NSF-WIDE INVESTMENTS

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

OVERVIEW

In the spirit of OneNSF and in response to the President's Materials Genome Initiative and Advanced Manufacturing Partnership, the Cyber-enabled Materials, Manufacturing, and Smart Systems (CEMMSS) framework includes a number of related science and engineering activities – breakthrough materials, advanced manufacturing, and smart systems – across the Foundation. NSF recognizes that substantive advances in the next generation of discoveries in any single CEMMSS domain are entirely dependent upon complementary advances in the other two domains. CEMMSS is a new investment framework that will pursue solutions to three major questions:

1) What is the scientific basis for designing, manufacturing, and deploying cyber-enabled smart systems and the new materials from which they will need to be composed?
2) Who will have the multidisciplinary skills to design, build, and implement these materials and systems? and
3) What gives us confidence that these materials and future systems will predictably perform as designed once transitioned into practice?

Materials science, advanced manufacturing, robotics, cyber-physical systems, and innovation are not new research topics for NSF. Over the years, elements of these areas of research have been included in core and cross-cutting programs in the Directorates for Computer and Information Science and Engineering (CISE), Engineering (ENG), Mathematical and Physical Sciences (MPS), Biological Sciences (BIO), and the Office of Cyberinfrastructure (OCI). Bringing these investments together under one umbrella emphasizes the important interdisciplinary research to be undertaken and the potential for interaction among various research ideas, boosting scientific discovery and the economic future of the Nation. The research needed to make progress includes the following three areas:

1. Breakthrough materials. New integrated computational, experimental, and data informatics tools are needed to create advanced materials; seamlessly integrate improved predictive modeling algorithms of materials behavior into product design tools; and design frameworks that enable rapid and holistic design engineering. Research areas include:

- Discovery and development of materials with multi-functional capabilities;
- Predictive algorithms that have the ability to model behavior and properties across multiple spatial and temporal scales;
- Computational mining of the genomic data from diverse biological systems to identify inspirations for the design and synthesis of new materials with defined properties and capabilities;
- Predictive synthetic biology to design new nanomaterials, particularly based on photosynthesis and other biological processes;
- Improved physics-based models that can be used in advanced techniques, such as high-throughput combinatorial processing;
- New synergies between experimental and computational methods; and
- Cyberinfrastructure for materials to facilitate multi-disciplinary communication, to accelerate the rate of innovation by sharing materials properties data, and to develop modeling and simulation tools that enable the creation of advanced materials with specific parameters.

2. Advanced manufacturing. This area focuses on product and process design, including novel features, functions and desirable attributes, increased quality and reliability, greater customization, production speed, productivity, reconfigurability, resource optimization, and sustainability. Research areas include:

- Robotics, autonomous systems, the role of simulation and modeling, and the role of big data from multiple sources to assist in computer-integrated and cyber-based manufacturing;
- Dynamic behavior of manufacturing and supply chain operations for more efficient and responsive production and distribution;
- Improved flexibility in interface protocols, interoperable applications and service architectures for advanced manufacturing;
- Novel paradigms for reconfigurable, evolvable, adaptive nano-hardware architectures, and the use of heterogeneous systems that can dynamically change via software mechanisms capable of combating error-prone devices at the nano-scale;
- More adaptive, responsive applications that are made possible by intelligent computation and communications; and
- Optimizations of low-power, self-calibrating, and inexpensive cyber systems.

3. Smart systems. New algorithms, materials, control schemes, user interfaces, communication protocols, and devices will be required to produce the physical world transducers and autonomous actuation devices needed for engineered systems to perform smartly in dynamic environments. Research areas include:

- Systems technology frameworks to support networked cyber-physical systems with built-in assurance of their critical properties, including safety and security, and correct, timely performance of their intended functions;
- Rigorous, systematic, scalable, and repeatable design, development, verification, and validation methods, particularly to integrate design, evolution, and certification and reduce the cost of including (or modifying) new Information Technology (IT)-based capabilities in products for public use;
- Development of the next generation of robotics to advance the capability and usability of such systems and artifacts and to encourage existing and new communities to focus on innovative application areas;
- Advances in extracting information from diverse inputs, including the continuous streams of data generated by embedded physical and chemical sensors, to provide timely and critical input into control loops that must make decisions and take actions in real time; and
- Fundamental cognitive and behavioral science needed to make devices that are trustworthy and will be effectively used by people in the U.S. and in markets around the world, as well as the economic, social, and decision science needed to understand adoption and deployment.

Why NSF? NSF is unique among federal agencies because it supports foundational academic research in computer science, engineering, the physical and biological sciences, and education; has long experience in developing and implementing interdisciplinary programs across these fields; and invests in innovation and transition of discoveries into practice. To accomplish the vision of cyber-enabled smart systems and the new materials from which they are composed, increasingly complementary and interdisciplinary research challenges need to be addressed. Each system conceived and developed at the intersection of these domains must evolve under both the constraints and degrees of freedom that each one contributes. Interdisciplinary advances are necessary to make progress in scientific and engineering foundations and for the emergence of novel smart systems application solutions.

Goals

The CEMMSS framework will focus on activities in three tracks – science and engineering, education and workforce, and cyberinfrastructure. The goals of the three tracks include:

1. *Science and engineering*: Establish a scientific basis, a codified knowledge base, and shared principles for designing, manufacturing, and deploying cyber-enabled, smart engineered systems.
2. *Education and workforce*: Educate a cadre of high caliber disciplinary and interdisciplinary researchers and develop a vibrant workforce so as to ensure a pipeline of talent and a growing community in this critical area.
3. *Cyberinfrastructure:* Develop the infrastructure that can be used to discover, test, refine, validate, and approve materials, designs, and manufacturing and development methods for smart engineered systems.

Approach

The interaction of research ideas that is promoted by CEMMSS multiplies their impact across multiple research communities. Bringing together researchers focused on breakthrough materials, advanced manufacturing, and smart systems will increase collaboration and communication among these research communities leading to enhanced disciplinary research, as well as more 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. While hints of what is possible are already apparent, 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.

Programmatic. To generate new capabilities with meaningful impact, NSF must develop a portfolio that coordinates and synchronizes activities across the three main areas – breakthrough materials, advanced manufacturing, and smart systems – and allows interdependencies and common research elements to surface and be exploited in each subsequent stage of the evolution of the program.

Organizational. An internal working group (WG) will be charged in FY 2012 to develop CEMMSS activities and implement the suite of activities over the next four years. The WG will also be asked to develop a set of metrics by which program progress can be evaluated over time.

Scope. Pair-wise connections already exist at NSF, e.g., between robotics and manufacturing; materials and manufacturing; cyber-physical systems and robotics; and robotics and the biological sciences. Activities that aim to bring together all of these research areas will be critical if this ambitious program is to succeed. NSF will hold workshops and request white papers for the associated research areas to contribute to the development and evolution of CEMMSS program solicitations and dear colleague letters. In addition, NSF will develop partnerships with other agencies and with industry to leverage CEMMSS investments.

INVESTMENT FRAMEWORK

FY 2012

This initiative aligns well with the President's commitment "to winning the future through investments in innovation, education, and infrastructure," which he launched in June 2011 through the Advanced Manufacturing Partnership[1], National Robotics Initiative[2], and Materials Genome Initiative[3], all activities in which NSF participates. The President's Council of Advisors on Science and Technology (PCAST)

[1] http://www1.eere.energy.gov/industry/amp/
[2] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641&org=CISE
[3] http://www.whitehouse.gov/sites/default/files/microsites/ostp/materials_genome_initiative-final.pdf

recently focused on these national priorities in the "Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology"[4] report.

To make progress across the three tracks, in FY 2012, the CEMMSS WG will leverage existing research and education programs, as well as initiate community development activities, as described in more detail below.

Science and engineering track. In the first year, the CEMMSS WG will start by developing a baseline derived from portfolio and gap analysis. The analysis will provide a better understanding of the state of the research and will identify the areas that need increased emphasis. The CEMMSS WG will also summarize the recommendations made in recent reports from the PCAST and National Academy of Sciences (NAS) on materials, advanced manufacturing, cyber-physical systems, and robotics. Based on the recommendations in these reports and the portfolio analysis carried out by the WG, it will develop a multi-year plan for CEMMSS with associated milestones and performance measures.

In FY 2012, CEMMSS support includes the NSF investments in Cyber-Physical Systems (CPS) ($31.5 million), the National Robotics Initiative (NRI) ($20.83 million), as well as activities in core research related to advanced manufacturing, robotics, and materials. NRI will provide U.S. leadership in science and engineering research and education aimed at the development of next generation robotics, conceived as co-robots that work beside, or cooperatively with people, increasing their productivity, performance, and safety, especially in manufacturing, while support for basic research in robotics will enable new functionalities and provide the next-generation of products and services for various industries. A number of pilot programs in materials and engineering will also start in FY 2012, including Designing Materials to Revolutionize and Engineer the Future (DMREF), involving MPS and ENG ($10.0 million).

To jumpstart the CEMMSS activity within the research communities, white papers will be requested, webinars and workshops will be held, and Early-Concept Grants for Exploratory Research (EAGER) awards will be made. A communications plan will also be developed and will include a website with links to relevant programs, information, and activities. During the year, the CEMMSS WG will present their recommendations for the plan to relevant NSF senior management as well as to directorate advisory committees to solicit their input.

Education and workforce track. Science and engineering education needs to be transformed to embrace the data- and computationally- intensive components of smart systems. In particular, changes in undergraduate and graduate education will be necessary to ensure a pipeline of a talented and vibrant workforce. In FY 2012, the CEMMSS WG will engage in portfolio and gap analysis; develop a logic model and an appropriately rigorous evaluation methodology; and begin to collect baseline data. NSF will support community workshops specifically focused on the educational aspects of materials, manufacturing, and smart systems. The CEMMSS WG will also partner with existing NSF education working groups, for example, CAREER, Integrative Graduate Education and Research Traineeships (IGERT), Computing Education for the 21st Century (CE21), and Cyberlearning Transforming Education (CTE), to further emphasize smart systems research and education throughout the Foundation.

