

**DIRECTORATE FOR COMPUTER AND INFORMATION
SCIENCE AND ENGINEERING (CISE)**

**\$950,250,000
+\$85,020,000 / 9.8%**

CISE Funding
(Dollars in Millions)

	FY 2012		FY 2014 Request	Change Over	
	FY 2012 Actual	Enacted/ Annualized FY 2013 CR		FY 2012 Enacted Amount	Percent
Advanced Cyberinfrastructure (ACI) ¹	\$283.84	\$211.64	\$221.35	\$9.71	4.6%
Computing and Communication Foundations (CCF)	179.03	179.13	200.46	\$21.33	11.9%
Computer and Network Systems (CNS)	212.36	212.50	238.87	\$26.37	12.4%
Information and Intelligent Systems (IIS)	176.58	176.50	200.42	\$23.92	13.6%
Information Technology Research (ITR)	85.35	85.46	89.15	\$3.69	4.3%
Total, CISE	\$937.16	\$865.23	\$950.25	\$85.02	9.8%

Totals may not add due to rounding.

¹ FY 2012 Actual includes obligations \$71.59 million over the enacted level for ACI (formerly OCI) due to recoveries of prior year unpaid obligations that were reobligated in FY 2012.

About CISE

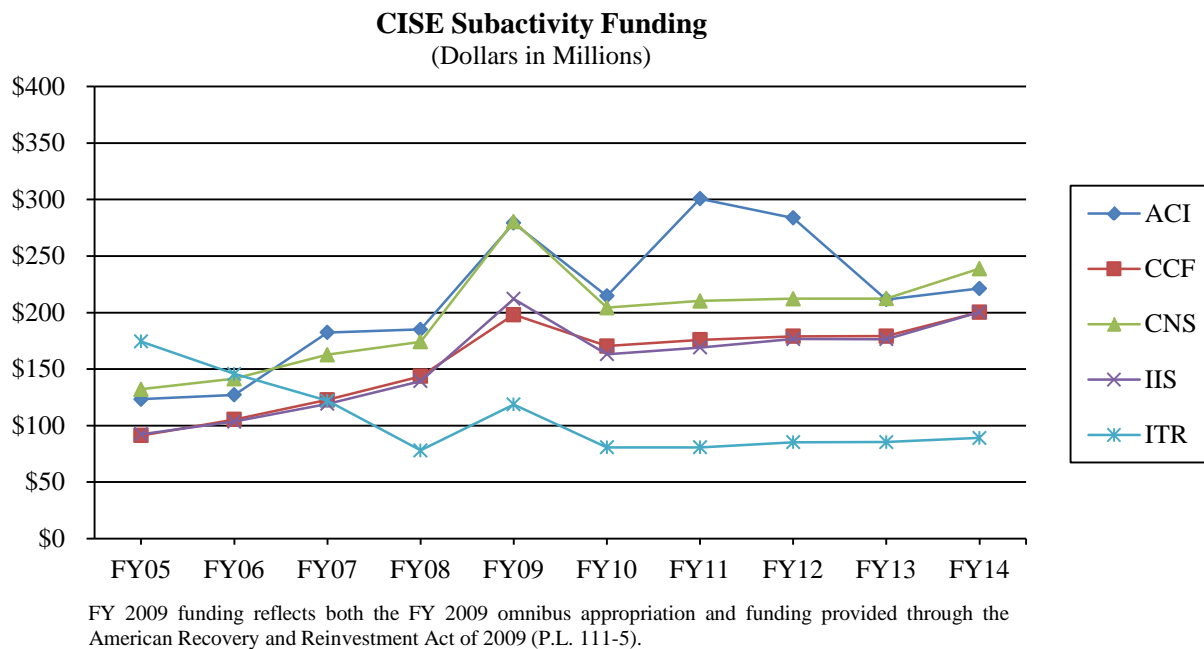
CISE’s mission is to promote the progress of computer and information science and engineering research and education, and advance the development and use of cyberinfrastructure; to promote understanding of the principles and uses of advanced computer, communications, and information systems in service to society; and to contribute to universal, transparent, and affordable participation in an information-based society. CISE supports ambitious long-term research and research infrastructure projects within and across the many sub-fields of computing, as well as cyberinfrastructure for all areas of science and engineering; contributes to the education and training of computing professionals; and, more broadly, informs the preparation of a U.S. workforce with computing and computational competencies essential to success in an increasingly competitive global market. CISE’s FY 2014 Budget Request is shaped by the following major NSF cross-foundation investments – Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMSS); Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21); Secure and Trustworthy Cyberspace (SaTC); Science, Engineering, and Education for Sustainability (SEES); Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE); and NSF Innovation Corps (I-Corps) – in addition to investments in its core research, education, and infrastructure programs.

CISE continues to play a leadership role in the multi-agency Subcommittee on Networking and Information Technology Research and Development (NITRD), which is co-chaired by the CISE Assistant Director. All research, education, and research infrastructure projects supported by CISE enrich the agency’s NITRD portfolio. As noted by the President’s Council of Advisors on Science and Technology (PCAST) in its *Report to the President and Congress - Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology* (January 2013)¹, advances in Networking and Information Technology (NIT) are key drivers of U.S. economic competitiveness.

¹ www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd2013.pdf

Fundamental ideas and concepts derived from basic computing research have enabled innovative products and applications that now permeate all areas of modern life. IT is integral to the Nation’s economy, as it drives discovery and innovation in many other areas, e.g., frontiers of scientific research, advanced manufacturing, education and workforce development, health and wellness technologies, sustainability and energy science, transportation, national and homeland security research, and public and private organizational effectiveness and efficiency. Innovation in IT will remain an essential and vital force in productivity gains and economic growth in both the manufacturing and service sectors for many years to come, positioning NSF and CISE as central and essential actors in improving the Nation’s economic outlook and advancing a highly trained, technologically astute workforce.

NSF provides approximately 82 percent of the total federal support for basic research at academic institutions in computer science.



FY 2014 Summary by Division

- ACI’s FY 2014 Budget Request is focused on maintaining investments in existing programs in computational science, software, data, networking, and cybersecurity, and providing leadership in the NSF-wide CIF21 activity through increased investments in programs, such as Data Infrastructure Building Blocks (DIBBs), Software Infrastructure for Sustained Innovation (SI²), and the cross-agency Core Techniques and Technologies to Advance Big Data Science and Engineering (BIGDATA). The goal of CIF21 is to accelerate and transform the progress of scientific discovery and innovation by providing cyberinfrastructure – including new data infrastructure and computational frameworks – that enable novel functionalities and capabilities in data-enabled, computational science and engineering. ACI continues to support other cross-disciplinary activities, including transitioning discoveries into practice in the SaTC program; leading the Computational- and Data-Intensive Science & Engineering (CDS&E) family of programs across the directorates, as well as the CIF21 track within the NSF Research Traineeships (NRT) program; and participating in INSPIRE and I-Corps.

- CCF's FY 2014 Budget Request is focused on enhancing support for its core programs and on support for NSF-wide investment areas. CCF will support the NSF-wide CIF21 program through increased investments in BIGDATA foundational research, including algorithms and software tools for managing massive amounts of heterogeneous, complex data; new functional capabilities in support of highly parallel computing, and multi-core and multi-machine data management systems. CCF, as part of the NSF-wide SEES portfolio, will increase investments in Cyber-Enabled Sustainability and Engineering (CyberSEES), focusing on the computational methods and models necessary to attain a sustainable future. CCF will increase investments in reliable wireless transmission; theoretical performance limits of spectrum sharing; technical and economic models for flexible spectrum access, real-time auctions, and on-demand spectrum services and support for the Enhancing Access to the Radio Spectrum (EARS) program. CCF will also increase its investments in eXploiting Parallelism and Scalability (XPS) as part of its core programs. CCF will support foundational research in SaTC, including new theories, models, methods, architectures, and tools that aim to achieve security-aware computing, self-healing hardware, and self-protecting software. As part of the National Nanotechnology Initiative, CCF will focus on research in nanoscale devices and systems.
- CNS's FY 2014 Budget Request is focused on enhancing support for its core programs, as well as on providing support for NSF-wide investment areas. In partnership with the other CISE divisions and the Directorates for Education and Human Resources (EHR), Engineering (ENG), Mathematical and Physical Sciences (MPS), and Social, Behavioral and Economic Sciences (SBE), CNS will continue to lead the SaTC program. CNS will maintain CISE's national leadership in developing the scientific foundations of cybersecurity as part of the Comprehensive National Cybersecurity Initiative (CNCD). Also, in partnership with other CISE divisions and NSF directorates, CNS will expand its support for CEMMSS through increased investment in research in Cyber-Physical Systems (CPS), Advanced Manufacturing (AM), and the National Robotics Initiative (NRI). CNS will increase support for research in wireless communication and mobile computing, as well as partner with ENG and MPS to support EARS research in spectrum sharing architectures and services. Additionally, CNS will support the NSF-wide CIF21 investment through BIGDATA research on pervasive computing, as well as large-scale data management systems. CISE and EHR will consolidate the Computing Education for the 21st Century (CE21) program and Math and Science Partnerships (MSP) programs into the Science, Technology, Engineering, and Mathematics, including Computing Partnerships (STEM-C Partnerships) program in FY 2014. CNS will increase its investment in the STEM-C Partnerships program. CNS will also continue its support of the Global Environment for Network Innovations (GENI) project, allowing for experimentation in future networks not possible elsewhere.
- IIS's FY 2014 Budget Request is focused on enhancing support for its core programs and on support for NSF-wide investment areas. IIS will participate in CEMMSS through leadership of NRI, in partnership with the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), and Department of Agriculture (USDA), as well as other NSF directorates ENG, EHR, and SBE. NRI will accelerate the development and use of robots in the United States that work beside, or cooperatively with, people. IIS will participate in the NSF-wide CIF21 activity through increased investments in BIGDATA analytics and e-science, including new approaches to data mining, machine learning, knowledge extraction, visualization, predictive modeling, and automated discovery as well as in DIBBs, which will develop, implement, and support the new methods, management structures, and technologies to store and manage the diversity, size, and complexity of current and future data sets and data streams. IIS will lead a joint NSF – NIH program, Smart and Connected Health (SCH), partnering with ENG and SBE, as well as with other CISE divisions. IIS will participate in the cyberlearning and on-line education program which aims to integrate advances in technology with advances in what is known about how people learn. IIS will

increase its investments in neuroscience, building on investments in computational neuroscience and foundational research programs to revolutionize understanding of brain functions.

