	Arizona State University and University of California, San Diego
Nanoscale Informal Science Education (NISE) Network	Museum of Science, Boston – main node
Nanoscale Science and Engineering Centers (NSEC)	University of Columbia – main node
Materials Science and Engineering Centers (MRSECs)	Distributed centers
Nanosystems Engineering Research Centers (NERC)	Distributed centers
Centers for the Environmental Implications of Nanotechnology (CEIN)	University of California, Los Angeles, and Duke University
Center for National Nanotechnology Applications and Career Knowledge (NACK)	Pennsylvania State University
NSF – Two Science and Technology Centers	
Center for Energy Efficient Electronics Science (nanoelectronics)	University of California, Berkeley
Emergent Behaviors of Integrated Cellular Systems (nanobiotechnology)	Massachusetts Institute of Technology
DOE – One Network of Five User Facilities	
Center for Functional Nanomaterials	Brookhaven National Laboratory
Center for Integrated Nanotechnologies	Sandia National Laboratory and Los Alamos National Laboratory
Center for Nanophase Materials Sciences	Oak Ridge National Laboratory
Center for Nanoscale Materials	Argonne National Laboratory
Center for Molecular Foundry	Lawrence Berkeley National Laboratory
NIH – Four networks	
NHLBI Program of Excellence in Nanotechnology	Four distributed centers
Nanomedicine Development Centers	Eight distributed centers
Centers of Cancer Nanotechnology Excellence	Eight distributed centers
Nanotechnology Characterization Laboratory (user facilities)	Frederick, Maryland campus
NIST – User Facility	
Center for Nanoscale Science and Technology (CNST), shared-use nanofabrication facility (NanoFab)	Gaithersburg, Maryland campus