Cyberinfrastructure track. Many reports on cyber-enabled materials, manufacturing, and smart systems establish the need for cyberinfrastructure to accelerate discovery and innovation. The CEMMSS WG will focus on developing partnerships with other NSF working groups, including Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21), to better align with their activities and to better understand how CEMMSS discoveries, materials, and systems might be transitioned into practice.

[4] http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf

FY 2013 Request

Focusing on the knowledge base developed in FY 2012, the CEMMSS WG will create a coordinated set of solicitations and dear colleague letters that cross over two or more areas, expanding on what has been accomplished to date. For example, one new activity will include a focus on the science and engineering foundations of 21st century smart systems and materials. This new program will emphasize, mid-scale team-based interdisciplinary research, building the knowledge base needed to make progress in cyber-enabled materials, manufacturing, and smart systems, with opportunities for transitioning discoveries into practice. In addition, the DMREF program piloted in FY 2012 will evolve to new interdisciplinary areas of cyber-enabled materials ($32.0 million). In FY 2013, CEMMSS will continue to support investments in NRI ($27.50 million) and CPS ($43.0 million).

To make progress across the three tracks, CEMMSS WG activities in FY 2013 will include:

- Workshops that bring together researchers from the different communities to develop grand challenge research problems in the overarching CEMMSS areas with clear outcome goals and performance measures. In addition, the associated big data and cyberinfrastructure components necessary for making advances in cyber-enabled materials, manufacturing, and smart systems will be identified.
- The first CEMMSS Principal Investigator (PI) meeting will be held to provide opportunities for building new interdisciplinary research communities.
- CEMMSS summer schools and new curricula for undergraduate and graduate students in engineering, computer science, materials, and biological sciences will be developed and deployed. To measure the impact of these efforts, the working group will continue the rigorous evaluation methodology started in FY 2012.
- Industry partnership development, interagency activities, and joint programs will be increasingly emphasized in order to leverage NSF investments.

FY 2014 – FY 2016

As the CEMMSS investment matures, 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. The CEMMSS WG will develop a coordinated set of integrated innovative solicitations that include all three focus areas and that encourage foundational and interdisciplinary research across them. For example, in FY 2014, CISE and ENG, working together with BIO, MPS, and OCI, will replace the Cyber-Physical Systems solicitation with one on CEMMSS to discover commonalities, leverage new knowledge, and transform fields. Starting in FY 2014, NSF plans to invest in center-scale multidisciplinary research across the CEMMSS activities.

NSF has worked with other agencies, such as the National Institute of Standards and Technology (NIST), the National Institutes of Health (NIH), the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Agriculture (USDA), 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. By developing partnerships with other agencies, NSF will pave the way to an interagency CEMMSS program starting in FY 2014 or FY 2015.

CEMMSS Funding

(Dollars in Millions)

Directorate/Office	FY 2012 Estimate	FY 2013 Request
BIO	$3.00	$5.00
CISE	50.00	91.00
ENG	56.00	110.42
MPS	32.15	50.00
OCI	0.50	1.00
Total, NSF	**$141.65**	**$257.42**

Totals may not add due to rounding.

EVALUATION FRAMEWORK

Using portfolio analysis tools, a baseline of NSF research and education activities in CEMMSS will be established. Metrics will be identified to measure progress across the three tracks. Possible indicators include:

- For science and engineering – increase in 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.

Based on the program goals and associated metrics, a plan will be developed by the start of FY 2013 for the following four years (FY 2013 through FY 2016) with milestones, subgoals, and evaluation plans at each stage. Yearly program assessments will be carried out by the CEMMSS WG and presented to NSF senior management.

OneNSF INVESTMENTS
CYBERINFRASTRUCTURE FRAMEWORK FOR 21ST CENTURY SCIENCE AND ENGINEERING (CIF21)

OVERVIEW

NSF has a long history of investments in cyberinfrastructure. Since the 1960s, NSF has sought to develop the foundational cyberinfrastructure technologies needed to maintain U.S. prominence in science and engineering (S&E). The shaping of CIF21, a new approach to managing and investing in cyberinfrastructure development and deployment, began in 2007 when NSF formed the Advisory Committee for Cyberinfrastructure (ACCI). Through its six task forces, the ACCI developed recommendations for future directions in the areas of bridging campuses, data and visualization, grand challenges, high-performance computing, learning and workforce development, and software. The recommendations, which are contained in task force final reports formally accepted in 2011, serve as a basis for CIF21 activities.

Goals

CIF21 will promote new research opportunities and partnerships across all S&E fields by providing integrated and scalable cyberinfrastructure that will leverage existing and new components. This includes identifying common methods and approaches in software, data, networking, cybersecurity, and advanced computing infrastructure, and leveraging the substantial existing cyberinfrastructure activities and efforts underway across NSF. CIF21 will ensure long-term sustainability for cyberinfrastructure by creating communities of users and providers and will also promote the development of a scientific workforce that has appropriate skills and training to develop, deploy, and use cyberinfrastructure. This will result in a greater number of scientific communities that can effectively use cyberinfrastructure to conduct research and education.

A new coordinated NSF-wide strategy for Advanced Computing Infrastructure (ACI) was developed in early FY 2012 as a key component of the CIF21 framework. This strategy seeks to position and support the entire spectrum of NSF-funded communities at the cutting edge of advanced computing technologies, hardware, and software. It also aims to move away from an approach centered on procurement and promote a more complementary, comprehensive, and balanced portfolio of advanced computing infrastructure and programs for research and education to support multidisciplinary computational and data-enabled science and engineering that supports the entire scientific, engineering, and education community. This approach is consistent with the recent PCAST review of NITRD (*PCAST, December 2010, "Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology.")*

Approach

CIF21 is governed by a steering committee, consisting of NSF assistant directors, which provides strategic direction for CIF21 activities. In FY 2012 this committee established a CIF21 Strategy and Leadership Group (SLG), with representation from each directorate and office; OCI provides both technical and administrative support. The SLG provides guidance for a portfolio of programs, including cross-directorate (common) and single directorate (unique) programs. It has four major areas of responsibility: 1) Development of solicitation guidance for common CIF21 programs; 2) coordination of common and unique CIF21 activities; 3) convening and charging of writing groups for common CIF21 programs; and 4) programmatic planning and budgeting for CIF21. The SLG has chartered initial writing groups in software development, data services, and computational and data-enabled science and

engineering (CDS&E). These groups will coordinate existing and new NSF programs, perform gap analyses, and develop new programs to fill the gaps.

INVESTMENT FRAMEWORK

FY 2012

FY 2012 is the first year of CIF21. Investments in FY 2012 begin to build the CIF21 portfolio by focusing on building new communities of developers and users of digital environments and beginning to make awards that develop core data and computational technologies to bridge scientific communities. This will position NSF to specify requirements for data systems and computational requirements and to further develop and integrate robust software resources in FY 2013.

Community Building

- The EarthCube program, involving GEO and OCI, is a multi-year initiative to support earth-system science. Early-Concept Grants for Exploratory Research (EAGER) and supplement awards are being used to develop concepts. A community-building event will be held mid-year and additional awards will be made in summer/fall 2012. OCI is providing $2.0 million and GEO is providing $4.0 million in support for FY 2012.
- The existing Research Coordination Networks (RCN) solicitation, supported by BIO, EHR, GEO, MPS, SBE, OPP, OISE, and OCI, has been expanded to involve two additional directorates, CISE and ENG.

Integration

- The Software Infrastructure for Sustained Innovation (SI^2) program involves BIO, ENG, MPS, and OCI. Its goal is to support the further development of existing scientific software to create tools that can be useful to broader communities. A new component of SI^2 is initiation of an Institutes track to establish center-scale awards of approximately $5.0 million per year, each, that bring together tools, data, and computational resources to advance grand challenge science goals. A novel, multi-stage process is being developed that will be science driven, risk-managed, and promote cross-disciplinary collaboration.
- The SLG is forging partnerships with other cyberinfrastructure efforts at the Foundation, including those involving construction of large facilities and the cyberinfrastructure track of the Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS) OneNSF investment.

Data and Computational Technologies

- The BigData Senior Steering Group (BDSSG) of the Networking and Information Technology Research and Development (NITRD) program, will launch a Core Techniques and Technologies for Advancing Science and Engineering (BIGDATA) solicitation involving CISE, MPS, and OCI at NSF, as well as other agencies, including several institutes at NIH. The program aims to develop new approaches and tools to address the challenges of managing, analyzing, visualizing, and extracting useful knowledge from large, diverse, distributed, and heterogeneous data sets. This includes the development of data analytics, algorithms, and statistical and mathematical methods.
- A new program in computational and data-enabled science and engineering in Mathematical and Statistical Sciences (CDS&E-MSS) is established jointly with OCI and the Division of Mathematical Sciences (DMS). Workforce development and community needs workshops are planned in order to determine unmet needs in the mathematics and statistical science communities with respect to computational resources.
- Multiple efforts have been initiated in the area of data cyberinfrastructure. A joint effort between MPS and OCI addresses long term data storage, management, and access issues. SBE and OCI have

a joint program in the area of metadata for long-standing large scale social science surveys META-SSS) that seeks to enhance data access and usability, and to facilitate interdisciplinary analyses. OCI, MPS, GEO, and the European Union (EU) are coordinating on a call for international data cyberinfrastructure proposals. The new OCI DataNet solicitation addresses the data cyberinfrastructure needs of multidisciplinary data-intensive researchers.

