

NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT (NITRD)

Total Funding for NITRD

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Biological Sciences	\$99.00	\$99.00	\$99.00
Computer and Information Science and Engineering	932.98	935.82	994.80
Education and Human Resources	9.50	9.50	9.50
Engineering	28.97	29.30	29.80
Geosciences	24.00	24.00	24.00
Mathematical and Physical Sciences	79.87	70.13	69.17
Social, Behavioral, and Economic Sciences	30.97	28.14	28.14
Total, NITRD	\$1,205.29	\$1,195.89	\$1,254.41

NSF's FY 2017 Budget Request for the Networking and Information Technology Research and Development (NITRD) program is \$1.25 billion, of which \$1.19 billion is discretionary funding and \$56.37 million is new mandatory funding. New mandatory funding for NITRD represents increased support for NITRD research in FY 2017 by the Computer and Information Science and Engineering (CISE) directorate. Details on new mandatory funding by NITRD Program Component Area (PCA) are listed below.

NSF is a primary supporter of the NITRD program, and NSF's NITRD portfolio includes all research, infrastructure, and education investments in CISE, as well as contributions from all other directorates across the agency, enabling investments in every NITRD 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 most of the PCA Coordinating Groups and three of the Senior Steering Groups.

In August 2015, the President's Council of Advisors on Science and Technology (PCAST) released the *Report to the President and Congress Ensuring Leadership in Federally Funded Research and Development in Information Technology*.¹ The report provides the PCAST's findings from its biennial review of the NITRD program and recommendations for modernizing the program's R&D investment portfolio and coordination process. The 2015 PCAST review of the NITRD program included a recommendation to revise the NITRD R&D investment portfolio to reflect both the current nature of information technology (IT) and the national priorities in which IT plays a major role. In response, the number of PCAs increased from eight to 10. Of the 10 PCAs, four are new (Enabling-R&D for High-Capability Systems; High Capability Computing Systems Infrastructure and Applications; Large-Scale Data Management and Analysis; and Robotics and Intelligent Systems). Three are impacted by the newly defined PCAs (Human Computer Interaction and Information Management; High Confidence Software and Systems; and Large Scale Networking), with the definition of one (Human Computer Interaction and Information Management) changing. The remaining three are unchanged (Cyber Security and Information Assurance; Software Design and Productivity; and Social, Economic, and Workforce Implication of IT and IT Workforce Development). Two of the eight PCAs previously used to describe the NITRD portfolio

¹ *Report to the President and Congress Ensuring Leadership in Federally Funded Research and Development in Information Technology*. August 2015, President's Council of Advisors on Science and Technology: https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/nitrd_report_aug_2015.pdf

(High End Computing Infrastructure and Applications (HEC I&A) and High End Computing R&D (HEC R&D)) were retired as part of this revision as well.

Several NSF-wide investments, both new and continuing, are reflected in various NITRD PCAs:

- The Comprehensive National Cybersecurity Initiative (CNCI) supports activities in Cybersecurity and Information Assurance.
- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS), a collaboration among the Biological Sciences (BIO), CISE, Engineering (ENG), Education and Human Resources (EHR), and the Mathematical and Physical Sciences (MPS) directorates, includes Advanced Manufacturing, Designing Materials to Revolutionize and Engineer our Future (DMREF), and Smart Systems, which will span a new investment area in Smart and Autonomous Systems (S&AS) as well as existing investments in Cyber-Physical Systems (CPS) and the National Robotics Initiative (NRI). CEMMSS is establishing a scientific basis for engineered systems interdependent with the physical world and social systems, is synthesizing multi-disciplinary knowledge to model and simulate systems in their full complexity and dynamics, and is developing a smart systems technology framework. CEMMSS supports activities primarily in High Confidence Software and Systems; Robotics and Intelligent Systems; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development. Additionally, the advanced manufacturing investment encompasses research in nanotechnology, cyber-physical systems, and robotics, as well as expanded industry/university cooperation. Activities are supported primarily in High Confidence Software and Systems, and Robotics and Intelligent Systems.
- Cyberinfrastructure Framework for 21st-Century Science, Engineering, and Education (CIF21), a collaboration among all NSF directorates, primarily supports investments in Enabling-R&D for High-Capability Computing Systems; High Capability Computing Systems Infrastructure and Applications; Large-Scale Data Management and Analysis; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development. CIF21 will conclude at the end of FY 2017; however, support for NITRD investments in this area will begin to transition to new activities as part of the new Data for Scientific Discovery and Action (D4SDA) investment area and the National Strategic Computing Initiative (NSCI) (see below).
- Data for Scientific Discovery and Action (D4SDA) is a cross-directorate investment that will enable moving 21st-century science, engineering, and education toward effective use of digital data to advance discovery. This investment supports Large-Scale Data Management and Analysis.
- The National Strategic Computing Initiative (NSCI), an NSF-wide investment led by CISE and MPS, aims to maximize the benefits of high-performance computing (HPC) for scientific discovery and economic competitiveness. The NSCI investment supports Enabling-R&D for High-Capability Computing Systems; High Capability Computing Systems Infrastructure and Applications; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- The Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) NSF-wide investment, supports Cybersecurity and Information Assurance; High Confidence Software and Systems; Large-Scale Data Management and Analysis; and Large Scale Networking.
- Investments in NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers 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 Risk and Resilience NSF-wide investment, a collaboration among the CISE, ENG, GEO, and Social, Behavioral, and Economic Sciences (SBE) directorates supports primarily Enabling-R&D for High-Capability Computing Systems; High Confidence Software and Systems; 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 recent federal cybersecurity strategies including

Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program;² the government-wide Comprehensive National Cybersecurity Initiative (CNCI); and the recent Cybersecurity Enhancement Act of 2014 (P.L. 113-274). SaTC supports the research and education that will ensure society's ubiquitous computing and communication systems deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. The SaTC investment supports Cybersecurity and Information Assurance; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.

- NSF investments in Smart & Connected Communities (S&CC), a collaboration among CISE, EHR, ENG, GEO and SBE, supports High Confidence Software and Systems, Human-Computer Interaction and Information Management, Large-Scale Data Management and Analysis, and Large Scale Networking activities.
- The Understanding the Brain (UtB) investment, a collaboration among BIO, SBE, CISE, EHR, ENG, and MPS, supports activities in High Confidence Software and Systems; Human Computer Interaction and Information Management; and Social, Economic, and Workforce Implications of IT and IT Workforce development. These activities also support part of NSF's contributions to the Administration's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative.

FY 2017 NSF Investments by Program Component Area (PCA)

The following information focuses on FY 2017 NSF investments, both new and continuing, by PCA.

Cybersecurity and Information Assurance (CSIA) (\$117.11 million: \$110.98 million in discretionary funding, \$6.13 million in new mandatory funding): CSIA includes support for CNCI and NSF's SaTC program. Increased CISE investments in SaTC, in partnership with ENG, MPS, and SBE, aim to support the research that will ensure society's ubiquitous computing and communication systems deliver the quality of service they are designed to achieve without disruption, while enabling and preserving privacy, security, and trust. 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.

Enabling-R&D for High-Capability Computing Systems (EHCS) (\$137.59 million: \$130.98 million in discretionary funding, \$6.61 million in new mandatory funding): EHCS includes support for CISE's nanotechnology research. EHCS also includes increased support for research in Clean Energy Technologies by CISE, focusing on research that will develop the theory and design principles to tackle energy versus computation and communication tradeoffs effectively; and the development of new theory, algorithms, and design principles to optimize energy-computational performance in high-capability computing and communications systems. Through investments in NSCI, EHCS will support advances in HPC systems, increasing the capacity, capability, and sustainability of an enduring national HPC ecosystem. EHCS also includes support for CIF21 to develop new functional capabilities in support of highly parallel computing and big data analytics; and CISE support for Risk and Resilience, enabling advances in large-scale resilient, secure, and interoperable research cyberinfrastructure. MPS will support research to advance computational algorithms and data analytics to address scientific and engineering challenges presented by the ever-expanding role of computational modeling and simulation combined with the explosion of data coming from digital and observational data sources. MPS also will support fundamental research on innovative materials integration and novel phenomena associated with quantum information science, optical computing, and neuro-computing.

