NSF-WIDE INVESTMENTS

Major FY 2014 Investments:

STEM Education:

Other NSF-wide Activities:

NSTC Activities

CYBER-ENABLED MATERIALS, MANUFACTURING, AND SMART SYSTEMS (CEMMSS)

Overview

In response to the Administration's Materials Genome Initiative (MGI), Advanced Manufacturing Partnership, and the National Robotics Initiative (NRI), the Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS) framework aims to integrate a number of science and engineering activities across the Foundation – breakthrough materials, advanced manufacturing, robotics, and cyber-physical systems. Through deployment of new cyber-enabled paradigms, materials with unique properties and functionality will be discovered and developed more reliably and efficiently. Further, using advanced manufacturing strategies, new materials can be fashioned into artifacts and systems embedded with computational intelligence, thereby transforming today's static systems, processes, and edifices into adaptive, pervasive smart systems.

The smart systems of tomorrow and the materials from which they will be composed will vastly exceed those of today in terms of adaptability, autonomy, functionality, efficiency, reliability, safety, usability, recoverability, and recyclability. These advances have the potential to accelerate scientific discoveries to address key national and societal challenges critical to U.S. security and competitiveness.

Total Funding for CEMMSS
(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
$144.32	**$141.65**	**$300.42**

Goals

Goal 1: Science and Engineering

Establish a scientific basis, a codified knowledge base, and shared approach that advance cyber- and data-enabled principles for discovery, design, development, and production of new classes of advanced materials. Develop and deploy advanced manufacturing methods to produce artifacts and systems with superior functionality, including embedded intelligence to make them smart, responsive, and adaptive. Develop the core science needed to engineer systems that build from and depend upon the synergy of computational and physical components in real-world contexts. The goal is integrated programs across CEMMSS research areas, for example, in cyber-manufacturing, materials informatics, and smart systems.

Goal 2: Education, Workforce Development, and Community Building

Create integrated research communities from incongruent disciplines. Educate a cadre of high caliber disciplinary and interdisciplinary researchers with a wide range of skills, including skills in the use of cyber- and data-enabled approaches to science and engineering. Engage the support of related research and education programs at the National Science Foundation (NSF), such as Engineering Research Centers; Materials Research Science and Engineering Centers; and Science, Technology, Education, and Mathematics (STEM) education programs. Partner with other government agencies, international funding organizations, and industry. The goal is to build a thriving CEMMSS ecosystem.

Goal 3: Research Infrastructure Development

Develop the critical research infrastructure – cyber and experimental – to be used to discover, develop, test, refine, and validate the advanced materials, design, manufacturing, and development methods as well

as to enable the transition to practice of smart systems from the lab to the field. In the short-term, the goal is cyberinfrastructure for advanced manufacturing, cyber-physical systems, robotics, and materials. The longer-term goal is to stitch together disparate testbeds for explorations at the CEMMSS frontiers.

Approach

The CEMMSS framework of bringing together researchers focused on breakthrough materials, advanced manufacturing, robotics, and cyber-physical systems is expected to increase collaboration and communication among these research communities, leading to enhanced disciplinary and interdisciplinary research. These efforts will transform static systems, processes, and edifices into adaptive, pervasive smart systems with embedded computational intelligence that can sense, adapt, and react. Success in CEMMSS will drive transformations that address the pressing technological challenges facing the Nation, promoting U.S. economic competitiveness.

Programmatic

To generate new capabilities with meaningful impact, NSF is developing a portfolio that coordinates and synchronizes activities across four main research areas – breakthrough materials, advanced manufacturing, robotics, and cyber-physical systems – and encourages interdependencies and common research elements to surface and be exploited at each subsequent stage of the evolution of the program.

Organizational

CEMMSS leadership is shared across the relevant division directors in the Directorate for Computer and Information Science and Engineering (CISE), the Directorate for Engineering (ENG) and the Directorate for Mathematical and Physical Sciences (MPS). The CEMMSS coordination team is comprised of program directors from CISE, ENG, MPS, and the Directorate for Biological Sciences (BIO). This group is charged with developing CEMMSS activities and implementing the suite of activities over the next four years. The team will also work with internal and external program evaluation experts to help develop a set of metrics by which program progress can be evaluated over time.

Scope

Numerous CEMMSS interdisciplinary connections already exist at NSF. Many are pairwise and expanding, such as robotics and manufacturing; materials and manufacturing; cyber-physical systems and robotics; cyber-physical systems and manufacturing materials; and robotics and the biological sciences. NSF has sponsored and will continue to hold community-building workshops and will request white papers to contribute to the development and evolution of CEMMSS. The intention is to go beyond these two-way collaborations and drive research in new directions. This will be achieved through a combination of new solicitations and Dear Colleague Letters (DCLs). CEMMSS currently includes many interagency activities; new cross-agency partnerships are continuously being developed. Industry partnerships also are a key element in CEMMSS's success; industry and venture capital groups will be invited to workshops and principal investigator (PI) meetings. NSF also expects that international activities will become increasingly relevant over the period of time that CEMMSS is an NSF-wide investment area. CEMMSS presents a unique opportunity to accelerate integrative research and educational activities. The interaction of research ideas that is promoted by CEMMSS multiplies their impact across multiple research communities.

Investment Framework

CEMMSS Funding by Directorate
(Dollars in Millions)

Directorate	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$3.00	$3.00	$5.00
Computer and Information Science and Engineering	50.50	50.50	103.00
Engineering	56.00	56.00	126.42
Mathematical and Physical Sciences	34.82	32.15	66.00
Total	**$144.32**	**$141.65**	**$300.42**

Totals may not add due to rounding.

FY 2012 – FY 2013

Science and Engineering
In 2012, NSF jumpstarted CEMMSS's science and engineering activities through a suite of activities, including DCLs, solicitations, and Early-concept Grants for Exploratory Research (EAGER) projects. These activities promoted smart systems by focusing on advanced manufacturing, robotics, cyber-physical systems, scalable nanomanufacturing, and advanced materials.

In FY 2013, the program is emphasizing mid-scale team-based interdisciplinary research that will build the knowledge necessary to make progress in CEMMSS, including opportunities for transitioning discoveries into practice. Investments will continue to build pair-wise programmatic activities across CEMMSS focus areas to develop the next generation of robots, cyber-physical systems, cyber-manufacturing tools, and advanced materials. For example, pilot programs will further integrate materials science and engineering with processing, design, and manufacturing research, including Designing Materials to Revolutionize and Engineer the Future (DMREF), NSF's premier program in support of MGI involving CISE, MPS, and ENG.

Education, Workforce Development, and Community Building
To foster and accelerate the building of integrated research communities among various disciplines, in FY 2012, NSF held technical workshops, design sessions, focused meetings, and panels about advanced manufacturing, MGI, and cybersecurity for cyber-physical systems. An organizational meeting was held with representatives from academic and industrial organizations to discuss collaborative work in health applications of emerging robotics technologies. NSF also continued to support the cyber-physical systems (CPS) Virtual Organization. Among the awards given in FY 2012, NRI funded the use of robotics to facilitate and motivate STEM learning across the K16 continuum. In addition to co-chairing the National Science and Technology Council Subcommittee for MGI and the CPS Senior Steering Group (SSG), NSF participated in interagency award meetings to structure a balanced NRI portfolio across agencies. NSF has worked to enhance CPS cooperation with other agencies through the NITRD program and has developed memoranda of understanding (MOUs) with Department of Defense agencies related to MGI.

In FY 2013, the associated big data and cyberinfrastructure components necessary for making advances in CEMMSS will be identified. NSF will continue to co-chair and/or participate in interagency NSTC Subcommittees, SSGs, and working groups. Each focus area will develop curriculum and new education

programs. In the area of advanced manufacturing, a program is being started with industry to provide support for undergraduate laboratories to use existing cyber-manufacturing infrastructure in project work. NSF has developed an MOU for interagency cooperation in CPS with the Department of Transportation

Research Infrastructure Development

In FY 2012, there were initial pilot investments in testbeds and prototypes for cyber-enabled materials, manufacturing, and smart systems. The NRI solicitation funded the development of co-robot testbeds for technology testing, demonstration, and validation. Pilot investments at Purdue University were utilized to integrate the NSF-funded HubZero cyberinfrastructure with the Department of Commerce-led National Digital Engineering and Manufacturing Consortium. Purdue has now launched ManufacturingHub.org, and is using this cyberinfrastructure to link manufacturers to state-of-the-art computational modeling and simulation tools to solve real world manufacturing problems more accurately and rapidly.

In FY 2013, NSF will build upon successful pilots and expand development of cybermanufacturing assets and link academic and government-furnished tools to industry needs and opportunities. NSF is also encouraging the development of new, or the use of existing, testbeds to evaluate advances in cyber-physical systems. DMREF plans to build an integrated network of platforms that develop and utilize advanced computational and experimental tools to accelerate the discovery, synthesis, and deployment of new materials as well as their transfer to the manufacturing sector.

FY 2014 Request

To advance the science and engineering goal in FY 2014, the focus will be on evolving a comprehensive, integrated program across the focus areas to encourage new connections, discoveries, and/or emerging fields of science and engineering. Investments will be made in advanced manufacturing ($159.73 million), including investments in scalable nanomanufacturing ($10.0 million); cyber-physical systems ($50.0 million); core programs that integrate materials science and engineering with processing, design, and manufacturing research ($36.0 million); DMREF/MGI ($42.0 million); and NRI ($31.50 million). A workshop is planned to bring together communities engaged in materials research on sensors and detectors with those in manufacturing and cyber-physical systems. This will enhance community building and identify science and engineering challenges for this new community. In addition, CEMMSS will conduct the first round of challenges and contests.

To advance the Education, Workforce Development, and Community Building goal, NSF will continue its role in interagency Subcommittees, SSGs, and working groups and will develop further partnerships with other agencies as well as with the European Union. Interagency MGI activities specific to DMREF will include evaluation methods for cross-agency projects, development of a strategic plan for MGI, and program assessment and planning meetings for subsequent solicitations. NSF will also expand its use of MOUs to share cyber and experimental facilities operated by interagency partners. NSF will continue to support the CPS Virtual Organization, which is a broad community of interest for CPS researchers and developers. There will be workshops and PI meetings in all four focus areas. For example, CPS/CEMMSS education workshops will address graduate curricula, undergraduate courses, and strategies for the new NSF Research Traineeships (NRT) program in CPS. Also, a workshop that will bring together the DMREF community will invite industry as well as venture capitalists to attend part of the workshop.

The Research Infrastructure Development goal will involve all four focus areas. The CPS solicitation will include a focus area on testbeds and will seek partnerships among CISE, ENG, and interagency partners. DMREF will invest in data sharing, analysis, and visualization capabilities to enhance data-driven material discovery, assessment, and deployment. The challenges and contests conducted as part of NRI in FY 2014 will highlight cyberinfrastructure goals by making four awards based on the following criteria: current cost to manufacture, expectation of broader impact, innovation of integrated solution, and ease of

transition to other projects and/or industry.

FY 2015 – FY 2017

To further develop the foundational science and engineering basis of CEMMSS, NSF will develop several integrated programs in cyber-manufacturing, advanced materials, and smart systems. The long-term goal is to build a thriving ecosystem of cyber-enabled systems and advanced materials. There will be a continued focus on bringing communities together by engaging students, teachers, and educators in cybermanufacturing workshops as well as workshops on other topics that cross the four areas, and by participating in working groups. NSF will expand partnerships with other agencies, international organizations, and industry. These will be grounded in the collaborations NSF has already initiated. To date, NSF has worked with other agencies, such as the National Institute of Standards and Technology, the National Institutes of Health, the National Oceanic and Atmospheric Administration, U.S. Department of Agriculture, and the Departments of Transportation and Defense, which are currently building and deploying smart systems of all kinds (e.g., underwater sensor networks; autonomous vehicles that swim, fly, crawl up walls; portable energy efficient storage devices, etc.). Combining mission agency investments with the basic science and engineering funded by NSF could have a significant impact on future U.S. critical infrastructure by embedding computational intelligence in the underlying systems and the materials from which they are composed.

Solicitations will emphasize a call for high impact solutions integrated across the CEMMSS disciplines, especially those that enhance manufacturing processes, and utilize advanced materials and computational intelligence. CEMMSS will also promote high-risk, breakthrough applications and testbeds in order to continue to push the boundaries of discovery in advanced materials, cybermanufacturing, and smart systems. In FY 2015, the CEMMSS coordination team will engage external contractors to conduct portfolio analysis, for example, identifying gaps and opportunities for further interagency, industry, and international cooperation in cyber-enabled materials, manufacturing, and smart systems.

Evaluation Framework

At the end of FY 2012, NSF contracted with the Science and Technology Policy Institute (STPI) to develop a framework for assessment and a set of program-specific metrics to be available for use within ten to eleven months.

STPI will assist with identifying metrics to measure progress across the three goals. Possible indicators include:

- For science and engineering – increases in the number and quality of breakthrough discoveries; the emergence of new fields; increasing agency, industry, and international partnerships; and increasing transition of discoveries into practice (i.e., patents, start-ups, new products);
- For education – increases in the number of smart systems courses offered, faculty recruited, and students graduating from academic programs; and
- For cyberinfrastructure – the development of de facto standards for interoperability; increased use of shared data analytic, simulation and modeling tools, and common software platforms; and the growth of computer-integrated and cyber-based manufacturing across the U.S.

The preliminary work to set out a baseline for these metrics will be carried out in FY 2013, allowing program evaluation to be deployed during FY 2014. Yearly program assessments will be carried out by the CEMMSS coordination team and presented to NSF senior management.

CYBERINFRASTRUCTURE FRAMEWORK FOR 21ST CENTURY SCIENCE, ENGINEERING, AND EDUCATION (CIF21)

Overview

The Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21) investment promises to accelerate and transform the processes and outcomes of scientific discovery and innovation by providing advanced cyberinfrastructure that enables new functional capabilities across all disciplines in computational and data-enabled science and engineering (CDS&E).

Future science, engineering, and education endeavors will be transformed by a comprehensive and scalable cyberinfrastructure that bridges diverse scientific communities and brings theoretical, computational, experimental, and observational approaches together. Large volumes of research data are being generated by scientific instruments, observing systems, surveys, mobile and embedded systems, as well as by publications, experiments, simulations, evaluations, and analyses. In addition, scientists using thousands of distributed scientific instruments, such as gene sequencers and sensors, are generating many more small data archives – creating the long-tail of science – that today generate heterogeneous data sets at an unprecedented rate. CIF21 is a portfolio of activities to provide integrated cyber resources that will enable 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.

Total Funding for CIF21

(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
$91.23	**$78.00**	**$155.47**

Goals

The goal of CIF21 is to accelerate the deployment and use of advanced cyberinfrastructure facilities and capabilities to support all areas of science, engineering, and education. CIF21 has three primary components: 1) establishment of a national data infrastructure; 2) development of new computational and data-intensive capabilities; and 3) community building and workforce development.

Approach

The overarching vision of CIF21 is to catalyze new thinking, paradigms, and practices in science and engineering by fostering a pervasive cyberinfrastructure that enables research and deployment at unprecedented scales, complexity, resolution, and accuracy by integrating and coordinating computation, data, and experiments in novel ways, nationally and internationally.

Organizational. The CIF21 organizational structure employs four interrelated groups to ensure that CIF21 continues to build upon NSF's history of providing leadership in the design, development, and use of the cyberinfrastructure required to transform science, engineering, and education in the 21st century.

- The Directorate for Computer and Information Science and Engineering (CISE), in particular the Division of Advanced Cyberinfrastructure (ACI) (formerly the Office of Cyberinfrastructure), provides leadership for CIF21 activities, including developing coordinated CIF21 programs and

solicitations and identifying common approaches for a scalable, comprehensive cyberinfrastructure.

- The CIF21 Steering Committee of assistant directors and office heads provides oversight and advice on strategic directions and programs for CIF21.
- The CIF21 Cyberinfrastructure Leadership Group (CLG) coordinates and manages CIF21 programs across NSF, including developing solicitation guidance for common CIF21 programs, coordinating common CIF21 activities, developing and maintaining an investment roadmap, and providing planning and budgeting for CIF21.
- The NSF Advisory Committee on Cyberinfrastructure (ACCI) reviews cyberinfrastructure activities and programs across all of NSF, and provides advice and strategic feedback on NSF plans and existing efforts.

Scope. To guide the approach of CIF21, the ACCI produced a set of six reports and recommendations for cyberinfrastructure.[1] These reports and recommendations have been critical in identifying new approaches and capabilities required to advance data,[2] computing infrastructure,[3] software,[4] and workforce development for CIF21. These reports, along with on-going focused workshops and events, help to further define and prioritize programs and activities within the CIF21 framework.

CIF21 uses a combination of solicitations, Dear Colleague Letters (DCL), programs, and focused workshops to fund the research, development, and deployment of cyberinfrastructure and related applications. Partnerships with industry are emphasized, especially as disruptive technologies change how a technology or approach should be used to support science. The ubiquity of cyberinfrastructure requires partnerships and joint collaborations with other federal agencies and international groups. Workshops, conferences, and focused IdeaLabs will be used to reach out to new communities of researchers and educators.

Investment Framework

CIF21 Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$2.00	$2.00	$6.50
Computer and Information Science and Engineering	47.94	35.00	90.67
Engineering	3.70	5.00	12.00
Geosciences	4.49	8.00	16.50
Mathematical and Physical Sciences	27.60	11.50	22.30
Social, Behavioral, and Economic Sciences	5.50	5.50	7.50
International and Integrative Activities	-	11.00	-
Total	**$91.23**	**$78.00**	**$155.47**

Totals may not add due to rounding.

[1] NSF Advisory Committee for Cyberinfrastructure: www.nsf.gov/od/oci/taskforces/index.jsp
[2] A Vision and Strategy for Data in Science, Engineering and Education: www.nsf.gov/od/oci/cif21/DataVision2012.pdf
[3] Advanced Computing Infrastructure: Vision and Strategic Plan: www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf12051
[4] Software for Science and Engineering; www.nsf.gov/od/oci/taskforces/index.jsp

FY 2012 – FY 2013

Multiple CIF21 solicitations and programs involving Biological Sciences (BIO), Computer and Information Science and Engineering (CISE), Engineering (ENG), Geological Sciences (GEO), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE) were issued in FY 2012. These solicitations focused on data-enabled science, software development, community research networks, new computational infrastructure, and access and connections to facilities.

In FY 2013, investments in CIF21 expanded both the scope and activities across the Foundation to support science, engineering, and education, with continued consideration of the ACCI Task Force reports. The National Big Data Research and Development Initiative remained a CIF21 centerpiece, focusing on the research and development of new capabilities for data-intensive and data-enabled science to create actionable information that leads to timely and more informed decisions. The NSF Big Data program invested in four key areas: innovation and new foundational research, cyberinfrastructure, community building, and education and workforce development. The science and engineering research and education scope of the Big Data solicitation expanded to include topics aligned with big data and new capabilities dedicated to creating large-scale, next-generation data resources and relevant analytic techniques to advance fundamental research in scientific fields supported by the SBE and Education and Human Resources (EHR) Directorates.

A unique virtual program in CDS&E was established by ACI, ENG, and MPS. It is rooted in the individual divisions and is also coordinated across directorates, responding to both disciplinary and cross-disciplinary needs.

CIF21 program activities fostered broadening of the cyberinfrastructure development and research communities in FY 2013. In particular, software programs and data activities expanded to include participation by new domains and included joint international software and data collaborations with the European Union, Australia, and China. Through the ACI-supported XSEDE (eXtreme Science and Engineering Discovery and Education) environment, new CIF21 research communities have access to advanced computational infrastructure, including two new significant computational resources that became operational in FY 2013: the University of Illinois at Urbana-Champaign Blue Waters project, and the Texas Advanced Computational Center's new Stampede project.

New research communities were also established to address multidisciplinary research challenges that are emerging as a result of new data and cyberinfrastructure capabilities. These include the EarthCube communities in the geosciences, and a new community effort to develop integrated data management infrastructure in the mathematical and physical sciences, which will create communities around grand challenge problems. The Building Community and Capacity solicitation supports the development of new research communities for SBE and EHR.