FY 2013 Request

Community Building

- The EarthCube program will develop additional community efforts and prototype systems for integrating scientific communities with respect to data, modeling, and analysis. New areas of common interest and joint solicitations will be developed with BIO, CISE, ENG, MPS, and OPP to create components of EarthCube. OCI will provide $5.0 million and GEO will provide $12.0 million to support EarthCube in FY 2013.
- The RCN will continue to build digital communities with new scientific communities, including OPP. Some of the evolving prototypes may transition to operational RCNs. International collaboration on data curation, standards, and access will be explored.

Integration

- Under the SI^2 program, it is expected that the first software institute will be established. This center will serve as a resource for software development to scientific communities. GEO and some of the large facility construction projects are expected to participate. Likely collaborators include the large telescopes, the High Energy Physics Center, the National Ecological Observatory Network, and the Ocean Observatories Initiative. A joint effort on exascale software development with the Department of Energy is being explored.
- NSF's large facilities are in many cases developers and users of significant cyberinfrastructure resources. A well attended breakout session at the spring 2011 Annual Large Facilities Operations workshop highlighted the concerns related to data and cybersecurity. A CIF21 WG consisting of program directors of large facilities is being considered. This will focus on common cyberinfrastructure needs of the major facilities.
- Efforts will continue to support cyberinfrastructure development for materials research in collaboration with the CEMMSS investment.

Data and Computational Technologies

- The Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIGDATA) program will be expanded to involve BIO, ENG, and SBE at NSF, as well as additional NITRD agencies. The initiative will expand to include education and workforce development activities, as well as competitions and prizes in areas relevant to big data challenges.
- OCI data cyberinfrastructure programs will include additional solicitations on data interoperability, storage, policy, and integration with increased international coordination.
- Large facility data requirements will be considered in the data storage, management, and access efforts. Joint solicitations to include BIO, ENG, and GEO, in addition to MPS and OCI, are planned.

Sustainability

- Efforts in programs across the portfolio of CIF21 programs will ensure development of the workforce required to sustain the Nation's cyberinfrastructure.

FY 2014 – FY 2016

In FY 2014 through FY 2016, it is expected that many of the development efforts will begin to produce practical tools for deployment and use by research communities. Relying on a spiral development approach, promising areas for additional investment will be considered by the Strategy and Leadership Group and AD Steering Committee for further development. Also, programs will begin to experiment with different funding approaches, including grand challenge prizes.

EarthCube is expected to develop a suite of tools to integrate the geoscience communities, and many are expected to become available and adapted for use by other scientific communities outside the geosciences.

The SI^2 program will mature by supporting a total of 2-3 institutes that will serve as a resource to software developers in academic communities, as well as a number of smaller software projects. These combined efforts will expand the network and library of accessible and useable software tools.

The Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIGDATA) solicitation will include education and workforce development activities, as well as competitions and prizes in areas relevant to big data challenges.

OCI data cyberinfrastructure programs will provide increasing levels of access to federally funded scientific data for national and international scientific and engineering collaborations.

Research to understand and solve issues of cyberinfrastructure sustainability, including shared governance, succession, and management of technological trajectories will be supported. The transition to practice focus and efforts in OCI help bridge the gap from idea to deployment. Awards will ensure that tools are created for scientists and that scientists develop skills and relationships with industry to create a full cycle of innovation for cyberinfrastructure.

CIF21 Funding

(Dollars in Millions)

Directorate/Office	FY 2012 Estimate	FY 2013 Request
BIO	$2.00	$4.00
CISE	12.00	16.00
ENG	5.00	11.00
GEO	4.00	12.00
MPS	11.50	19.55
SBE	5.50	6.00
OCI	23.00	32.03
OISE	-	1.00
OPP	4.00	4.50
IA	11.00	-
EHR	-	-
Total, NSF	**$78.00**	**$106.08**

Totals may not add due to rounding.

EVALUATION FRAMEWORK

The CIF21 investment will be evaluated by the Strategy and Leadership Group (SLG) in the short term and by an independent contractor in the long term.

In the short term (FY 2012 – FY 2013) the SLG, in concert with its writing groups, will be performing assessments to inform decision making at the close of each fiscal year. The writing groups will be evaluating directorate and office efforts and solicitations that support ongoing discipline-driven cyberinfrastructure to assess how these efforts can be coordinated with existing and planned CIF21 programs. These assessments will inform decisions concerning the overall CIF21 portfolio balance as well as provide a basis for suggested changes to other directorate and office programs involving cyberinfrastructure to focus on common approaches and leverage CIF21-specific programs.

Prior to the end of FY 2013, the investment-wide assessment will be shared with both the AD steering committee as well as the external advisory committee, ACCI, in order to gain insight in strategic directions. Adjustments to existing programs and formulation of plans will result. A proposal for an independent evaluation by an outside party may be initiated before the end of FY 2013 to help further define data needs with respect to overall portfolio evaluation.

In FY 2014 or FY 2015 a summative evaluation will be carried out through an outside party. The evaluation will examine outcomes of awards to establish the degree to which the goals of scalability, integration, and sustainability have been achieved, as well as the degree to which the cyberinfrastructure has supported new scientific discoveries. Specific metrics might include the value of CI tools associated with new discoveries, the level of use of new coupled systems, the degree of coupling of existing systems, disciplinary diversity of system users, and perceptions of the level of CI support in various communities. The impact of CIF21 in computing and cyberinfrastructure programs will extend beyond the programs directly affiliated with CIF21, so it will not be appropriate to compare programs under the CIF21 framework with those outside it.

OneNSF INVESTMENTS
E^2: EXPEDITIONS IN EDUCATION

OVERVIEW

Expeditions in Education (E^2) is an NSF initiative to infuse cutting-edge science, engineering, and innovation into the preparation of a world-class scientific workforce for the twenty-first century, and to ensure that all of NSF's education and workforce investments are drawing on the latest educational theory, research, and evidence. The initiative will draw in new ideas on the best and most exciting of NSF-supported scientific advances and knowledge.

The resources committed to E^2 in FY 2013 will be used to develop pilot activities among all NSF directorates and offices to engage, empower, and energize learners in science, technology, engineering, and mathematics (STEM). This initiative is planned to last five years with planning beginning in FY 2012; pilot activities will be launched in FY 2013; and further shaping and definition will occur in FYs 2014-2017. Additional focus areas may emerge over time.

Goals

E^2 activities will integrate STEM education research and development to improve learning in science and engineering disciplines and capitalize on the scientific assets across NSF to bring engaging new evidence-based practices, content, knowledge, and real-world applications to more learners.

Scope

The E^2 initiative brings the educational and research missions of NSF together to consolidate, leverage, and focus efforts to "move the dial" towards achieving important national goals in STEM education and human capital development. E^2 encompasses all of the science and engineering fields that NSF funds to develop approaches to engaging all citizens in STEM in both formal and informal settings. As such it involves multiple directorates and offices in each of the three focus areas: Transforming Undergraduate STEM Learning through Science and Engineering, Learning and Understanding Sustainability and Cyberlearning, Data and Observations of STEM Education. E^2 is a research-intensive activity and the goal for all components must be to address a challenge in STEM learning or education using current or emerging areas of science. This will require disciplinary and interdisciplinary collaboration among cognitive scientists, STEM education researchers, and disciplinary researchers.

Organizational Structure

The E^2 initiative will be managed jointly, with the research directorates/offices leading areas in their disciplines and EHR providing coordination, evidence-based practices, and evaluation expertise. Research directorates and offices will participate in E^2 by providing funds to jointly support the R&D projects and by re-defining ongoing R&RA-based education efforts to fit within E^2 and consolidating efforts where appropriate and advantageous. To facilitate its coordination and evaluation role, EHR will make available expert staff liaisons to link to other directorates, divisions, and offices.

A Dear Colleague Letter will be issued in FY 2013 to invite proposals for each of the three focus areas, calling attention to the programs across NSF that are part of the portfolio. Within each program announcement for this set, the E^2-specific expectations and language will be included. Review and award decisions will be undertaken as a joint effort among all participating directorates and offices. EHR will match financial and staffing commitments made by the other directorates and offices for FY 2013 E^2 activities. All projects funded across the Foundation within the E^2 initiative in FY 2013 will become part of a phase-one E^2 portfolio that will be managed jointly.

This portfolio will be subject to a set of common metrics, common data collection and reporting standards, and a comprehensive rigorous evaluation. A set of E^2 draft guiding principles is under development in FY 2012 to define what will constitute an E^2 activity. These principles will be refined over time as the E^2 activity matures, and will be central to the Dear Colleague Letter.

Approach

The Nation's capacity for innovation and global competitiveness depends on a science and engineering workforce well prepared for the twenty-first century and a citizenry that is science-literate. This means ensuring that learners have access to current science and opportunities to glimpse the frontiers. E^2 investments will leverage two important assets of NSF:

- Research that is transforming the frontiers of science and engineering and leading to innovation for society; and
- Research and development to improve STEM teaching and learning for the twenty-first century.

The E^2 vision is to *engage*, *empower*, and *energize* America's populace with STEM and to help create tomorrow's STEM leaders. *Engagement*, in part through the exciting content of NSF-funded research programs, will bring learners at all levels, in both formal and informal settings, into evidence-driven educational environments and settings. There they can be *empowered* through evidence-based instruction, and innovative curricular offerings. NSF-wide educational programs will provide tested models for potential national-scale transformation to *energize* tomorrow's STEM workforce, creating deeper levels of knowledge and more dynamic pathways to economic innovation across U.S. society.

Over time, E^2 will transform NSF's education portfolio into a coordinated and strategic set of investments spanning: basic research and theory about STEM learning; design, implementation, and assessment of models for STEM learning and workforce development; evidence-based models for building institutional and human capacity; and innovative approaches to adaptation and scale-up. Collaboration and coordination among all directorates and offices will lead to a systemic and coherent NSF approach to improved learning in the science and engineering disciplines that capitalizes on the scientific assets across NSF. In addition to the programmatic activity of E^2, the re-envisioning of the EHR Directorate proposed for FY 2013 is intended to provide a full set of core investments in STEM education R&D.