- ITR’s FY 2014 Budget Request will provide support for emerging high-priority areas of potentially transformative research. Through I-Corps, ITR will develop and nurture a national innovation ecosystem that builds on foundational research and guides the output of scientific discoveries to the development of technologies, products, and processes that benefit society. ITR will continue to invest in the Expeditions in Computing program, which encourages researchers to come together to identify the compelling ideas that promise transformations in computing and information sciences for years to come. ITR will invest in multi-disciplinary research networks, aiming to build communities across emerging areas of research and education. ITR will increase its investments in mid-scale infrastructure, leveraging previous investments in GENI and developing new cloud testbeds. This effort will extend virtualization beyond the network to large-scale, interconnected computing resources by investing in mid-scale prototypes for an NSF Cloud research infrastructure. Through US Ignite, ITR will continue to expand and provide U.S. campuses with network testbeds that advance networking and systems research through experimentation and explorations at scale, and jumpstart public sector gigabit application development and deployment.

Major Investments

CISE Major Investments

(Dollars in Millions)

Area of Investment	FY 2012	FY 2012	FY 2014	Change Over	
	Actual	Enacted/ Annualized FY 2013 CR	Request	FY 2012 Enacted Amount	Percent
Advanced Manufacturing	\$27.80	\$27.80	\$39.63	\$11.83	42.6%
CAREER	51.26	52.24	56.64	4.40	8.4%
CEMMSS	50.50	50.50	103.00	52.50	104.0%
CIF21	47.94	35.00	90.67	55.67	159.1%
Clean Energy Technology	18.00	18.00	23.50	5.50	30.6%
CNCI	57.42	59.00	51.00	-8.00	-13.6%
EARS	7.00	7.00	24.00	17.00	242.9%
I-Corps	2.55	2.75	9.00	6.25	227.3%
INSPIRE	3.84	0.50	5.00	4.50	900.0%
NRI	13.54	12.50	21.50	9.00	72.0%
SEES	9.02	9.50	19.00	9.50	100.0%
SaTC	58.89	59.00	75.00	16.00	27.1%
STEM-C Partnerships	-	-	16.50	16.50	N/A

Major investments may have funding overlap and thus should not be summed.

- **Advanced Manufacturing:** As part of CEMMSS, CISE will invest in research that integrates ubiquitous sensors, computational tools, and highly connected cyber-physical systems in smart processing and advanced manufacturing systems, resulting in higher quality products with greater efficiency and sustainability produced by the factories of the future. CISE will also invest in basic research to advance robotics technology in order to enable new functionalities and provide the next-generation of products and services in various industries. In addition, CISE will support research

aimed at the development of next-generation robotics, conceived as co-robots that work alongside, or cooperatively with, people in manufacturing environments to increase their productivity, performance, and safety.

- CAREER: This program invests in the integration of research and education of early-career researchers and contributes to the development of future generations of computer and information scientists and engineers, as well as computational scientists across all areas of science and engineering.
- CEMMSS: CISE aims to 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. As part of CEMMSS, the CPS program, funded jointly with ENG, will be expanded through investments from MPS, SBE, and the Directorate for Biological Sciences (BIO) to accelerate advances in 21st century smart engineered systems. CEMMSS also includes CISE investments in the multi-agency NRI. As part of this research activity, CISE will also synergize investments across multiple research communities and programs in order to transform static systems, processes, and edifices into adaptive, pervasive smart systems with embedded computational intelligence that can sense, adapt, and react.
- CIF21: CISE will lead CIF21 in support of advances in the cross-agency BIGDATA research program and through investments in the DIBBS program. BIGDATA research will focus on core scientific and technological means of managing, analyzing, visualizing, and extracting useful information from large, diverse, distributed, and heterogeneous data sets. DIBBS aims to develop, implement, and support new cyberinfrastructure to store and manage the diversity, size, and complexity of current and future data sets and data streams. To advance new computational infrastructure, CISE will support SI², catalyzing new paradigms and practices in the development and use of software that is robust, reliable, usable, and sustainable. CIF21 researchers can now take advantage of two new significant computational resources that became available in FY 2013 – Blue Waters and Stampede.
- Clean Energy Technology: CISE will support foundational research in energy-intelligent computing; the development of new theory, algorithms, and design principles to effectively tackle energy versus computation and communication tradeoffs; and the scalability and sustainability of smart energy production software and hardware. CISE research on clean energy is partially supported via investments in SEES.
- CNCI: CISE will focus on the development of the science of cybersecurity, as well as on four game-changing research areas – designed-in security, moving target defense, tailored trustworthy spaces, and cyber economic incentives. CISE will also actively work to transition mature discoveries into a secure research infrastructure. In partnership with SBE, CISE will invest in research at the intersection of economic and computer sciences to achieve secure practices through the development of mechanisms that incentivize good behavior in cyberspace.
- EARS, including wireless and mobile computing: CISE will increase support for research in wireless communication, spectrum sharing, and mobile computing, as well as the development of wireless and spectrum testbeds. Collaborations with ENG and MPS in EARS will strengthen U.S. leadership in the global wireless technology marketplace.

- I-Corps: CISE's investment will seek to identify NSF-funded researchers who will receive additional support – in the forms of mentoring and funding – to accelerate innovation that can attract subsequent third-party investment. In FY 2013, NSF initiated two additional I-Corps subcomponents – Sites and Nodes – to further build, utilize, and sustain a national innovation ecosystem that continues to augment the development of technologies, products, and processes that benefit the Nation. I-Corps Sites are funded at academic institutions, having already existing innovation or entrepreneurial units, to enable them to nurture and support multiple, local teams to transition their ideas, devices, processes or other intellectual activities into the marketplace. The I-Corps Nodes subcomponent's goal is to establish regional nodes to provide training to I-Corps Teams; develop tools and resources that will impact and expand the benefits of the entire I-Corps program within a two to three year timeframe; and identify and pursue longer-term research and development projects.
- INSPIRE: CISE will integrate a suite of new activities with existing efforts to foster and support transformative interdisciplinary research. In FY 2014, CISE will invest in several mid-scale awards to build a new pool of potential innovators.
- NRI: The NRI is a national multi-agency research program led by NSF in partnership with NIH, NASA, and USDA that aims to accelerate the development and use of co-robots. In partnership with EHR, ENG, and SBE, NRI will support fundamental science and engineering in robotics research, and enhance understanding of the social and economic impacts of co-robots. NRI is a primary component of the smart systems research investment in CEMMSS.
- SEES: CISE will invest in CyberSEES, which aims to advance interdisciplinary research in which the science and engineering of sustainability are enabled by advances in computational- and data-intensive research and education. CISE will also invest in *Interdisciplinary Research in Hazards and Disasters* (Hazards SEES) to catalyze well-integrated interdisciplinary research efforts in hazards-related science and engineering.
- SaTC: NSF is aligning its cybersecurity investments (including investments from EHR, ENG, MPS, and SBE) with the Administration's national cybersecurity strategy, *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program*. SaTC aims to support scientific foundations, induce change, maximize research impact, and accelerate the transition to practice. This investment also includes support for CNCI. 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.
- STEM-C Partnerships: CISE and EHR will consolidate the Computing Education for the 21st Century (CE21) program and Math and Science Partnerships (MSP) programs into the Science, Technology, Engineering, and Mathematics, including Computing Partnerships (STEM-C Partnerships) program in FY 2014. This program will enlarge the pool of K-14 students and teachers who develop and practice computational competencies in a variety of contexts, as well as the pool of early postsecondary students who are engaged and have the background in computing necessary to successfully pursue degrees in computing-related and computationally-intensive fields of study.

CISE Funding for Centers Programs and Facilities

CISE Funding for Centers Programs

(Dollars in Millions)

	FY 2012		FY 2014 Request	Change Over	
	FY 2012	Enacted/ Annualized		FY 2012	Enacted
	Actual	FY 2013 CR		Amount	Percent
Centers Programs Total	\$11.25	\$11.50	\$9.69	-\$1.82	-15.8%
STC: Team for Research in Ubiquitous Secure Technology (CCF)	4.00	4.00	2.66	-1.34	-33.5%
STC: Science of Information (CCF)	5.00	5.00	5.00	-	-
SLC: Pittsburgh Science of Learning Center - LearnLab (ITR)	2.25	2.50	2.03	-0.48	-19.0%

Total may not add due to rounding.

For detailed information on individual centers, please see the NSF-Wide Investments chapter.

