NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT (NITRD)

Total Funding for NITRD

(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request
Biological Sciences	$99.00	$99.00	$99.00
Computer and Information Science and Engineering	892.60	921.73	954.41
Education and Human Resources	9.50	9.50	9.50
Engineering	19.80	18.75	18.75
Geosciences	24.00	24.00	23.00
Mathematical and Physical Sciences	78.72	81.80	81.10
Social, Behavioral, and Economic Sciences	28.23	31.20	31.20
Total, NITRD	**$1,151.85**	**$1,185.98**	**$1,216.96**

Totals may not add due to rounding.

The National Science Foundation is a primary supporter of the Networking and Information Technology Research and Development (NITRD) program. NSF's NITRD portfolio includes all research, infrastructure, and education investments in the Computer and Information Science and Engineering (CISE) directorate, as well as contributions from all other directorates across the agency, enabling investments in every NITRD Program Component Area (PCA). NSF's Assistant Director for CISE is co-chair of the NITRD Subcommittee of the National Science and Technology Council's Committee on Technology. In addition, NSF works in close collaboration with other NITRD agencies and participates at the co-chair level in five of the seven PCA Coordinating Groups and three of the Senior Steering Groups.

NSF's FY 2016 Request continues strong support for NITRD at a level of $1.22 billion; this represents an increase of 2.6 percent above the FY 2015 Estimate. NITRD activities represent approximately 16 percent of NSF's FY 2016 budget. CISE's support comprises approximately 78 percent of NSF's NITRD activities.

Several NSF-wide investments, both new and continuing, are reflected in various NITRD PCAs:
- Advanced Manufacturing investments encompass research in nanotechnology, cyber-physical systems, and robotics, as well as expanded industry/university cooperation. Activities are supported in High End Computing Research and Development; High End Computing Infrastructure and Applications; and High Confidence Software and Systems.
- The Comprehensive National Cybersecurity Initiative (CNCI) supports activities in Cybersecurity and Information Assurance.
- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS), a collaboration among BIO, CISE, ENG, and MPS, expands advanced manufacturing technologies research in the Cyber-Physical Systems (CPS) program, the National Robotics Initiative (NRI), and the Materials Genome Initiative to accelerate advances in 21st century smart engineered systems. CEMMSS will establish a scientific basis for engineered systems interdependent with the physical world and social systems, synthesize multi-disciplinary knowledge to model and simulate systems in their full complexity and dynamics, and develop a smart systems technology framework. CEMMSS supports activities in High End Computing Research and Development; High Confidence Software and Systems; Human-Computer Interaction and Information Management; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.

- Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21), a collaboration among all NSF directorates, is designed to develop and deploy comprehensive, integrated, sustainable, and secure cyberinfrastructure to accelerate research and new functional capabilities in computational and data-intensive science and engineering, primarily supporting investments in six program component areas: High End Computing Research and Development; High End Computing Infrastructure and Applications; Large Scale Networking; Human-Computer Interaction and Information Management; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- Enhancing Access to the Radio Spectrum (EARS) is a collaboration among CISE, ENG, and MPS to identify bold new concepts with the potential to improve the efficiency of radio spectrum utilization, and in the ability for traditionally underserved Americans to benefit from current and future wireless-enabled goods and services. Investment in EARS supports High End Computing Research and Development, High End Computing Infrastructure and Applications, and Large Scale Networking.
- The new Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) investment, a collaboration among all NSF directorates, supports Cybersecurity and Information Assurance, High Confidence Software and Systems, Large Scale Networking, and Software Design and Productivity. It also includes support for High End Computing Infrastructure and Applications through investments in advanced computational infrastructure that will provide additional resources in support of multidisciplinary research in INFEWS.
- Investments in NSF INCLUDES (Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science), a collaboration among all NSF directorates, support the Social, Economic, and Workforce Implications of IT and IT Workforce Development activity.
- The National Robotics Initiative (NRI), a cross-agency initiative engaging four U.S. agencies (NSF, National Aeronautics and Space Administration, National Institutes of Health, and the U.S. Department of Agriculture) and four directorates at NSF (CISE, ENG, EHR and SBE) provides U.S. leadership in robotics science and engineering research and education aimed at the development of co-robots, which work cooperatively with humans in application domains, such as advanced manufacturing, emergency response, and assistive healthcare. Activities are supported in Human-Computer Interaction and Information Management; High Confidence Software and Systems; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- The new Risk and Resilience NSF-wide investment area, a collaboration among CISE, ENG, GEO and SBE, supports High End Computing; Research and Development; Large Scale Networking; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- Secure and Trustworthy Cyberspace (SaTC), a collaboration among CISE, EHR, ENG, MPS and SBE, aligns NSF's cybersecurity investments with the national cybersecurity strategy, *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program*.[1] SaTC supports scientific foundations, induces change, maximizes research impact, and accelerates transitions to practice. SaTC supports activities in Cybersecurity and Information Assurance.
- The Understanding the Brain (UtB) investment, a collaboration among BIO, CISE, EHR, ENG, MPS and SBE, supports activities in High End Computing Infrastructure and Applications End Computing Infrastructure and Applications; High Confidence Software and Systems; Human Computer Interaction and Information Management; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce development. These activities also support part