The E^2 approach will evolve in three stages: conceptualization and planning (underway in FY 2012); pilot effort in three focus areas (FY 2013); longer-term structure, evaluation, and expansion to enhance NSF encouragement of cross-disciplinary science in STEM education and learning (FYs 2013-2017).

INVESTMENT FRAMEWORK

FY 2012

In FY 2012 planning efforts are underway, beginning with establishing the baseline portfolio of NSF investment in the three E^2 focus areas (undergraduate STEM education, sustainability, and cyberlearning/data). Town hall meetings, focus groups, and webinars will be held internally and with the PI community to determine interest and capacity in the field and the agency to sharpen the focus areas. An investment framework and operational roadmap for E^2 in FY 2013 will be developed by a committee of program officers.

Evaluation planning also will begin in FY 2012.

FY 2013 Request

In FY 2013, E^2 will comprise three initial focus areas:

1. ***Transforming Undergraduate STEM Learning through Science and Engineering***
   This focus area will bring evidence-based practices in teaching, learning, assessment, and research to undergraduate science and engineering education across disciplines, and will enrich the undergraduate curriculum so that all students can have access to inspiring and authentic science learning opportunities. Goals include actively engaging students in the science and engineering enterprise to prepare them either as practitioners or science-savvy citizens, and the initiative will emphasize undergraduate student research and preparation for graduate studies in STEM. As solicitations are developed, principal investigators (PIs) will be asked to frame a major question that they will pursue through their research, such as "How can introductory courses in the physical sciences (both disciplinary and interdisciplinary) be effectively re-imagined and re-designed to put undergraduate research experiences at the center, as a means of enabling more students to continue in STEM and perhaps consider graduate school?" Parallel efforts by STEM education researchers will build theory and knowledge about the impact of such experiences on learners and faculty. An emphasis will be placed on programs that have the potential to be scaled up nationally and potentially affect national statistics for STEM student retention and other important outcome indicators. This will build on several core programs in EHR, such as Transforming Undergraduate Education in STEM (TUES), STEM Talent Expansion Program (STEP), and other learning programs across the agency. For example, the Directorate for Biological Sciences (BIO) will develop a portfolio of investments to catalyze and support the implementation of improvements in undergraduate biology education through the Transforming Undergraduate Biology Education (TUBE) program.

2. ***Learning and Understanding Sustainability***
   In this focus area we will build on current investments in Science, Engineering and Education for Sustainability (SEES) about sustainability. SEES programs, including the Sustainability Research Network (SRNs), are creating new interdisciplinary learning experiences for graduate and undergraduate students as well as literacy programs. The ongoing Climate Change Education program (CCE) that is directed toward K-12 levels will be included in this portfolio beginning in FY 2013. Within this E^2 focus we will draw in new ways on the assets and science underway in NSF facilities and centers to bring meaningful data and current scientific practice to learners. Participating programs will reframe solicitations to ask PIs to identify a major learning question that they will pursue in the area of sustainability education (e.g., How do students develop systems thinking skills? Does undergraduate student participation in sustainability research lead to greater interest in STEM careers? Can research centers that focus on sustainability effectively integrate education and public outreach components and demonstrate impact on learning?). This element will place particular emphasis on the role of interdisciplinary science and engineering in transforming learning outcomes at the national scale, with strong partnership between EHR and participating research directorates and offices.

3. ***Cyberlearning, Data, and Observations for STEM Education***
   Modern research in science and engineering generates substantial volumes of data. Increasingly, these data are dynamic and are delivered in real-time through observatories, such as the Ocean Observatories Initiative (OOI) and the National Ecological Observatory Network (NEON), and many other large facilities and major research centers supported by NSF. Most of these facilities and centers invest in education and outreach, but the activities are not always fully integrated into NSF education efforts. NSF-funded Research in cyberlearning, funded in several NSF directorates, is advancing learning using tools for networking, visualization, and other capabilities. For example,

BIO will likely support this focus area to increase its investment in education/workforce development activities at its Centers for Analysis and Synthesis, NEON and in major Advances in Biological Informatics (ABI) investments. Leveraging the data generated by major facilities and centers with the advancements being made in cyberlearning research has the potential to greatly enhance the STEM learning experience. For example, cyber-enabled simulation and data-intensive virtual labs at the secondary and undergraduate level could be developed with the integration of data from major NSF facilities. Additionally, mechanisms could be developed for the submission of samples gathered in K-12 or informal science education settings by scientists with the data processed using instruments based at NSF-funded facilities and university labs. The overall goal of this activity is to address the many questions associated with how STEM learning can be enhanced and how new content can be introduced using these new cyberlearning resources and tools. For example, "what are the premier approaches to pedagogy and faculty development for the "connected" age, and how can these technologies be used to advance a diverse workforce for science and engineering, build a science-savvy populace, or derive value from citizen science?

The first phase of investments, totaling $49.0 million, within the E^2 frame will begin in FY 2013.

FY 2014 – FY 2017

By FY 2017, as a result of increasing scope and experience with E^2, the following specific outcomes are anticipated:

- As noted in the EHR chapter, the EHR portfolio is being reframed to have clear emphasis on a set of core research and development (R&D) activities that provide the intellectual foundation for STEM learning and a set of highly-successful and strongly-leveraged E^2 partnerships with the research directorates and offices.
- EHR's STEM education and workforce development portfolio is distinguished from that of other agencies, particularly the U.S. Department of Education, by an emphasis on the learning opportunities in frontier science and the emerging practice of science for the twenty-first century. The STEM education and workforce programs across NSF are conceptualized and managed in partnership with EHR.
- NSF's scientific staff includes a set of individuals, based both in EHR and in other parts of the agency, with formal expertise, training, or experience at the national level in STEM education learning research.
- The E^2 initiative will become the agency's signature vehicle for presenting a coherent and exciting set of opportunities in STEM learning investments with an emphasis on well-evaluated learning outcomes for programs that have the potential to operate at the national scale. .

EHR, over the next five fiscal years, will include a stronger and more deliberate infusion of cutting-edge science, engineering, and innovation in all programs designed to prepare a world-class scientific workforce for the twenty-first century. E^2 also will lead to changes in the education investments made within NSF's research directorates and offices by enabling much stronger connections to the existing base of research and theory about STEM learning and stronger evaluation of STEM education activities lead by EHR.

Expeditions in Education (E^2) Funding

(Dollars in Millions)

Directorate/ Office	FY 2011 Actuals	FY 2012 Estimate	FY 2013 Request	Focus Area
BIO	-	-	$2.00	Transforming Undergraduate STEM Learning through Science and Engineering
CISE	-	-	4.00	Cyberlearning, Data, and Observations for STEM Education
ENG	-	-	1.00	Cyberlearning, Data, and Observations for STEM Education
GEO	-	-	12.00	$6M- Transforming Undergraduate STEM Learning through Science and Engineering, $6M- Learning and Understanding Sustainability
MPS	-	-	5.00	$2M- Transforming Undergraduate STEM Learning through Science and Engineering, $3M- Cyberlearning, Data, and Observations for STEM Education
SBE	-	-	1.00	Cyberlearning, Data, and Observations for STEM Education
OCI	-	-	1.50	Cyberlearning, Data, and Observations for STEM Education
OISE	-	-	0.50	Cyberlearning, Data, and Observations for STEM Education
OPP	-	-	1.50	Learning and Understanding Sustainability
IA	-	-	-	
EHR	-	-	20.50	$8M- Transforming Undergraduate STEM Learning through Science and Engineering, $8.17M- Learning and Understanding Sustainability, $4.33M- Cyberlearning, Data, and Observations for STEM Education
Total, NSF	**-**	**-**	**$49.00**	

Totals may not add due to rounding.

EVALUATION FRAMEWORK

A single evaluation and monitoring framework will be developed for the E^2 activity, with customization as appropriate underneath each focus area. The following are additional details about what activities will be undertaken each year.

FY 2012

- Establish the unifying goal and framework and clarify sub-goals within each focus area;
- Develop roadmaps and a logic model for each focus under the unifying framework;
- Identify metrics to be used in common across focus areas;

- Develop indices to estimate interdisciplinary scope;
- Align evaluation and monitoring processes with E^2 metrics; and
- Undertake feasibility studies for evaluation planning in **E^2** ***Cyberlearning, Data, and Observations for STEM Education*** focus area.

FY 2013

- Use roadmaps and logic models to determine implementation plans and activities;
- Establish evaluation contract for all E^2 activity;
- Assure that baseline data is collected for **E^2** ***Transforming Undergraduate STEM Learning through Science and Engineering*** focus area;
- Incorporate E^2 focus on undergraduate transformation in planning for FY 2013 NSF priority goal on undergraduate instruction as the evaluation baseline;
- Determine longer-term goals for E^2 impact on EHR and R&RA programs;
- Develop baseline data gathering plan for **E^2*****Learning and Understanding Sustainability*** focus area; and
- Launch evaluation studies of **E^2** ***Cyberlearning, Data, and Observations for STEM Education*** focus area.

FY 2014 – 2017

- Launch a comprehensive evaluation of impacts on NSF's undergraduate education investments;
- Continue long-term monitoring and focus area evaluations;
- Create a plan and begin implementation for studying impact on EHR programs and R&RA programs; and
- Refine E^2 investments based on data; and
- Launch evaluation of **E^2*****Learning and Understanding Sustainability*** focus area.

OneNSF INVESTMENTS
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] INSPIRE will strengthen NSF's support of interdisciplinary, potentially transformative research by complementing existing efforts with a suite of new, highly innovative Foundation-wide activities and funding opportunities.