- CISE will provide the tenth and final year of funding, at a reduced level as the program ramps down, for the Science and Technology Center (STC) Team for Research in Ubiquitous Secure Technology (TRUST) at the University of California at Berkeley. TRUST is focused on the development of cybersecurity science and technology that will radically transform the ability of organizations to design, build, and operate trustworthy information systems for the Nation's critical infrastructure by addressing the technical, operational, legal, policy, and economic issues affecting security, privacy, and data protection, as well as the challenges of developing, deploying, and using trustworthy systems.
- CISE will provide the fourth year of funding for the STC: Center for the Science of Information at Purdue University. The goal of this center is to develop a new science of information that incorporates common features associated with data/information, such as space, time, structure, semantics, and context, that are not addressed by earlier mathematical theories, e.g., data obfuscation and hiding techniques that enhance robustness and the principles of redundancy and fault tolerance found in natural systems.
- CISE continues to support the LearnLab, formerly known as Pittsburgh Science of Learning Center (SLC) for Robust Learning, at a reduced level as the project ramps down. The Pittsburgh SLC leverages cognitive theory and cognitive modeling to identify the instructional conditions that result in robust student learning and to support field-based experimentation, data collection, and data mining in math, science, and language courses.

CISE Funding for Facilities

(Dollars in Millions)

	FY 2012		FY 2014 Request	Change Over	
	FY 2012	Enacted/ Annualized		FY 2012	Enacted
	Actual	FY 2013 CR		Amount	Percent
Facilities Total	\$0.60	\$0.60	\$0.60	-	-
National Nanotechnology Infrastructure Network (CCF)	0.60	0.60	0.60	-	-

For detailed information on individual facilities, please see the Facilities chapter.

Summary and Funding Profile

CISE supports investments in core and interdisciplinary research and education, as well as in computing research infrastructure.

In FY 2014, the number of research grant proposals is expected to increase by approximately 16 percent compared to FY 2012 Enacted Estimate. CISE expects to award approximately 1,800 research grants in FY 2014. Average annualized award size is expected to increase, while the average award duration is expected to increase slightly between the FY 2012 Enacted Estimate and FY 2014.

Funding for research infrastructure accounts for 17 percent of the CISE Request.

CISE Funding Profile			
	FY 2012 Actual Estimate	FY 2012 Enacted/ Annualized FY 2013 CR Estimate ¹	FY 2014 Estimate
Statistics for Competitive Awards:			
Number of Proposals	7,704	7,690	8,900
Number of New Awards	1,750	1,555	2,100
Funding Rate	23%	20%	24%
Statistics for Research Grants:			
Number of Research Grant Proposals	7,381	7,330	8,500
Number of Research Grants	1,495	1,335	1,800
Funding Rate	20%	18%	21%
Median Annualized Award Size	\$163,352	\$152,170	\$175,000
Average Annualized Award Size	\$210,210	\$186,077	\$225,000
Average Award Duration, in years	2.9	3.0	3.1

¹ Award Estimates for FY 2013, such as numbers of awards and size/duration, are based upon the FY 2012 Enacted level.

Program Monitoring and Evaluation

Committees of Visitors (COV):

- In FY 2014, CISE plans to hold a Committee of Visitors (COV) review, which will examine and assess the quality of the CISE merit review process.

Science and Technology Policy Institute (STPI) Reports and Evaluations:

- CISE management has established a contract with the Science and Technology Policy Institute (STPI) to conduct program evaluation feasibility studies for the SaTC and CEMMSS programs. These feasibility studies will examine baseline portfolio investments and identify metrics to measure progress toward program goals. The studies will be conducted to develop a plan for impact assessments of SaTC and CEMMSS investments. A contract was put into place, and a kick-off meeting was held at the end of the fourth quarter of FY 2012. The preliminary work to set out baseline evaluation metrics will be carried out in FY 2013, allowing program evaluation analyses to be deployed during FY 2014. Yearly program assessments will be carried out by the CEMMSS and SaTC working groups and presented to NSF senior management.

STEM Evaluation:

- Evaluation is a vital part of CISE’s STEM education programs. Each of the STEM-C Partnerships projects managed by CISE will provide a rigorous research and/or evaluation plan designed to guide project progress and measure its impact. The plan will include a description of the instrument and metrics that will be used. Across the STEM-C Partnerships portfolio managed by CISE, a set of common metrics and a design for evaluation instruments are being developed. The expectation is that the design will be completed in FY 2013 and the first program evaluation will be completed under a new contract to be negotiated in FY 2014.

Reports:

- To better assess the long-term economic impact of CISE investments, CISE funded the National Academy of Sciences (NAS) Computer Science and Telecommunications Board (CSTB) to study the IT innovation ecosystem. The report, *Assessing the Impacts of Changes in the Information Technology R&D Ecosystem*, published in 2009, includes an in-depth articulation of the creation since 1965 of almost 20 IT industries valued at a billion dollars. To update this study, CISE funded CSTB to identify recent IT industries that have reached the billion dollar mark; develop a brief report that highlights the updated figures; and summarize results-to-date of IT research, including the nature and successes of U.S. research partnerships among government, industry, and universities, and the economic payoffs of these research investments. The report, *Continuing Innovation in Information Technology*, was published in 2012.
- In FY 2011-2012, the CISE Directorate supported several community activities to assess future research and infrastructure needs. A workshop organized by the CISE-funded Computing Community Consortium (CCC) resulted in a report – *Science, Engineering, and Education of Sustainability: The Role of Information Sciences and Engineering* – that defines a vision for fundamental research at the intersection of sustainability and IT.² A subsequent study by the CSTB, *Computing Research for Sustainability*, specifies a framework for how innovation in computing will be essential to finding real world solutions to sustainability challenges, such as electricity production and delivery, global food production, and environmental adaptation.³ Separately, a CSTB study, *The Future of Computing Performance: Game Over or Next Level?*,⁴ together with a CCC white paper, *21st Century Computer Architecture*, outline the need for advances in computer architecture research.⁵

The Performance chapter provides details regarding the periodic reviews of programs and portfolios of programs by external COV and directorate Advisory Committees. Please see this chapter for additional information.

Number of People Involved in CISE Activities			
	FY 2012	FY 2013	FY 2014
	Actual	Estimate	Estimate
Senior Researchers	8,706	7,800	9,500
Other Professionals	1,108	900	1,200
Postdoctorates	415	500	500
Graduate Students	6,099	5,400	6,700
Undergraduate Students	2,639	2,000	2,900
Total Number of People	18,967	16,600	20,800

² http://cra.org/ccc/docs/RISES_Workshop_Final_Report-5-10-2011.pdf

³ www.nap.edu/catalog.php?record_id=13415

⁴ www.nap.edu/openbook.php?record_id=12980

⁵ <http://cra.org/ccc/docs/init/21stcenturyarchitecturewhitepaper.pdf>

DIVISION OF ADVANCED CYBERINFRASTRUCTURE (ACI)

\$221,350,000
+\$9,710,000 / 4.6%

ACI Funding
(Dollars in Millions)

	FY 2012 Actual ¹	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request	Change Over FY 2012 Enacted	
				Amount	Percent
Total, ACI	\$283.84	\$211.64	\$221.35	9.71	4.6%
Research	66.30	87.48	98.80	11.32	12.9%
CAREER	4.08	3.97	4.54	0.57	14.4%
Education	7.23	7.60	7.95	0.35	4.6%
Infrastructure	210.32	116.56	114.60	-1.96	-1.7%
Networking and Computational Resources Infrastructure and Services	210.32	116.56	114.60	-1.96	-1.7%

Totals may not add due to rounding.

¹ FY 2012 Actual includes obligations \$71.59 million over the enacted level for ACI (formerly OCI) due to recoveries of prior year unpaid obligations that were reobligated in FY 2012.

ACI enables science and engineering research and education by developing, creating, and supporting secure, advanced, global cyberinfrastructure (CI). ACI partners with NSF directorates and offices to support research and development across the entire range of cyberinfrastructure activities, including acquisition, integration, coordination, and operations associated with data, networking, computation, software, and the development of CDS&E tools and expertise. ACI focuses on the development of these resources and capabilities, as well as on the expertise to conduct next generation science and engineering, in order to better address complex and multidisciplinary discovery, prediction, and innovation. ACI also supports international activities in networking, data, and computation, including connectivity to major international resources and scientific instruments, and computational support to more than 8,000 faculty and researchers.

In general, about 31 percent of the ACI research and infrastructure portfolio is available for new research grants. The remaining 69 percent is used primarily to fund continuing grants made in previous years.

Approximately 60 percent of ACI's budget is used to support individuals and small groups of researchers, while about 40 percent of the budget goes to support larger cyberinfrastructure consortia and facilities, including the eXtreme Digital (XD) services program, the Blue Waters Petascale Computing Program, and mid-scale pilots and prototypes toward an integrated data infrastructure.

FY 2014 Summary

All funding decreases/increases represent change over the FY 2012 Enacted level.

Research

- ACI will continue support for early-career researchers through increased investments (+\$570,000 to a total of \$4.54 million) in the CAREER program.
- ACI will provide leadership for the NSF-wide CIF21 portfolio and increase its investments (+\$43.17 million to a total of \$66.17 million) in the portfolio of activities that provide integrated cyber resources, enabling multidisciplinary research opportunities in all areas of science and engineering. It

will leverage ongoing cyberinfrastructure investments across NSF by coordinating and deploying common approaches and components to manage data, provide computational support, and develop new multidisciplinary research communities. ACI's data investments include the Data Infrastructure Building Blocks (DIBBs) and BIGDATA programs, as well as development of mid-scale pilots and prototypes toward a national data infrastructure. DIBBs, a program initiated in FY 2012 to support data conceptualization and data pilot awards, will be added to the CIF21 portfolio in FY 2014 and represents \$33.17 million of the funding increase to CIF21 in FY 2014. ACI continues to support and invest in software innovation, development, and sustainability with additional investments in multi-directorate community building, and computational infrastructure activities.