²www.whitehouse.gov/sites/default/files/microsites/ostp/fed_cybersecurity_rd_strategic_plan_2011.pdf

High-Capability Computing Systems Infrastructure and Applications (HCSIA) (\$190.41 million: \$183.19 million in discretionary funding, \$7.22 million in new mandatory funding): HCSIA 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 in alignment with NSCI. HCSIA also includes MPS, ENG, and CISE investments in new computational methods, algorithms, scientific databases, and other computational tools to support researchers in the mathematical and physical sciences, and engineering through support for programs such as Computational and Data-Enabled Science and Engineering. The CISE investment in computational infrastructure as part of CIF21 is reflected here alongside GEO's support for EarthCube, a cyberinfrastructure investment for the geosciences. GEO's continued support for the operations and maintenance of the National Center for Atmospheric Research (NCAR) Wyoming Supercomputer facility and associated modeling efforts also is reflected in this area. HCSIA also includes BIO's support for the application of high performance computing to a range of grand challenge problems in the biological sciences including, Understanding the Brain (UtB), genotype to phenotype, and the environmental sciences.

High Confidence Software and Systems (HCSS) (\$91.08 million: \$86.53 million in discretionary funding, \$4.55 million in new mandatory funding): CISE will provide initial support for a new investment on Smart & Autonomous Systems as part of CEMMSS that will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. Along with ENG, CISE will also support advanced manufacturing technologies research in cyber-physical systems, including cybermanufacturing, such as smart infrastructure that will blend traditional concrete-and-steel physical infrastructure systems with cyberinfrastructure 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, as part of a new NSF-wide activity on S&CC, CISE, in collaboration with EHR, ENG, GEO and SBE, will support fundamental research on advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities. 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 and information science and engineering design.

Human Computer Interaction and Information Management (HCI&IM) (\$190.79 million: \$183.19 million in discretionary funding, \$7.99 million in new mandatory funding): HCI&IM includes CISE support for S&CC, Smart and Connected Health (SCH), and UtB. S&CC supports the decision making, together with the necessary community building efforts, to improve quality of life, health, well-being, and learning in smart and connected communities. 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 ENG's support of projects to harness group expertise, intelligence, and insights as well as BIO's support of BIO team-based approaches to the understanding of complex biological processes through activities such as the Synthesis and Cyberinfrastructure Centers. These centers enable research

communities to manage and utilize large data sets and other information in efficient ways for best advancing progress in the biological sciences. MPS investments include continued support for user interface work funded by the Division of Astronomical Sciences, both through its regular research grants program, and from its observatories, who are charged to serve their user communities with archives and human computer interface tools. MPS also will support the provision of new automated data-analysis pipelines that will provide initial reference images for the data-rich radio interferometers, 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.

Large-Scale Data Management and Analysis (LSDMA) (\$115.19 million: \$111.25 million in discretionary funding, \$3.94 million in new mandatory funding): LSDMA includes NSF investments in CIF21 and D4SDA related to BIGDATA analytics and visualization tools, and the development of mid-scale pilots and prototypes toward a comprehensive, scalable data infrastructure as part of Data Infrastructure Building Blocks (DIBBs). Through NSF's support of the new D4SDA investment, LSDMA will focus on the development of novel computational, statistical, and mathematical techniques and technologies for data mining, machine learning, knowledge extraction, visualization, predictive modeling, automated discovery, and decision making, as applied to big data challenges. LSDMA also includes support for INFEWS focusing on novel approaches for large-scale, real-time data analytics. S&CC will support fundamental research on technologies integrating data-intensive computing; physical sensors/devices; and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities.

LSDMA also includes ENG's support of the cyberinfrastructure for the Natural Hazards Engineering Research Infrastructure (NHERI), which provides access to, and the storage and analysis of massive amounts of data related to natural disasters. A number of exploratory research projects in data analytics are also included. Moreover, the PCA includes support for CIF21 Investments from SBE such as the Resource Implementations for Data Intensive Research in the Social Behavioral and Economic Sciences (RIDIR) program and its contribution in support of the NSF-wide Public Access activity. Additional support from BIO related to this PCA includes research focused exclusively on managing large diverse data sets in order to extract knowledge from them, in particular, for the integrative modeling of complex biological processes. MPS support in this area includes support for research efforts to develop and advance theories and techniques for analyzing and extracting information from large and disparate data sets.