Background

INSPIRE was announced in February 2011 in the NSF FY 2012 Budget Request to Congress, which included funding of $12.35 million in the Integrative Activities (IA) budget for new funding opportunities, to be augmented by co-funding from directorates and offices. 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 reauthorization of the America COMPETES Act, 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. INSPIRE directly supports NSF's strategic goal of *Transform the Frontiers* and performance goal T-1 (make investments that lead to emerging new fields of science and engineering and shifts in existing fields).

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.

> INSPIRE seeks to empower program officers to encourage and support bold, interdisciplinary projects. Program officers report that a variety of factors create pressure toward funding of lower risk, more conventional disciplinary choices. INSPIRE will provide financial incentives through co-funding and establish an expectation that NSF management will promote a bolder interdisciplinary and potentially transformative vision. INSPIRE will identify changes to NSF systems and training practices to enable and facilitate interdisciplinary activities.

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

> Existing NSF programs support potentially transformative interdisciplinary research through the agency's highly-regarded merit review process. INSPIRE seeks to increase NSF's support of

[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).

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.

Approach

Programmatic structure: INSPIRE will address its two goals through two programmatic tracks. Goal 1 will be addressed through Track 1, which focuses on how NSF supports science that may fall outside of the scope of existing NSF programs. In particular, Track 1 activities will encompass improvements in business practices, funding culture, training, and evaluation. Goal 2 will be addressed through Track 2, which will support the development of new funding opportunities and mechanisms that encourage the pursuit of novel, creative projects. New INSPIRE funding mechanisms will demonstrate to research communities the priority that NSF places on interdisciplinary and potentially transformative research.

Organizational structure: The NSF Office of Integrative Activities (OIA) will serve as the organizational lead for INSPIRE. The INSPIRE Working Group (IWG) has been established to guide INSPIRE's activities and is co-chaired by members from OIA and one of 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: By design, the scope of INSPIRE is broad. For Track 1 activities, all research directorates and offices will be engaged. In addition, the Office of Information and Resource Management (OIRM) and the Office of Budget, Finance, and Award Management (BFA) will be called on to address issues, e.g., business systems, performance plans, and novel forms of evaluation. For Track 2, each research directorate and office will participate by providing co-funds to support research projects. OIA will also provide matching support. Program officers from every research directorate and office will be 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.

INVESTMENT FRAMEWORK

FY 2011-FY 2012

- **(Track 1)** Based on report recommendations, input from NSF advisory committees, and feedback from NSF scientists and the research community, a detailed implementation plan for INSPIRE will be developed. Also in this timeframe, baseline data on NSF-supported IDR will be gathered for use in subsequent evaluation of the impact of INSPIRE funding mechanisms. Adjustments to NSF's eBusiness systems will be made to enable principal investigators (PIs) to identify multiple NSF programs of interest and to enable program officers to more easily collaborate on review of proposals shared across programs. Tracking of co-funded proposals and training of program officers on IDR review processes will also be enhanced.
- **(Track 2)** In November 2011, Dear Colleague Letter NSF 12-011[4] announced the pilot CREATIV (Creative Research Awards for Transformative Interdisciplinary Ventures) award mechanism, which will award the INSPIRE funds for FY 2012. CREATIV awards, with a maximum award size of $1.0 million, will generally be internally reviewed and will support bold high-risk IDR projects. In general terms, the new CREATIV funding mechanism will:

[4] www.nsf.gov/pubs/2012/nsf12011/nsf12011.jsp

  - Provide $12.35 million in FY 2012 in new centralized integrative activities (IA) funds, matched by directorates and offices, for approximately 30 new awards;
  - Target individuals and small groups of investigators;
  - Be open to potentially transformative ideas on any NSF-supported topic;
  - Use primarily internal NSF Program Officer merit review; and
  - Have aggressive outreach to the research community.
- **(Track 2)** Work will include planning and piloting an expansion of NSF INSPIRE to support awards up to the range of $2.5-$3.0 million for open, untargeted interdisciplinary research efforts that are larger in scale than CREATIV.
- **(Track 2)** Baseline data gathering for recipients and declined applicants of CREATIV awards and their institutions as part of INSPIRE evaluation will be initiated.

FY 2013 Request

- **(Track 1)** For the internal practices, systems, and evaluation, the INSPIRE IWG will continue to oversee implementation and gathering of data, with attendant AOAM budgetary needs, such as IT systems development and support, contract evaluations, and staffing.
- **(Track 2)** The INSPIRE activities will continue, supporting the second year of the CREATIV pilot and expanding to include larger "mid-scale" awards up to the range of $2.5-$3.0 million. Directorates and offices will co-fund INSPIRE awards funded through the integrated activities centralized funding source for a total INSPIRE FY 2013 budget of $63.0 million. In general, the new pilot INSPIRE "mid-scale" mechanism will be open to interdisciplinary proposals on any NSF-supported topic and use novel merit review mechanisms involving both internal and external review.

FY 2014 – FY 2016

The program will continue with the CREATIV and INSPIRE mid-scale award activities, and in FY 2014 will potentially introduce annual honorific Director's INSPIRE Awards. These are envisioned as highly prestigious awards for potentially transformative future research. Implementation of Track 1 activities will continue and broaden with time.

INSPIRE Funding

(Dollars in Millions)

Directorate/Office	FY 2011 Actuals	FY 2012 Estimate	FY 2013 Request
BIO	-	$2.00	$4.00
CISE	-	-	4.00
ENG	-	-	6.00
GEO	-	2.00	5.00
MPS	-	3.00	7.00
SBE	-	0.50	1.00
OCI	-	0.50	1.00
OISE	-	-	1.00
OPP	-	-	1.00
IA	-	12.35	31.00
EHR	-	-	2.00
Total, NSF	**-**	**$20.35**	**$63.00**

Totals may not add due to rounding.

EVALUATION FRAMEWORK

FY 2011-2012

The primary tasks for evaluation in these years are 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. Refresh the baseline of data that was collected in the 2007 Booz Allen Hamilton (BAH) proposer survey that was done as part of the IPAMM (Impact of Proposal and Award Management Mechanisms) study.[5] Conduct a feasibility study to do: (1) a short-term portfolio analysis, (2) a medium-term collection of data on outcomes from awards funded by INSPIRE and non-INSPIRE mechanisms, and (3) a long-term study plan for a possible impact study.

FY 2013

Baseline results from previous years will make it possible to:

- Analyze the INSPIRE portfolio of awards 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 transformative results are expected to provide helpful information.
- Analyze the results from program monitoring to determine whether results suggest that a rigorous impact evaluation is feasible.

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

OneNSF INVESTMENTS
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 help jumpstart a national innovation ecosystem, NSF has established the NSF Innovation Corps (I-Corps). 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 purpose of the I-Corps grant is to give 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 will be 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.

I-Corps has its genesis in many of the long standing innovation ecosystem programs. Most closely related to I-Corps is the 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) grantees and other institutions. Their complementary focus will spur the development of discoveries into innovative technologies through collaboration.

Both I-Corps and AIR are designed to strengthen the U.S. innovation ecosystem.

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 PFI, AIR, ERCs, STCs and SBIR/STTR, and will utilize additional support from NSF's 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. This support will be used to support entrepreneurship and innovation costs not normally supported by NSF.

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.

Scope

The Deshpande Foundation and the Kauffman Foundation have joined with NSF as founding members of the I-Corps public-private partnership. The Deshpande Foundation has been a strong supporter of innovation as a catalyst for positive change. Their support of I-Corps is their first partnership with NSF. The Kauffman Foundation has a history devoted to the support of entrepreneurship and entrepreneurship education, and their participation in I-Corps continues a rich relationship with NSF. For example, Kauffman provided invaluable advice and structure to our Innovation Fellows Post-Doctoral program, carried out in partnership with the American Society for Engineering Education (ASEE), in 2009 - 2010. Donations to the I-Corps program, which will leverage NSF appropriated funds, are currently estimated to be $1.20 million over the first two years.

Organizational Structure

NSF participation includes every directorate and NSF's Offices of Cyberinfrastructure and Polar Programs. The structure of I-Corps mirrors the NSF Director's vision of OneNSF, working together seamlessly in well-integrated and efficient ways across organizational and disciplinary boundaries. The internal review structure for the program involves a core of cognizant program officers in partnership with topic-specific program officers in each of the seven directorates and the Offices of Cyberinfrastructure and Polar Programs.

The I-Corps award mechanism includes funding, mentorship, and focused instruction in a hypothesis-driven approach to evaluating potential commercial viability. The I-Corps execution model will involve, at least initially, only a single solicitation. As NSF learns more about the community response to this program, NSF may modify the structure. Modifications might include award size, award duration, education, and mentorship requirements, just to suggest a few possibilities. For example, I-Corps awards could be increased to $75,000 from the current $50,000 to provide the team additional resources.

INVESTMENT FRAMEWORK

FY 2011-FY 2012

The Innovation Corps program is a key element in a series of NSF-supported programs concentrating on the innovation ecosystem. As explained in the Overview, 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. Of course, 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 will initially support up to 150 projects annually, at $50,000 each, for up to six months. The projects are submitted to NSF in response to NSF solicitation 11-560 and are reviewed under NSF's standard Grants for Rapid Response Research (RAPID) mechanism.

FY 2013 Request

The FY 2013 Request begins with the basic I-Corps structure developed in 2011-2012, the elements of which will not change substantively in 2013. In FY 2013, NSF anticipates supporting up to 375 awards at $50,000 each or 250 awards at $75,000 each. However, based on lessons we will learn in the execution of I-Corps in 2012, we may make some adjustments to the program. Potential adjustments include:

- The size and duration of the award;
- The extent to which all I-Corps team members are required to participate in all aspects of the educational elements of the program; and
- The specific providers of the educational content of the program.