- ACI will support the NSF-wide SEES portfolio (+\$1.50 million to a total of \$3.0 million) through cyberinfrastructure-enabled sustainability research, including the development of advanced and high-performance simulations and models.
- ACI will continue to support INSPIRE (+\$500,000 to a total of \$1.0 million), addressing some of the most complicated and pressing scientific problems that lie at the intersection of traditional disciplines.
- ACI will continue support of the I-Corps program (+\$750,000 to a total of \$1.0 million), which aims to guide the output of scientific discoveries closer to the development of technologies, products, and processes that benefit society. Additional investments will be put into I-Corps Sites and Nodes, which are designed to build and support a national innovation ecosystem that continues the development of technologies, products and processes that benefit the Nation.

Education

- With all CISE divisions, ACI will continue support for Research Experiences for Undergraduates (REU) sites and supplements (+\$150,000 to a total of \$1.25 million).
- ACI is home to the Cyberinfrastructure Postdoctoral Fellowship program (CI TRaCS). It is also a significant contributor to the CIF21 track within the Foundation-wide NSF Research Traineeships (NRT) program; it supports the Expeditions in Training, Research, and Education for Mathematics and Statistics through Quantitative Explorations of Data (EXTREEMS-QED) program with MPS; and it invests in the STEM-C Partnerships activity. This portion of the ACI Education portfolio totals to \$6.70 million (+\$200,000) in FY 2014.

Infrastructure

- The ACI Networking programs will increase investments (+\$2.35 million to a total of \$26.60 million) in improvements and re-engineering at the campus level to leverage dynamic network services to support a range of scientific data transfers and movement. The program also supports network integration activities tied to achieving higher levels of performance, reliability, security and predictability for science applications and distributed research projects.
- ACI will invest in the NSF-wide SaTC program (+\$2.0 million to a total of \$6.0 million) through support of efforts to transition cybersecurity research into practice, including more participation with campuses. The focus is on applied research, development, prototyping, testing, and experimental deployment, resulting in fielded capabilities and innovations of direct benefit to networks, systems, and environments supporting NSF science and engineering research and education.
- The High Performance Computing (HPC) program (-\$6.31 million to a total of \$82.0 million) will provide ongoing support for the eXtreme Digital (XD) services program, an advanced nationally distributed open cyberinfrastructure comprised of shared user and management services; the operation and maintenance of the Blue Waters Petascale Computing program; and ongoing support for experimental/innovative HPC. There are no HPC acquisitions planned for FY 2014. Refer to Appendix A in this chapter for more information on the HPC portfolio.

**DIVISION OF COMPUTING AND COMMUNICATION
FOUNDATIONS (CCF)**

**\$200,460,000
+\$21,330,000 / 11.9%**

CCF Funding
(Dollars in Millions)

	FY 2012		FY 2014 Request	Change Over FY 2012 Enacted	
	FY 2012 Actual	Enacted/ Annualized FY 2013 CR		FY 2012 Enacted Amount	Percent
Total, CCF	\$179.03	\$179.13	\$200.46	\$21.33	11.9%
Research	171.13	171.03	192.11	21.08	12.3%
CAREER	15.24	15.37	16.97	1.60	10.4%
Centers Funding (total)	9.00	9.00	7.66	-1.34	-14.9%
STC: Team for Research in Ubiquitous Secure Technology	4.00	4.00	2.66	-1.34	-33.5%
STC: Science of Information	5.00	5.00	5.00	0.00	-
Education	7.30	7.50	7.75	0.25	3.3%
Infrastructure	0.60	0.60	0.60	0.00	-
Nat'l Nanotechnology Infrastructure Network	0.60	0.60	0.60	0.00	-

Totals may not add due to rounding.

CCF supports research and education activities that explore the foundations and limits of computation, communication, and information; advance algorithmic knowledge for research areas both within and outside computer science; and advance software, hardware, and computer system design. CCF's research investments support advances in the design and analysis of algorithms, computational complexity, theoretical and experimental studies of algorithms and their resource requirements, and formal models of computation, including models for parallel, distributed, and heterogeneous multi-core machines. CCF invests in research that addresses the theoretical underpinnings and enabling technologies for information acquisition, transmission, and processing in communication and information networks, such as sensor networks, wireless and multimedia networks, biological networks, and networks of quantum devices. CCF investments advance the design, verification, evaluation, and utilization of computing hardware and software through new theories and high-leverage tools that focus on performance, correctness, usability, dependability, reliability, and scalability. CCF also invests in research that explores the potential impact of emerging technologies on computation and communication, including nanotechnology, biotechnology, and quantum systems.

In general, about 74 percent of the CCF portfolio is available for new research grants. The remaining 26 percent is used primarily to fund continuing grants.

FY 2014 Summary

All funding decreases/increases represent change over the FY 2012 Enacted level.

Research

- CCF continues support for early-career researchers through increased investments in the CAREER program (+\$1.60 million to a total of \$16.97 million).
- CCF will support the NSF-wide CIF21 portfolio (+\$5.50 million to a total of \$9.50 million) through BIGDATA foundational research, including algorithms and software tools for managing massive amounts of heterogeneous, complex data; models and theories for massive data sets; streaming, sub-

linear, space-limited, and probabilistic algorithms; methods to validate and verify data; and tools and algorithms to extract knowledge from massive data sets and enable new discoveries.

- CCF will support the NSF-wide SEES portfolio (+\$4.77 million to a total of \$8.27 million) through research on cyber-enabled sustainability, which includes new approaches based on optimization, modeling, simulation, and inference; large-scale data management and analytics; and smart management of engineered systems. In CyberSEES, CCF will support research that addresses holistic, integrative approaches to sustainable computing and information technologies across the lifecycle of design, use, and reuse with the associated consumption of energy, materials, and other resources. In Hazards SEES, CCF will support computational research in the areas of decision-making under extreme conditions, increasing knowledge about natural and technological hazards.
- CCF will invest in wireless communication research (\$8.0 million) as part of EARS-related research, with a focus on reliable transmission in the presence of channel impairments; the theoretical performance limits for communication systems using spectrum sharing; and the management of spectrum sharing based on the principles of cognitive networking, game-theoretic and economic models, and computationally-efficient algorithms.
- CCF will invest in XPS at a funding level of \$6.50 million through foundational research advancing parallel and scalable computing; challenging the validity of the traditional computer hardware and software stack for today's heterogeneous parallel systems; and focusing on new foundational principles and cross-layer approaches that integrate both software and hardware through new programming languages, models, algorithms, compilers, runtime systems, and architectures. The goal is to achieve scalable performance and energy efficiency in systems while also addressing programmability, reliability, and domain-specific design.
- CCF will support the NSF-wide SaTC program (+\$3.0 million to a total of \$14.50 million) through research on the foundations of secure and trustworthy computing, including theories, models, algorithms, architectures, languages, tools, and cryptography.
- CCF will participate in the NSF-wide CEMMSS portfolio through NRI (+\$1.0 million to a total of \$3.0 million) and CPS (+\$2.0 million to a total of \$6.0 million). Focusing on the development of smart systems, research will emphasize new formal and semi-formal methods for specification, development, and verification of software, hardware, and embedded systems for various sectors, including advanced manufacturing.
- CCF will support INSPIRE at a funding level of \$1.0 million, addressing some of the most complicated and pressing scientific problems that lie at the intersection of traditional disciplines.
- As part of the National Nanotechnology Initiative, CCF will maintain its investment in the Nanotechnology Signature Initiatives (\$3.83 million).
- CCF will participate in the cross-cutting SCH program (\$3.0 million, level with FY 2012 Enacted).
- CCF will continue to support the STC, Science of Information, at Purdue University at the \$5.0 million level; and the TRUST STC at the University of California at Berkeley at a reduced level of funding as the project ramps down (-\$1.34 million to a total of \$2.66 million).

Education

- CCF will provide support for the STEM-C Partnerships activity (\$4.0 million, level with FY 2012 Enacted) with the other CISE divisions and EHR.
- Along with the other CISE divisions, CCF will continue support for REU sites and supplements (\$3.0 million, level with the FY 2012 Enacted).

Infrastructure

- CCF co-funds the National Nanotechnology Infrastructure Network, supported primarily by ENG, at a level of \$600,000.

DIVISION OF COMPUTER AND NETWORK SYSTEMS (CNS)

\$238,870,000
\$26,370,000 / 12.4%

CNS Funding

(Dollars in Millions)

	FY 2012	FY 2012	FY 2014	Change Over	
	Actual	Enacted/ Annualized FY 2013 CR	Request	FY 2012 Enacted Amount	Percent
Total, CNS	\$212.36	\$212.50	\$238.87	\$26.37	12.4%
Research	166.99	166.60	191.98	25.38	15.2%
CAREER	14.68	15.15	16.35	1.20	7.9%
Education	17.29	15.90	16.89	0.99	6.2%
Infrastructure	28.08	30.00	30.00	-	-
Research Resources	28.08	30.00	30.00	-	-

Totals may not add due to rounding.