FY 2014 Request

In FY 2014, CIF21 will make the following investments:

- The National Data Infrastructure program will be expanded in scope to address issues associated with open access and will invest in one or two pilots to address management and use of multidisciplinary data.
- The Big Data solicitation will be expanded to include additional themes critical to the missions of NSF directorates; workshops will be convened to develop R&D pathways for the next five to ten years, including exploring partnerships and participation with more agencies and industry.
- CDS&E program activities will be expanded to include new efforts and approaches for simulation and modeling; new prototypes in specific domains will be developed with an emphasis upon collaboration across disciplines. Based on the response to FY 2013's consolidated solicitation, additional changes will be made to the program with a specific focus to scale CDS&E efforts.

- New data conceptualization and data pilot awards will be made in collaboration with additional directorates and offices through the Data Infrastructure Building Blocks (DIBBs) program and data coordination pilots in development in BIO and GEO. The data program will broaden the base and use of advanced computational services and capabilities across disciplines that have not used advanced cyberinfrastructure resources before; and it will explore new approaches to data-intensive computational resources, including a mix of clouds, data centers, and distributed computing systems.
- Conceptualization awards, along with early pilots, prototypes, and best practices approaches, will be made to several communities to develop data and software; to resolve governance issues; and develop requirements to support multidisciplinary communities.
- Additional community-building awards will focus on the development of new research communities, including next generation data resources and access.
- The CIF21 track within the NSF Research Traineeships (NRT) will address the need to educate and support the next generation of researchers able to address fundamental challenges in: 1) core techniques and technologies for advancing big data science and engineering; 2) analyzing and dealing with challenging CDS&E problems; and 3) researching, providing, and using cyberinfrastructure that makes cutting-edge CDS&E research possible in any and all disciplines.
- EarthCube will expand its support for the development of community-guided cyberinfrastructure to integrate data into a framework that will expedite the delivery of geoscience knowledge to the science and engineering enterprise.

FY 2015 – Beyond

To further accelerate scientific discovery and innovation in FY 2015 and beyond, it is essential to develop a national data infrastructure ecosystem that provides new capabilities and functionalities to support a broad spectrum of science, engineering, and education users and communities. These activities include provision of data access and data exchange; development of at-scale multi-disciplinary data pilots and prototypes; and continued development of new algorithms, tools, and software, as well as expanding both the scope and depth of new research communities and the future CDS&E workforce.

- National Data Infrastructure efforts will be expanded to include more participation and collaboration across all NSF directorates, with an emphasis on coordination and common approaches to leverage investments and ensure interoperability. The efforts will also include development of new partnerships with campuses, other federal agencies, and international partners.
- Based on portfolio analyses, cyberinfrastructure programs and activities will be restructured to more fully support long-term data and computational needs for research and education, including open access, curation, preservation, and development of expertise to meet data-intensive science across all disciplines.
- Foundational research efforts will be expanded to include additional analysis and discovery tools, software and computational capabilities, including new domains and research communities. One focus will be on the transition of data analysis tools into practice, especially those that have applicability across multiple domains and are based on analyses of the Big Data and National Data Infrastructure portfolios and the results achieved to date. Another focus will be on new computational approaches for science that bridge across multiple domains, especially supporting long-tail science and users that have not been able to effectively leverage CDS&E resources. This will also include broadening and expanding the base and diversity of users (e.g., faculty, students, and the public) to take advantage of new capabilities in data and computation.
- Additional prototype and proof-of-concept approaches for CDS&E will be developed; involvement from other federal agencies, such as the Department of Energy, the National Institutes of Health, the National Aeronautics and Space Administration, and the U.S. Geological Survey will be pursued. Based on continued community input from all scientific domains and cyberinfrastructure communities, solicitations and programs will be revised and updated to support and develop new research communities, including effective use of new technologies, and the rapidly developing

national data infrastructure.

- The CIF21 track in NRT will be expanded to support the education of the next generation of researchers able to address fundamental challenges in advancing big data science and engineering.
- EarthCube will continue its support for the development of community-guided cyberinfrastructure to integrate data into a framework that will expedite the delivery of geoscience knowledge to the science and engineering enterprise.

Evaluation Framework

NSF will deploy a variety of tools to evaluate the scientific and educational impact and progress of the various CIF21 programs. The CIF21 Steering Committee and the CIF21 Leadership Group will consider a matrix of assessment methods and measures, including incorporating input and guidance from the NSF Advisory Committee on Cyberinfrastructure. In the short-term, these groups will conduct portfolio analyses and identify metrics. In the long-term, NSF will engage an external organization to conduct an assessment of CIF21 research, infrastructure, and education investments and outcomes.

INTEGRATED NSF SUPPORT PROMOTING INTERDISCIPLINARY RESEARCH AND EDUCATION (INSPIRE)

Overview

INSPIRE was established to address some of the most complicated and pressing scientific problems that lie at the intersections of traditional disciplines and to advance the NSF's strategic goal of *Transform the Frontiers*[1] and Performance Goal T-1: *Make investments that lead to emerging new fields of science and engineering and shifts in existing fields.* INSPIRE will strengthen NSF's support of interdisciplinary, potentially transformative research by complementing existing efforts with a suite of highly innovative Foundation-wide activities and funding opportunities. It responds to issues raised in a variety of external and internal publications, including a National Academies report[2] that identified barriers to interdisciplinary research (IDR), documents relating to the America COMPETES Reauthorization Act of 2010, the report of the NSF Facilitating Transformative and Interdisciplinary Research (FacTIR) working group,[3] and to perceptions in the research community that NSF does not always provide good opportunities for comprehensive review and support of unsolicited IDR proposals that cross traditional boundaries.

Total Funding for INSPIRE
(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
$29.10	**$20.35**	**$63.00**

Goals

Goal 1: NSF program officers will have the necessary tools and management support to empower cross-cutting collaboration and risk-taking in developing and managing their awards portfolio.

Goal 2: Researchers will submit and NSF will support a greater proportion of unusually novel, creative interdisciplinary proposals.

Approach

Approach 1: Toward Goal 1, INSPIRE seeks to empower program officers to overcome a variety of factors that create pressure toward funding of safe, conventional, disciplinary choices. INSPIRE provides financial incentives through co-funding and establishes an expectation that NSF management will promote a bolder interdisciplinary and potentially transformative vision. INSPIRE identifies changes to NSF systems and training practices to enable and facilitate interdisciplinary activities.

Approach 2: Toward Goal 2, while existing NSF programs support potentially transformative IDR through the agency's highly regarded merit review process, INSPIRE seeks to increase NSF's support of bold, high-risk interdisciplinary projects that transcend typical programmatic scope, through novel funding and merit review mechanisms. These mechanisms are intended to increase the community's submissions of such proposals and will provide additional funding for their support. The value of a

[1] *Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years (FY) 2011-2016,* www.nsf.gov/news/strategicplan/index.jsp (2011).
[2] Committee on Facilitating Interdisciplinary Research, Committee on Science, Engineering, and Public Policy (2004). *Facilitating interdisciplinary research.* National Academies. Washington: National Academy Press.
[3] Final Report, *Facilitating Transformative and Interdisciplinary Research (FacTIR),* www.inside.nsf.gov/od/factir/FacTIRFinalReport_091221.pdf (2009).

portfolio of merit review mechanisms at agencies has been called out in a recent PCAST report.[4]

The desired outcome will be a portfolio of novel, high-impact IDR projects and a larger community of researchers that develops and submits such proposals to NSF.

- **Lifecycle of activity:** The ramp-up phase of INSPIRE is planned to cover the five-year period of FY 2012-2016. After that, the awards programs are planned to maintain a steady state at that level, subject to a thorough review of INSPIRE as discussed below. Evaluation activities for each INSPIRE goal will be ongoing.
- **Mechanisms to be used:** INSPIRE will address its two goals through two approaches. Goal 1 will be addressed primarily through Approach 1, which focuses on how NSF supports science that may fall outside of the scope of existing NSF programs. In particular, Approach 1 activities will encompass improvements in business practices, funding culture, training, and evaluation. Goal 2 will be addressed primarily through Approach 2, which supports the development of new funding opportunities and mechanisms that encourage the pursuit of novel, creative projects. New INSPIRE funding mechanisms will signal to research communities the priority that NSF places on interdisciplinary and potentially transformative research.
- **Leadership structure and governance:** The NSF Office of International and Integrative Activities (OIIA) serves as the organizational lead for INSPIRE. The INSPIRE Working Group (IWG) was established to guide INSPIRE's activities and is co-chaired by members from OIIA and the research directorates. All research directorates and programmatic offices are represented. The IWG reports to the NSF Director through NSF's Senior Management Roundtable.
- **Scope within NSF:** By design, the scope of INSPIRE is broad. For Approach 1 activities, all research directorates and offices are engaged. In addition, the Office of Information and Resource Management (OIRM) and the Office of Budget, Finance, and Award Management (BFA) are called on to address issues, e.g., business systems, performance plans, and novel forms of evaluation. For Approach 2, each directorate participates by providing co-funding to support research projects. Funding from the Integrative and International Activities (IIA) budget line also provides matching support. Program officers from every research directorate and office are engaged in communicating the goals of INSPIRE to their communities and facilitating cross-Foundational partnering in the review and support of individual proposals. INSPIRE proposals can be in any field of science and engineering supported by NSF.
- **External stakeholders:** For the external research community, INSPIRE will establish a new high-visibility awards program to support pioneering, potentially transformative IDR, to build IDR communities, to foster IDR career pathways, and to provide interdisciplinary training of the scientific workforce.

[4] President's Council of Advisors on Science and Technology, *Transformation and Opportunity: The Future of the U.S. Research Enterprise*, www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_future_research_enterprise_20121130.pdf (2012).

Investment Framework

INSPIRE Funding by Directorate

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$3.06	$2.00	$4.00
Computer and Information Science and Engineering	3.84	0.50	5.00
Education and Human Resources	0.64	-	2.00
Engineering	2.99	-	6.00
Geosciences	0.86	2.00	6.00
Mathematical and Physical Sciences	1.97	3.00	7.00
Social, Behavioral and Economic Sciences	3.32	0.50	1.00
International and Integrative Activities	12.43	12.35	32.00
Total	**$29.10**	**$20.35**	**$63.00**

Totals may not add due to rounding.

FY 2010-FY 2013

INSPIRE was announced in February 2011 in the NSF FY 2012 Budget Request to Congress, which included funding on the IIA budget line, to be augmented by co-funding from directorates and offices. The IWG was established in FY 2011, and program planning was initiated.

Under Approach 1, web-based inquiry and letter-of-intent forms were developed to enable principal investigators (PIs) to identify multiple NSF programs of interest and to enable program officers to more easily collaborate on evaluation of INSPIRE funding inquiries shared across programs; this became the pathway to eventual proposals and awards under Approach 2. Tracking of web-based inquiries was implemented, and text-based classification and clustering methods were developed to analyze the scientific content of the inquiries. In FY 2013 a statement of work is in progress for baseline data gathering and a feasibility study (see the Evaluation Framework section below). Review and improvement of internal practices, systems, and evaluation is ongoing.

Under Approach 2, the IWG designed the first INSPIRE award mechanism in FY 2012. It was initially called CREATIV, then simply referred to as INSPIRE, and now evolved into "INSPIRE Track 1" in FY 2013. INSPIRE Track 1 targets individuals and small investigator groups and is open to potentially transformative interdisciplinary ideas on any NSF-supported topic. Forty awards of up to $1.0 million each, generally internally reviewed, were made for almost $30.0 million in FY 2012.

In FY 2013, the program includes mid-scale "INSPIRE Track 2" awards of greater scope. These awards are chosen by a combination of internal and external review. Additionally, the program will make prestigious "Director's INSPIRE Awards" to interdisciplinary individual investigators nominated by program officers from Track 1 submissions and selected by the NSF Director after a rigorous multi-stage process.

FY 2014 Request

In Approach 1, the baseline data and feasibility study will inform an outcome evaluation and impact

assessment of the first two years of INSPIRE Track 1. The Track 1 outcome evaluation design will be modified as needed for INSPIRE Track 2 and Director's INSPIRE Awards, and an internal report will describe the modified design. In consultation with BFA and OIRM, NSF will begin a review to determine feasible improvements to eBusiness systems to facilitate IDR by allowing for interdisciplinary classification of proposals and awards, and will develop an implementation plan.

In Approach 2, the INSPIRE awards program will continue to ramp up to a total of $63.0 million (with approximate breakdowns of: INSPIRE Track 1, $23.0 million; INSPIRE Track 2, $35.0 million; and Director's INSPIRE Awards, $5.0 million).

FY 2015 – FY 2016

In Approach 1, the first two years of INSPIRE Track 2 and Director's INSPIRE Awards will be evaluated. In FY 2015, plan recommendations for changes to eBusiness systems will be implemented. These plans will continue in FY 2016.

In Approach 2, funding is planned to increase in FY 2015 and FY 2016, divided (approximately) between INSPIRE Track 1 (about 25% of funds), INSPIRE Track 2 (about 58% of funds), and Director's INSPIRE Awards (about 17% of funds).

Evaluation Framework

In FY 2011-2013, the primary tasks for evaluation were: (1) to develop a logic model for the INSPIRE funding mechanism, identify metrics, develop indices to estimate interdisciplinarity, and determine failure targets for high-risk research, and refresh the baseline of data that was collected in the 2007 proposer survey that was done as part of the IPAMM (Impact of Proposal and Award Management Mechanisms) study; [5] and (2) to initiate a feasibility study to do (a) a short-term portfolio analysis, (b) a medium-term collection of data on outcomes from awards funded by INSPIRE and non-INSPIRE mechanisms, and (c) a long-term study plan for a possible impact study.

In FY 2014 and beyond, baseline results from previous years' portfolio of awards will make it possible to determine whether the new mechanism is resulting in types of awards that were not being funded with previous mechanisms. Case studies and qualitative assessments of the review process for projects with promising results are expected to provide helpful information. Analyses of the results from program monitoring will determine whether these results suggest that a rigorous impact evaluation is feasible.

Consistent with the goal of providing model business practices at NSF, INSPIRE aims to pilot new streamlined review procedures. NSF has made the mitigation of additional internal and external workload implications a high priority in formulating INSPIRE activities. In FY 2013, Letters of Intent were introduced and will be reviewed to establish the appropriateness of full proposal invitations. In this way, approximately 90 percent of inquiries are expected to be resolved without the internal workload associated with a proposal submission. As was the case for the FY 2012 CREATIV opportunity (now evolved into INSPIRE Track 1), most of the authorized INSPIRE full proposals will be awarded through internal review, placing no burden on the external reviewer community. The larger INSPIRE Track 2 and prestigious individual Director's INSPIRE Awards will involve an element of external review through the use of a Blue Ribbon Panel. The success of these pilot processes will be studied on an ongoing basis, including surveys and topical analyses to determine the extent to which INSPIRE has better positioned NSF to enable interdisciplinary and potentially transformative research.

[5] www.nsf.gov/od/ipamm/ipamm_2007 survey.jsp

NSF INNOVATION CORPS (I-Corps)

Overview

The National Science Foundation (NSF) seeks to develop and nurture a national innovation ecosystem that builds upon fundamental research to guide the output of scientific research toward the development of technologies, products, and processes that benefit society.

In order to cultivate a national innovation ecosystem, NSF established the NSF Innovation Corps (I-Corps) in FY 2011. The NSF I-Corps' purpose is to support NSF-funded researchers who, with teams, are interested in transitioning their research out of the lab. I-Corps awards are based the on maturity of the effort (i.e. is the research ready to leave the lab), strength of the team, and anticipated market value. The teams selected for I-Corps awards will receive additional support – in the form of mentoring and funding – to accelerate innovation that can attract subsequent third-party funding.

The I-Corps Team grant gives the project team access to resources to help determine the readiness to commercialize technology developed by previously-funded or currently-funded NSF projects. The outcome of the I-Corps projects is threefold: 1) a clear go/no go decision regarding viability of products and services, 2) should the decision be to move the effort forward, a transition plan to do so, and 3) a technology demonstration for potential partners.

In FY 2014 NSF will support two additional I-Corps competitions – Sites and Nodes – to further build, utilize, and sustain a national innovation ecosystem that augments 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 will 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 (five+ years) research and development projects.

I-Corps has its genesis in many of the long standing innovation ecosystem programs. Most closely related to I-Corps is the Partnership for Innovations' (PFI) Accelerating Innovation Research (AIR) program in the Directorate for Engineering (ENG), started in FY 2011. The AIR program:

- encourages the translation of the numerous, technologically-promising, fundamental discoveries made by NSF researchers, while drawing upon and building the entrepreneurial spirit of the researchers and students; and
- fosters connections between existing NSF innovation research alliances.

Those existing NSF innovation research alliances include consortia such as Engineering Research Centers (ERC), Industry University Cooperative Research Centers (I/UCRC), Partnerships for Innovation (PFI), Science and Technology Centers (STC), Nanoscale Science and Engineering Centers (NSEC), Materials Research Science and Engineering Centers (MRSEC), and other institutions. Their complementary focus will spur the development of discoveries into innovative technologies through collaboration.

All of these activities are designed to strengthen the U.S. innovation ecosystem.

Total Funding for I-Corps

(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
$6.77	**$7.50**	**$24.85**

Goals

The goals of the I-Corps program are:

- to build on NSF's investment in fundamental research;
- to offer academic researchers and students an opportunity to learn firsthand about technological innovation and entrepreneurship, and thereby fulfill the promise of their discoveries; and
- to prepare students for real-world experience through curricular enhancements, and provide them with opportunities to learn about and participate in the process of transforming scientific and engineering discoveries to meet societal needs.

Approach

NSF's core mission is to fund basic research in all fields of science and engineering. I-Corps supports this mission by helping to transform scientific output into technological innovation. I-Corps will leverage existing funding for programs like Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR), and will utilize additional support from private-sector and regional partners, including universities, industries, venture capitalists, and nonprofits. The partnership with universities will also contribute to the development of novel pedagogical tools.

The I-Corps program will also help create a new network that will strategically connect NSF-funded scientists and innovators to the national innovation ecosystem, including direct connections with mentors and potential future investors.

Leadership structure and governance: I-Corps is led by a core group of cognizant NSF program officers comprised of representatives from all directorates. The lead program officer is from ENG and is currently detailed to the Office of International and Integrative Activities. In addition to working closely with all subject matter experts within the directorates and offices, the lead program officer and the I-Corps team regularly meet with other federal agency representatives who have expressed interest in implementing similar programs within their own agency.

Scope within NSF: Principal Investigators (PIs) from every directorate, previously or currently supported for their research and education activities by NSF, are now benefiting from this educational and financial support through I-Corps.

External stakeholders: The primary focus of I-Corps is to help the 'traditional' academic research community better connect with experts in innovation and entrepreneurship, who can in turn help those in the academic community evaluate the commercial viability of their ideas. The program has been well received by future small business interests, the venture capital community, and large established enterprises interested in the intellectual property generated by NSF-supported researchers.

Investment Framework

I-Corps Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$0.10	$0.50	$2.00
Computer and Information Science and Engineering	2.55	2.75	9.00
Education and Human Resources	0.36	-	0.30
Engineering	2.72	2.50	8.00
Geosciences	0.19	0.25	1.75
Mathematical and Physical Sciences	0.65	1.00	3.30
Social, Behavioral, and Economic Sciences	0.20	0.50	0.50
Total, NSF	**$6.77**	**$7.50**	**$24.85**

Totals may not add due to rounding.

FY 2011-FY 2013

The Innovation Corps program is a key element in a series of NSF-supported programs concentrating on the innovation ecosystem. As explained above, I-Corps has its genesis in a number of long-standing programs within the NSF that support the innovation ecosystem. In FY 2011 and FY 2012, investments in the inaugural year for I-Corps complemented these long-standing investments in programs, such as ERC, I/UCRC, PFI, STC, NSEC, and MRSEC. All of these programs are built on the backbone of support for core research, primarily to individual investigators, found in every directorate at NSF.

The I-Corps program is comprised of three elements, namely:

- Financial support to the team for the development of a prototype or a proof of concept;
- A specific structure for the I-Corps team, comprised of a principal investigator, an entrepreneurial lead, and an innovation/entrepreneurial mentor; and
- A strong educational component focusing on a hypothesis-driven approach to developing a methodology for evaluating both the technical merits and the marketability of the concept being proposed.

In FY 2012, the I-Corps program supported 124 Team awards, at $50,000 each, for up to six months. The projects were submitted to NSF in response to NSF solicitation 11-560 and were reviewed under NSF's standard Grants for Rapid Response Research (RAPID) mechanism.

The FY 2013 plan begins with the basic I-Corps structure developed in 2011-2012, the elements of which will not change substantively in 2013.