Today, a hypothesis driven approach to evaluating technical and market viability is offered to all principal investigators. This approach has proven to be very successful and experience to date indicates it provides significant "value added" to the principal investigator (PI). While this curriculum is currently offered to the PIs by one university, the expectation is that other universities will be able to leverage this curriculum and integrate it into similarly productive curricula. We anticipate, in FY 2013, to offer 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. We also anticipate the establishment of regional I-Corps nodes, wherein the hypothesis driven innovation educational offerings for PIs and their teams would be developed and provided by the universities involved in these nodes.

FY 2014 – FY 2016

In the next three to five years following FY 2013, full-scale integration and dissemination of this program throughout the country, utilizing a regional hub model, is anticipated. The Foundation has purposely

restricted opportunities for providing the educational content of I-Corps to one institution for the first full year of the program (FY 2012), so that we can collect data from the FY 2011 and FY 2012 awardees and learn the advantages and disadvantages of that particular approach. 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 outyears, a substantial cohort of SBIR proposers and winners will develop from successful I-Corps recipients. NSF has already seen, in just the short time since launching this program in July of 2011, a significant number of SBIR proposals from among the I-Corps cohort.

I-Corps Funding

(Dollars in Millions)

Directorate/Office	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request
BIO	$0.05	$0.50	$2.00
CISE	0.20	2.50	6.00
ENG	0.45	2.50	6.00
GEO	-	0.25	1.00
MPS	0.20	1.00	1.30
SBE	0.05	0.50	0.50
OCI	-	0.25	1.00
OPP	-	-	0.75
EHR	0.10	-	0.30
Total, NSF	**$1.06**	**$7.50**	**$18.85**

Totals may not add due to rounding.

EVALUATION FRAMEWORK

I-Corps is the focus of 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 relevant 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.

Additional primary outcomes and milestones for the I-Corps program center on those 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, 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.

While the expectation is that the I-Corps program will have a positive impact on all these measures, establishing a realistic *timeline* over which these measures will change is more challenging. Because of 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 more than a one-year cycle to see real and substantive changes in these measures. For this reason, quantifiable *measures of progress* that indicate NSF is indeed likely to see improvements in the above metrics as a result of I-Corps investments need to be used**.**

With the exception of the performance target established in the priority goal, at this early stage in the development and evolution of I-Corps, it is difficult to assign specific numerical targets around the metrics listed above. However, there is the expectation that numerical growth in all these areas will take place as a result of NSF's I-Corps investments. Initial evaluations will focus on process measures primarily, such as level of interest and number of proposals, and the ability to expand the mentor network. More substantive indicators such as start-ups, SBIR submissions, and third party investment will become critical as the program matures. Being very analytical, but also realistic, about the measures of success and when it will be appropriate to use each particular metric, a projected timeline is:

FY 2011: 21 awards at $50,000 each – Primary evaluation, conducted by NSF staff, done on operations and process only; make procedural adjustments as necessary.

FY 2012: Up to 150 awards at $50,000 each – The Foundation will establish baseline activities "Pre I-Corps" and begin data collection of the metrics described above.

FY 2013: Up to 375 at $50,000 each or 250 awards at $75,000 each – The Foundation will initiate evaluations utilizing the baseline metrics developed in FY 2012.

FY 2014-FY 2016: NSF will continue with regular evaluations of the previously described metrics, developing a chronological database that allows for more detailed historical analysis of program success. The approach will be similar to that taken with the very successful Engineering Research Centers and Industry/University Cooperative Research Centers programs since 1985.

OneNSF INVESTMENTS
SCIENCE, ENGINEERING, AND EDUCATION FOR SUSTAINABILITY

OVERVIEW

A sustainable world is one in which human needs are met 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 resource and 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.

Goals

SEES has three main goals to advance sustainability:
1. Support interdisciplinary research and education to 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 will be a blend of activities – formal solicitations and informational 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 will continue to be supported and emphasized across NSF and will be matched by increased emphasis on activities focused on sustainable materials and clean energy technologies. NSF will also work 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 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 to provide long-term planning and provide overall guidance;
- A cross-agency integration 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 MOUs/MOAs, or other arrangements for collaboration.

INVESTMENT FRAMEWORK

FY 2010-FY 2012

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 $70.0 million.

In FY 2011, NSF requested an increment of $105.0 million for new SEES activities. Facing budgetary uncertainties, NSF maintained momentum in the SEES investment area by augmenting existing interdisciplinary programs (Coupled Natural and Human Systems, Research Coordination Networks) 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. An additional approximately $24.0 million in SEES activities was supported from existing 2011 resources through these activities.

In its FY 2012 Budget Request, NSF proposed to expand SEES by $233.0 million above the FY 2011 Request, through significant investments in programs related to energy and collaborative networks. During FY 2011, interdisciplinary working groups drafted and NSF released solicitations consistent with those plans, although at reduced scope and funding levels, for four new activities totaling approximately $60.0 million. The four new activities initiated in FY 2012 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 SEES-focused Partnerships for International Research and Education (PIRE), which advances international networks.

FY 2013 Request

In FY 2013, NSF plans to initiate five SEES programs that complement existing programs, including those recently developed for FY 2012. In addition, the five programs 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 rapidly changing geographic areas:

- *Coastal SEES* is designed to enable place-based system-level understanding of vulnerable coastal systems; yield outcomes with quantitative predictive value; identify pathways to enhance coastal resilience; and communicate outcomes and develop international connections.

- *Arctic Regions (ArcSEES)* seeks fundamental research that improves our ability to evaluate the sustainability of the Arctic human-environmental system as well as integrated efforts that will provide community-relevant sustainability pathways and engineering solutions.

Two programs related to environmental and societal resilience:

- *Creating a More Disaster-Resilient America (CaMRA)* aims to catalyze basic research and education efforts in hazard-related science, engineering, risk assessment and decision making in order to improve forecasting and prediction of natural and technological hazards, mitigate their effects, and prepare communities to respond to, and recover from disasters.
- *Sustainable Chemistry, Engineering and Materials (SusCHEM)* responds to the America COMPETES Reauthorization Act of 2010 (P.L. 111-358 Section 509), which called for NSF to establish a Green Chemistry Basic Research program that embraces concepts such as renewable feed stocks, atom economy, less hazardous chemical syntheses, life cycle planning and designing safer chemicals. Consistent with the goals of SEES, SusCHEM aims to enable the basic science and engineering discoveries that will reduce dependence on non-renewable resources and improve the efficiency of industrial processes. Example research goals are to utilize new (non-petroleum based) sources of important raw materials; replace toxic chemicals and materials with benign alternatives; economically recycle chemicals that cannot be replaced, such as phosphorus; and devise chemical reactions and processes that require little energy, water and organic solvents, and minimize undesirable by-products.

One program related to energy conservation:

- *Role of Information Sciences and Engineering in SEES (RISES)* addresses the goal of decreasing energy consumption, which can be advanced by information technologies through improved hardware and software, increased use of renewable energy sources, and optimization strategies that minimize energy usage and reduce impacts on the environment. Along with many other efforts, SEES research and communication that is computationally intensive will benefit directly from the efficiencies discovered.

These five programs will total $76.70 million in FY 2013, and are primarily responsible for the $45.50 million increase over the FY 2012 Estimate. Funding for the five programs is partially offset by the Sustainable Energy Pathways (SEP) solicitation, which is released in alternate years (FY 2012 and FY 2014). The FY 2013 programs have strong support throughout all of NSF's directorates and offices. The remaining $125.80 million, which brings SEES to a total of $202.50 million in FY 2013, supports SEES programs that were initiated in prior years.

FY 2014 – FY 2019

In FY 2014 and beyond, it is anticipated that SEES will focus on further development and refinement of the investments that were established in FY 2011, 2012, and 2013. Additional focused five-year emphasis areas may be initiated in FY 2014 and FY 2015. Future years will emphasize consolidation and coordination of existing activities; incorporation of any new emphasis areas; 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 progress towards a sustainable human future. With respect to the three over-arching SEES goals, NSF expects to achieve the following three outcomes:

1. Goal 1, Research and Education: the sustainability science and engineering knowledge base is 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: transdisciplinary approaches to sustainability education are common practice; the U.S. has a robust and appropriately sized cadre of early career scientists and engineers to address sustainability issues.

As programs have been phased into SEES each year, it is expected that the various programs will not necessarily end simultaneously. Based on the results of rolling assessments, programs will have variable lifetimes, and successful programs of continued relevance will be folded into core research in directorates and offices. Thus, while the SEES portfolio has a planned conclusion, the critical research, engineering, and education on sustainability that has been catalyzed by the initiative will continue to have impact throughout NSF.

SEES Funding

(Dollars in Millions)

Directorate/Office	FY 2011 Actuals	FY 2012 Estimate	FY 2013 Request
BIO	$24.59	$27.25	$34.75
CISE	2.25	8.00	11.50
ENG	3.28	19.25	20.00
GEO	28.85	44.25	70.75
MPS	2.72	16.50	27.20
SBE	6.25	7.75	8.75
OCI	5.61	1.50	3.00
OISE	1.33	12.00	11.55
OPP	7.00	14.50	14.50
EHR	6.08	6.00	0.50
Total, NSF	**$87.96**	**$157.00**	**$202.50**

Totals may not add due to rounding.

EVALUATION FRAMEWORK

NSF will employ a variety of tools to evaluate the scientific impact and progress of the various programs in the SEES portfolio. The senior leadership will consider a matrix of assessment methods and measures that captures a range of outcomes and impacts. Planned evaluation activities include, by main SEES goal:

Goal 1: Research and Education

- *Short-term:* Conduct a portfolio analysis to examine the representation of multiple disciplines in proposals, and project reports. Use the portfolio analysis to identify gaps.
- *Long-term:* Engage an external group to conduct an independent assessment of the legacy of funding through SEES.