CNS supports research and education activities that advance understanding of the fundamental properties of computer systems and networks; explore new ways to address the limitations of existing computer and networked systems to make better use of these technologies; and develop novel paradigms, abstractions, and tools for designing, analyzing, and building next generation computer and networked systems that are robust, secure, and trustworthy. CNS investments in computer systems research focus on: distributed, mobile, and embedded systems; sensing and control systems; dynamically configured, multiple-component systems; and parallel systems. CNS investments in fundamental network research create new insights into the dynamics of complex networks and explore new architectures for future-generation networks and services. CNS provides scientific leadership in cybersecurity, supporting research and education activities that will ensure society’s ubiquitous and distributed computing and communications systems deliver the quality of service they are designed to achieve, without disruption, while enabling and preserving privacy, security, and trust. CNS also plays a leadership role in coordinating CISE investments in research infrastructure resources and in the development of the computing workforce of the future.

In general, about 62 percent of the CNS portfolio is available for new research grants. The remaining 38 percent is used primarily to fund continuing grants.

FY 2014 Summary

All funding decreases/increases represent change over the FY 2012 Enacted level.

Research

- CNS continues support for early-career researchers through increased investments in the CAREER program (+\$1.20 million to a total of \$16.35 million).
- In partnership with EHR, ENG, MPS, SBE, and the other CISE divisions, CNS will continue to lead the SaTC program (+\$8.0 million to a total of \$44.0 million), which aligns with the Administration’s national cybersecurity strategy, *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program*. SaTC will invest in game-changing research in support of CNCI, develop scientific foundations, maximize research impact, and accelerate transitions to practice, in addition to addressing education and workforce issues. CNS will invest in large-scale collaborations requiring multi-disciplinary teams to focus on cybersecurity grand challenges.

- In partnership with ENG, MPS, and the other CISE divisions, CNS will expand on the portfolio that has been developed under the CEMMSS initiative. As part of the CPS program under CEMMSS (+\$13.0 million to a total of \$31.0 million), CNS will support the foundational interdisciplinary research and education necessary to transform static systems, processes, and edifices into adaptive, pervasive smart systems, as well as to further the understanding of fundamentals arising from grand challenge applications, ranging from advanced manufacturing and transportation to critical infrastructure, such as the Smart Grid, medical devices, and disaster response. As part of the CEMMSS portfolio, CNS will invest in NRI (+\$1.50 million to a total of \$5.0 million).
- CNS will expand support for research in wireless communication, spectrum sharing, and mobile computing and the development of wireless testbeds (+\$7.0 million to a total of \$10.0 million). CNS will also collaborate with ENG, MPS, and other CISE divisions in EARS, including research in advancing spectrum sensing techniques; exploring machine learning and game theory for dynamic spectrum management; understanding incentive mechanisms; and developing mid-scale experimental infrastructure to test theoretical innovations, wireless devices, protocols, and algorithms.
- CNS will support XPS at a funding level of \$3.50 million, which invests in new approaches to the traditional computer hardware and software stack in multi-core, multi-machine, cloud, data-intensive, and highly concurrent systems.
- CNS will participate in the CIF21 investment (+\$1.0 million to a total of \$4.0 million) through the BIGDATA program. This includes research in pervasive computing, combining distributed sensing with data analytics and distributed response, as well as work on large-scale data management systems.
- CNS will support the NSF-wide SEES investment (+\$1.0 million to a total of \$3.50 million) through research in large-scale, intelligent data management and analysis; widespread, heterogeneous sensing and control; new methods for addressing power, thermal, and sustainability issues in the design and operation of computing systems at all scales; and disaster avoidance through advanced sensing.
- CNS will support INSPIRE at a funding level of \$1.0 million, addressing some of the most complicated and pressing scientific problems that lie at the intersection of traditional disciplines.
- CNS will participate in other cross-cutting research programs, including SCH (\$3.0 million, level with the FY 2012 Enacted) and the cyberlearning and on-line education program (\$2.0 million, level with the FY 2012 Enacted).

Education

- CNS will increase its investments in the joint CISE/EHR STEM-C Partnerships activity, which seeks to enhance computational competencies for all students (+\$4.0 million to a total of \$8.0 million). This program will enlarge the pool of K-14 students and teachers who develop and practice computational competencies in a variety of contexts, as well as the pool of early postsecondary students who are engaged and have the background in computing necessary to successfully pursue degrees in computing-related and computationally-intensive fields of study.
- Along with the other CISE divisions, CNS will continue support for REU sites and supplements (\$3.50 million, level with the FY 2012 Enacted).
- CNS maintains support for the ADVANCE program at a funding level of \$2.95 million, which endeavors to increase the participation and advancement of women in academic science and engineering careers.

Infrastructure

- Through the Computing Research Infrastructure program (\$18.0 million), CNS supports acquisition, enhancement, and operation of state-of-the-art infrastructure that enables high-quality computing research and education in a diverse range of institutions and projects.
- CNS will maintain its support for the development of world-class, mid-scale computing research infrastructure through GENI and cloud testbeds (\$12.0 million) by investing in a suite of wireline and wireless interconnected testbeds, campuses, cities, research backbones, and regional optical networks.

DIVISION OF INFORMATION AND INTELLIGENT SYSTEMS (IIS)

\$200,420,000
+\$23,920,000 / 13.6%

IIS Funding
(Dollars in Millions)

	FY 2012		FY 2014 Request	Change Over	
	FY 2012 Actual	Enacted/ Annualized FY 2013 CR		FY 2012 Enacted	Amount
Total, IIS	\$176.58	\$176.50	\$200.42	\$23.92	13.6%
Research	167.41	168.50	191.17	22.67	13.5%
CAREER	16.86	17.75	18.78	1.03	5.8%
Education	9.17	8.00	9.25	1.25	15.6%

Totals may not add due to rounding.

IIS supports research and education that develop and apply new IT to enhance the capabilities of people and machines to create, discover, and reason by advancing their ability to represent, collect, store, organize, visualize, and communicate data and information; develop new knowledge to support people in the design and use of IT; and advance knowledge about how computational systems can perform tasks autonomously, robustly, and flexibly.

IIS research investments support the exploration of novel theories and innovative technologies that advance our understanding of the complex and increasingly coupled relationships between people and computing, promising to enhance quality of life. Investments in information integration and informatics focus on the processes and technologies involved in creating, managing, visualizing, and fusing diverse data, information, and knowledge from disparate and uncoordinated sources within a changing landscape of computing platforms, from personal devices to globally-distributed networks. IIS also invests in research on artificial intelligence, computer vision, natural language, robotics, machine learning, computational neuroscience, cognitive science, and areas leading to the computational understanding and modeling of intelligence in complex, realistic contexts, including investments to revolutionize understanding of brain functions.

In general, about 70 percent of the IIS portfolio is available for new research grants. The remaining 30 percent is used primarily to fund continuing grants.

FY 2014 Summary

All funding decreases/increases represent change over the FY 2012 Enacted level.

Research

- IIS continues support for early-career researchers through increased investments in the CAREER program (+\$1.03 million to a total of \$18.78 million).
- In partnership with three other federal agencies (NASA, NIH, and USDA), three other NSF directorates (ENG, SBE, and EHR), and two other CISE divisions (CCF and CNS), IIS will continue to lead the NRI program (+\$6.5 million to a total of \$13.50 million). IIS will focus on fundamental research in robotics as a critical underpinning of the NSF-wide CEMMSS investment, which includes advanced sensing, control, and power sources; integrated problem-solving architectures and decision algorithms; and safe and soft structures. NRI will focus on human-centered research in developing service robots, requiring significant advances in human-robot interaction, including safety standards for robots touching humans and recovery from errors in robot interpretation and action. Application

domains include robots as co-workers in advanced manufacturing environments, aides supporting emergency responders in the field, and service robots assisting the elderly and infirm to live independently.

- IIS will support the NSF-wide CIF21 investment (+\$6.0 million to a total of \$11.0 million), advancing BIGDATA core techniques and technologies to propel novel discoveries and capabilities, and through participation in DIBBs, developing the associated data infrastructure required to collect, store, manage, and scale large data sets. Research includes cloud-database architectures, trusted and secure data, data mining methods, and data- and information-fusion techniques. CIF21 advances machine learning, predictive modeling, and automated discovery of phenomena and causality in data.
- The IIS division will lead the cyberlearning and on-line education program jointly with EHR and SBE, through an evolution of the Cyberlearning Transforming Education (CTE) program (+\$4.0 million to a total of \$12.0 million). Research will integrate advances in technology with advances in the ways people learn; resolve how to more effectively use technology for promoting learning; and design new technologies for integration in learning environments and evaluate their use. Interdisciplinary researchers will study the deluge of data potentially produced from new on-line teaching paradigms, such as from implementations of massive open on-line courses, to better understand learning mechanisms and enable productive, personalized, and customized education.
- In partnership with NIH, two other NSF directorates (ENG and SBE), and two other CISE divisions (CCF and CNS), IIS will lead the SCH program (\$9.0 million, level with FY 2012 Enacted). IIS will pursue improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies through innovations in computer and information science and engineering. The program addresses changing age demographics with investments in assistive cyber-physical engineered systems that are embedded in the local environment and are easily accessed and used.
- As part of its CEMMSS investment, IIS will support the CPS program (+\$2.0 million to a total of \$5.0 million). IIS will support basic research in smart systems with embedded computational intelligence that can sense, adapt, and react and that will enable new functionalities and provide the next-generation of products and services in various sectors, including advanced manufacturing.
- IIS will support the NSF-wide SaTC program (+\$3.00 million to a total of \$10.50 million) through research in secure and privacy-protecting mechanisms for multi-sourced aggregated data and for visualizing complex levels of access to personal information.
- IIS will support the NSF-wide SEES portfolio (+\$2.23 million to a total of \$4.23 million). CyberSEES investments will focus on the information processing dimensions of energy utilization and pursue breakthroughs needed in optimization, modeling, simulation, and inference. IIS will also support investments in Hazards SEES, an interdisciplinary research program in disaster prevention, mitigation, and recovery that will improve the ability to prepare for, mitigate, respond to, and recover from natural and technological hazards.
- IIS will invest in innovative wireline and wireless applications in areas of societal and economic benefit (\$2.0 million) as part of EARS-related research.
- IIS will support INSPIRE at a funding level of \$2.0 million, addressing some of the most complicated and pressing scientific problems that lie at the intersection of traditional disciplines.