Today, a hypothesis-driven approach to evaluating technical and market viability is offered to all I-Corps teams. The I-Corps program delivers this immersive curriculum through regional I-Corps nodes, wherein the hypothesis driven innovation educational offerings for PIs and their teams are developed and provided by the universities involved in these nodes. This approach appears to be very successful and experience to date indicates it provides significant "value added" to the PI and their teams. In FY 2011, there was one I-Corps Node and in FY 2012, there were two. In FY 2013, NSF is offering opportunities to other universities to develop the curriculum, using the lessons learned in the execution of the I-Corps program

in FY 2011 and FY 2012 and to compete for more I-Corps Nodes.

Recognizing several universities have existing institutional infrastructure and mechanisms to support entrepreneurship within their campuses, NSF plans to launch I-Corps Sites. These sites will provide infrastructure, advice, resources, networking opportunities, training, and modest funding to enable formation of teams that can apply to the I-Corps program.

FY 2014 Request

- NSF will support up to 175 Innovation Team awards to fund NSF-funded researchers who will receive additional support - in the form of mentoring and funding - to accelerate innovation that can attract subsequent third-party funding. Each I-Corps grant provides the project team with resources to determine the readiness to commercialize technology developed by previously-funded or currently-funded NSF projects.

- NSF will support approximately 15 new Innovation Corps Sites in FY 2014. NSF provides up to $100,000 per year for three years to established academic institutions that already have existing innovation or entrepreneurial units to nurture and support multiple teams.

- NSF will support up to three new Innovation Corps Nodes in FY 2014. NSF provides $350,000 to $1.25 million per year for up to three years, depending upon the number of institutions involved, to establish regional nodes to provide training, tools, and resources for longer term (5+ years) projects that meet I-Corps program goals.

FY 2015 and beyond

NSF plans to achieve full-scale integration and dissemination of this program throughout the country, in the FY 2016 – FY 2017 timeframe utilizing a regional hub model. Full-scale implementation will likely include approximately 270 I-Corps Teams annually, a steady state of approximately 40 active I-Corps Sites and 10 regional I-Corps Nodes. The intention, from the outset, has been to solicit participation of universities throughout the country in offering these dynamic and powerful curricula for innovation. NSF also anticipates that, in the out years, several I-Corps recipients will apply to the SBIR program. NSF has already seen, in just the short time since launching this program in July of 2011, a significant number (24) of SBIR proposals from among the I-Corps cohorts resulting in 14 SBIR awards.

Evaluation Framework

I-Corps directly contributes to one of NSF's three Priority Goals for FY 2012 and FY 2013. Progress towards Priority Goals is assessed quarterly by agency senior management and reported on the website *Performance.gov*. The Priority Goal is to increase the number of entrepreneurs emerging from university laboratories. Specifically, the Priority Goal states that by September 30, 2013, 80 percent of teams participating in the Innovation Corps program will have tested the commercial viability of their product or service as evidenced by completion of the I-Corps immersion course, where teams make 'Go/No-Go' decisions about moving forward with commercialization.

Additional primary outcomes and milestones for the I-Corps program center on tangible measures that relate directly to the societal application realized from NSF's investments in basic research. For example, successful completion of the I-Corps grant would be expected to contribute to one or more of the following:

- New start-up businesses, 25-30 percent of I-Corps recipients;
- Licensing of patents or trademarks to third parties, 5 percent of recipients;
- SBIR proposals, 10-15 percent of recipients;
- A business plan suitable for review by third-party investors, 10-15 percent of recipients;

- Students prepared to be entrepreneurially competitive, 80 percent of recipients; and
- New curriculum development or improvement in current curricula focusing on entrepreneurship and innovation.

In time, the I-Corps program will have a positive impact on all these measures. Given the high visibility and high community interest in I-Corps, there is naturally going to be close examination almost immediately of the impact of this program on metrics such as these. It may take several years to gather data to see real and substantive outcomes on these measures, and for this reason, approaches to tracking short-term progress also needs to be implemented.

Therefore, initial evaluations will focus on input measures primarily, such as level of interest and number of proposals, and the ability to expand the mentor network. Outcome indicators such as start-ups, SBIR submissions, and third party investment will become critical as the program matures. The projected timeline is:

- FY 2012: The Foundation established a baseline of "Pre I-Corps" activities.
- FY 2013: The Foundation will initiate evaluations and initiate the I-Corps Nodes and I-Corps Sites programs.
- FY 2014: NSF will continue with regular evaluations of the previously described metrics and develop a chronological database that allows for more detailed historical analysis of program impact. The approach will be similar to that taken with the ERC and I/UCRC programs since 1985.

SCIENCE, ENGINEERING, AND EDUCATION FOR SUSTAINABILITY (SEES)

Overview

A sustainable world is one in which human needs are met equitably without harm to the environment, and without sacrificing the ability of future generations to meet their needs. Meeting this formidable challenge requires a substantial increase in our understanding of the integrated system of supply chains, society, the natural world, and the alterations humans bring to Earth. Given the pressing national and global need to realize a sustainable human future, the National Science Foundation (NSF) has developed a coordinated research portfolio spanning the entire range of scientific domains at NSF: the Science, Engineering, and Education for Sustainability (SEES) program.

SEES is a broad investment in the scientific underpinnings of sustainability at numerous temporal and spatial scales. Multiple perspectives and areas of expertise are required to increase our understanding of integrated systems of human society and the natural world. Thematic programs are aimed at building the knowledge base, while simultaneously encouraging interdisciplinary linkages, new partnerships, and education and outreach efforts.

Total Funding for SEES

(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
$157.55	**$157.00**	**$222.79**

Goals

SEES has three main goals to advance sustainability:

1. Support interdisciplinary research and education that can facilitate the move towards global sustainability (Research and Education);
2. Build linkages among existing projects and partners and add new participants in the sustainability research enterprise (Collaboration); and
3. Develop a workforce trained in the interdisciplinary scholarship needed to understand and address the complex issues of sustainability (Workforce).

Approach

SEES is planned to be a decade-long effort across NSF to coordinate and grow research and education associated with the environment, energy, and sustainability. NSF's work under SEES is a blend of activities – formal solicitations and less formal announcements of interest (e.g., Dear Colleague Letters) that span across scientific disciplines and require input and oversight from multiple NSF directorates. Research in such areas as complex environmental and climate-system responses and pathways continue to be supported and emphasized across NSF and are supplemented by increased emphasis on activities focused on sustainable and clean energy technologies and engineering processes. NSF also works with other federal agencies and national and international stakeholder groups whose function and mission complement NSF's role to ensure that sustainability goals are carried forward.

The portfolio approach—as opposed to a large single program—facilitates communication, coordination, monitoring, and impact across the major investment areas and also across NSF, as SEES activities are complex and highly interdisciplinary. The SEES organizational structure includes:

- A senior leadership committee composed of assistant directors/office heads who provide long-term planning and overall guidance;

- A cross-agency implementation group composed of division directors and lead program directors, who develop consistent guidelines, provide internal and external communication, and shape evaluation plans; and
- Working groups of program directors, each overseen by assistant directors/office heads/division directors who are most relevant to the specific activity to manage programs or activities. When interagency or international partnerships, such as with the European Union (EU), have been established, then members of those entities may also be members of the working group to facilitate preparation of joint solicitations, establishment of Memoranda of Understanding (MOU)/Memorandum of Agreement (MOAs), or other arrangements for collaboration.

Investment Framework

SEES Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$27.25	$27.25	$35.75
Computer and Information Science and Engineering	9.02	9.50	19.00
Education and Human Resources	6.00	6.00	0.50
Engineering	19.77	19.25	26.76
Geosciences	58.75	58.75	86.27
Mathematical and Physical Sciences	17.03	16.50	35.26
Social, Behavioral, and Economic Sciences	7.75	7.75	9.25
International and Integrative Activities	11.98	12.00	10.00
Total	**$157.55**	**$157.00**	**$222.79**

Totals may not add due to rounding.

FY 2010-FY 2013

In FY 2010, NSF developed SEES in response to numerous major community reports, including the August 2009 National Science Board (NSB) report *Building a Sustainable Energy Future*, which emphasized the need for a coordinated program. Initial efforts focused on developing and coordinating a suite of research and education programs at the intersection of climate and environment, with specific attention to human behavior. These solicitations (Dimensions of Biodiversity; Regional and Decadal Earth System Modeling; Ocean Acidification; Water Sustainability and Climate; and the Climate Change Education Program) resulted in awards totaling approximately $70 million.

In FY 2011, NSF maintained momentum in the SEES investment area by augmenting existing interdisciplinary programs (Coupled Natural and Human Systems (CNH), Research Coordination Networks (RCN)) and issuing a Dear Colleague Letter (DCL) that advanced the research and education activities proposed for 2011 and laid the groundwork for programs proposed for continuance and expansion in FY 2012.

In its FY 2012 Budget Request, NSF proposed to expand SEES through significant investments in programs related to energy and collaborative networks. During FY 2011, interdisciplinary working groups drafted and NSF released solicitations, although at reduced scope and funding levels, for four new activities consistent with the FY 2012 plans. These four new activities were: the NSF SEES Fellows

program, at the postdoctoral level; Sustainability Research Networks (SRN), that include existing and new centers of collaboration; Sustainable Energy Pathways (SEP) focused on integrated energy resource utilization; and a SEES-focused Partnerships for International Research and Education (PIRE) competition, which advances international networks.

In FY 2013, NSF initiated five SEES programs that complemented programs developed in FY 2012 and prior years. These investments are consistent with long term planning for the SEES investment area, and focus on environmental, technological, and societal resilience; dissemination of results, responsiveness to societal needs, and workforce development. These five programs are:

Two programs related to complex interactions in highly vulnerable areas:

- *Coastal SEES* is designed to enable place-based system-level understanding of coastal systems on a variety of spatial and temporal scales; yield outcomes with predictive value in coastal systems; and identify pathways by which outcomes could be used to enhance coastal sustainability.
- *Arctic (ArcSEES)* seeks both fundamental research that improves our ability to evaluate the sustainability of the Arctic human-environmental system as well as integrated efforts which will provide community-relevant sustainability pathways and engineering solutions.

Two programs related to environmental and societal resilience:

- *Hazards SEES* seeks to: (1) advance understanding of fundamental processes associated with specific natural hazards and technological hazards linked to natural phenomena, and their interactions; (2) better understand causes, interdependencies, impacts and cumulative effects of hazards on individuals, the natural and built environment, and society as a whole; and (3) improve capabilities for forecasting or predicting hazards, mitigating their effects, and enhancing capacity to respond to and recover from resultant disasters.
- *Sustainable Chemistry, Engineering and Materials (SusChEM)* will enable the basic science and engineering discoveries needed to utilize new (non-petroleum based) sources of important raw materials; replace rare, expensive and/or toxic chemicals and materials with earth abundant, inexpensive and benign alternatives; economically recycle chemicals and materials that cannot be replaced such as the rare earth elements; and devise environmentally friendly chemical reactions and processes that require less energy, water and organic solvents and generate less waste than current practice.

One program that will advance sustainability on many fronts:

- *Cyber SEES* aims to advance interdisciplinary research in which the science and engineering of sustainability are enabled by new advances in computing, and where computational innovation is grounded in the context of sustainability problems.

FY 2014 Request

In FY 2014, the SEES portfolio increases by $65.79 million, or 41.9 percent, over the FY 2012 Enacted level. Although no new programs will be added in FY 2014, existing programs established in FY 2011-FY 2013 will be augmented. In particular, the five programs initiated in FY 2013 will continue to grow. *Sustainable Chemistry* will support additional research on replacing and recycling earth abundant, single source critical elements; *Coastal SEES* will shift to full research proposals from incubator awards; and *Hazards SEES* will focus on the collaborative science of disaster mitigation, preparedness, and response. Also in FY 2014, *Dimensions of Biodiversity* and *Water Sustainability and Climate* will issue follow-on solicitations, per multi-year plans for these programs.

FY 2015 – FY 2019

Up to $3.0 million may be redirected for community planning for a new focus area in FY 2015 on sustainable and resilient food systems. This interdisciplinary challenge will focus on processes aimed at meeting current food needs without comprising the ability to meet needs of future generations; thriving in the face of challenges that affect the supply and/or distribution of food; and conserving, protecting, and regenerating the biogeophysical and human environments. Example activities include workshops, research coordination networks in the CNH track, supplements to existing SEES awards, and exploration of alternative programmatic means to advance fundamental research on this topic.

Long-term planning will continue to stress consolidation and coordination of existing activities; networking and dissemination of information from the rapidly growing SEES knowledge base to the scientific community, policy-makers, and the public; and the workforce development critical for producing the next generation of sustainability scientists and engineers.

At the conclusion of SEES, NSF, in collaboration with its partners across government, academia, and industry, expects to have made significant investment and progress towards a sustainable human future. With respect to the three over-arching SEES goals, NSF expects to see:

1. Goal 1, Research and Education: the sustainability science and engineering knowledge base available and accessible to scientists, decision-makers, and society at large;
2. Goal 2, Collaboration: the private sector will be able to more rapidly identify and deploy technologies and methods to address sustainability issues; and
3. Goal 3, Workforce: multidisciplinary approaches to sustainability education are common practice; the U.S. has a robust cadre of early career scientists and engineers to address sustainability issues.

Evaluation Framework

NSF employs a variety of tools to evaluate the scientific impact and progress of the various programs in the SEES portfolio. NSF is conducting select evaluation activities using internal resources, and will seek external support for evaluation activities that require specialized expertise.

Examples of planned evaluation activities for the SEES portfolio include:

Goal 1: Research and Education

Short-term: Text and data analysis of project reports, PI meeting reports, workshop and symposia reports to analyze the growth of sustainability research under the SEES portfolio.

Long-term: Historical review to determine the types of sustainability activities that were conducted and supported by NSF before and after establishment of the SEES portfolio.

Goal 2: Collaboration

Short-term: Portfolio analyses to identify collaborations, evidence of increased interdisciplinarity, and new tools and data sets developed under the SEES portfolio.

Long-term: Network analyses to identify collaborations, and evidence of increased interdisciplinarity.

Goal 3: Workforce

Short-term: Develop and baseline a monitoring system to collect metrics associated with the goals of SEES workforce development programs (such as SEES Fellows).

Long-term:

- Comparative analysis to examine whether education and career pathways of individuals involved in SEES projects differ from individuals in the same disciplines who did not participate in SEES projects; and
- Use monitoring data to determine if a formal impact evaluation for large investments is indicated.

Currently, many of these evaluation activities are underway or have been successfully completed, including:

- Developed evaluation questions and draft logic model for SEES portfolio and WSC program;
- Received feedback on evaluation strategy from NSF's Advisory Committee for Environmental Research and Education during fall 2012 committee meeting; and
- Multiple transdisciplinary workshops, including: WSC PI Meeting: Synthesis, Observations, Systems and Modeling (Nov 2011); Geothermal at the Environmental, Energy and Economy Nexus (Nov 2011); Natural and Engineered Carbon Sequestration (Oct 2011); Research in Landscape Sustainability: Earth-surface processes in the SEES context (Oct 2011); Research at Intersection of Marine/Hydrokinetic Energy and Aquatic Environment (Oct 2011); Sustainability Science: Enhancing Cooperation between Non-Governmental Organizations and Scientists (Oct 2011); Earth System Modeling PI Meeting (July 2012); and SusChEM Workshop (Jan 2012).

Because solicitations are a key component of the SEES portfolio, NSF program directors will be looking for success indicators such as representation of multiple disciplines in proposals, development of new international collaborations, and increased number of proposals received indicating engagement of the field with new interdisciplinary solicitations. NSF is particularly interested in measuring results in terms of new and productive connections made between researchers in a range of disciplines, and the development of new knowledge and concepts that advance the over-arching goal of a sustainable human future; and development of a workforce capable of meeting sustainability challenges. NSF senior leadership will take into consideration the findings and recommendations based on evaluation activities for purposes of outyear planning and budgeting. Evaluation findings may inform development of future SEES focus areas, as well as subject areas ready for a diminished emphasis and investment.

SECURE AND TRUSTWORTHY CYBERSPACE (SaTC)

Overview

The Secure and Trustworthy Cyberspace (SaTC) investment is aimed at building a cybersecure society and providing a strong competitive edge in the Nation's ability to produce high-quality digital systems and a well-trained workforce. Achieving a cybersecure society is a critical challenge in today's world, as corporations, agencies, national infrastructure, and individuals have been victims of cyber-attacks. These attacks exploit weaknesses in technical infrastructures and human behavior. Understanding the motivations and incentives of individuals and institutions, both as attackers and defenders, can aid in creating a more secure and trustworthy cyberspace. Addressing this problem requires multi-disciplinary expertise in computational, statistical, mathematical, economic, and computer sciences, and ultimately the transition of new concepts and technologies to practice.

Fundamental research in algorithms, models, probability theory, reliability, statistical theory and analysis, cryptanalysis, system structures, and secure computing is needed to stay ahead of new threats enabled by new technologies. The increasing power and ubiquity of computers implies that in the next era of computing many existing algorithms used to secure transmissions will no longer be robust or adequate. Research is needed in market mechanisms that can align incentives, hedge risks, and reduce the frequency and severity of attacks, and research that provides a deeper understanding of the social and behavioral factors affecting cybersecurity. The development and deployment of innovative cybersecurity models and practices throughout scientific environments is also required. This research and development requires a well-trained professional workforce with new skills and knowledge, necessitating creative and innovative approaches to the education and preparation of tomorrow's cybersecurity researchers.

Total Funding for SaTC

(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
$113.37	**$111.75**	**$110.25**

Goal

The long-term goal of the SaTC program is to build the knowledge base in cybersecurity that enables discovery, learning, and innovation in this critical area, and ultimately leads to a more secure and trustworthy cyberspace. The program aligns with the President's *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program* (released in December 2011), which details four subgoals that together cover a set of interrelated priorities for the federal agencies that conduct or sponsor research and development in cybersecurity. These four goals are: (1) inducing change, (2) developing scientific foundations, (3) maximizing research impact, and (4) accelerating transition to practice. In order to achieve these goals, a coordinated, interdisciplinary program is needed.

Approach

The Directorates for Computer and Information Science and Engineering (CISE); Education and Human Resources (EHR); Engineering (ENG); Mathematical and Physical Sciences (MPS); and Social, Behavioral, and Economic Sciences (SBE) participate in this program. Each of these organizations supports a research community whose abilities are needed to collectively build the envisioned cybersecure and trustworthy environment and to prepare the scientists and supporting workforce needed

to sustain and improve that environment. The SaTC program is managed by a Working Group (WG) made up of program directors from the participating directorates.

EHR invests in the CyberCorps: Scholarship for Service (SFS) program, which supports cybersecurity education and workforce development. SFS has funded more than 1,700 students and provides capacity building grants to promote cybersecurity education and research at higher education institutions. SFS will continue its focus on increasing the number of qualified students entering the fields of information assurance and cybersecurity, and enhancing the capacity of the United States higher education enterprise to continue to produce professionals in these fields to secure the Nation's cyberinfrastructure.

The following paragraphs describe the specific objectives of NSF's SaTC program, and how they relate to the four thrusts of the Federal Cybersecurity Strategic Plan:

Inducing Change

- Focus the direction of research on four game-changing research topics – designed-in security, moving target defense, tailored trustworthy space, and cyber economic and behavioral incentives – to better understand the motivations, incentives, and behaviors of users, attackers, and defenders. For example, study how information flows within and between these groups, how organizations or policies can be developed to align individual and societal incentives, or how targets are selected and defended.
- Provide the foundations and tools for privacy, confidentiality, accountability, and anonymity, as well as extraction of knowledge from massive datasets without compromising societal values.
- Advance the design and implementation of software that exhibits resiliency in the face of an attack, the design and composition of software components into large-scale systems with known security properties, the design of reliable systems including attention to behavior and human factors that can function dependably even if some subset of components do not function as intended, and support the transition of novel software into shared cyberinfrastructure.

Developing Scientific Foundations

- Develop the scientific foundations for digital systems that can resist attacks, including a range of cryptographic algorithms and statistical tools that can withstand attacks from novel computing engines, such as quantum computers, and that support operation in environments with restricted computational resources.
- Develop the mathematical and statistical theory and methodologies required to model and predict the behavior of large-scale, complex systems; assure that the large-scale computations in many fields of research are not vulnerable to manipulation or compromise; and develop and implement improved cybersecurity defenses for scientific environments and cyberinfrastructure.
- Develop the scientific foundations to understand how individuals, groups, organizations, and other actors make decisions in the realm of cybersecurity.
- Develop market-based approaches to align incentives for investments, efficiently share risks, and internalize externalities.