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[1] www.whitehouse.gov/sites/default/files/microsites/ostp/fed_cybersecurity_rd_strategic_plan_2011.pdf

of NSF's contributions to the Administration's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative. It also includes support for High End Computing Infrastructure and Applications through investments in advanced computational infrastructure that will provide additional resources in support of multidisciplinary research in UtB.

- NSF investments in urban science, a collaboration among CISE, ENG and SBE, support the High Confidence Software and Systems activity.

FY 2016 NSF Investments by Program Component Area (PCA)

The following information focuses on FY 2016 NSF investments, both new and continuing, by PCA.

Large Scale Networking (LSN) ($130.84 million) CISE, ENG, and MPS will support research in new wireless communications, spectrum sharing architectures and services, and mobile computing, as well as development of wireless testbeds as part of EARS. A portion of NSF's investment in CIF21 will address broadband applications and research on end-to-end performance from the desktop to major scientific and computational facilities. Through INFEWS, CISE will invest in research related to control, automation, and optimization of the complex systems underlying the nexus of food, energy and water. Moreover, CISE will support advances in large-scale resilient, secure, and interoperable research cyberinfrastructure through the Risk and Resilience investment area. CISE will also provide additional support for networking and computing infrastructure.

Cybersecurity and Information Assurance (CSIA) ($111.73 million) CSIA includes support for CNCI and NSF's SaTC program. Increased CISE investments in SaTC, in partnership with EHR, ENG, MPS, and SBE, aim to support scientific foundations, induce change, maximize research impact, and accelerate transition to practice. This area also includes support from CISE for the NSF-wide INFEWS investment, with a focus on ensuring the safety and security of food, energy, and water resources, and the systems that facilitate their generation, distribution, and consumption through comprehensive, integrated research and modeling of these sociotechnical systems.

High End Computing Research and Development (HEC R&D) ($138.37 million) HEC R&D support includes continued increased investment in Risk and Resilience, which focuses on advances in large-scale resilient, secure and interoperable research cyberinfrastructure and systems. Additionally, support is provided for CISE's nanotechnology research, including participation in the National Nanotechnology Initiative. HEC R&D also includes increased support for research in Clean Energy Technologies by CISE, focusing on research that will develop the theory and design principles to effectively tackle energy versus computation and communication tradeoffs; and the development of new theory, algorithms, and design principles to optimize energy-computational performance in computing and communications systems. HEC R&D also includes support for CIF21 to develop new functional capabilities in support of highly parallel computing and big data analytics, as well as research on technical and economic models for flexible spectrum access, real-time auctions, and on-demand spectrum services as part of EARS. MPS will support research on quantum effects and their use for information science, potentially leading to new paradigms for high end computing.