Education

- IIS will invest in the STEM-C Partnerships activity (\$4.0 million, level with FY 2012 Enacted) partnering with the other CISE divisions and EHR.
- With all CISE Divisions, IIS will continue support for REU sites and supplements (\$3.50 million, level with FY 2012 Enacted).

DIVISION OF INFORMATION TECHNOLOGY RESEARCH (ITR) \$89,150,000
+\$3,690,000 / 4.3%

ITR Funding

(Dollars in Millions)

	FY 2012		FY 2014 Request	Change Over FY 2012 Enacted	
	FY 2012 Actual	Enacted/ Annualized/ FY 2013 CR		Amount	Percent
Total, ITR	\$85.35	\$85.46	\$89.15	\$3.69	4.3%
Research	81.85	81.46	69.82	-11.64	-14.3%
CAREER	0.39	-	-	0.00	N/A
SLC: Pittsburgh Science of Learning Center -- LearnLab	2.25	2.50	2.03	-0.48	-19.0%
Education	0.30	-	2.33	2.33	N/A
Infrastructure	3.19	4.00	17.00	13.00	325.0%
Research Resources	3.19	4.00	17.00	13.00	325.0%

Totals may not add due to rounding.

ITR provides support for transformative explorations in computer and information science and engineering research, infrastructure, and related education activities, emphasizing the funding of high-risk, multi-investigator, and multidisciplinary projects.

In general, about 51 percent of the ITR portfolio is available for new research grants. The remaining 49 percent is used primarily to fund continuing grants.

FY 2014 Summary

All funding decreases/increases represent change over the FY 2012 Enacted level.

Research

- Through I-Corps (+\$5.50 million to a total of \$8.0 million), ITR will invest in NSF-funded researchers who will receive additional support – in the form of mentoring and funding – to accelerate innovation and transfer of knowledge from lab to practice. ITR will also invest in two additional I-Corps subcomponents that were initiated in FY 2013 – Sites and Nodes – to further build, utilize, and sustain a national innovation ecosystem that continues to augment the development of technologies, products, and processes that benefit the Nation.
- Leveraging previous investments in GENI, ITR will invest in US Ignite (\$3.0 million), an effort to promote U.S. leadership in developing gigabit public sector applications and services for ultra-fast broadband and software-defined networks. As part of US Ignite, ITR will invest in foundational wireline, wireless, cloud computing, security, and distributed systems research and experimentation, as well as gigabit application development.
- In collaboration with ENG, CISE will continue to support innovative partnerships and collaborations between universities and industries, in part through the Industry/University Cooperative Research (I/UCRC) program which will continue to establish centers that partner industry with university research efforts (+\$1.0 million to a total of \$8.0 million).
- ITR will maintain its investments in the Expeditions in Computing program (\$12.0 million, level with FY 2012 Enacted). This program identifies projects with transformative research agendas that promise to accelerate discovery at the frontiers of computing and communication. It will also

continue to encourage researchers to come together within or across departments and/or institutions to identify the compelling ideas that promise transformations in computing and information sciences for many years to come.

- ITR will continue to support development and deployment of wireless testbeds (\$4.0 million, level with the FY 2012 Enacted).
- ITR will invest in multi-disciplinary research networks, including the Science Across Virtual Institutes (SAVI) activity (\$2.0 million, level with FY 2012 Enacted). These research networks will provide opportunities to develop collaborations in areas of emerging interest to computer and information science and engineering, including international partnerships.
- ITR will continue to provide support for emerging and urgent high-priority areas of potentially transformative research through various award mechanisms, such as Early-concept Grants for Exploratory Research (EAGERS) and Grants for Rapid Response Research (RAPIDs), and through co-funding of awards with other NSF directorates to pursue important emerging areas.
- CISE will continue its support of the SLC: LearnLab, formerly known as Pittsburgh SLC for Robust Learning (-\$470,000 to a total of \$2.03 million). Support is at a reduced level in FY 2014 as the project ramps down.

Education

- With the other CISE Divisions, ITR will support REU supplements (+\$1.63 million to a total of \$1.63 million). This additional funding will support enhanced research experiences for students in their first two years of college as recommended by the President's Council of Advisors on Science and Technology (PCAST) in their report, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*.

Infrastructure

- As part of US Ignite, ITR will expand the current mid-scale infrastructure investment in GENI, at a funding level of \$7.0 million, to a national scale by research-enabling and/or integrating additional U.S. campuses, regional and research backbone networks, commercial equipment, and cities across the Nation to create a unique at-scale infrastructure available for future network research and infrastructure experimentation that is not possible elsewhere.
- Building on the success of GENI, ITR will extend virtualization beyond the network to large-scale, interconnected computing resources by developing mid-scale prototypes for an NSF Cloud research infrastructure, enabling future cloud and distributed computing experimentation not possible elsewhere (\$6.0 million).

APPENDIX A – HIGH PERFORMANCE COMPUTING PORTFOLIO

ACI High Performance Computing Funding

(Dollars in Millions)

	Prior Years ¹	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Petascale (Track 1) ²	\$140.97	\$128.55	\$39.41	\$30.00
Innovative HPC Program	176.49	24.57	48.90	25.00
Teragrid - Phase III (XD)	233.19	22.52	-	27.00
Total	\$550.65	\$175.64	\$88.31	\$82.00

Totals may not add due to rounding.

¹ The following adjustments have been made to Prior Years:

- Petascale decreased by \$49.5 million and XD increased by the same amount to reflect a coding error correction made in the NSF financial system. In FY 2011, an award was miscoded to Petascale, rather than to XD.

- Petascale decreased by \$90.5 million and XD decreased by \$71.59 million to reflect deobligations of prior year funds that were later reobligated. See footnote 2.

- Petascale decreased by \$140.61 million and XD increased by the same to reflect that the TeraGrid program is a predecessor to the XD program. TeraGrid transitioned to XD in FY 2010.

² FY 2012 Actual includes obligations over the enacted level for ACI (formerly OCI) due to recoveries of prior year unpaid obligations that were reobligated in FY 2012.

NSF has been a leader in High Performance Computing (HPC) for almost four decades. Due to the continuing rapid change in computing and related technologies, coupled with the exponential growth and complexity of data, NSF has created a new vision and strategy towards advanced computing infrastructure, which will expand NSF’s leadership role in the science, engineering, and education enterprise. This coordinated NSF-wide strategy, which is a key component of the CIF21 framework, seeks to position and support the entire spectrum of NSF-funded communities at the cutting edge of advanced computing technologies, hardware, and software. It also aims to promote a more complementary, comprehensive, and balanced portfolio of advanced computing infrastructure and programs for research and education to support multidisciplinary computational and data-enabled science and engineering that supports the entire scientific, engineering, and education community. This shift away from a focus on procurement is consistent with the recommendations of a 2010 review and 2012 follow-up review⁶ of the Federal Networking and Information Technology R&D (NITRD) program by the President’s Council of Advisors on Science and Technology.

PETASCALE COMPUTING (TRACK 1) – BLUE WATERS

Description

The National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC) has provided the capability for researchers to tackle much larger and more complex research challenges than previously possible, by acquiring, deploying, and operating a sustained petascale leadership class high-performance computational resource known as Blue Waters. This investment complements the Department of Energy (DOE) Office of Science’s program on computing hardware, which focuses on peak petascale performance, with Blue Waters providing sustained petascale performance. Blue Waters will be in full production in mid-FY 2013. It is operated by NCSA and its

⁶ *Designing a Digital Future: Federally Funded Research and Development Networking and Information Technology*, President’s Council of Advisors on Science and Technology, January 2013.

partners in the Great Lakes Consortium for Petascale Computing (GLC).

The Blue Waters project also includes education and outreach programs that target pre-college, undergraduate, graduate, and post-graduate levels. A virtual school of computational science and engineering has been established to create courses that focus on petascale computing and petascale-enabled science and engineering. The virtual school explores new instructional technologies and creates courses, curricula, and certificate programs tailored to science and engineering students. It also sponsors workshops, conferences, summer schools, and seminars.

The project includes an annual series of workshops targeted at the developers of simulation packages and aspiring application developers. In addition, the project includes two industrial partnership activities: the Industry Partners in Petascale Engagement (IPIPE) program provides industrial partners with a first look at the technological and scientific developments that flow from the petascale program; and the Independent Software Vendor Application Scalability Forum promotes collaborations among consortium members, independent software vendors, and the industrial end-user community.

The broader impacts of this award include: provisioning of unique infrastructure for research and education; extensive efforts accelerating education and training in the use of high-performance computation in science; training in petascale computing techniques; promoting an exchange of information between academia and industry about the applications of petascale computing; and broadening participation in computational science through NCSA's Girls Engaged in Mathematics and Science (GEMS) program. GEMS is designed to encourage middle-school girls to consider mathematics-oriented and science-oriented careers.