Maximizing Research Impact

- Ensure that the Nation's populace understands the security and privacy characteristics and limitations of the digital systems on which they rely daily.
- Coordinate with the NSF Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS) investment to support foundational research in cybersecurity issues arising in advanced manufacturing, robotics, and critical infrastructure, such as Smart Grids.

- Investigate opportunities and challenges in organizational alliances around cybersecurity; examine alternative governance mechanisms, for example, private-public partnerships and international agreements.

Accelerating Transition to Practice

- Provide insight and incentives into the process for innovation diffusion and adoption at the organizational, group, and individual levels.
- Drive innovation through applied research, development, and experimental deployment. Transition successful basic research results and commercial innovations into early adoption and use tailored for NSF communities and learning environments. Enable NSF cyberinfrastructure as a premier proving ground and state-of-the-art environment for advancing cybersecurity solutions and moving them into technical and organizational practice.

In addition, SaTC will address the pivotal issues in the education and preparation of tomorrow's cybersecurity researchers. Specific objectives are:

- Promote innovation and development of new curricula and learning opportunities to create and sustain an unrivaled cybersecurity workforce, capable of developing sound and secure cyberinfrastructure components and systems.
- Study new approaches to training and education in cybersecurity to understand their impact and provide a basis for continual refinement and improvement.

Investment Framework

SaTC Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Computer and Information Science and Engineering	$58.89	$59.00	$75.00
Education and Human Resources	44.98	45.00	25.00
Engineering	5.00	3.25	4.25
Mathematical and Physical Sciences	0.50	0.50	2.00
Social, Behavioral, and Economic Sciences	4.00	4.00	4.00
Total	**$113.37**	**$111.75**	**$110.25**

Totals may not add due to rounding.

FY 2012 – FY 2013

In FY 2012, 61 SaTC proposals were funded from a solicitation jointly issued by CISE (including the Division of Advanced Cyberinfrastructure, formerly the Office of Cyberinfrastructure), MPS, and SBE. These proposals support the four thrust areas of the Federal Cybersecurity Strategic Plan: inducing change, developing scientific foundations, maximizing research impact, and accelerating transition to practice. In addition, six CAREER awards associated with SaTC were funded in FY 2012. In FY 2013, a SaTC solicitation was jointly issued by CISE, EHR, ENG, MPS, and SBE to elicit research proposals to expand research and development of secure and trustworthy cyberspace using the approach outlined above in the Federal Cybersecurity Strategic Plan.

To develop the SaTC community, in FY 2012, the directorates held community-building workshops and Principal Investigator (PI) meetings. In 2013, meetings will be held to facilitate the exchange of ideas on the SaTC program and related research and development. Interdisciplinary workshops that focus on specific problems (e.g., metrics, fundamental results, evidence-based research) in the scientific foundations of cybersecurity are planned, as well as meetings to educate SaTC program directors about other NSF programs that focus on transitions to practice, such as NSF Innovation Corps and the Accelerating Innovation Research activity in the Partnerships for Innovation program. NSF held a workshop in partnership with the Computing Community Consortium and the Semiconductor Research Corporation on fundamental cybersecurity issues of interest to both industry and academic researchers.

NSF has collaborated with, and will continue to collaborate with, other federal partners on cybersecurity: NSF co-chairs the NITRD Cyber Security and Information Assurance Senior Steering Group, which provides leadership across the government in cybersecurity R&D and provides a forum for information sharing. In addition, NSF and the Department of Education co-lead the Formal Education Component of the National Initiative for Cybersecurity Education. In FY 2012, NSF and the National Security Agency (NSA) jointly held a Principal Investigator (PI) workshop, as well as jointly funded the Cyber-Physical Systems Virtual Organization at Vanderbilt University to encourage it to extend its scope into cybersecurity and to better understand how it relates to smart systems.

In FY 2012, the SFS program continued its focus on increasing the number of qualified students entering the fields of information assurance and cybersecurity and enhancing the capacity of the United States higher education enterprise to continue to produce professionals in these fields to meet the needs of our increasingly technological society. SFS funded 43 projects in FY 2012. In FY 2013, NSF will continue funding SFS capacity building proposals focusing on broadening participation of women, veterans, and underrepresented minority groups. At least two university pilots on cybersecurity education and secure programming, jointly supported by CISE and EHR, will be launched in FY 2013. NSF will hold a workshop to help create a community of researchers and students interested in cross CISE-SBE-EHR related issues. These efforts will include the development of a National Virtual Lab for Cybersecurity Education to promote collaboration and resource sharing.

In FY 2013, a fourth perspective on cybersecurity education has been added to the SaTC solicitation with the aim to promote innovation, development, and assessment of new learning opportunities and to create and sustain an unrivaled cybersecurity workforce capable of developing secure cyberinfrastructure components and systems, as well as to raise the awareness of cybersecurity challenges to a more general population.

FY 2014 Request

The following activities are planned:

- Expand the research portfolio to include more cross-disciplinary projects to cover a broader set of research topics and to increase transition to practice.
- Fund up to two large, multi-institutional projects that provide high-level visibility to grand challenge research areas.
- Develop a mechanism for supporting foundational research that has industrial impact, such as Grant Opportunities for Academic Liaison with Industry (GOALI) supplements or co-funding with an industrial consortium.
- Expand cybersecurity outreach and collaboration efforts by establishing a partnership with at least one other agency (e.g., the Department of Homeland Security, National Institute of Standards and Technology, NSA) for co-funding or transition of projects, and hold a workshop with the European Union to determine mutual interests.
- Hold a SaTC PI meeting to help build a broad community that crosses disciplinary interests.

- Expand the education and preparation of cybersecurity researchers by funding projects on curriculum development and evaluation in cybersecurity. Support efforts to define a cybersecurity body of knowledge and to establish curricula recommendations for new courses, degree programs, and educational pathways.

FY 2015 – Beyond

Building on the knowledge base developed during the previous years, SaTC will continue to focus on game-changing research and education and the development of digital systems that are resistant to attacks. In coordination with the CEMMSS WG, the focus will be to secure advanced manufacturing systems, robotics, and critical infrastructure; and transition to practice research results ready for experimental deployment, early adoption, commercial innovation, or implementation in cyberinfrastructure. To more effectively achieve its long-term goals, SaTC will develop partnerships with other agencies, industry, and international organizations. The cybersecurity research community is also expected to grow to include more researchers who cross the boundaries between computer science, engineering, economics, social and behavioral sciences, statistics, and mathematics, thereby creating a flourishing cybersecurity research and development ecosystem.

NSF will continue to promote the development of new curricula and learning opportunities to augment the cybersecurity workforce with focused efforts to recruit and retain underrepresented minorities, women, first-generation/low-income students, and/or veterans.

Evaluation Framework

NSF has engaged the Science Technology Policy Institute (STPI) to conduct a program evaluation feasibility study for the SaTC program. This evaluation feasibility study will examine the baseline portfolio of SaTC investments and identify metrics to measure progress of goals as part of an impact assessment.

This feasibility study will be conducted to develop a plan for an impact assessment of the SaTC investment. The approach outlined below will be followed:

- Meetings will be held with the SaTC WG and SaTC management to examine the past and current portfolio of awards, including an assessment of the components of the portfolio by technical and scientific content. In addition, various recommendations from federal advisory boards and stakeholder communities on how to structure future cybersecurity investments will be synthesized.
- A roadmap will be refined to help NSF track progress toward its major scientific objectives (e.g., discovery of the root causes of threats and attacks and continuous investment in transformational approaches that improve the security of cyberspace; development of a systematic scientific approach to cybersecurity, including discovery of laws and principles). This effort may entail workshops with the stakeholder community to define the major research questions and research goals for SaTC.

Based on the results of the workshops and related activities (stated above), a third party contractor and NSF will develop the appropriate plan for assessing progress across NSF's SaTC activities.

The initial contract for the evaluation feasibility study was put into place and a kick-off meeting was held during the fourth quarter of FY 2012. Work is ongoing to establish an evaluation framework, which will be in place by the end of FY 2013.

Additionally, in FY 2012, NSF and the Organizational Assessment Group of the U.S. Office of Personnel Management (OPM) worked together to assess the extent to which the SFS program achieved its major goals. The OPM evaluation team conducted focus groups, administered surveys to the different stakeholders of the SFS program (e.g., students, graduates, PIs, faculty, agency supervisors, hiring officials and recruiters), and also conducted a workforce analysis to project the federal hiring demands

for computer professionals. The evaluation is expected to be completed in October 2013. In FY 2013, NSF and OPM plan to look for ways to increase the marketing of the SFS program to agencies and expand the internship opportunities for students. A competency gap analysis of competencies needed once on the job is underway.

CATALYZING ADVANCES IN UNDERGRADUATE STEM EDUCATION (CAUSE)

Overview

A diverse and globally engaged U.S. science, technology, engineering and mathematics (STEM) workforce, able to innovate and well prepared for the changing scientific landscape, is crucial to the national health and economy. Yet there is rising concern that the numbers of graduates earning STEM degrees will not meet the demand for workers with STEM skills that is driven by technological innovation. Furthermore, the engagement of U.S. citizens from underrepresented groups in STEM is still alarmingly low. The National Science Foundation (NSF) is committed to serving a leadership role across the U.S. government in addressing these critical challenges and achieving important goals for increasing the numbers of STEM professionals. The cross-agency priority goal in STEM Education states, "…the Federal Government will work with education partners to improve the quality of science, technology, engineering and math (STEM) education at all levels to help increase the number of well-prepared graduates with STEM degrees by one-third over the next 10 years, resulting in an additional one million graduates with degrees in STEM subjects."[1] Likewise, the Committee on Science, Technology, Engineering, and Mathematics Education (CoSTEM) has identified undergraduate STEM education as a priority.[2]

The opportunities for increasing the numbers of STEM graduates have been analyzed in recent national reports. The President's Council of Advisors on Science and Technology (PCAST) report, *Engage to Excel*, and the National Academies report, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*, underscore the lack of persistence of STEM students from all groups in the first two years of college. Further, the PCAST report recommends widespread implementation of evidence-based teaching practices, including the integration of discovery-based laboratories as having strong potential to enhance retention.[3] The National Research Council report, *Discipline-based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*, provides an analysis of effective practices and a research agenda for continuing to build the STEM education knowledge base.

In alignment with the Administration's bold reorganization of STEM education, NSF will become the government–wide leader for undergraduate STEM education in FY 2014. NSF's new Catalyzing Advances in Undergraduate STEM Education (CAUSE) program is a natural evolution and consolidation of the Foundation's ongoing efforts to couple STEM disciplinary expertise with education research expertise to better understand and improve undergraduate STEM learning and persistence of students from all groups and to support STEM workforce development. CAUSE provides coherence across all NSF undergraduate education programs to maximize the effectiveness of NSF investments in improving the STEM learning experiences of all undergraduates. In addition, the CAUSE framework allows for incorporation of undergraduate improvement goals shared across federal agencies.

CAUSE is built upon a knowledge base informed by decades of work on STEM undergraduate education. It integrates education research with frontier science and engineering research to develop an innovative STEM workforce. Using a principle-based framework and investment strategy, CAUSE establishes four guiding principles for NSF's undergraduate portfolio:

- *NSF investments in undergraduate education will be focused, strategic investments centered on addressing the challenges in U.S. undergraduate education.* The greatest obstacle relative to the

[1] http://goals.performance.gov/goals_2013

[2] Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education Investments: Progress Report (February 2012) www.whitehouse.gov/sites/default/files/microsites/ostp/nstc_federal_stem_education_coordination_report.pdf

[3] From the PCAST report, *Engage to Excel*: "Retaining more students in STEM majors is the lowest-cost, fastest policy option to providing the STEM professionals that the nation needs for economic and societal well-being. (p. i.)

development of U.S. STEM talent is student retention. The U.S. lags behind much of the world in college degree attainment and production of STEM scientists and engineers as only 40 percent of U.S. students who start in STEM majors finish.

- *The CAUSE portfolio will be established through collaboration among all directorates.* Creating this unified portfolio will entail sunsetting and consolidating existing programs, incorporating goals from programs outside of NSF as appropriate, reviewing new programs for alignment with the CAUSE framework, increasing NSF-wide planning and coordination, and developing common metrics and expectations for outcomes.
- *CAUSE will be informed by input from multiple sources, including the STEM disciplines and education research.* Input from experts and leaders in the STEM fields will be integral to the development of CAUSE and will improve the NSF undergraduate investment.
- *Development and future growth of the CAUSE portfolio will be based on demonstrated impact and effectiveness of NSF investments.* Evaluation and assessment of NSF's investments in undergraduate education is essential and will inform decisions aimed at increasing the net funding available for improvement of undergraduate education.

Total Funding for CAUSE

(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
-	-	**$123.08**

Goals

To maximize impact on STEM undergraduate education, a research and development-based planning matrix will be used to build coherence and complementarity in education investments across NSF and to inform strategic planning. CAUSE investments will align with the following three goals:

- Improve STEM learning and learning environments.
- Broaden participation in STEM and increase institutional capacity.
- Build the STEM workforce of tomorrow.

Approach

The goals of CAUSE will be pursued through three investment strategies:

- *Foundational research.* These investments focus on core research questions–such as how learners move towards expertise in a discipline, or best learn about concepts that are interdisciplinary – that are foundational for the improvement of teaching, learning, engagement, and retention and for serving as a basis for development, adoption/adaptation, and implementation of models, prototypes, and innovations.
- *Design-based research.* These investments support iterative approaches to design, implementation, analysis, and revision, including prototyping and building and refining models.
- *Scale-up and effectiveness studies.* These investments focus on the potential for leveraging NSF's investments in foundational and design and development research. Key goals include the scaling of successful efforts on learning and learning environments, broadening participation, workforce preparation, and employing emerging technologies.

These funding strategies clarify the unique federal role in research and development in undergraduate STEM education and underscore the importance of leveraging these investments.

Scope

CAUSE is an NSF-wide investment that incorporates funding from established programs in the EHR directorate and other NSF directorates funded though the Research and Related Activities (R&RA) account. It is created by consolidating three Division of Undergraduate Education (DUE) programs: STEM Talent Expansion Program (STEP), Widening Implementation and Demonstration of Evidence-based Reforms (WIDER), and Transforming Undergraduate Education in STEM (TUES); several R&RA programs: BIO's Transforming Undergraduate Biology Education (TUBE); ENG's Research in Engineering Education and Nanotechnology Undergraduate Education (NUE); GEO's Geosciences Education and Opportunities for Enhancing Diversity in the Geosciences (OEDG); and the cross-NSF program, Climate Change Education (CCE).

NSF will fund a range of project types from foundational research to scaling and effectiveness studies. Funding will be available for individual investigators and research teams with expertise cutting across one or more STEM disciplines and STEM education research, including discipline-based education research and the social and behavioral sciences. The intent of CAUSE is to build on NSF's unique strengths across the STEM disciplines and STEM education to focus sustained research on the goals described above. Such research is inherently interdisciplinary in nature. Aligned with the funding strategy will be the development of robust indicators and metrics to gauge progress towards these goals.

Organizational Structure

CAUSE leadership will be provided by an Assistant Director (AD) Council; comprised of ADs designated by the Director and chaired by the EHR AD. EHR is charged with implementing CAUSE across all directorates and working with internal and external program evaluation experts to help develop a set of metrics by which program progress can be evaluated over time.

Investment Framework

CAUSE Funding by Directorate

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	-	-	$2.50
Education and Human Resources	-	-	97.08
Engineering	-	-	12.60
Geosciences	-	-	10.90
Total	**-**	**-**	**$123.08**

Totals may not add due to rounding.

FY 2013

In FY 2013, the CAUSE AD Council will make recommendations to NSF leadership regarding governance, the framework for investment in undergraduate STEM education, and the timeline and roadmap for CAUSE implementation.

Key governance issues include:

- Discuss how reviewing and funding recommendations will be managed in FY 2013 and FY 2014, including how directorate contributions will be viewed (e.g., aimed to specific disciplinary needs, funds combined for the purpose of making awards at the initiative level, etc.).
- Discuss relationship to CoSTEM reports and other agencies' capabilities.
- Discuss how evaluation and assessment of the holistic STEM undergraduate education portfolio will be defined, mapped, and monitored for the intended impacts according to the three CAUSE goals.
- Establish a program officer implementation team to report to the AD Council.

To solidify and articulate NSF's framework for investment in undergraduate STEM education across the agency, the CAUSE AD Council will refine the proposed investment framework detailed above. Current programs and projects will be incorporated into the framework as a basis for achieving portfolio coherence beginning with FY 2013 awards (including analysis of projects by discipline).

A timeline and roadmap that spans the directorates will allow for synchronization of solicitations, common text, and narratives for FY 2014. Staff expertise in undergraduate STEM education and discipline-based educational research will be reviewed, with hiring proposed as appropriate. Coordination of PI meetings, processes for setting CAUSE priorities and special emphases, including plans for explaining the merger/integrated program to the multiple communities involved, also will be guided by the CAUSE AD Council.

FY 2014 Request

The FY 2014 requested funding will allow for awards in foundational research, design-based implementation, and scale-up effectiveness studies. The size and duration of the awards will be determined by the strength of the evidence behind the proposed intervention/project and resources necessary to achieve the desired outcomes. Based on lessons learned in the initial implementation of CAUSE, future adjustments will be made to the program, including size and duration of awards.

Evaluation Framework

The success of this framework will depend upon the development of realistic, robust metrics and indicators for gauging progress toward the larger national goals outlined above, notably improving retention among STEM undergraduates and broadening participation in STEM fields.

These metrics and indicators will be tailored to the three investment strategies and aligned with the CAUSE goals. While the specific metrics and indicators will need additional consideration, NSF's recent experience in this area points to a number of promising approaches.

Potential Assessment Framework: NSF CAUSE Investment

Investment Strategy	Potential Measure/Indicator	Relationship to Desired Outcome
Foundational Research	• Strategic monitoring of approaches and investment mechanisms, beginning with pre-award activities (development of logic models aligned with framework, issuance of announcements/solicitations; community response) • Identification of discipline-specific gaps in the literature and baseline evidence	Will enable strategic NSF investment to create knowledge underpinnings in areas of specific need (e.g., research on the teaching and learning of computer science at the undergraduate level), and complementary investment based in EHR or R&RA directorates as appropriate that are aligned within the CAUSE Framework.

Design-Based Research	• Evidence of activities that promote design of solutions to issues and discipline-specific STEM challenges and test those solutions under local or ideal conditions (e.g., efficacy studies).	Creates a set of tested models and prototypes that allow for strategic investment in efforts at scale.
Scale-up and effectiveness	• Partnerships and leveraging activities that take effective design and development efforts to scale and look at impact on particular groups, in particular contexts, etc.	Well designed and evidence-based approaches are implemented at scale for direct impact on improving retention and broadening participation in undergraduate education.

MAJOR INVESTMENTS IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) GRADUATE EDUCATION

Overview

The U.S. federal government invests significantly to support science, technology, engineering, and mathematics (STEM) graduate education through traineeships and fellowships, along with a substantial investment through faculty research grants where graduate students are supported as research assistants.[1] To underscore the importance of these investments, the FY 2014 Budget Request introduces a coherent and streamlined NSF investment strategy for the preparation of tomorrow's science and engineering (S&E) workforce. This plan builds on the ideas generated through the strategic planning process of the National Science and Technology Council's Committee on Science, Technology, Engineering, and Mathematics Education (Co-STEM) and on-going interagency discussions of mechanisms for improved effectiveness.

Approach

NSF will provide leadership in developing a more coherent and streamlined strategy for investing in graduate STEM education through a national fellowship program and a new traineeship program.

The NSF strategy for building human capital in graduate education has centered on the NSF Graduate Research Fellowship (GRF) and the Integrative Graduate Education and Research Traineeship (IGERT) programs managed in the Division of Graduate Education (DGE). GRF invites applications from the Nation's most promising students in any STEM field, thereby identifying and supporting the disciplines that are foundational to tomorrow's science and engineering (S&E). With this FY 2014 request, the GRF program will be expanded into a National Graduate Research Fellowship program (NGRF) to incorporate features and opportunities that allow fellows to gain specialized experiences and training in key STEM areas. IGERT will evolve into a new program, NSF Research Traineeships (NRT) that will allow for institutional traineeship program applications that will incorporate plans for transforming aspects of graduate programs and experiences at those institutions, and that will focus on specific areas of need for both the federal government and the STEM enterprise.