High End Computing Infrastructure and Applications (HEC I&A) ($221.40 million) HEC I&A includes increased efforts by the Advanced Cyberinfrastructure (ACI) division in CISE to develop software and algorithms for high end computing systems as well as Advanced Computational Infrastructure. Through increased data and computational capacity, CISE will support multidisciplinary research in NSF priority areas including INFEWS and UtB. HEC I&A also includes MPS, ENG, and CISE investments in new computational methods, algorithms, robust software, and other computational tools to support researchers in the mathematical and physical sciences, and engineering through support for programs such as Computational Data-Enabled Science and Engineering. The CISE investment in computational

infrastructure as part of CIF21 is reflected here, as well as the development of wireless testbeds that support experimentation with new wireless technology services as part of EARS. GEO supports EarthCube, a CIF21 investment that sustains cyberinfrastructure for the geosciences. HEC I&A also includes investments in innovative partnerships and collaborations between universities and industries, including the Industry/University Cooperative Research Centers program (I/UCRC); GEO's support for operations and maintenance for the NCAR Wyoming Supercomputer facility; and BIO's support for development of pioneering informatics tools and resources including the iPlant Collaborative that have the potential to transform research in biology.

High Confidence Software and Systems (HCSS) ($97.94 million) CISE and ENG will increase investments in NRI and in CPS as part of CEMMSS, as well as continue investments in Smart and Connected Health (SCH). As development of the next generation of robotics proceeds, complete confidence in the systems supporting those that work beside, or cooperatively with, people in application domains, such as advanced manufacturing, emergency response, and healthcare, become increasingly important. High confidence surgical robots and medical devices are central to high-quality healthcare and building trust in robotic aids. CISE and ENG will support advanced manufacturing technologies research in cyber-physical systems, such as smart infrastructure that will blend traditional concrete-and-steel physical infrastructure systems with cyber-infrastructure systems such as computers, networks, and sensors. CISE's support for HCSS also includes investments in INFEWS and UtB. INFEWS investments focus on innovative optimization techniques, algorithms, and software development. UtB investments (which include support of the BRAIN Initiative) seek to foster new computational models across multiple scales, from molecules to behavior, toward accomplishing the ultimate goal of establishing an integrative, quantitative, and predictive theory of brain function in action and in context. Additionally, CISE, in collaboration with ENG and SBE, will support effective integration of networked computing systems, physical devices, data sources, and infrastructure leading to smart cities as part of a new multi-directorate activity in urban science. BIO's support for HCSS will expand and enhance access to the national resource of digital biological and paleontological data, and the Bio/computation Evolution in Action CONsortium (BEACON) Center established to study the power of evolutionary processes and to transfer those discoveries from biology into computer science and engineering design.

Human Computer Interaction and Information Management (HCI&IM) ($296.99 million) HCI&IM includes CISE support for NRI, a component of CEMMSS, SCH, and UtB. As part of the next generation of robotics, co-robot systems will be characterized by their flexibility and resourcefulness. They will use a variety of modeling or reasoning approaches, and use real-world data in real-time, demonstrating a level of intelligence and adaptability seen in humans and animals. SCH support will focus on human-centered intelligent information systems and tools that collect, mine, synthesize, protect, and share appropriate data and knowledge with healthcare organizations, practitioners, caregivers, and individuals to enable effective, safe, and well-informed decision-making by all stakeholders. UtB investments will enable the research needed to integrate computational models across scales; the development of innovative neurotechnologies to monitor brain function; and the expansion of the capacity of neuroscience infrastructure to integrate data across levels of analysis from molecular to behavioral scales.

HCI&IM also includes NSF investments in CIF21 related to BIGDATA analytics and visualization tools, and the development of mid-scale pilots and prototypes toward a comprehensive, scalable data infrastructure. BIO investments in HCI&IM will facilitate discovery through tools that integrate the published literature with the expanding universe of digital data collections, expand capacity for understanding through virtual environments, and make it practical for scientists to search vast collections of biological images simply and quickly. MPS investments will focus on the provision of new automated data-analysis pipelines that will provide initial reference images for the data-rich radio interferometers that are just coming on line, with analysis tools and guidance for those scientists who need to interact with the data in order to achieve image fidelities beyond those that can be delivered using automated

processing techniques. SBE will continue investments to increase the benefit of computer technologies to scientists, as well as non-science users, to develop user-friendly large-scale next-generation data resources and relevant analytic techniques to advance fundamental research in SBE areas of study, to support research on privacy in today's networked world, and to focus on research that advances the core scientific and technological means of managing, analyzing, visualizing, and extracting information from large data sets.