Current Status

In late September 2011, UIUC selected a new vendor, Cray, for the Blue Waters project. By March 2012, a Blue Waters Early Science System, representing about 15 percent of the overall capacity of the system, became operational. In November/December 2012, the acceptance milestone was approved by NSF, and the entire system became available to 33 NSF-approved science and engineering teams (called friendly users) to help test and evaluate the system. It is currently in friendly user mode while UIUC completes the final stages of testing of the archival storage environment. It is expected to be in full production in mid-2013 and will then enter a five-year operations phase.

The Blue Waters education and outreach projects are ongoing, with components on undergraduate education, graduate education, training workshops, and outreach. A December 2011 workshop provided scientists and engineers with knowledge and expertise to develop applications for Blue Waters and other petascale computers. The Blue Waters team hosts summer workshops and has created and offered courses through the virtual school of computational science and engineering. The Blue Waters project partners with the Shodor Foundation to provide undergraduate course materials and internships. With the change in vendor to Cray, which was approved by NSF following external panel review in September 2011, some of the funds originally designated for hardware funding were designated for extending and expanding the outreach, education, and parallel algorithm development aspects of the project.

Science and engineering research and education activities enabled by Blue Waters

When Blue Waters is in full production, it will permit investigators across the country to conduct innovative research demanding petascale capabilities. Allocations of time on Blue Waters have been requested for research on: complex biological behavior in fluctuating environments; the electronic properties of strongly correlated systems; the properties of hydrogen and hydrogen-helium mixtures in astrophysically relevant conditions; the electronic and magnetic structures of transition metal compounds; the molecular dynamics responsible for the properties of liquid water; and the propagation of seismic energy through a detailed structural model of Southern California, together with the predicting of ground

motion and the modeling of the response of buildings and other structures. Other allocations address testing hypotheses about the role of cloud processes and ocean mesoscale eddy mixing in the dynamics of climate and improving climate models; the formation of the first galaxies; turbulent stellar hydrodynamics; binary black hole and neutron star systems as sources of gamma ray bursts; and other intense radiation phenomena, contagion, and particle physics.

Management and Oversight

NSF Structure: The project is managed and overseen by ACI program staff and a grants officer from the Division of Grants and Agreements. These NSF staff members receive strategic advice from NSF's CIF21 Cyberinfrastructure Leadership group which includes representatives from the various directorates and offices. Advice from the Office of General Counsel is sought as necessary.

External Structure: During the development and acquisition phase of this project, UIUC oversaw work by a number of sub-awardees, conducted software development, and assisted competitively selected research groups to prepare to use the Blue Waters system. The primary sub-awardee, Cray, was responsible for implementation of the hardware, system software, and main program development tools. Other sub-awardees worked on performance modeling, the evaluation of an astrophysical modeling framework, the engagement of applications groups, scalable performance tools, undergraduate training, and broadening the participation of underrepresented groups in high-performance computing. The project team is advised by a Petascale Executive Advisory Committee composed of senior personnel with technical and management expertise in high-performance scientific computing, the management of acquisition contracts for leading-edge computing systems, and the operation of large computing centers.

Risks: Any activity of this nature, and at this scale, comes with a certain element of risk. The extensive review process, conducted prior to award included reviewing and analyzing the risks as presented in the proposal and identifying any additional risk that should be considered. The Petascale Computing (Track 1) award required that risks be identified and analyzed, and that a mitigation plan be created and followed. One of the activities of the periodic NSF external reviews, by a panel of experts, is to revisit and assess the risk situation and make recommendations as deemed necessary. Risks that are no longer applicable are retired. New risks may be added, or degree of risk promoted or demoted as necessary, all of which is documented in a risk register. In addition to the discussion of risks that occurs between UIUC and NSF, periodic closed session updates to the National Science Board (NSB) identify any major changes in risk assessment.

Reviews: The project was selected through a competitive review in 2007. An external panel of experts, selected by NSF, periodically reviews the progress of the project including project management, risk management, hardware and software development, and the provision of advanced user support to research groups receiving provisional resource allocations on the Blue Waters system. One of the important roles of this external review panel is to analyze the awardee's assessments of the deliverables from its sub-awardees, together with the awardee's and sub-awardees' plans for remedial action when necessary, and to provide NSF with advice on whether these assessments and plans are reasonable. These external reviews have been conducted in February 2008, April 2008, October 2008, April 2009, July 2009, December 2009, April 2010, September 2010, December 2010, February 2011, May 2011, September 2011, March 2012, August 2012, and December 2012.

INNOVATIVE HPC PROGRAM

Description

Using lessons learned during the execution of the HPC Track 2 program and informed by the NSF Advisory Committee for Cyberinfrastructure's (ACCI) High Performance Computing task force, the HPC Track 2 program was renamed Innovative HPC in 2011. Innovative HPC awards are made in the context of the eXtreme Digital (XD) services program (described below). While the Petascale Computing (Track 1) system is targeted to provide sustained petascale performance, the Innovative HPC systems provide, at most, petascale peak performance. Each system is capable of supporting hundreds to thousands of researchers (over the course of a year) engaged in leading-edge science and engineering across a broad array of disciplines.

There is a direct relationship between the Innovative HPC awards and the XD activity. Several systems are currently serving as allocatable resources within XD. Initially, Innovative HPC awards were generally made as two parts: a) an acquisition component and associated funding, and b) an operations and maintenance component and associated funding. More recent awards in the Innovative HPC program (including FutureGrid, Gordon, and Keeneland) did not separate these components due to the experimental nature of the systems. When an award was made, funding was provided to the institution, which issued sub-awards to vendors for acquisitions as necessary. Once the system has passed the acceptance process, vendors receive final payment for the system. After the system has been fully tested, it becomes an XD resource and the institution becomes an XD resource provider and has access to the operations and maintenance funding component of the award.

Beginning with the FY 2011 solicitation, *High Performance System Acquisition: Enhancing the Petascale Computing Environment for Science and Engineering*, based on feedback from the scientific and engineering community, a more sustained approach to core HPC services was initiated. This provides a longer time horizon for funding of HPC providers in recognition of the value and time required for building and retaining staff skilled in interdisciplinary computational science. Thus, an eight to ten year horizon is envisioned for a core HPC provider. This timeline begins with an acquisition award, which allows for the possibility of a renewal acquisition award four years after the original award. In addition to the acquisition awards, accompanying operations and maintenance (O&M) awards are planned.

Current Status

Machines and facilities that are currently operational in the Innovative HPC program include Keeneland, Blacklight, FutureGrid, Gordon, Kraken, Lonestar, Longhorn, Ranger, Stampede, and Trestles. Keeneland is a new, highly innovative experimental system that became fully operational in FY 2013. Stampede, at the University of Texas at Austin, is a comprehensive computing, data analysis, and visualization system. It went online in January 2013 and is the most powerful system in the NSF XD environment.

The largest resource in the NSF portfolio designed for capacity computing, Kraken, located at the National Institute for Computational Sciences at the University of Tennessee, has reached the end of its useful lifetime. An additional year of funding was provided to Kraken in FY 2012, while a new solicitation was issued in FY 2012, and a review process was conducted during late FY 2012 through early FY 2013. New award(s) are expected in FY 2013 to provide the capacity level computational needs of the open science community.

NSF issued a new solicitation in FY 2013, *High Performance System Acquisition: Building a More Inclusive Computing Environment for Science and Engineering*, for a total of \$30,000,000 to fund up to three new resources, both computational and data related. The solicitation encourages the community to think broadly about resources which would: 1) complement existing XD resources; and 2) enlarge the

horizon to include research communities that are not users of traditional HPC systems, but who would benefit from advanced computational capabilities at the national level. The solicitation explicitly mentioned the use of virtual machines, efficient cloud computing capabilities, expanding the range of data-intensive computing, and high throughput applications among others. The proposal submission deadline is April 15, 2013.

Science and engineering research and education activities enabled by Innovative HPC

- The complete spectrum of scientific research is supported, including: climate and weather modeling, economics, cosmology and astrophysics, geosciences, physics, chemistry, biology and medicine, earthquake engineering, and mechanical engineering.
- Innovative HPC will enable world-leading transformative advances in science and engineering research, in the integration of research and education, and in broadening participation in science and engineering by underrepresented groups; by providing researchers and educators with usable access to computational resources, beyond those typically available on most campuses, together with the interfaces, consulting support, and training necessary to facilitate their use.
- Through the unifying XD framework and services, Innovative HPC will enable researchers to manipulate extremely large amounts of digital information from simulation, sensors, and experiments, and add needed capabilities in remote visualization, an increasingly important analysis tool for modern science and engineering.
- Outreach and training critical to reducing the barriers to the use of HPC systems by the research and education community will be provided by engaging research universities and foundations. Innovative HPC will incorporate new computational technologies and new approaches to software and data management, together with the expertise to enable researchers and students to complement theory and experiment with an equal emphasis in computation.

Management and Oversight

NSF Structure: The Division of Advanced Cyberinfrastructure's program officers provide direct oversight during both the acquisition and operations phase. Formal reporting consists of quarterly and annual reports, which are reviewed by the program officer. There are also bi-weekly teleconferences with NSF program officers.

External Structure: Each Innovative HPC award is managed under a cooperative agreement. Each awardee is responsible for the satisfactory completion of milestones in order for the spending authorization to be raised. Progress is evaluated by the review process and the NSF program officer.

Each project has a detailed management plan in place. Each cooperative agreement includes the management structure, milestones, spending authorization levels, and review schedule.