Investment Framework

National Graduate Research Fellowship Program

The goal of NGRF is to help build the U.S. S&E human capital necessary to ensure the Nation's leadership in advancing S&E and innovation. NGRF will select, recognize, and financially support graduate students with demonstrated high potential for excellence in STEM and potential for excelling in their ultimate chosen career.

NGRF will support outstanding graduate students in disciplines where there is significant national need and in areas of particular interest to mission agencies. NGRF awardees would be offered the opportunity to compete for targeted opportunities through which they will be able to develop specialized expertise in critical areas. Such targeted opportunities may involve, for example, internships in industry or government laboratories, work on projects of interest to federal agencies, specialized or advanced training, or international experiences. This set of options build upon the structures currently in place within the GRF program, such as Graduate Research Opportunities Worldwide (GROW) and the Engineering Innovation Fellows program. This model allows NSF to maintain the high standards and broad scope of the GRF program while adding targeted opportunities to meet evolving federal priorities

[1] At NSF, about 40,000 graduate students are supported annually at a level of about $1 billion. These dollars are distributed across traineeships (6-8 percent), fellowships (10-15 percent), and research assistantships in individual grants and centers (80 percent).

and emerging workforce needs. This approach will provide flexibility and access to opportunities for students at different stages of their graduate career, while leveraging the federal investment in these students.

The NGRF program will be managed within the current general GRF framework, including consultation with all NSF directorates and other agencies to help ensure the most effective practices are used and suitable targeted opportunities are provided. The stipend, duration, and cost-of-education allowance will be the same as the current GRF.

NGRF Funding by Directorate

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Education and Human Resources	$109.24	$109.64	$162.57
International and Integrative Activities	88.50	88.50	162.57
Total	**$197.74**	**$198.14**	**$325.14**

Totals may not add due to rounding.

Funding for NGRF increases by $127.0 million above the FY 2012 Enacted for a total investment of $325.14 million. This 64 percent increase aligns with the Administration's commitment to coherence and efficiency of investment in STEM graduate education activities across the federal government and will allow for an increase of approximately 700 fellows bringing the total estimated number of new fellows awarded in FY 2014 to 2,700.

NSF Research Traineeships Program

In FY 2014, NSF will challenge the STEM graduate education community to build "NSF Research Traineeships" projects through the NRT program. These projects will design and implement traineeships programs in emphasis areas that align with national priorities where new areas of science are emerging rapidly. NRT will also provide a mechanism for learning about the implementation and impact of innovative graduate traineeship programs or graduate education policies. The program will build on what has been learned through IGERT, the Graduate STEM Fellows in K-12 Education (GK-12) program, and in other relevant NSF-sponsored efforts. NRT will seek transformative approaches to graduate education that keep pace with the transformation of science in emerging fields and in specialized areas.

NRT Funding by Directorate[1]
(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$3.25	$3.25	$3.25
Computer and Information Science and Engineering	5.20	4.20	5.69
Education and Human Resources	31.01	31.20	26.33
Engineering	10.68	7.00	4.44
Geosciences	6.39	6.39	3.64
Mathematical and Physical Sciences	4.53	3.48	3.69
Social, Behavioral, and Economic Sciences	4.30	4.30	3.03
International and Integrative Activities	0.07	-	5.00
Total	**$65.43**	**$59.82**	**$55.07**

Totals may not add due to rounding.

[1] The FY 2012 Actul and the FY 2012 Enacted/FY 2013 Annualized CR funding levels represent investments made through IGERT. In FY 2014, $33.71 million is for continuing IGERT commitments. The remaining $21.36 million is for new NRT investments.

A total investment of $21.36 million for NRT aligns with the Administration's commitment to more coherence in STEM graduate education activities across the federal government. This will allow for a significant launch of the new NRT program in FY 2014 with particular focus areas to be identified in FY 2013. NRT will encourage much stronger and documented efforts at innovation and new design in graduate programs to support growth and trainees within this targeted emphasis area.

Evaluation Framework

The evaluation framework for both NGRF and NRT is outlined in the table below.

	Potential Measure/Indicator	**Desired Outcome**

Program Development	• Development of coherent solicitations for a fellowship and traineeships program
	• Implementation of effective collaboration across NSF directorates and federal agencies in graduate fellowships and traineeship investment
	• Identification of agreed-upon outcomes of federal investments in graduate students and graduate education
	• Development of targeted opportunities for NGRF and areas of research focus for NRT
		• Graduate STEM fellowship and traineeship investments that:
		  • Serve missions of federal agencies
		  • Provide clarity and efficiency for applicants for fellowship support
		  • Provide opportunities for training for work in areas of national needs
		• A successful initial step in considering frameworks for graduate education investment that can be applied across fellowship, traineeship and research assistantship investments.

Student Development	• Metrics will include:
	  • student educational decisions;
	  • degree attainment;
		• Diverse population of students who are well prepared for:
		  • a range of career options and potential

	• student preparation in identified areas of national need; and • performance of groups under-represented in STEM. • Quality of education and career development, comparing student experiences based on funding mechanism.	changes in career paths; • work in areas of national need/missions of federal agencies; and • national leadership in STEM in the private and public sectors.
Career Impact	• Metrics will include information concerning: • career trajectories; • range of career paths; • productivity appropriate for careers; and • leadership roles in public and private sectors.	• Diverse workforce that: • makes significant contributions through a range of careers; • conducts research at the frontiers of S&E; • develops innovations of high impact; and • provides national leadership in the public and private sectors.

NATIONAL SCIENCE FOUNDATION CENTERS

NSF supports a variety of centers programs that contribute to the Foundation's mission and vision. Centers exploit opportunities in science, engineering, and technology in which the complexity of the research program or the resources needed to solve the problem require the advantages of scope, scale, duration, equipment, facilities, and students. Centers are a principle means by which NSF fosters interdisciplinary research.

NSF Centers
(Dollars in Millions)

	Program Initiation	Number of Centers in FY 2012	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request	Change Over FY 2012 Enacted Amount	Change Over FY 2012 Enacted Percent
Centers for Analysis & Synthesis	1995	4	$26.29	$26.32	$26.40	$0.08	0.3%
Centers for Chemical Innovation	1998	14	26.03	24.00	33.25	9.25	38.5%
Engineering Research Centers	1985	20	70.36	70.00	70.50	0.50	0.7%
Materials Centers	1994	24	49.56	44.35	56.00	11.65	26.3%
Nanoscale Science & Engineering Centers	2001	13	33.47	31.48	12.87	-18.61	-59.1%
Science & Technology Centers[1]	1987	17	50.02	50.75	71.71	20.96	41.3%
Science of Learning Centers	2003	6	21.94	20.37	19.00	-1.37	-6.7%
Totals		**98**	**$277.66**	**$267.27**	**$289.73**	**$22.46**	**8.4%**

Totals may not add due to rounding.

[1] Six of the 17 Science and Technology Centers supported in FY 2012 are from the FY 2002 cohort. These centers received extensions to their periods of performance in FY 2012 but no additional funding.

Description of Major Changes

Centers for Analysis and Synthesis - BIO

The Socio-Environmental Synthesis Center (SESYNC) uses a variety of approaches to synthesize scientific information, data, and knowledge to advance the understanding of environmental complexity. Emerging environmental challenges are anticipated and managed through the active involvement of environmental and social scientists. Approaches include discussions between scientists and policy makers, working groups from the broad socio-environmental community, and an array of computational and technical service providers. The FY 2014 Request is $6.0 million (no change from FY 2012 Enacted).

The iPlant Collaborative provides a cyberinfrastructure to enable new conceptual advances in plant sciences through integrative, computational thinking. iPlant focuses on grand challenge questions in the plant sciences, including innovative approaches to education, outreach, and the study of social networks. The FY 2014 Request is $12.0 million (no change from FY 2012 Enacted).

The National Evolutionary Synthesis Center (NESCENT) promotes the synthesis of information, concepts, and knowledge to address significant, emerging, or novel questions in evolutionary science and its applications. NESCENT funds graduate students engaged in center synthesis activities; supports activities to expand the conceptual reach of the center; and initiates a formalized, three-tiered assessment of the center that includes milestones for reporting on the impact of center activities. The FY 2014

Request is $4.40 million (-$1.10 million below FY 2012 Enacted) as NSF funding ramps down. FY 2014 is expected to be the final year of funding for NESCENT.

The National Institute for Mathematical and Biological Synthesis (NIMBIOS) supports creative solutions to complex problems at the interface between mathematics and biology. The center is designing education programs aimed at the mathematics/biology interface, thereby building the capacity of mathematically competent, biologically knowledgeable, and computationally adept researchers needed to address the vast array of challenging questions in this century of biology. The FY 2014 Request is $4.0 million (+$1.18 million over FY 2012 Enacted) as the center ramps up cyberinfrastructure capabilities and services.

Centers for Chemical Innovation (CCI) - MPS

The CCI program is designed to address major, long-term fundamental chemical research challenges attracting broad scientific and public interest as well as to provide a rich environment for education, outreach, and innovation. In 2012, managing directors and education/outreach staff from five Phase II CCIs established a Leadership Network as a forum to discuss common challenges and coordinate activities across centers. As a result of this meeting, the CCIs are increasing their engagement with minority-serving organizations. Another meeting is planned for fall 2013 to share scientific progress on Grand Challenges. These activities will continue in FY 2014. In addition, NSF Division of Chemistry staff are developing metrics and collecting data in preparation for the first CCI program evaluation scheduled for FY 2017.

The CCI program is structured as a two-phase competition. Phase I centers, which are funded for three years, may compete for larger Phase II awards, which are funded for five years with the opportunity to be renewed for an additional five years. The FY 2014 Request is $33.25 million (+$9.25 million above FY 2012 Enacted). This will support the following:

- Up to eight Phase II awards. This includes six ongoing Phase II CCIs and up to two new and/or renewing Phase II CCIs. At $4.0 million per center per year, FY 2014 funding for Phase II centers will range from $24.0 million (ongoing centers only; no new/renewing centers) to $32.0 million (eight ongoing and new/renewing centers).
- Up to six Phase I awards: The three centers initiated in FY 2012 and the one to three centers to be initiated in FY 2013 will be eligible for Phase II status in FY 2014. No new Phase I competition is planned for FY 2014. As all Phase I centers are funded as standard grants up to $1.75 million, FY 2014 funding for Phase I centers will range from zero (no Phase I awardees are selected in FY 2013) to $5.25 million (three Phase I awardees are selected in FY 2013).

Engineering Research Centers (ERC) – ENG

NSF Engineering Research Centers (ERCs) enable innovation through partnerships, bridging the intellectual curiosity of discovery-focused university research and the engineered systems and technology opportunities of industry research. The centers also educate a technology-enabled workforce with hands-on, real-world experience. These characteristics catalyze the development of marketable technologies to generate wealth and address grand challenges. ERCs are investigating intelligent electric power grid systems to provide electricity from renewable sources, devising healthcare innovations through tissue engineering and microelectronics research, creating sensing systems that improve the prediction of tornados, and demonstrating intelligent robotic systems to assist people who are elderly or disabled in daily tasks.

ERCs face two renewal reviews, one in year three to determine if they are structured effectively, and another in year six to determine if they are making an impact, delivering on goals, and positioning themselves for more challenging tasks to warrant further support. The ERC program periodically commissions program-level evaluations by external evaluators such as SRI International; the Science and

Technology Policy Institute (STPI); and ABT Associates to determine the effectiveness of ERC graduates in industry and the benefits of ERC membership to industry and others. A recent update of a past survey of the 35 ERCs that have graduated from NSF support after 10 years finds that 29 (83 percent) are self-sustaining with strong financial support and most ERC features in place.

The FY 2014 Request is $70.50 million (+$500,000 over FY 2012 Enacted). Building on the long-standing ERC program model, NSF will maintain funding for the existing portfolio of 17 ERC's and support three new centers as part of the Class of 2014 for a total of 20 ERCs. The FY 2014 ERC competition will include tracks for both traditional Generation-3 ERC's and for the second class of Nanosystems ERC's (NERCs). The anticipated outcome of the competition is to make a combination of Generation-3 ERC awards and focused NERC awards dependent upon the quality of the proposals and relationship to areas of national need and grand challenges.

Materials Centers – MPS

Materials Research Science and Engineering Centers (MRSECs) advance materials research and provide students with an interdisciplinary education, including global experiences. These centers address fundamental research problems of intellectual and strategic importance that will advance U.S. competitiveness and the development of new technologies.

The MRSEC program will continue to support the Materials Research Facilities Network (MRFN), which links the instrumentation and subject matter expertise of MRSECs to the larger materials-related community as well as encourages MRSEC-to-MRSEC collaborations. The MRFN network will be used to nucleate new Materials Innovation Platforms (MIP). These Platforms will be networked to address instrument and technique development capabilities and capacity for discovery of new materials.

The MRSEC program will also continue to support the interaction of MRSEC Education Coordinators with the NSF Directorate for Education and Human Resources' (EHR) Division of Research on Learning in Formal and Informal Settings (ERL) to formulate methodologies for standardizing outreach program assessment and evaluation. In addition, the program will continue to support the interaction of the Georgia Institute of Technology MRSEC with DRL to increase training opportunities for students with disabilities through the Research in Disabilities Education (RDE) program. MRSECs also interact with minority serving institutions (MSIs) through the Partnership for Research and Education in Materials (PREM) program. In FY 2014, there will be 14 active PREM awards, 13 of which are connected to MRSECs.

The FY 2014 Request is $56.0 million (+$11.65 million over the FY 2012 Enacted). This will support 18 MRSECs. The Materials Centers program holds triennial competitions. In the FY 2014 competition, 14 current centers are expected to re-compete, along with about 70 new applicants. Nine awards are expected to be made. This will reduce the number of centers in this class from 14 to 9 in keeping with the advice from the 2007 NRC report, which recommended increasing award size. Nine centers awarded during the last competition in FY 2011 will also continue to be funded. The FY 2014 request is higher than the FY2013 year estimate because there was forward funding in FY 2012 towards the mortgage of continuing awards in FY 2013.

Nanoscale Science and Engineering Centers (NSEC) – ENG

Nanotechnology, which addresses the smallest of scales, is projected to be one of the largest drivers of technological innovation for the next decade and beyond. This potential was recognized in the National Nanotechnology Initiative, particularly in the burgeoning area of nanomanufacturing. Research at the nanoscale through NSF-funded NSECs aims to advance the development of the ultra-small technology that will transform electronics, materials, medicine, environmental science, and many other fields. Each center has an extended vision for research. Together they provide coherence and a long-term outlook to

U.S. nanotechnology research and education and also address the social and ethical implications of such research. NSEC funding supports education and outreach programs from K-12 to the graduate level, which is designed to develop a highly skilled workforce, advance pre-college training, and further public understanding of nanoscale science and engineering. These centers have strong partnerships with industry, national laboratories, and international centers of excellence, which puts in place the necessary elements to bring discoveries in the laboratory to real-world, marketable innovations and technologies.

The FY 2014 Request is $12.87 million (-$18.61 million below the FY 2012 Enacted). This will support five continuing NSECs. The decrease in funding is chiefly due to six centers that will receive their final year of NSF support in FY 2013. Investments in NSECs will continue to decrease as the program no longer needs as much support due to center graduations and a transition to NERCs (see the ERC section above). The five existing centers are expected to be supported through the end of their current award cycles. No new NSEC competitions are planned.

Science and Technology Centers: Integrative Partnerships (STCs) - multi-directorate

The Science and Technology Centers: Integrative Partnerships (STC) program advances interdisciplinary discovery and innovation in science and engineering through the integration of cutting-edge research, excellence in education, targeted knowledge transfer, and the development of a diverse workforce. The STC portfolio reflects NSF-supported disciplines. Examples of investments include: engineering of biological systems; energy-efficient electronics; global and regional environmental systems − sustainability and change; new ways of handling the extraction, manipulation, and exchange of information; cyber security; and new materials for optical and electronic applications. STCs engage the Nation's intellectual talent and collaborate with partners in academia, industry, national laboratories, and government. STCs strengthen the caliber of the Nation's science, technology, engineering, and mathematics (STEM) workforce through intellectually challenging research experiences for students, postdoctoral fellows, researchers, and educators and advance public scientific understanding through partnerships with K-12 and informal education communities.

The FY 2014 Request is $71.71 million (+$20.96 million over FY 2012 Enacted). This will support 16 existing STCs – up to five from the 2013 cohort, five from the 2010 cohort, and six from the 2005/2006 cohort; and the administrative costs ($1.30 million) associated with management and oversight of the program. Awards are usually made for five years, with possible renewal for an additional five years. Support ranges from $4.0 million to $5.0 million per year, except for the class of 2005/2006 centers as they ramp down in preparation for sunset in FY 2014.

Science of Learning Centers (SLC) - multi-directorate

The Science of Learning Centers (SLC) program supports six large-scale, long-term centers that create the intellectual, organizational, and physical infrastructure needed for the advancement of Science of Learning research. It supports research that harnesses and integrates knowledge across multiple disciplines to create a common groundwork of conceptualization, experimentation, and explanation that anchor new lines of thinking and inquiry towards a deeper understanding of learning. The SLC program goal is to advance the frontiers of all the sciences of learning through integrated research; to connect the research to specific scientific, technological, educational, and workforce challenges; to enable research communities to capitalize on new opportunities and discoveries; and to respond to new challenges. The SLC portfolio represents synergistic, exciting research efforts that address many different dimensions of learning.

Each SLC's scientific and other activities are reviewed each year through a site visit review. In 2009, a Committee of Visitors (COV) review of the Science of Learning Centers reported it to be "a major success." In addition, an extensive program level evaluation will be conducted in 2013.

The first cohort of four SLCs was funded in FY 2004. One center was decommissioned in its second year due to its failure to show adequate progress. Support for the three remaining centers in this cohort -- Pittsburgh Science of Learning Center (PSLC), Learning in Formal and Informal Environments (LIFE), and the Center of Excellence for Learning in Education, Science and Technology (CELEST) – will end in FY 2014. The second cohort of three SLCs was funded in FY 2006. Of this cohort, support for the Visual Language and Visual Learning Center (VL2) will end in FY 2014 and support for the Temporal Dynamics of Learning Center (TDLC) and the Spatial Intelligence and Learning Center (SILC) will end in FY 2015.

The Directorate for Social, Behavioral, and Economic Sciences (SBE) initiated external discussion on the future of the SLC program and the science it supports. Following its May 2010 Advisory Committee (A/C) meeting, SBE established a subcommittee under the A/C to explore future directions for the Science of Learning. The subcommittee held one workshop at NSF in October 2012 and held a second workshop in February 2013; a report on findings will be presented at the May 2013 A/C meeting.

The FY 2014 Request is $19.0 million (-$1.37 below FY 2012 Enacted). This will support six SLCs. SBE will continue to oversee management of all six centers, with co-funding from the NSF Directorates for Biological Sciences, Computer and Information Science and Engineering, and Engineering. Since 2012, NSF's funding for the centers has started ramping down as the centers approach the end of their award periods.

Estimates for Centers Participation in 2012

(Dollars in Millions)

	Number Participating Institutions	Number Partners	Total FY 2012 NSF Support	Total Leveraged Support	Number Participants
Centers for Analysis & Synthesis	679	63	$26	$10	1,686
Centers for Chemical Innovation	85	67	$33	$4	591
Engineering Research Centers	621	252	$70	$125	3,964
Materials Centers	382	332	$56	$43	5,813
Nanoscale Science & Engineering Centers	593	544	$13	$47	3,500
Science & Technology Centers	227	581	$72	$56	2,629
Science of Learning Centers	53	220	$19	$33	971

No. of Participating Institutions: All academic institutions participating in activities at the centers.

No. of Partners: The total number of non-academic participants, including industry, states, and other federal agencies at the centers.

Total Leveraged Support: Funding for centers from sources other than NSF.

Number of Participants: The total number of people who use center facilities, not just persons directly support by NSF.