Large Scale Networking (LSN) (\$147.34 million: \$139.02 million in discretionary funding, \$8.32 million in new mandatory funding): 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. As part of S&CC, LSN will support a network of regional research hubs that will advance fundamental research in advanced networking, physical sensors/devices, and large-scale data management, analysis, and decision making to improve quality of life, health, well-being, and learning in smart and connected communities. CISE will also provide additional support for next-generation software-defined infrastructure, including wireless testbeds that enable research on topics ranging from radio access networks to spectrum sharing and adaptability.

Robotics and Intelligent Systems (RIS) (\$45.37 million: \$43.49 million in discretionary funding, \$1.88 million in new discretionary funding): CISE will provide initial support for a new investment on S&AS as part of CEMMSS that will focus on fundamental science and engineering addressing how intelligent physical systems sense, perceive, and operate in environments that are dynamic, uncertain, and unanticipated. In addition, RIS will include continued support for NRI, a component of CEMMSS and research in ENG related to the design, application, and use of robotics to augment human function, promote human-robot interaction, or to increase robot autonomy. 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, along with real-world data in real-time, demonstrating a level of intelligence and adaptability seen in humans and animals. 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.

Software Design and Productivity (SDP) (\$86.37 million: \$82.73 million in discretionary funding, \$3.64 million in new mandatory funding): SDP support reflects investment in CIF21 and NSCI, 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 (SI²) program to catalyze new thinking, paradigms, and practices in developing and using software that is robust, reliable, usable, and sustainable under the CIF21 umbrella. SI² support will transition to NSCI as CIF21 sunsets. 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. SBE will continue to collaborate with CISE in exploring the emerging interface between computer and information science and the social, behavioral, and economic sciences as part of its support for SDP.

Social, Economic, and Workforce (SEW) Implications of IT and IT Workforce Development (\$133.16 million, \$127.07 million in discretionary funding, \$6.09 million in new mandatory funding): 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. 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. Some of these investments will transition to S&CC, which will support health- and learning-related research in support of smart and connected communities. SEW also reflects CISE support for e-science collaboration tools as part of CIF21.

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 in the cyber-workforce, including as part of the CISE support for the NSF INCLUDES investment area. BIO support for SEW (for example, through 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. SEW includes CISE investment in the NSF Research Traineeship (NRT) program that will support the development of bold, new, potentially transformative and scalable models for STEM graduate training focusing on research areas of national priority.

SBE will continue to support SEW by focusing on the nature and dynamics of IT impacts on technical and social systems. SEW also includes SBE funding for cyberinfrastructure related to support of its "Big Three Surveys" (American National Election Studies, the Panel Study of Income Dynamics, and the General

Social Survey), which are national data infrastructures for researchers. Through support for the surveys and the related cyberinfrastructure, SBE supports research that enables examination of societal concerns such as competitiveness, security, economic development, and wellbeing.

NITRD Funding by Program Component Area

(Dollars in Millions)

	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
Cyber Security and Information Assurance	\$107.31	\$110.54	\$117.11
Enabling-R&D for High-Capability Computing Systems	133.05	129.81	137.59
High Capability Computing Systems Infrastructure and Applications	188.98	180.42	190.41
High Confidence Software and Systems	83.67	85.82	91.08
Human Computer Interaction and Information Management	187.52	187.38	190.79
Large-Scale Data Management and Analysis	110.69	110.42	115.19
Large Scale Networking	134.81	137.76	147.34
Robotics and Intelligent Systems	43.08	42.99	45.37
Software Design and Productivity	89.08	84.59	86.37
Social, Economic, and Workforce Implications of IT and IT Workforce Development	127.10	126.16	133.16
Total, NITRD	\$1,205.29	\$1,195.89	\$1,254.41

Totals may not add due to rounding.