Risks: Any activity of this nature, and at this scale, comes with a certain element of risk. The review process, conducted prior to award, reviews and analyzes the risks as presented in the proposal and identifies any additional risk that should be considered. The awards are experimental, by nature, and therefore encompass high-risk, high-reward scenarios. The award process requires that risks be identified and analyzed, and that a mitigation plan be created and followed. One of the activities of the periodic NSF external reviews, conducted by a panel of experts, is to revisit and assess the risk situation and make recommendations as necessary. Risks that are no longer applicable are retired. New risks may be added, or degree of risk promoted or demoted as necessary, all of which is documented in a risk register.

Reviews: Annual reviews are performed as part of the XD review. Semi-annual reviews are performed as part of the acquisition phase. The reviews are arranged by the NSF program officer. The reviewers' backgrounds include scientific research, project management, and large-scale systems acquisitions and

operations, and include familiarity with projects funded by NSF, as well as other federal agencies. To the extent possible, continuity through the series of reviews is provided by using the same set of reviewers.

FutureGrid Experimental High Performance Grid Testbed at Indiana University (IU)

Description

- An Indiana University-led project team has provided a significant new experimental computing grid and cloud test-bed, named FutureGrid. FutureGrid enables research communities to tackle complex research challenges in computer science related to the use and security of grids and clouds.
- The test-bed includes a geographically distributed set of heterogeneous computing systems, a data management system that will hold both metadata and a growing library of software images, and a dedicated network allowing isolatable, secure experiments.
- The test-bed supports virtual machine-based environments, as well as native operating systems for experiments aimed at minimizing overhead and maximizing performance.
- The project partners integrate existing open-source software packages to create an easy-to-use software environment that supports the instantiation, execution, and recording of grid and cloud computing experiments.
- The FutureGrid project team is part of the Service Providers Forum and participates in the discussions every week. While FutureGrid does not allocate cycles, it is available to the research community as a testbed and continues to be used internally by the eXtreme Science and Engineering Discovery Environment (XSEDE), part of the XD program as described below, as a testbed for systems that may become integrated into mainstream XSEDE activities. FutureGrid is being used to test cloud and virtualization capabilities; advanced digital services the user community is expected to request.

Gordon Data-Intensive Computing at San Diego Supercomputer Center (SDSC)

Description

- In FY 2012, Gordon became fully operational as an allocatable resource within the XSEDE environment. The University of California at San Diego (UCSD) provided this ground-breaking new computing facility, which is available to the research community together with advanced user support for researchers with data-intensive problems that may not parallelize well or will require access to very large amounts of memory.
- The distinguishing features are the integration of solid state disks (SSDs) and very large shared memory. This system is optimized to support research with very large data-sets or very large input-output requirements. It provides a step-up in capability for data-intensive applications that scale poorly on current large-scale architectures, providing a resource that will enable transformative research in many research domains.

Keeneland Experimental High Performance Computing at Georgia Institute of Technology

Description

- Keeneland, provided by the Georgia Tech Research Corporation (GTRC), is a new, experimental high-performance computing facility with unconventional computing architectures. The system allows scientific and engineering researchers to evaluate the relative merit of these new architectures. Keeneland became fully operational in January 2013.
- The distinguishing feature of Keeneland is the inclusion of General-Purpose computation on Graphics Processing Units processors (GPGPU) as a general purpose technique for computational acceleration in large systems. The goal is to address computational problems that are challenging to more conventional supercomputing architectures. Productivity is of particular interest in using Open Computing Language (OpenCL) as a mechanism to program the GPGPUs.

- Applications will require additional development and testing to be appropriately prepared to effectively use this new type of architecture.

Stampede – Enabling, Enhancing and Extending Petascale Computing for Science and Engineering at University of Texas at Austin

Description

- The Stampede project at the University of Texas at Austin adds a new system to NSF XD cyberinfrastructure services.
- The new resource and accompanying services target science and engineering researchers using both advanced computational methods and emerging data-intensive approaches.
- The new system will boost XD resources to nearly twice their current capacity. It provides researchers with early access to a potentially transformative new approach to performance via Intel Many Integrated Core (MIC) processors. An addition of the second generation of the MIC processors is planned in late FY 2015.

Current Status

Consideration for system acceptance was reviewed by an external panel at the end of January 2013. NSF approved the acceptance milestone in February 2013.

TERAGRID PHASE III: EXTREME DIGITAL (XD)

Description

- XD, successor to the TeraGrid program, is an advanced, nationally distributed, open cyberinfrastructure comprised of shared user and management services, supercomputing, storage, analysis, visualization systems, data services, and science gateways connected by high-bandwidth networks, integrated by coordinated policies and operations, and supported by computing and technology experts.
- XD enables and supports leading-edge scientific discovery and promotes science and technology education.
- XD has taken a significant step forward by encouraging innovation in the design and implementation of an effective, efficient, increasingly virtualized approach to the provision of high-end digital services – extreme digital services – while ensuring that the infrastructure continues to deliver high-quality access for the many researchers and educators that use it in their work.

Current Status

Two planning grants, one to UCSD (\$1.60 million) and one to UIUC (\$1.62 million), were made in FY 2009 to obtain community input and engagement in order to develop the ideas and expanded horizons that will be required to deploy the advanced infrastructure required for XD. The planning grants were reviewed in February 2010 and the two teams submitted their full proposals in July 2010. The full proposals were reviewed by an external panel of experts in the fourth quarter of FY 2010. A recommendation for a \$121.0 million, five-year award to UIUC, entitled XSEDE, was approved by the NSB and awarded July 1, 2011. XSEDE had its first annual review in June 2012 at NSF. Progress in Year 1 and plans for Year 2 were evaluated. The review committee found that the project had made extraordinary progress over its first year and identified issues for consideration moving forward.

XSEDE, which manages the XD shared user and management services, is the final component of the XD program. XSEDE is a partnership of 17 institutions that links computers, data and people around the world to establish a single, virtual system that scientists can interactively use to conduct research.

Initially, XSEDE will support 16 supercomputers across the country. It also will include other specialized digital resources and services to complement these computers. These resources will be expanded throughout the lifetime of the project.

Science and engineering research and education activities enabled by XD

- XD services enable transformative advances in science and engineering research, in the integration of research and education, and in broadening participation in science and engineering to under-represented groups, by providing researchers and educators with coherent and highly usable access to extreme-scale digital resources beyond those typically available on most campuses, together with the interfaces, consulting, advanced user support, and training necessary to facilitate their use.
- XD provides high-performance computing services, enables researchers to manipulate extremely large amounts of digital information from simulations, sensors, and experiments, and adds needed capabilities in remote visualization, an increasingly important analysis tool for modern science and engineering.
- XD is developing tools and services that not only link users to national facilities, but enables scientific collaborations within and across university campuses, government laboratories, and experimental facilities.
- The project includes outreach and training critical to reducing the barriers to the use of advanced digital systems by the research and education communities. XD incorporates new ideas and technologies to enable researchers and students to move transparently between local and national resources, substantially lowering the barriers to effective use of cyberinfrastructure and promoting enhanced productivity.

Management and Oversight

NSF Structure:

- XD is managed by ACI, informed by the ACCI and its task forces, with ongoing strategic guidance from the NSF cross-directorate CIF21 Leadership Group. The project has an external advisory board, a user board, and a service provider board to ensure that all stakeholders can provide project input. These boards provide substantial ongoing community input to the XD project. ACI participates in the management of XSEDE via weekly teleconferences with the senior XSEDE personnel.
- XD shared services consist of several inter-related parts – High-Performance Remote Visualization Service (HPRVS); Technology Audit Service (TAS); Technology Insertion Service (TIS); Coordination and Management Service (CMS); Advanced User Support Service (AUSS); and Training, Education and Outreach Service (TEOS). The last three elements constitute the XSEDE project that manages shared services in the XD program.

These elements are designed and implemented in a way that is consistent with sound system engineering principles, clearly tied to the user requirements of the science and engineering research community using a flexible methodology that permits the architecture to evolve in response to changing user needs and presents the individual user with a common user environment regardless of where the resource or user is located.

- The HPRVS was reviewed in FY 2009 and two awards were made, one to the University of Texas at Austin (\$7.0 million) and one to the University of Tennessee-Knoxville (\$10.0 million).
- The TAS and TIS components of XD were reviewed in FY 2010 and two awards were made; one award to the University of Buffalo for the TAS (\$7.75 million) and one award to the University of Illinois at Urbana-Champaign for the TIS (\$9.0 million). These two awards have facilitated the TeraGrid to XD transition and are already functioning successfully in the new environment.
- XSEDE, the final component of XD, which includes CMS, AUSS, and TEOS, was awarded to the University of Illinois Urbana-Champaign (UIUC) in July 2011. This is a five-year award for \$121.0

million and involves four other major partners. They are the University of Pittsburgh, University of Texas at Austin, University of California San Diego (UCSD) and the University of Tennessee at Knoxville. XSEDE also involves twelve other institutions.

External Structure: The final configuration of XD consists of an access and accompanying services component, and compute, visualization, and storage resources at a number of sites. The sites contain a range of high-performance computing platforms, large disk storage devices, computational platforms specifically tailored for remote visualization, high-bandwidth networks, a broad set of user services and an education, outreach, and training component designed to fulfill the needs of current users of high-performance computing, as well as to broaden participation to new communities and under-represented groups in science and engineering. The composition of these sites will change in time as new resources become part of the XD family and other resources are retired. University partners may be part of XSEDE services either by providing and receiving services to the project or by simply using the digital products being developed by XSEDE in their own local environment.