Centers Supported by NSF in FY 2012

Center	Institution	State
Centers for Analysis and Synthesis		
National Evolutionary Synthesis Center	Duke, NC State U, U of N. Carolina	NC
National Institute for Mathematical & Biological Synthesis	U of Tennessee-Knoxville	TN
Plant Science Cyberinfrastructure Collaborative	U of Arizona	AZ
SocioEnvironmental Synthesis Center	U of Maryland	MD
Centers for Chemical Innovation		
Chemistry at the Space-Time Limit (phase II)	U of California-Irvine	CA
Center for Aerosol Impacts on Climate and Environment (phase I)	U of California-San Diego	VA
Center for Chemical Evolution (phase II)	Georgia Institute of Technology	GA
Center for Enabling New Technologies through Catalysis (phase II)	U of Washington	WA
Center for Multiscale Theory and Simulation (phase I)	U Chicago	IL
Center for Nanostructured Electronic Materials (phase I)	U of Florida	FL
Center for Stereoselective C-H Functionalization (phase II)	Emory U	GA
Center for Sustainable Materials Chemistry (phase II)	Oregon State U	OH
Center for Sustainable Nanotechnology (phase I)	U of Wisconsin-Madison	WI
Center for Sustainable Polymers (phase I)	U of Minnesota-Twin Cities	MN
Center for Sustainable Renewable Feedstocks (phase I)	U of California-Santa Barbara	CA
CO2 as a Sustainable Feedstock (phase I)	Brown U	RI
Powering the Planet (phase II)	California Institute of Tech	CA
Quantum Information Center for Quantum Chemistry (phase I)	Purdue U	IN
Engineering Research Centers		
Biomimetic Microelectronic Systems	U of Southern California	CA
Biorenewable Chemicals	Iowa State U	IA
Center for Ultra-wide-area Resilient Electric Energy Transmission Network (CURENT)	U of Tennessee Knoxville	TN
Collaborative Adaptive Sensing of the Atmosphere	U of Mass-Amherst	MA
Compact and Efficient Fluid Power	U of Minnesota	MN
Extreme Ultraviolet Science and Technology	Colorado State	CO
Future Renewable Electric Energy Delivery & Mgmt. Systems	North Carolina State U	NC
Integrated Access Networks	U of Arizona	AZ
Mid-IR Tech for Health and the Environment	Princeton	NJ
Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)	North Carolina State U	NC
Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Energy Technologies (NASCENT)	U of Texas	TX
Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems (TANMS)	U of California-Los Angeles	CA
Quality of Life Technology	Carnegie Mellon/U of Pittsburgh	PA
Quantum Energy and Sustainable Solar Technologies (QESST)	Arizona State U	AZ
Re-inventing the Nation's Urban Water Infrastructure	Stanford University	CA
Revolutionizing Metallic Biomaterials	North Carolina A&T U	NC
Sensorimotor Neural Engineering	U of Washington	WA
Smart Lighting	Rensselaer Polytechnic Institute	NY
Structured Organic Composites	Rutgers	NJ
Synthetic Biology	U of California-Berkeley	CA
Materials Centers		
Brandeis Materials Research Science and Engineering Center	Brandeis U	MA
Princeton Center for Complex Materials	Princeton	NJ
Center for Emergent Materials	Ohio State U	OH
Cornell Center for Materials Research	Cornell	NY
Center for Materials Science and Engineering	Massachusetts Institute of Tech	MA
Center for Multifunctional Nanoscale Materials Structures	Northwestern	IL
Quantum and Spin Phenomena in Nanomagnetic Structures	U of Nebraska	NE

Center for Nanoscale Science	Pennsylvania State	PA
Center for Nanostructured Interfaces	U of Wisconsin	WI
Center for Interface Structures and Phenomena	Yale	CT
Center for Photonics and Multiscale Nanomaterials	U. Michigan	MI
Center for Science and Engineering of Materials	California Institute of Tech	CA
Liquid Crystals Materials Research Center	U of Colorado-Boulder	CO
Laboratory for Research on the Structure of Matter	U of Pennsylvania	PA
Materials Research Center	U of Chicago	IL
Materials Research Science and Engineering Center	Harvard	MA
Materials Research Science and Engineering Center	Georgia Institute of Tech	GA
Materials Research Science and Engineering Center	New York U	NY
Materials Research Science and Engineering Center	U of California-Santa Barbara	CA
Materials Research Science and Engineering Center	U of Minnesota	MN
Materials Research Science and Engineering Center	U. Utah	UT
Materials Research Science and Engineering Center on Polymers	U of Massachusetts	MA
Renewable Energy Materials Science and Engineering Center	Colorado School of Mines	CO
Triangle Materials Research Science and Engineering Center	Duke	NC
Nanoscale Science and Engineering Centers		
Affordable Nanoengineering of Polymer Biomedical Devices	Ohio State	OH
Center for Environmental Implications of Nanotechnology (CEIN)	Duke	NC
Center for Integrated and Scalable Nanomanufacturing	U of California-Los Angeles	CA
High Rate Nanomanufacturing	Northeastern, U of New Hampshire, U of Mass-Lowell	MA, NH
Integrated Nanomechanical Systems	U of California-Berkeley, Cal Tech, Stanford, U of California-Merced	CA
Molecular Function at the Nano/Bio Interface	U of Pennsylvania	PA
Nanotechnology in Society Network: Center at ASU	Arizona State U	AZ
Nanotechnology in Society Network: Center at UCSB	U of California-Berkeley	CA
Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems	U of Illinois-Urbana Champaign	IL
National Nanomanufacturing Network: Center for Hierarchical Manufacturing	U of Massachusetts-Amherst	MA
Predictive Toxicology Assessment & Safe Implementation of Nanotechnology in the Environment (CEIN)	U of California-Los Angeles	CA
Probing the Nanoscale	Stanford, IBM	CA
Templated Synthesis and Assembly at the Nanoscale	U of Wisconsin-Madison	WI
Science and Technology Centers		
An NSF Center for the Study of Evolution in Action	Michigan State U	MI
Center of Adv. Materials for the Purification of H2O with Systems[1]	U of Illinois-Urbana Champaign	IL
Center for Biophotonics Science and Technology[1]	U of California-Davis	CA
Center for Coastal Margin Observation and Prediction	Oregon Health and Science U	OR
Center for Dark Energy Biosphere Investigations	U of Southern California	CA
Center for Energy Efficient Electronics Science	U of California-Berkeley	CA
Center for Embedded Networked Sensing[1]	U of California-Los Angeles	CA
Center for Integrated Space Weather Modeling[1]	Boston U	MA
Center for Layered Polymeric Systems	Case Western Reserve U	OH
Center for Microbial Oceanography: Research and Education	U of Hawaii-Manoa	HI
Center for Multi-Scale Modeling of Atmospheric Processes	Colorado State U	CO
Center for Remote Sensing of Ice Sheets	U of Kansas	KS
Emergent Behaviors of Integrated Cellular Systems	MIT	MA
Emerging Frontiers of Science Information	Purdue U	IN
National Center for Earth Surface Dynamics[1]	U of Minnesota-Twin Cities	MN
Center on Materials and Devices for Info. Technology Research[1]	U of Washington	WA
Team for Research in Ubiquitous Secure Technology	U of California-Berkeley	CA
Science of Learning Centers		
Center for Excellence for Learning in Education, Science, & Tech.	Boston U	MA
Pittsburgh Science of Learning Center - Studying Robust Learning	Carnegie Mellon	PA

with Learning Experiments in Real Classrooms		
LIFE Center - Learning in Formal and Informal Environments	U of Washington	WA
Spatial Intelligence and Learning Center	Temple	PA
The Temporal Dynamics of Learning Center	U of California-San Diego	CA
Visual Language and Visual Learning	Gallaudet	DC

[1] These STCs from the FY 2002 cohort received extensions to their periods of performance in FY 2012 but no additional funding.

MERIT REVIEW PROCESS IMPROVEMENTS

Overview

The merit review process is one of NSF's critical business functions. Effective merit review recognizes high-quality research including high-risk, high-payoff or potentially transformative ideas, empowers NSF to support such proposals, and retains the confidence and trust of NSF's external stakeholders. NSF's current approach to merit review relies on NSF staff making funding recommendations advised by *ad hoc* (mail) reviews and face-to-face panels. This process is time-and resource-intensive.

NSF's merit-review programs face extraordinary pressures as proposal numbers grow. Competition for funding has increased significantly since 2000; the number of research proposals evaluated increased by 80 percent and funding rates dropped dramatically. Workload has increased for researchers, reviewers, and NSF staff. These systemic stresses may be prompting some researchers to submit fewer innovative ideas. The workload of panel reviewers and the travel time involved means that some experts are reluctant or unable to serve on review panels held at NSF. The growth in the number of review panels has led to a steady growth of 9 percent per year between FY 2007 and FY 2012 in NSF's travel-related obligations. In FY 2011, the direct cost to NSF of holding face-to-face panels, excluding salary, was over $38.0 million. To mitigate some of the stresses on NSF's merit review system, a number of critical investments, described below, have been identified.

Total Funding for Merit Review Process Improvements

(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
-	-	**$4.09**

Goals

The goals of NSF's Merit Review Process Improvement activities are:

- Reduce the amount of staff time, per proposal, required to conduct merit review;
- Reduce the average time burden placed on individual reviewers;
- Increase the number of qualified individuals who participate in the review process;
- Reduce the per-proposal cost of the review process; and
- Improve the ability of institutions to submit successful proposals.

Approach

NSF looked at the merit review processes used by other research funding agencies; discussed the benefits and drawbacks of different possible approaches with researchers and university administrators on numerous NSF Advisory Committees; talked with reviewers; and consulted with the National Science Board (NSB). Based on this, significant improvements in workload and cost of could be achieved by focused investments in information and communications technology, personnel, increased use of automation, training, and outreach to institutions. In addition, the aging technologies that NSF uses to support its merit review processes constitutes a risk to one of NSF's critical lines of business. The principal components of this plan are separated into two phases, a first phase that can be pursued economically in FY 2014 and a second phase that will require a greater investment at a later date:

Phase 1

- Deployment of personnel and infrastructure to support use of virtual meeting technologies for panels;
- Outreach to individual institutions to help increase proposal success rates and reduce the submission of non-competitive proposals; and
- Assessment of impacts of improvements in merit review processes.

Phase 2

- Deployment of a more capable infrastructure to support the identification, selection, and recruitment of reviewers and to manage the receipt of reviews; and
- Increased use of automation in the preliminary processing of proposals.

The efforts to further improve NSF's merit review process are led by staff within the Office of International and Integrative Activities in collaboration with staff in the research directorates, the Office of Information and Resource Management, and the Office of Budget, Finance, and Award Management.

Use of Virtual Meeting Technologies for Merit Review

The predominant review method used has become the review panel, convened at NSF, where a set of experts assemble to evaluate proposals. The travel costs associated with review panels are an increasing budget burden. Recently, NSF has experimented with using virtual meeting technologies to hold synchronous virtual review panels including teleconferences, commercial video-conferencing technologies, and "virtual world" software. This investment expands NSF's use of virtual review panels and will restrain the growth in panel costs, broaden the range of reviewers participating in panels, and reduce the average workload of individual reviewers. The investment includes:

- Infrastructure to enable NSF to conduct a significant fraction of review panels as virtual panels;
- Development of online training for moderators and reviewers; and
- Collection of feedback from participants to continually improve the efficacy of virtual panels.

Demand Management

The rate at which submitted proposals to NSF are funded varies widely between institutions and by a factor of three among the top 100 institutions. Reducing this variation would improve the workloads of researchers submitting proposals, of reviewers, and of NSF staff. NSF plans a program of enhanced outreach that is tailored to individual institutions. The outreach will include:

- A discussion of statistics describing the institution's proposal submission rate, success rate, and participation in the merit review process; a comparison to other institutions; and an exploration of possible reasons for anomalies;
- A discussion of the institution's policies on proposal submission and impacts on proposers and reviewers; and
- Assistance in the design of mentoring programs for the faculty on proposal preparation and review.

The outreach will propagate best practices; encourage networking between institutions; and improve flow of ideas between NSF and the research community. The potential return on investment for NSF is significant; even a 1 percent reduction in overall proposal pressure corresponds to a reduction in staff workload that is similar to adding five or six new staff members. Reductions in the number of proposals that institutions must submit to support their faculty members' research programs benefits both their faculty and staff.

Assessments of Impacts of Merit Review Pilot Activities

In FY 2013 - 2014, NSF staff will undertake pilot activities to test achieving further efficiencies. NSF will engage an external party to conduct surveys of NSF reviewers; investigators and panel moderators to assess workload; the impacts of the technologies used; and the quality of feedback provided to proposers.

These will be used to assess the impacts of the pilot activities to be included in NSF's report to the NSB on the merit review process.

Technological Support for the Management of Reviewers and Reviews

This future investment aims to reduce the NSF staff time used in identifying potential reviewers and communicating with reviewers, and to improve the return rate for *ad hoc* reviews. It involves the following set of enhancements to NSF's eBusiness:

- Replace outdated and expensive client-server technology with modern, web-based technology;
- Develop and deploy a more sophisticated database of reviewers with enhanced search features;
- Enhance Research.gov so that researchers and other experts can volunteer online to serve as reviewers;
- Enhance tools to identify possible reviewers to include automatic suggestions of potential reviewers based on matching key criteria such as proposal topics, reviewer expertise, and review history;
- Deploy an automated tool that flags potential conflicts of interest; and
- Add an eBusiness system module that tracks review requests and responses, and that automatically sends reminders about outstanding requests to reviewers and NSF staff.

Increased Automation of the Preliminary Processing of Proposals

Although NSF's current online submission system performs some automatic checks of the structure and content of submitted proposals, many of the proposal preparation requirements are not automatically checked. NSF staff manually checks proposals for compliance, detracting from the time available for other parts of the merit review process. In the future, NSF will ameliorate this situation by deploying an enhanced automated compliance checker based on a relatively general rules engine. This will involve:

- Revision of proposal preparation criteria to simplify implementation as business rules in an automated, rule-based compliance checking system;
- Enhancements to FastLane to check for compliance with high-value business rules;
- Requirements definition, development, testing, and initial deployment of the expanded compliance checking functionality in the online proposal submission system; and
- Ongoing maintenance of the expanded compliance checking system.

Investment Framework

Merit Review Process Improvements Funding Estimates
(Dollars in Millions)

Activity	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Virtual Meeting Technologies	-	-	$3.79
Impact Assessment	-	-	0.30
Total	**-**	**-**	**$4.09**

Totals may not add due to rounding.

Demand Management-related activities, primarily staff costs and travel, are funded by the Agency Operations and Award Management (AOAM) account. For information on associated staffing and travel costs, see the AOAM chapter.

FY 2012 – FY 2013

Use of Virtual Meeting Technologies for Merit Review
In FY 2012 NSF initiated an assessment of several technological and organizational approaches to virtual meetings and began developing training modules for NSF staff and reviewers. In FY 2013 NSF will: conduct a pilot activity with a goal of at least 5 percent of review panels being wholly virtual; conduct a smaller scale pilot activity using asynchronous virtual panel technology; develop online training tools; and assess the impacts of the use of virtual panels. The FY 2013 investment includes a modest scale-up of NSF's network infrastructure, enhanced desktop equipment, and cloud-based virtual meeting services.

Demand management
In FY 2013, a pilot activity with outreach to ten institutions will be conducted using existing staff.

Assessments of Impacts of Merit Review Pilot Activities
In FY 2013, a baseline survey of reviewers, investigators, and panel moderators will be conducted.

Increased automation of the preliminary processing of proposals
Using existing staff resources in FY 2013, NSF will revise its proposal preparation criteria to simplify implementation in an automated rule-based compliance checking system; enhance FastLane to implement additional high priority business rules; and begin planning for a more robust business rules system.

FY 2014 Request

Use of virtual meeting technologies for merit review
Use of virtual panels at scale with at least 15 percent of review panels being virtual panels. The funds requested will support spending on infrastructure (including cloud services) and contract services to provide user support to NSF staff and reviewers. A more functional, semi-automated system will be created to support asynchronous virtual panels. The activities supported by FY 2014 funding include the continued scale up of NSF's in-house network infrastructure, conference room upgrades, enhanced desktop equipment, and cloud-based virtual meeting services.

Demand Management
Undertake a program of targeted outreach to approximately 100 different institutions per year.

Assessments of Impacts of Merit Review Pilot Activities
In FY 2014, a follow-on survey of reviewers, investigators, and panel moderators will be conducted.

FY 2015 and Beyond

Use of virtual meeting technologies for merit review
Support for virtual panels will continue with a target that at least 25 percent of panels are virtual.

Demand management
Continue a program of targeted outreach to approximately 100 different institutions per year.

Assessments of Impacts of Merit Review Pilot Activities
In FY 2015, a follow-on survey of reviewers, investigators, and panel moderators will be conducted.

Technological support for the management of reviewers and reviews
In FY 2015, begin requirements definition, development, testing, and initial deployment of a modernization of NSF eBusiness systems to support streamlined management of the review process. In FY 2016 - FY 2017, complete deployment of the modifications to NSF eBusiness systems.

Increased automation of the preliminary processing of proposals
In FY 2015, begin requirements definition, development and initial testing of an automated proposal compliance checking system with an estimated FY 2016 deployment.

Evaluation Framework

Use of virtual meeting technologies for merit review
NSF will track the number, size, duration and cost of virtual panels. It will compare per-proposal review costs of virtual and in-person panels, and collect feedback from virtual panel participants and moderators. This feedback will be discussed with Advisory Committees. NSF will make agency-wide statistical comparisons of merit review indicators for virtual and in-person panels, including statistics on the success rates of demographic groups of investigators and the various classes of proposing institutions. NSF will examine trends in the number of individual panelists used and their average workload.

Demand management
NSF will solicit feedback from institutions visited and will examine the rate of submissions and proposal funding in years following outreach and compare with baseline data.

Assessments of Impacts of Merit Review Pilot Activities
Surveys will be used to assess the impacts of Merit Review pilot activities undertaken by NSF.

Technological support for the management of reviewers and reviews
NSF will collect data on the staff time spent identifying, selecting, recruiting, and obtaining reviews from reviewers. Pre- and post-deployment data will be compared.

Increased automation of the preliminary processing of proposals
NSF will collect feedback from NSF staff on early prototypes and after the initial deployment. Feedback from submitting institutions will be collected during a pilot deployment. The feedback will be used as input to the final stages of development and deployment, and help determine efficacy and accuracy.

NSF EVALUATION CAPABILITY

Overview

Evaluation must be central to NSF's decision-making and the agency must have capacity to operate from a basis of evidence in policy decisions. In FY 2014 NSF will expand and coordinate program evaluation, and collection and management of NSF programmatic data through an expansion of NSF's Evaluation Capability.

At NSF, evaluation activities have traditionally been initiated and managed locally, within the directorate of the program being evaluated, with little centralized coordination. Although the distributed approach allows for the input of local program knowledge, there are significant advantages to building evaluation capacity centrally in order to promote rigor, integrate evaluation into performance measurement, and ensure that the results of evaluations are consistently used to inform decisions. Centralized coordination of evaluation activities also provides the opportunity to oversee theme evaluations that encompass multiple programs and consolidate data collection activities. This is particularly important for agency-wide programs involving multiple directorates, or programs with similar goals that are dispersed across the organization.

NSF is implementing a multi-stage approach to enhancing this capability: establishing mechanisms for Foundation-wide leadership and coordination in program evaluation; providing expert support and resources for data collection, integration and management; and improving directorate/office evaluation capacity. The Evaluation Capability, established within the Office of International and Integrative Activities (OIIA) in FY 2011, will be strengthened and augmented, with a national search for a leader underway in FY 2013 and additional staff to be added in FY 2014. Expert centralized support and adequate resources for data collection, study and survey design, and management will be put in place. These actions will allow NSF to more consistently evaluate the impacts of its investments, to make more data-driven decisions, and to establish a culture of evidence-based planning and policy-making.

NSF's evaluation efforts will be comprehensive yet flexible enough to capture the impact and return on investment in three main areas.

- ***Investments in fundamental science and engineering*** in general and specific areas, is critical. The largest proportion of NSF funding goes to support basic research across all science and engineering disciplines and their interdisciplinary connections, including basic research about STEM education.
- ***Investments in people,*** directly through human capital programs such as the National Graduate Research Fellowship Program, CAREER, Career-Life Balance, Research Experiences for Undergraduates (REU), and programs in EHR's Human Resource Development Division (HRD), and indirectly by supporting research done by students, post-docs, and faculty.
- ***Strategic investments*** that combine the outcomes of investments in research and people and often address areas of national priority such as sustainability, innovation, and advanced manufacturing. It is important to have a data and evaluation strategy that is flexible enough to accommodate complex activities.

Goals

The Evaluation Capability will provide expanded leadership, expertise, and resources to:

- Encourage a culture of evidence-based planning and policy making that routinely articulates program goals, milestones and metrics.
- Enable consistent evaluation of the impact of NSF investments with a high degree of rigor and independence.
- Develop and implement a coordinated framework for evaluating NSF-wide investments that is consistent with agency strategic and performance plans.