Goal 2: Collaboration

- *Short-term:* Monitor indicators of collaboration such as the number of new international collaborations, private and public sector participants in networks, papers in publications, or fora applicable to private and public sector concerns.
- *Long-term:* Use a network analysis to measure changes in nodes and links through time.

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:* Use monitoring data to determine if a formal impact evaluation for large investments is indicated.

As solicitations are a key component of the SEES portfolio, NSF program directors will be looking for success indicators such as increased number of highly-rated proposals received, representation of multiple disciplines in proposals, and development of new international collaborations. NSF is particularly interested in measuring results in terms of new and productive connections made between researchers in a range of disciplines; 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.

OneNSF INVESTMENTS
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 statistical, mathematical, computational, 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 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 that provides a deeper understanding of the social and behavioral factors that affect cybersecurity. Development and deployment of innovative cybersecurity models and practices throughout scientific environments, including research and education communities, to embed innovative curricula within these models and practice 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.

The 2010 President's Council of Advisors on Science and Technology (PCAST) report on Networking and Information Technology R&D (NITRD) and several National Academy of Sciences reports[1] have argued strongly for the need to increase U.S. cybersecurity research and development. The NITRD *Strategic Plan for the Federal Cybersecurity Research and Development Program* (released in December 2011) details four thrusts that together cover a set of interrelated priorities for the federal agencies that conduct or sponsor research and development in cybersecurity. These four thrusts are: (1) inducing change, which provides four game-changing research themes to direct efforts towards understanding the root causes of current threats, namely designed-in security, moving target defense, tailored trustworthy space, and cyber economic and behavioral incentives; (2) developing scientific foundations, which calls for the development of an organized, cohesive scientific foundation for the body of knowledge that informs the field of cybersecurity; (3) maximizing research impact, which aims to catalyze integration across the research themes, to increase cooperation between governmental and private-sector communities, to increase collaboration across international borders, and to protect critical infrastructure, such as Health IT and Smart Grid; and (4) accelerating transition to practice, which calls for focusing efforts on ensuring adoption and implementation of the new technologies that emerge from the research themes and scientific foundations, so as to create measureable improvements in the cybersecurity landscape.

Specific objectives of NSF's SaTC program, and how they relate to the four thrusts of the Federal Cybersecurity Strategic Plan, include:

[1] Reports available from http://sites.nationalacademies.org/CSTB/CSTB_059144

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, including attention to behavior and human factors, of reliable systems that can function dependably even if some subset of components do not function as intended; and support 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.

Goals

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 *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); Social, Behavioral, and Economic Sciences (SBE); and the Office of Cyberinfrastructure (OCI) will participate in this program. Each of these organizations supports a research community whose abilities are needed to 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 and offices.

Under the OneNSF umbrella, the SaTC working group will coordinate with the EHR Scholarship for Service (SFS) program to help align opportunities for cybersecurity education and workforce development. SFS, which focuses on cybersecurity education and workforce development, has funded more than 1,500 students. Over 1,100 of these students have been successfully placed in internships and full-time positions in more than 120 federal agencies and departments. Furthermore, SFS capacity building grants have increased the capacity of the higher education enterprise in cybersecurity education and research.

NSF is uniquely positioned to support the broad, open, long-term, foundational research and education needed to establish a sound basis for progress in this critical area. There are currently about 500 active projects in the CISE cybersecurity programs that pre-date the FY 2012 SaTC program. This research portfolio includes projects addressing security from the microscopic level (e.g., detecting whether a silicon chip may contain a malicious circuit) to the macroscopic level (e.g., determining strategies for securing the next generation electrical power grid). The portfolio also ranges from mathematical algorithms and statistical tools – cryptography, cryptographic protocol analysis, formal specification and verification techniques, reliability, probabilistic modeling, risk analysis, data and text-mining, static and dynamic program analysis, and security testing methods – to human-centric systems that include web applications, smart phones, medical devices, and automotive systems. Through the interagency NITRD program, NSF plays a number of key roles in cross-agency coordination of the federal government's cybersecurity research investments. NSF is active in the NITRD Cyber Security and Information Assurance Interagency Working Group (CSIA IWG), which has a leadership role in executing and coordinating the *Strategic Plan for the Federal Cybersecurity Research and Development Program* across the thirteen member agencies. In addition with its co-chair role on the Senior Steering Group (SSG) for

Cybersecurity R&D, NSF helps define, coordinate, and recommend strategic federal R&D objectives in cybersecurity, and to communicate research needs and proposed budget priorities to policy makers and budget officials, including recommendations to OSTP, OMB, and the Joint Inter-Agency Cyber Task Force (JIACTF).

INVESTMENT FRAMEWORK

FY 2012

In FY 2012, CISE, MPS, SBE, and OCI issued a joint solicitation for the new Secure and Trustworthy Cyberspace (SaTC) program that called for proposals that build teams across these different research communities. To help develop this community, the directorates are planning community-building workshops and a PI meeting with interagency representation that will be held in 2012.

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 meet the needs of our increasingly technological society.

FY 2013 Request

The following activities are planned for FY 2013:

- Expand the number of large, multi-institution projects that provide high-level visibility to grand challenge research areas.
- Expand the research portfolio to include more cross-disciplinary projects and broaden the portfolio to both cover a broader set of research topics and to increase transition to practice.
- Coordinate SaTC efforts with Cyber-enabled Materials, Manufacturing, and Smart Systems, which supports foundational research in cybersecurity issues arising in advanced manufacturing, critical infrastructure, and robotics.
- Continue to facilitate the development of a National Virtual Lab for Cybersecurity Education to promote collaboration and resource sharing.
- Hold a PI meeting that brings together SaTC funded PIs with interested parties from industry and government agencies in support of the NITRD *Strategic Plan for the Federal Cybersecurity Research and Development Program* thrust of accelerating transition to practice.
- Support efforts to define a cybersecurity body of knowledge and to establish curricula recommendations for new courses, degree programs, and educational pathways.
- Through SFS, continue to support efforts to define the knowledge base in cybersecurity education and work with the community to develop recommendations for new courses, degree programs, and educational pathways based on evidence of effective practice. SFS supports innovative and creative projects, which lead to an increase in the ability of the United States higher education enterprise to produce information assurance and cybersecurity professionals.

FY 2014 – FY 2016

Building on the knowledge base developed during the previous years, SaTC will continue to focus on game-changing research and education; the development of digital systems that are resistant to attacks; coordination with the CEMMSS WG to secure advanced manufacturing systems, robotics, and critical infrastructure; and transition to practice of the 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, creating a flourishing cybersecurity research and development ecosystem.

SaTC Funding

(Dollars in Millions)

Directorate/Office	FY 2012 Estimate	FY 2013 Request
CISE	55.00	69.00
ENG	3.25	4.25
MPS	0.50	2.00
SBE	4.00	4.00
OCI	4.00	6.00
EHR	45.00	25.00
Total, NSF	**$111.75**	**$110.25**

Totals may not add due to rounding.

EVALUATION FRAMEWORK

Using information collected by the SaTC WG and the recommendations in the recent national strategic plan on cybersecurity, the WG will conduct gap and portfolio analysis to develop a shared understanding of program goals, milestones, and outcomes over the next four years. Each year, the program will conduct an annual review based on those assessments and report its results to NSF senior management as well as to the NITRD CSIA Senior Steering Group for feedback and recommendations.

Based on the four subgoals of SaTC, the outcomes will include: for inducing change – discovery of the root causes of threats and attacks and continuous investment in transformational approaches that improve the security of cyberspace; for developing scientific foundations – development of a systematic scientific approach to cybersecurity, including discovery of laws and principles; for maximizing research impact – partnerships with other agencies, industry, and international collaborators as well as linkages to national priorities, such as health IT or Smart Grid; and for accelerating transition to practice – new patents, products, services, companies, and research that can be transitioned into cyberinfrastructure.

The SaTC program will convene biennial PI meetings to monitor progress in this area of research. In addition, a trend analysis based on the annual reviews will be presented to the CISE Committee of Visitors, which is held every three years.

The SFS program will be evaluated by the Office of Personnel Management's Human Resources Solution (HRS) group with input from the NSF SFS program directors and the OPM SFS Program Office. An evaluation plan and design that links SFS program objectives with measures, data sources, and expected and unexpected outcomes will be submitted and agreed upon in January/February of 2012. The mixed method evaluation is designed to provide information to the program for purposes of program improvement, accountability, and learning, and builds on the previous evaluation that was released in January 2008 by the Assessment Services Branch of the Division for Human Resources Products and Services, U.S. Office of Personnel Management (OPM). As the current evaluation proceeds, HRS will continue to consult with NSF in the design and execution of the evaluation of the SFS program. The evaluation is expected to be completed in FY 2013.

NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)

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 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.

NNI by Program Component Area

(Dollars in Millions)

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request
1. Fundamental Nanoscale Phenomena & Processes	$182.13	$146.29	$146.29
2. Nanomaterials	98.53	78.80	81.30
3. Nanoscale Devices & Systems	55.77	52.43	53.93
4. Instr. Research, Metrology, & Standards for Nanotech	12.89	12.05	12.05
5. Nanomanufacturing	44.83	47.77	52.77
6. Major Research Facilities & Instrumentation Acquisition	35.11	28.53	28.53
7. Environmental Health & Safety	22.42	30.01	29.91
8a. Education	29.31	24.79	24.79
8b. Societal Dimensions (ELSI)	4.09	5.33	5.33
Total, National Nanotechnology Initiative	**$485.08**	**$426.00**	**$434.90**

Totals may not add due to rounding.