Software Design and Productivity (SDP) ($90.63 million) SDP support reflects increased investment in CIF21 with a focus on software sustainability, and new research on smart systems as part of CEMMSS. ENG's support for this PCA is primarily associated with the CPS and NRI components of the CEMMSS investment. CISE will make investments in the Software Institutes for Sustained Innovation (SI^2) program to catalyze new thinking, paradigms, and practices in developing and using software that is robust, reliable, usable, and sustainable under the CIF21 umbrella. CISE will also provide increased support for software as part of increased computational capacity supported by NSF. BIO support for SDP includes support for the interagency and international Collaborative Research in Computational Neuroscience program. BIO funds research involving the development of software and other computational tools to advance biological knowledge and computational innovations. SDP also includes support for SBE's National Center for Science and Engineering Statistics (NCSES) to continue exploration of new methods to enhance data collections, analysis, and sharing capabilities, which will help NCSES better serve its role of providing information on the science and engineering enterprise. In addition, SBE will continue to partner with CISE in exploring the emerging interface between computer science and the social, behavioral, and economic sciences.

Social, Economic, and Workforce (SEW) Implications of IT and IT Workforce Development ($129.06 million) As part of NRI, SEW research in CISE will focus on human-centered research in developing service robots, requiring significant advances in human-robot interaction. In addition, CISE's continued emphasis on SCH focuses on, for example, improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies. This also reflects CISE support for BIGDATA and e-science collaboration tools as part of CIF21, and support for cyberlearning and on-line education programs. CISE, ENG, and EHR will also continue to support the Cyberlearning and Future Learning Technologies program, which aims to integrate advances in technology with advances in understanding how people learn, with a focus on online learning environments. Research in cyberlearning will integrate advances in technology with learning, designing new technologies for integration in learning environments, and evaluating their use. EHR will continue to study the impact of information and communication technology on educational practice, new approaches to using technology in education, application and adaptation of technologies to promote learning in a variety of fields and settings, the effects of technology of learning, and efforts that advance teaching and learning opportunities utilizing cyberinfrastructure as part of its support. CISE will collaborate with EHR to support cyber-secure workforce development to enable a growing pipeline of researchers and educators, and to develop a citizenry that understands the security and privacy of the digital systems on which society depends. These efforts also will support science, technology, engineering, and mathematics education for the cyber-workforce through workforce programs and research and development in learning sciences. Such efforts will look to produce rapid progress on changing the balance of diversity and increase diversity in the cyber-workforce as part of the CISE support for the new NSF INCLUDES investment area. BIO support for SEW (for example through SESync, the National Socio-Environmental Synthesis Center) focuses on advancing the Nation's ability to incorporate and apply biological knowledge to economic development and other issues of societal importance. SBE will continue to support SEW by focusing on the nature and dynamics of IT impacts on technical and social systems.

NITRD Funding by Program Component Area

(Dollars in Millions)

	FY 2014 Actual	FY 2015 Estimate	FY 2016 Request
Large Scale Networking	$131.67	$127.91	$130.84
Cybersecurity and Information Assurance	103.42	106.80	111.73
High End Computing R&D	115.96	131.82	138.37
High End Computing Infrastructure and Applications	233.58	217.85	221.40
High Confidence Software and Systems	87.15	94.92	97.94
Human-Computer Interaction and Info Management	282.63	292.34	296.99
Software Design and Productivity	77.63	88.59	90.63
Social, Economic, and Workforce	119.80	125.75	129.06
Total, NITRD	**$1,151.85**	**$1,185.98**	**$1,216.96**

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