- Coordinate and consolidate data collection activities and storage to make data more useful for guiding decision making and evaluation.
- Use the results of evaluation to inform decisions.

Investment Framework

Evaluation Capability Funding
(Dollars in Millions)

Activity	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Data Collection, Study Design, and Management	-	-	5.50
Total	**-**	**-**	**$5.50**

Totals may not add due to rounding.

FY 2014 Request

NSF's approach will be to first expand expert centralized support and adequate resources to facilitate in-house developmental activities such as logic-modeling, feasibility studies, portfolio analysis, and gap analysis. Staff will also manage evaluations that are conducted by contractors. The new Evaluation Capability leadership will recommend and establish policies and best practices that will promote rigor, transparency, and independence. In FY 2014 evaluations for two to three major NSF activities that cross organizational boundaries will be initiated. The programs chosen will either be major NSF-wide programs or strategic investments. These initial evaluations are intended to supply models of how an NSF-wide approach that facilitates comparisons across programs can provide valuable information to guide decision-making. The specific evaluations or data collections to begin in FY 2014 will be based on both needs for decision making and what can be learned about how we evaluate the three types of science investments made by NSF (fundamental science, people, and strategic). The Evaluation Capability staff will collaborate with the performance improvement staff in the Budget Division on the strategic monitoring of key Foundation-wide programs, with the evaluation of strategic investments being an important component. Preparing for the consolidation of data collection and storage with the continuation of pilots that are currently under way will also provide an NSF-wide paradigm. The Evaluation Capability staff will be responsible for assessing the pilots for bringing data in-house, recommending a course for the future, and establishing a business plan for any changes that are recommended.

NSF PUBLIC ACCESS INITIATIVE

Overview

NSF will launch a Public Access Initiative that will make the results of NSF-funded research broadly available with minimal barriers. NSF's public access policy will accelerate progress in scientific research, encourage citizens to become scientifically literate, and foster creative partnerships with the private sector. Building on progress made in FY 2012 and FY 2013, during FY 2014 NSF will design and test system architecture to manage a subset of NSF-supported research products (at a minimum, journal articles, conference proceedings, and book chapters). During FY 2014 NSF will also pursue capabilities that will capture relevant information from the public access system for seamless inclusion in NSF's reporting and proposal systems. The appropriate organizational structure and unit within the Foundation with operational responsibility will be identified.

Pursuant to the memorandum recently released by OSTP, *Increasing Access to the Results of Federally Funded Scientific Research*[1], NSF intends to articulate a policy and develop plans that will require recipients of NSF funding to deposit a copy of their work in a proposed public access system and to manage the data resulting from their NSF awards. Conditions of deposit are likely to vary, depending on the nature of the product (data or publications), publishers' policies, and the length of time before the publication will be made available free of charge. NSF will consult widely with stakeholders during FY 2013 and FY 2014, before final award terms and policies are established.

Total Funding for
NSF Public Access Initiative
(Dollars in Millions)

FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
-	-	**$2.50**

Goals

NSF will work with concerned communities to establish a mechanism for NSF-funded investigators to make the products of their work available to the public. In order to do this, NSF will:

1. **Consult as needed with stakeholders, both inside and outside NSF.** NSF will work closely with stakeholders (scientists, universities, professional associations, private and public research sponsors and philanthropies, and publishers) to articulate public access policies that balance the concerns of all groups.

2. **Establish policies and make changes to NSF agreements with awardees that will enable public access and ensure compliance**. Procedures, terms and conditions for proposals, awards, and reporting are contained in the *Proposal and Award Policies and Procedures Guide (PAPPG)*. Updates and revisions to the PAPPG to align public access requirements with NSF policies and procedures will be made according to the required schedule with appropriate announcements in the Federal Register.

[1] www.whitehouse.gov/blog/2013/02/22/expanding-public-access-results-federally-funded-research

3. **Establish a publicly-accessible system architecture through which NSF-funded investigators can make their work available**. The requirements and specifications for this system will be developed during the FY 2013-FY 2014 planning phase. Consultations with stakeholders inside and outside of NSF, including scientific communities, professional societies, curatorial and stewardship institutions, publishers, and other stakeholder groups, will provide more specificity concerning attributes of the eventual repository system. NSF expects to consider carefully the merits of leveraging the existing PubMed Central (PMC) infrastructure built by the National Institutes of Health (NIH) and forging an interagency service that meets Administration priorities.[2] The roles of other federally funded infrastructure (e.g., Department of Energy's Office of Scientific and Technical Information (OSTI) new dataset registering service) will also be considered.

   The first implementation of the architecture will focus on peer-reviewed scientific papers, as required by the recent OSTP Memorandum on increasing access to the results of federally funded research.[3] Later implementation stages will address other kinds of research products, including data, for which there are fewer established frameworks.

4. **Establish mechanisms to integrate with NSF's internal data systems and externally-facing proposal and reporting systems, in a way that creates as little burden on awardees and investigators as possible**. How NSF integrates relevant information into its administrative and reporting systems will depend on the eventual system architecture. Because the technology will be fluid and all systems will be updated, this technology development and maintenance will be an ongoing need after the initial build-out.

Investment Framework

The NSF Public Access Initiative will have two structural elements: a planning process, comprising a steering committee and subcommittees focused respectively on publications and data and, eventually, a dedicated organizational unit, which will be directly responsible for administering the repository system. This unit will be advised by a working group made up of representatives from across the Foundation.

In FY 2013 and FY 2014, NSF will undertake planning and development activities including, but not limited to, the plans required by the OSTP memorandum, *Increasing Access to the Results of Federally Funded Scientific Research*, and will establish a process for determining which organization will be designated with responsibility for this activity. This will be pursued through a small working group composed of representatives from the Office of Information and Resource Management (OIRM) and the Office of Budget, Finance, and Award Management (BFA), individuals with relevant expertise recruited from the program directorates and offices, and other units of the Foundation as appropriate. This responsibility is expected to require two full-time equivalents (a newly-created position for a lead of the activity with one additional position for support functions). The lead official will oversee contracts and Memorandum of Understandings (MOUs) for piloting, testing, and services and will coordinate the design and requirements discussions associated with the contract. This will include articulating overall requirements for the initial roll out and for subsequent and potentially more complex implementations, monitoring the performance of the system and its uptake within the scientific community, and updating the system capabilities as necessary. These individuals will also coordinate the interface between the information in the Public Access system and other administrative units in the Foundation and will participate in discussions with the NSF Policy Office and various consultative activities. These may include coordination with publishers, professional societies, curatorial and stewardship institutions, and other organizations that manage the information and data infrastructure. During the early years, travel

[2] www.ncbi.nlm.nih.gov/pmc/
[3] www.whitehouse.gov/sites/default/files/microsites/ostp/ostp_public_access_memo_2013.pdf

will be required. Associated with this will be a standing working group with membership drawn from the NSF science staff to foster communication and information exchange.

In addition, the Division of Information Systems will develop and build appropriate technology to link the content from the repository with NSF's internal proposal and reporting systems. Other units of the Foundation, notably the Office of Legislative and Public Affairs (OLPA), the Office of the General Counsel (OGC), and the NSF Policy Office will contribute through efforts of public outreach and for updates to the PAPPG. The program directorates and offices may also undertake Public Access outreach activities with their respective communities at their discretion. Program directorates and offices will also be engaged to ensure that they have a role in developing, testing, and evaluating the system.

Public Access Initiative Funding and Estimates

(Dollars in Millions)

Activity	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Goal 1, Stakeholder Consultation	-	-	$1.25
Goal 2, NSF Policy Changes	-	-	-
Goal 3, Public Data Repository	-	-	0.50
Goal 4, Internal NSF System Changes	-	-	0.75
Total	**-**	**-**	**$2.50**

Totals may not add due to rounding.

FY 2014 Request

A key activity in 2014 will be developing and testing the first implementation of the NSF Public Access system. This will include: (1) integration of relevant elements with the NSF internal and external systems; (2) identifying appropriate partners based on consideration of alternatives, capabilities, and requirements; (3) extensive testing prior to launch (anticipated in FY 2015), which will require implementing appropriate interagency agreements or third-party contracts; (4) defining the nature of post-launch monitoring; and (5) developing and evaluating system metrics, which include both performance and usage metrics. In this first implementation (FY 2015), NSF anticipates that only peer-reviewed papers will be accommodated within the system. After it is clear that the system works effectively for these kinds of works, NSF will begin to consider other kinds of work products, to take place in FY 2015 and beyond. Implementation of plans for managing data may require more extensive study and more time.

Preparation for a successful launch in FY 2015 will also necessitate coordination with the NSF Policy Office and with OLPA to ensure that relevant changes have been appropriately communicated with relevant constituencies. All of the programs across the Foundation will be impacted, therefore, coordination with the staff in the directorates and offices, and with senior management through working groups will be critical for effective communication and implementation with awardees.

Anticipated FY 2014 investments:

- Staffing, travel, and outreach;
- Ongoing contract for external repository services; and
- Ongoing development and maintenance of technology for interface between repository and NSF systems.

FY 2015 and Beyond

Beyond 2014, NSF expects to launch the system, monitor its use, and expand it strategically based on performance and usage metrics, as well as responses from the research community and other stakeholders. When the system is functioning robustly, NSF will begin the process of adding additional types of research products and additional functionality. Within two years of the launch for first implementation, NSF will revisit and update the plan and evaluate the project from the perspective of its support for the research process. This effort will engage directorates and offices, the NSB, OSTP, other agencies, and stakeholder groups.

SELECTED CROSSCUTTING PROGRAMS

NSF crosscutting programs include interdisciplinary programs and programs that are supported by multiple directorates. For full funding data about Selected Crosscutting programs discussed here, see the Summary Tables chapter. Examples of major crosscutting activities include the following:

ADVANCE
In FY 2014, ADVANCE will fund transformative efforts to address the systemic barriers to women's full participation in academic science, technology, engineering, and mathematics (STEM) with funding of $16.63 million, a decrease of $1.32 million below the FY 2012 Enacted level of $17.95 million. Although there is a program reduction, a major focus in 2014 will be broadening the spectrum of institutions participating in the program, to include more undergraduate and minority serving institutions and community colleges, thereby increasing the participation and advancement of women across higher education in academic science and engineering careers. ADVANCE also participates in NSF's Career Life Balance (CLB) initiative; a ten-year initiative that integrates family-friendly practices into NSF's programs.

Catalyzing Advances in Undergraduate STEM Education (CAUSE)
The FY 2014 Request includes $123.08 million for a new undergraduate education program CAUSE that incorporates funding from established programs in the EHR directorate and other NSF directorates funded though the Research and Related Activities (R&RA) account. It is created by consolidating three Division of Undergraduate Education (DUE) programs: STEM Talent Expansion Program (STEP), Widening Implementation and Demonstration of Evidence-based Reforms (WIDER), and Transforming Undergraduate Education in STEM (TUES); several R&RA programs: BIO's Transforming Undergraduate Biology Education (TUBE); ENG's Research in Engineering Education and Nanotechnology Undergraduate Education (NUE), GEO's Geosciences Education and Opportunities for Enhancing Diversity in the Geosciences (OEDG); and the cross-NSF program, Climate Change Education (CCE). The FY 2014 funding will allow for awards in foundational research, design-based implementation, and scale-up effectiveness studies. For more information, see the CAUSE narrative in this chapter.

Cyberlearning Transforming Education (CTE)
The FY 2014 Budget Request includes $30.08 million for CTE, a decrease of $1.0 million below the FY 2012 Enacted level of $31.08 million. Funding for CTE is provided by the Directorates for Computer and Information Science and Engineering (CISE), Social, Behavioral, and Economic Sciences (SBE), and Education and Human Resources (EHR). Through CTE, NSF seeks to integrate advances in technology with advances in what is known about how people learn. Of particular interest are technological advances that allow more personalized learning experiences, draw in and promote learning among those in populations not served well by current educational practices, allow access to learning resources anytime and anywhere, and provide new ways of assessing capabilities. It is expected that cyberlearning research will shed light on how technology can enable new forms of educational practice and that broad implementation of its findings will result in a more actively-engaged and productive citizenry and workforce.

Enhancing Access to the Radio Spectrum (EARS)
NSF's FY 2014 Budget Request provides $50.0 million for EARS, an increase of $35.0 million above the FY 2012 Enacted level of $15.0 million (the first year of the EARS program was in FY 2012). EARS' purpose is to fund interdisciplinary research that can enhance the efficiency with which radio spectrum is used, and/or lead to improved access to wireless services for all Americans. The increased support for EARS in FY 2014 is a ramp-up that is consistent with the 2010 NSF supported workshop report,

Enhanced Access to the Radio Spectrum: A Path Forward[1], which highlighted the need for research on new and innovative ways to utilize the spectrum more efficiently. EARS is a collaboration among the Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), and Mathematical and Physical Sciences (MPS).

Ethics Education in Science and Engineering (EESE)
NSF's FY 2014 Budget Request provides $2.44 million for EESE, a decrease of $310,000 below the FY 2012 Enacted level of $2.75 million. The EESE program aims to deepen the understanding of ethical dilemmas in science and engineering, and provide cutting edge, effective research and educational materials to train the next generation of scientists and engineers. It funds research and educational projects that improve ethics education in all fields of science and engineering supported by NSF. Although the primary focus is on improving ethics education for graduate students in NSF-funded fields, advanced undergraduates benefit as well. Funding for EESE is provided by BIO, CISE, ENG, GEO, SBE, and IIA.

Faculty Early Career Development (CAREER)
The FY 2014 Budget Request provides $223.73 million for the CAREER program, an increase of $17.38 million over the FY 2012 Enacted level of $206.35 million. This will support approximately 500 new CAREER awards, which support exceptionally promising college and university junior faculty who are committed to the integration of research and education and who are most likely to become the leaders in their fields. In December 2012, the CAREER Coordinating Committee convened a special Advisory Committee (AC) to examine CAREER and to provide strategic advice on the scope and direction of the program. A report from the committee is anticipated by the end of FY 2013. CAREER also participates in NSF's Career Life Balance (CLB) initiative; a ten-year initiative that integrates family-friendly practices into NSF's programs.

Graduate Fellowships and Traineeships
The FY 2014 Request provides $380.21 million for NSF's graduate fellowship and traineeship programs. This funding will enable NSF to support an estimated 7,200 graduate students, including 2,700 new graduate research fellows in FY 2014 as part of the expanded National Graduate Research Fellowship (NGRF) program, which will include new targeted opportunities to enable students to develop specialized expertise in critical areas.

- In FY 2014, NGRF will represent a flagship STEM graduate fellowship program for the federal government at a level of $325.14 million, an increase of $127.0 million over the FY 2012 Enacted level of $198.14 million. Funding for the program is divided equally between the Education and Human Resources account and the Research and Related Activities account. Through this expanded program, NSF will be able to award approximately 700 additional fellows bringing the total estimated number of new fellowships awarded in FY 2014 to 2,700. NGRF will provide fellows up to three years of support over a five-year period. For more information see the Major Investments in Science, Technology, Engineering, and Mathematics (STEM) Graduate Education narrative in this chapter. NGRF also participates in NSF's Career Life Balance (CLB) initiative; a ten-year initiative that integrates family-friendly practices into NSF's programs.

[1] www.nsf.gov/mps/ast/nsf_ears_workshop_2010_final_report.pdf

National Graduate Research Fellowship Program

	Total Number of Fellows	Number of New Fellows	Projected Fellows on Tenure[1]
FY 2013 Estimate	7,800	2,000	4,200
FY 2014 Estimate	8,900	2,700	6,200

[1]Fellowship tenure status is the period of time during which fellows actively utilize the fellowship award to pursue an advanced degree in the science, technology, engineering, or mathematics fields supported by NSF.

- In FY 2014, NSF will challenge the community to expand innovation in graduate education through the NSF Research Traineeships (NRT) program, the successor to the Integrative Graduate Education and Research Traineeship (IGERT) program. Funding at a level of $55.07 million is requested for NRT and will support an estimated 1,000 graduate students in FY 2014. $33.71 million of the requested funding is for continuing IGERT awards made in prior years and the remaining $21.36 million will support the design and implementation of traineeship programs in areas where new science is emerging and will introduce new approaches to preparing graduate students for a range of career options. For more information see the Major Investments in Science, Technology, Engineering, and Mathematics (STEM) Graduate Education narrative in this chapter.
- No funding is requested in FY 2014 for the NSF Graduate STEM Fellows in K-12 Education (GK-12) program as it was terminated.

Long-Term Ecological Research (LTER)

The FY 2014 Request provides $27.59 million, an increase of $190,000 above the FY 2012 Enacted level of $27.40 million. LTER supports fundamental ecological research that requires data collection over long time periods and often at large spatial scales. This program supports a loosely coordinated network of more than two dozen field sites that focus on: 1) understanding ecological phenomena that occur over long temporal and broad spatial scales; 2) creating a legacy of well-designed, long-term ecological experiments; 3) conducting major syntheses and theoretical efforts; and 4) providing information to identify and to address environmental problems. LTER projects represent a diversity of habitats in continental North America, the Caribbean, Pacific Ocean, and the Antarctic, including coral reefs, arid grasslands, estuaries, lakes, prairies, various forests, alpine and Arctic tundra, urban areas, and agroecosystems. The increased support for LTER in FY 2014 covers planned periodic increases to cover higher costs as sites are renewed. Funding for LTER is provided by BIO, GEO, and SBE.

In FY 2012, NEON infrastructure was co-located at eleven LTER sites. NEON is a continental-scale infrastructure facility providing standardized physical and data resources to researchers and educators. LTER is a network of long-term research projects aimed at understanding ecological processes in a wide range of ecosystems. Ongoing research at LTER sites may take advantage of data generated using NEON infrastructure. In addition, the co-location of NEON infrastructure at LTER sites will stimulate new research that builds on the long history of LTER research by enhancing the ability to extend site-based knowledge to regional and continental scales.

Research Experiences for Teachers (RET)

The FY 2014 Request for NSF's RET program totals $6.95 million, a decrease of $30,000 below the FY 2012 Enacted level of $6.98 million. Funding will provide pre-service and in-service K-12 teachers, and community college faculty with discovery-based learning experiences. The professional development gained by the participants through this unique experience has enriched their performance in the classroom and their guidance of students in science and engineering. Funding for RET is provided by BIO, CISE, ENG, GEO, and MPS.

Research Experiences for Undergraduates (REU)
In FY 2014, $79.18 million in funding is requested for the Research Experiences for Undergraduates (REU) Sites and Supplements program, an increase of $13.19 million over the FY 2012 Enacted level of $65.99 million. $10.00 million of 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.* The request for FY 2014 reflects the importance of undergraduate research experiences in building students' interest and competence in STEM disciplines, and aligns with the Administration's focus on improving undergraduate STEM education. REU grants involve students at all stages of undergraduate education, including the freshman and sophomore levels, which enhances retention and graduation rates in STEM. REU Supplements allow students to join research projects that are supported by NSF research grants. REU Sites support cohorts of students to conduct research within STEM disciplines or on topics that cut across disciplines. Most of the students in an REU Site come from outside the host institution. This feature enables the program to involve students in research who might not otherwise have the opportunity, particularly students from institutions where research activities are limited. The REU program encourages partnerships between community colleges and baccalaureate degree-granting institutions to provide research opportunities for community college STEM students and faculty. Funding for REU is provided by BIO, CISE, ENG, GEO, MPS, and SBE.

Research in Undergraduate Institutions (RUI)
The FY 2014 Request for NSF's RUI program totals $39.95 million, or $200,000 below the FY 2012 Enacted level of $40.15 million. The RUI activity supports research by faculty members of predominantly undergraduate institutions through the funding of (1) individual and collaborative research projects, (2) the purchase of shared-use research instrumentation, and (3) Research Opportunity Awards for work with NSF-supported investigators at other institutions. Funding for RUI is provided by BIO, CISE, GEO, MPS, and SBE.

NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

NNI Funding

(Dollars in Millions)

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

Totals may not add due to rounding.

NSF's contribution to the multiagency National Nanotechnology Initiative (NNI) encompasses the systematic understanding, organization, manipulation, and control of matter at the atomic, molecular, and supramolecular levels in the size range of about 1 to 100 nanometers. Novel materials, devices, and systems – with their building blocks designed on the scale of nanometers – open up new directions in science, engineering, and technology with potentially profound implications for society. With the capacity to control and manipulate matter at this scale, science, engineering, and technology are realizing revolutionary advances in areas such as catalysts for industry; individualized pharmaceuticals; new drug delivery systems; order-of-magnitude faster computer chips; more resilient materials and fabrics; and sustainable development for water and energy resources utilization.

FY 2014 NNI Funding

NSF supports nanoscale science and engineering throughout all the research and education directorates as a means to advance discovery and innovation and integrate various fields of research. NNI enables increased interdisciplinarity at atomic and molecular levels for about 5,000 active awards with full or partial contents on nanoscale science and engineering (NSE). About 10,000 students and teachers will be educated and trained in nanoscale science and engineering in FY 2014. NSF contributes to the goals and eight program component areas (PCAs) outlined in the NNI Strategic Plan (www.nano.gov). Increases of $1.63 million in the Nanomanufacturing PCA and $1.91 million in the Nanomaterials PCA will be dedicated to research on breakthrough materials and advanced manufacturing as part of the Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) NSF-wide investment, which coordinates and synchronizes activities across four main areas – breakthrough materials, advanced manufacturing, robotics, and smart systems – and allows interdependencies and common research elements to surface. Three Nanosystems Engineering Research Centers (NERC), with a total estimated budget of approximately $55.0 million for five years, were established in September 2012 and started full operation in FY 2013. Partnerships of new NERCs with small businesses in the areas of nanomanufacturing and commercialization will be strengthened while maintaining about the same level of NSF investment. In FY 2014 the agency continues its contributions to translational innovation programs, including Grant Opportunities for Academic Liaison with Industry (GOALI); Industry/University Cooperative Research Centers (I/UCRC); the NSF Innovation Corps (I-Corps) program; and the two subcomponents of Partnerships for Innovation (PFI) – Accelerating Innovation Research (AIR) and

Building Innovation Capacity (BIC). The NSF Small Business Innovation Research (SBIR) program has an ongoing nanotechnology topic with subtopics for nanomaterials, nanomanufacturing, nanoelectronics and active nanostructures, nanotechnology for biological and medical applications, and instrumentation for nanotechnology. Overall, NNI funding in the FY 2014 Request will increase by $4.91 million, or 1.2 percent, over the FY 2012 Enacted.

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

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

NSF sponsored an international study on long-term research entitled "Nanotechnology Research Directions for Societal Needs in 2020" (NSF/WTEC 2010, Springer, available on www.nsf.gov/nano and www.wtec.org/nano2/). It provides assessment of nanotechnology development in the last ten years (2000-2010) and a long-term vision of the field in the next decade (2010-2020). This study evaluates the outcomes as recommended by the first report "Nanotechnology Research Directions: A vision for the next decade" (1999), adopted as an official document of the National Science and Technology Council (NSTC).

Fundamental Nanoscale Phenomena and Processes

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

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

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

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

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

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

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

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

Major Research Facilities and Instrumentation Acquisition

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

Environmental, Health, and Safety

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

Education and Societal Dimensions

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

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

Coordination with Other Agencies

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

NNI by Program Component Area

(Dollars in Millions)

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

Totals may not add due to rounding.

NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT (NITRD)

Total Funding for NITRD
(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$99.00	$99.00	$99.00
Computer and Information Science and Engineering [1]	937.11	865.23	950.25
Education and Human Resources	9.50	9.50	9.50
Engineering	18.30	18.30	19.80
Geosciences	20.00	22.98	24.00
Mathematical and Physical Sciences	101.25	93.75	94.15
Social, Behavioral, and Economic Sciences	31.09	29.51	30.70
Total	**$1,216.25**	**$1,138.27**	**$1,227.40**

Totals may not add due to rounding.

[1] FY 2012 Actual includes obligations $71.59 million over the enacted level for CISE due to recoveries of prior year unpaid obligations that were reobligated in FY 2012.

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

NSF's FY 2014 Request continues strong support for NITRD at a level of $1.23 billion, a 7.8 percent increase over the FY 2012 Enacted level. NITRD activities represent approximately 16 percent of NSF's FY 2014 budget. CISE's support comprises 77.4 percent of NSF's NITRD activities.

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

- Advanced Manufacturing investments encompass research in nanotechnology, cyber-physical systems, and robotics, as well as expanded industry/university cooperation. Activities are supported in High End Computing Research and Development (R&D), High End Computing Infrastructure and Applications (I&A), and High Confidence Software and Systems.
- The Comprehensive National Cybersecurity Initiative (CNCI) supports activities in Cybersecurity and Information Assurance.
- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) expands advanced manufacturing technologies research in the Cyber-Physical Systems (CPS) program, and the National Robotics Initiative (NRI) to accelerate advances in 21st century smart engineered systems. CEMMSS will begin 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. CEMMSS supports activities in High End Computing R&D; High Confidence Software and Systems; Human-Computer Interaction and Information Management; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.

- Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21), designed to develop and deploy comprehensive, integrated, sustainable, and secure cyberinfrastructure to accelerate research and new functional capabilities in computational and data-intensive science and engineering, primarily supports investments in six program component areas: High End Computing R&D; High End Computing I&A; Large Scale Networking; Human-Computer Interaction and Information Management; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- Enhancing Access to the Radio Spectrum (EARS), which invests in wireless communication, spectrum sharing, and mobile computing, as well as the development of wireless testbeds, is supported in Large Scale Networking, High End Computing R&D, and High End Computing I&A.
- The National Robotics Initiative (NRI), a cross-agency initiative engaging four U.S. agencies (NSF, National Aeronautics and Space Administration, National Institutes of Health and the U.S. Department of Agriculture) provides U.S. leadership in robotics science and engineering research and education aimed at the development of co-robots, which work cooperatively with humans in application domains, such as advanced manufacturing, emergency response, and assistive healthcare. Activities are supported in Human-Computer Interaction and Information Management; High Confidence Software and Systems; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.
- Secure and Trustworthy Cyberspace (SaTC) aligns NSF cybersecurity investments with the President's national cybersecurity strategy, *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program*. SaTC supports scientific foundations, induces change, maximizes research impact, and accelerates transitions to practice. SaTC supports activities in Cybersecurity and Information Assurance.
- The Science, Engineering, and Education for Sustainability (SEES) investment supports activities in High End Computing R&D; Large Scale Networking; Software Design and Productivity; and Social, Economic, and Workforce Implications of IT and IT Workforce Development.

FY 2014 NSF Investments by Program Component Area (PCA)
The following information focuses on FY 2014 NSF investments, both new and continuing, by PCA.

Large Scale Networking (LSN) ($136.34 million) CISE and ENG will support research in new wireless communications, spectrum sharing architectures and services, and mobile computing, as well as development of wireless testbeds as part of EARS. A portion of NSF's investment in CIF21 will address broadband applications and research on end-to-end performance from the desktop to major scientific and computational facilities.

Cybersecurity and Information Assurance (CSIA) ($114.28 million) CSIA includes support for the CNCI and for NSF's SaTC program. CISE investments in SaTC, in partnership with EHR, ENG, MPS, and SBE, aim to support scientific foundations, induce change, maximize research impact, and accelerate transition to practice.

High-End Computing R&D (HEC R&D) ($113.57 million) Support is provided for CISE's nanotechnology research, including participation in the National Nanotechnology Initiative. HEC R&D also includes support for NSF's investment in SEES, focusing on research that will develop the theory and design principles to effectively tackle energy versus computation and communication tradeoffs and the development of new theory, algorithms, and design principles to optimize energy-computational performance in computing and communications systems. HEC R&D also includes support for CIF21 to develop new functional capabilities in support of highly parallel computing and BIGDATA analytics, as well as research on technical and economic models for flexible spectrum access, real-time auctions, and on-demand spectrum services as part of EARS. MPS, through the Division of Materials Research, will

support research on quantum effects and their use for information science, potentially leading to new paradigms for high-end computing.

High-End Computing Infrastructure and Applications (HEC I&A) ($248.44 million) HEC I&A includes increased efforts by CISE's Division of Advanced Cyberinfrastructure (ACI) to develop software and algorithms for high-end computing systems. It also includes MPS and ENG investments in new computational methods, algorithms, robust software, and other computational tools to support researchers in the mathematical and physical sciences and engineering. The CISE investment in computational infrastructure as part of CIF21 is reflected here, as well as the development of wireless testbeds that support experimentation with new wireless technology services as part of EARS. GEO supports EarthCube, a CIF21 investment that sustains cyberinfrastructure for the geosciences. HEC I&A also includes investments in innovative partnerships and collaborations between universities and industries, including the Industry/University Cooperative Research Centers program (I/UCRC); GEO's support for operations and maintenance for the NCAR Wyoming Supercomputer facility; and BIO's support for development of pioneering informatics tools and resources that have the potential to transform research in biology.

High Confidence Software and Systems (HCSS) ($103.27 million) CISE and ENG will increase investments in NRI and in CPS as part of CEMMSS as well as continue investments in Smart and Connected Health. As development of the next generation of robotics proceeds, complete confidence in the systems supporting those that work beside, or cooperatively with, people in application domains, such as advanced manufacturing, emergency response, and healthcare, become increasingly important. High confidence surgical robots and medical devices are central to high quality healthcare and building trust in robotic aids. CISE and ENG will support advanced manufacturing technologies research in cyber-physical systems, such as smart infrastructure that will blend traditional concrete-and-steel physical infrastructure systems with cyber-infrastructure systems such as computers, networks, and sensors. BIO's support for HCSS will expand and enhance access to the national resource of digital biological and paleontological data, and the Bio/computation Evolution in Action CONsortium (BEACON) Center established to study the power of evolutionary processes and to transfer those discoveries from biology into computer science and engineering design.

Human Computer Interaction and Information Management (HCI&IM) ($299.90 million) HCI&IM includes CISE support for the National Robotics Initiative, part of CEMMSS, as well as support for Smart and Connected Health. As part of the next generation of robotics, co-robot systems will be characterized by their flexibility and resourcefulness. They will use a variety of modeling or reasoning approaches, and use real-world data in real-time, demonstrating a level of intelligence and adaptability seen in humans and animals. Research in Smart and Connected Health will focus on human-centered intelligent information systems and tools that collect, mine, synthesize, protect, and share appropriate data and knowledge with healthcare organizations, practitioners, caregivers, and individuals to enable effective, safe, and well-informed decision-making by all stakeholders. HCI&IM also includes NSF investments in CIF21 related to BIGDATA analytics and visualization tools, and the development of mid-scale pilots and prototypes toward a comprehensive, scalable data infrastructure. BIO investments in HCI&IM will facilitate discovery through tools that integrate the published literature with the expanding universe of digital data collections, expand capacity for understanding through virtual environments, and make it practical for scientists to search vast collections of biological images simply and quickly. MPS investments will focus on the provision of new automated data-analysis pipelines that will provide initial reference images for the data-rich radio interferometers that are just coming on line, with analysis tools and guidance for those scientists who need to interact with the data in order to achieve image fidelities beyond those that can be delivered using automated processing techniques. SBE will continue investments to increase the benefit of computer technologies to scientists, as well as non-science users, facilitate opportunities for SBE researchers to understand human behavior and cognition and the effectiveness of virtual organizations in

the context of 21st century networked society (via CIF21) and focus on research that advances the core scientific and technological means of managing, analyzing, visualizing, and extracting information from large data sets.

Software Design and Productivity (SDP) ($89.61 million) SDP support reflects increased investment in CIF21 with a focus on software sustainability, and new research on smart systems as part of CEMMSS. ENG's support for this PCA is primarily associated with the CPS and NRI components of the CEMMSS investment. CISE will make investments in the Software Institutes for Sustained Innovation (SI^2) program to catalyze new thinking, paradigms, and practices in developing and using software that is robust, reliable, usable, and sustainable under the CIF21 umbrella. BIO support for SDP includes support for the interagency and international Collaborative Research in Computational Neuroscience program. BIO funds research involving the development of software and other computational tools to advance biological knowledge, as well as computational innovations. SDP also includes support for SBE's National Center for Science and Engineering Statistics (NCSES) to continue exploration of new methods to enhance data collections, analysis, and sharing capabilities, which will help NCSES better serve its role of providing information on the science and engineering enterprise. In addition, SBE will continue to partner with CISE in exploring the emerging interface between computer science and social and behavioral science.

Social, Economic, and Workforce (SEW) Implications of IT and IT Workforce Development ($121.99 million) As part of NRI, SEW research in CISE will focus on human-centered research in developing service robots, requiring significant advances in human-robot interaction. In addition, CISE's continued emphasis on Smart and Connected Health focuses on, for example, improvements in safe, effective, efficient, and patient-centered proactive and predictive health and wellness technologies. This also reflects CISE support for BIGDATA and e-science collaboration tools as part of CIF21, and support for cyberlearning and on-line education programs. Research in cyberlearning will integrate advances in technology with learning, design new technologies for integration in learning environments, and evaluate their use. EHR will continue to study the impact of information and communication technology on educational practice, new approaches to using technology in education, application and adaptation of technologies to promote learning in a variety of fields and settings, the effects of technology of learning, and efforts that advance teaching and learning opportunities utilizing cyberinfrastructure. These efforts also will support science, technology, engineering, and mathematics education for the cyber-workforce through workforce programs and research and development in learning sciences. BIO support for SEW focuses on advancing the Nation's ability to incorporate and apply biological knowledge to economic development and other issues of societal importance. SBE will continue to support the social, economic, and workforce aspects of information technology, focusing on the nature and dynamics of IT impacts on technical and social systems.

NITRD Funding by Program Component Area

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Large Scale Networking	$127.55	$121.76	$136.34
Cybersecurity and Information Assurance	99.20	98.49	114.28
High End Computing R&D	109.59	102.98	113.57
High End Computing Infrastructure and Applications[1]	329.27	249.96	248.44
High Confidence Software and Systems	88.36	84.67	103.27
Human-Computer Interaction and Info Management	270.62	291.98	299.90
Software Design and Productivity	85.20	78.26	89.61
Social, Economic, and Workforce	106.46	110.17	121.99
Total	**$1,216.25**	**$1,138.27**	**$1,227.40**

Totals may not add due to rounding.

[1] FY 2012 Actual includes obligations $71.59 million over the enacted level for CISE due to recoveries of prior year unpaid obligations that were reobligated in FY 2012.

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP)

Total Funding for USGCRP

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	$89.00	$89.00	$91.00
Geosciences	217.10	217.10	205.15
Mathematical and Physical Sciences	5.03	5.03	7.00
Social, Behavioral and Economic Sciences	22.23	22.23	23.23
Total	**$333.36**	**$333.36**	**$326.38**

Totals may not add due to rounding.

Climate and global change effects on the U.S. through impacts on the environment, natural resources, and the economy are pervasive. Global change encompasses a wide range of planetary- and regional-scale changes in the Earth's natural and human systems. These changes involve atmospheric and ocean circulation and composition, the water cycle, biogeochemical cycles, land and sea ice, biological diversity, marine and terrestrial ecosystem health, resource and land use, urbanization, economic development, and more. The U.S. Global Change Research Program (USGCRP) provides the Nation and the world with the scientific knowledge necessary for understanding and predicting climate change and environmental responses, managing risk, and anticipating opportunities that may result from changes in climate and climate variability. Research conducted through the USGCRP (www.globalchange.gov) builds on the scientific advances of recent decades and deepens our understanding of how the interplay between human and natural systems affects the climate system, and how the changing climate impacts those systems. The USGCRP involves thirteen U.S. agencies in a concerted interagency program of basic research, comprehensive observations, integrative modeling, and new approaches for translating scientific information for use by decision-makers. NSF provides support for a broad range of fundamental research activities that provide a sound scientific basis for climate-related policy and decisions.

The Earth's climate is determined by highly complex interactions between and among the atmosphere, hydrosphere, cryosphere, geosphere, and biosphere – all significantly influenced by human activities. NSF programs address these components by investing in: fundamental discovery that utilizes the full range of intellectual resources of the scientific community; research infrastructure that provides advanced capabilities; and innovative educational activities. NSF strongly encourages interdisciplinary approaches, and focuses on fundamental Earth system processes and the consequences of change. High priorities for the agency include: data acquisition and information management activities necessary to support, and disseminate the results of, global change research; the enhancement of models designed to improve our understanding of Earth system processes and of feedbacks between ecosystems and the physical climate; the development of new, innovative Earth observing instruments and networks; the development of advanced analytic research methods; and preparation of a scientific workforce equipped to deal with the complexities of global change. NSF also supports fundamental research on the processes used by organizations to identify and evaluate policies for mitigation, adaptation, and other responses to varying environmental conditions. NSF-supported research on the science of impacts, vulnerability and resilience as well as the enhancement and development of a range of climate and process models will continue to make an important contribution to climate assessment activities.

FY 2014 Areas of Emphasis

NSF's FY 2014 investment in USGCRP decreases by $6.98 million, or 2.1 percent, below the FY 2012 Enacted Level. NSF's USGCRP investments reflect two major integrated NSF initiatives, the Science, Engineering, and Education for Sustainability (SEES) and the Cyberinfrastructure Framework for 21st Century Science, Engineering, and Education (CIF21). The major USGCRP foci in FY 2014 include:

Improving our knowledge of Earth's past and present climate variability and change – NSF investments include activities to document and understand long-term climate cycles across the globe, as well as to better understand the natural variability of climate and the processes responsible for climate changes using a range of paleoclimate and instrumental data and modeling approaches. NSF also supports activities to improve our understanding of the frequency and intensity of extreme climate events in the past and how those may be manifested in the future. Upgrading and expanding critical environmental observing systems and ensuring data quality and access are integral parts of NSF's investments that will be supported under the CIF21 portfolio.

Improving our understanding of natural and human forces of climate change – NSF activities in this area span a broad range of disciplines and topics that seek to better understand the physical, geological, chemical, biological, and human components of the Earth system and their interactions. Examples of major foci include fundamental research on all aspects of the carbon cycle, the water cycle, atmospheric composition and greenhouse gas processes, marine and terrestrial ecosystems, and ocean and atmospheric circulations that both drive and respond to climate and global change. Human drivers of change include urbanization, population growth, and economic development. NSF has a strong commitment to fostering new interdisciplinary research approaches that allow exploration of the interdependencies across these areas. Such efforts will be enhanced with the sustainability focus under the SEES portfolio.

Improving our capability to model and predict future conditions and impacts – NSF-supported research will examine major feedback processes between the climate and natural and human systems and will incorporate these into the next generation Community Earth System Model (CESM). High priority will be given to developing more complete representations of coupled interactive atmospheric chemistry, terrestrial and marine ecosystems, biogeochemical cycling, and middle atmospheric processes. NSF will continue to devote significant resources to advancing climate modeling capabilities from global and centennial to regional and decadal scales. In addition, NSF is encouraging the development of ecosystem and water models at regional scales, as well as models that integrate human system components such as risk, vulnerability, and decision-making. These efforts will depend on new computational resources and tools that will be developed through the CIF21 efforts.

Assessing the Nation's vulnerability to current and anticipated impacts of climate change – A key focus of the USGCRP is developing better means of assessing the impacts of climate change and the vulnerability and resilience of both human and natural systems to those changes, particularly in highly sensitive regions such as the Arctic. NSF supports the basic research that underpins the National Climate Assessment effort, particularly in developing the range of models needed for these assessments. NSF will support fundamental research regarding the science of adaptation, defined as the adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. This research ranges from developing the theoretical framework for evaluating adaptation options (and avoiding unintended consequences of adaptation choices) to risk assessment and decision making. Through SEES, NSF will continue interdisciplinary research (including human factors) in water sustainability, biodiversity, ocean acidification, and vulnerable areas such as the Arctic.

Providing climate information and decision support tools – NSF supports basic research on how humans impact climate and other natural systems, how people respond to changing natural conditions, and how human and natural systems engage in complex interactions across multiple spatial, temporal, and

organizational scales. Support will continue for basic research on decision making under uncertainty associated with climate change, as well as for developing and testing decision-support tools that can be used by stakeholders to improve their decision making processes.

USGCRP Funding by Program Component Area

(Dollars in Millions)

	FY 2012 Actual	FY 2012 Enacted/ Annualized FY 2013 CR	FY 2014 Request
Integrated Observations	$81.36	$81.36	$78.00
Multidisciplinary Earth and Human System Understanding	198.19	198.19	194.85
Integrated Modeling	39.31	39.31	37.78
Science of Adaptation and Science to Inform Adaptation Decision	10.00	10.00	15.75
Communication and Education	4.50	4.50	-
Total	**$333.36**	**$333.36**	**$326.38**

Totals may not add due to rounding.