FY 2013 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 2013. NSF contributes to the goals and eight program component areas (PCAs) outlined in the NNI Strategic Plan (www.nano.gov). Increases of $5.0 million in the Nanomanufacturing PCA and $2.50 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) OneNSF investment, which coordinates and synchronizes activities across three main areas – breakthrough materials, advanced manufacturing, 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 $10.0 million, will be established in the summer of 2012 and start to fully operate 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 2013 the agency continues its contributions to translational innovation programs, including GOALI (Grant Opportunities for Academic Liaison with Industry), I/UCRC (Industry/University Cooperative Research Centers), the Innovation-Corps program, AIR (Accelerating Innovation Research), PFI (Partnerships for Innovation), and PFI's Building Innovation Capacity (BIC) component. 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 2013 Request will increase by $8.90 million, or 2.1 percent, over the FY 2012 Estimate.

A portion of NSF's FY 2013 NNI funding is for the NNI Signature Initiatives. FY 2013 funding for the Nanoelectronics for 2020 and Beyond Signature Initiative is $45.0 million, which is distributed in the Fundamental Nanoscale Phenomena and Processes, Nanomaterials, and Nanoscale Devices PCAs. These three PCAs also include FY 2013 funding of $31.67 million for the Nanotechnology for Solar Energy Collection and Conversion Signature Initiative. In addition, FY 2013 funding of $23.40 million for Sustainable Nanomanufacturing is contained within the Nanomanufacturing PCA.

In FY 2013, NSF will continue its funding for the Environmental, Health and Safety (EHS) PCA at $29.91 million, representing about 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 2013 Request includes $146.29 million, unchanged from the FY 2012 Estimate, 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 2013 Request includes $81.30 million, an increase $2.50 million over the FY 2012 Estimate, 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 2013 Request includes $53.93 million, an increase of $1.50 million from the FY 2012 Estimate, for R&D that applies the principles of nanoscale science and engineering to create novel, or to improve existing, devices and systems. The increase is for nanoscale engineering design in ENG. A portion of support is for CISE's participation in the Nanoelectronics for 2020 and Beyond Signature Initiative. 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 2013 Request includes $12.05 million – unchanged from the FY 2012 Estimate – 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 2013 Request includes an increase of $5.0 million above the FY 2012 Estimate, to $52.77 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); (c) 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 2013 Request increase is primarily associated with $5.0 million for sustainable nanomanufacturing.

Major Research Facilities and Instrumentation Acquisition

The FY 2013 Request includes $28.53 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), the National Network for Nanomanufacturing (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 2013 Request will support planned growth supplements to the first class of three new NERCs funded in FY 2012.

Environmental, Health, and Safety

The FY 2013 Estimate includes $29.91 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 2013 Request includes $30.12 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 ($24.79 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 ($5.33 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); 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.

NNI Funding

(Dollars in Millions)

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request
Biological Sciences	$56.36	$56.10	$57.10
Computer and Information Science and Engineering	17.45	17.75	17.75
Engineering	181.59	166.37	174.37
Geosciences	0.85	0.85	0.75
Mathematical and Physical Sciences	224.56	183.16	183.16
Social, Behavioral and Economic Sciences	1.67	1.67	1.67
Office of International Science and Engineering	0.10	0.10	0.10
Subtotal, Research and Related Activities	482.58	426.00	434.90
Education and Human Resources	2.50	-	-
Total, National Nanotechnology Initiative	**$485.08**	**$426.00**	**$434.90**

Totals may not add due to rounding.

NETWORKING AND INFORMATION TECHNOLOGY R&D

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 funding in the Directorate for Computer and Information Science and Engineering (CISE) and the Office of Cyberinfrastructure (OCI), and contributions from all of the agency's other directorates. NSF makes research, education, or research infrastructure 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, and OCI provides NSF representation to the subcommittee. 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 2013 Request continues strong support for NITRD at a level of $1.207 billion, a 6.1 percent increase over the FY 2012 Estimate. NITRD activities represent approximately 16 percent of NSF's FY 2013 budget. CISE and OCI's combined support comprises 77 percent of NSF's NITRD activities.

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

- Cyberinfrastructure Framework for 21st Century Science and Engineering (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: Large Scale Networking; High End Computing Research and Development (R&D); High End Computing Infrastructure and Applications; Human-Computer Interaction and Information Management; Software Design and Productivity; and Social/Economic/Workforce Implications of IT and IT Workforce Development.
- The Science, Engineering, and Education for Sustainability (SEES) cross-Foundation investment supports activities in Large Scale Networking as well as in Software Design and Productivity, High End Computing R&D, and Social/Economic/Workforce Implications of IT and IT Workforce Development.
- The National Robotics Initiative (NRI), a cross-agency initiative engaging four U.S. agencies (NSF, NASA, NIH and USDA) in a concerted program to provide U.S. leadership in science and engineering research and education aimed at the development of next generation robotics, supports activities in Human-Computer Interaction and Information Management, High Confidence Software and Systems, and Social/Economic/Workforce Implications of IT and IT Workforce Development.
- 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 R&D, High End Computing Infrastructure and Applications, and High Confidence Software and Systems.
- Enhancing Access to the Radio Spectrum (EARS), which supports research in wireless communication, spectrum sharing, and mobile computing, as well as the development of wireless testbeds, supports activities in Large Scale Networking, High End Computing R&D, and High End Computing Infrastructure and Applications.
- Cyber-Enabled Materials, Manufacturing, and Smart Systems (CEMMSS), expands the Cyber-Physical Systems (CPS) program 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 includes investments in the National Robotics Initiative (NRI), an important multi-agency activity. 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/Workforce Implications of IT and IT Workforce Development.

- The Comprehensive National Cybersecurity Initiative (CNCI) supports activities in Cybersecurity and Information Assurance.
- Secure and Trustworthy Cyberspace (SaTC) aligns NSF cybersecurity investments (including investments from CISE, OCI, SBE, MPS, and ENG) 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.
- Expeditions in Education (E^2) aims to generate a stronger and more deliberate infusion of cutting-edge science, engineering, and innovation into programs that focus on preparing a world-class scientific workforce for the twenty-first century, and to ensure that all of NSF's education and workforce investments are drawing on the latest educational theory, research, and evidence. E^2 supports activities in Social/Economic/Workforce Implications of IT and IT Workforce Development.

Networking and Information Technology Research and Development Funding

(Dollars in Millions)

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request
Biological Sciences	$93.00	$99.00	$99.00
Computer and Information Science and Engineering	636.06	653.59	709.72
Engineering	21.00	18.30	19.80
Geosciences	22.98	22.98	26.98
Mathematical and Physical Sciences	83.88	93.75	94.75
Social, Behavioral, and Economic Sciences	22.21	29.51	29.20
Office of Cyberinfrastructure [1]	300.75	211.64	218.27
Subtotal, Research and Related Activities	$1,179.88	$1,128.77	$1,197.72
Education and Human Resources	9.50	9.50	9.50
Total, NITRD	**$1,189.38**	**$1,138.27**	**$1,207.22**

Totals may not add due to rounding.

[1] FY 2011 Actual includes $90.50 million in funds that were obligated in FY 2010, de-obligated in FY 2011, and then obligated to other projects in the OCI portfolio.

FY 2013 NSF Investments by Program Component Area

The following information focuses on FY 2013 NSF investments, both new and continuing, by PCA.

Large Scale Networking (LSN) ($131.39 million) CISE and ENG will support research in new wireless communications and spectrum sharing architectures and services as part of Enhancing Access to the Radio Spectrum (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) ($114.12 million) CSIA includes support for the Comprehensive National Cybersecurity Initiative (CNCI) at $57.0 million and for NSF's Secure and Trustworthy Cyberspace (SaTC) program. CISE investments in SaTC, in partnership with EHR, ENG, MPS, OCI, and SBE, include developing scientific foundations; inducing change through designed-in security, moving target defense, tailored trustworthy space, and cyber economic and behavioral incentives; and accelerating transition to practice.

High-End Computing R&D (HEC R&D) ($109.85 million) Support is provided for CISE's nanotechnology research, including participation in the National Nanotechnology Initiative Signature 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 CIF21to develop new functional capabilities in support of highly parallel computing and for 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) ($255.62 million) HEC I&A includes increased efforts by OCI to develop software and algorithms for high-end computing systems. It also includes MPS and ENG investment 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. 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 support for operations and maintenance for the new 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) ($97.64 million) CISE and ENG will increase investments in the National Robotics Initiative and in Cyber-Physical Systems as part of CEMMSS as well as continue investments in smart health and wellbeing. As development of the next generation of robotics proceeds, complete confidence in the systems supporting robots that work beside, or cooperatively with, people in areas such as manufacturing, space, and undersea exploration must be assured. 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 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) ($297.24) HCI&IM includes CISE support for the National Robotics Initiative, part of CEMMSS, as well as support for smart health and wellbeing. 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 health and wellbeing 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 big data, data analytics, and visualization tools and a focus on expanding the national data infrastructure through the DataNet and Virtual Organizations programs in OCI. 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.

Software Design and Productivity (SDP) ($83.69 million) SDP support reflects increased investment in CIF21 with a focus on software sustainability, and new research on smart systems as part of CEMMSS. OCI support for SDP includes increasing investment in the Software Institutes for Sustainable Innovation (SI2) program to support efforts to create and maintain usable software. The program supports both individual software development efforts and centers of excellence that will become long-term resources to ensure sustainable software infrastructure within scientific communities. BIO support for SDP includes support for the interagency and international Collaborative Research in Computational Neuroscience program (CR-CNS). 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 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 partner with CISE in exploring the emerging interface between computer science and economics.

Social, Economic and Workforce (SEW) Implications of IT and IT Workforce Development ($117.67 million) As part of the National Robotics Initiative, SEW research in CISE will focus on human-robot interaction, a critical component in achieving effective human robot partnerships in manufacturing, education, space exploration, etc. In addition, CISE's continued emphasis on smart health and wellbeing focuses on, for example, assistive technologies and quality of life aids. This also reflects CISE support for big data and e-science collaboration tools as part of CIF21 and support for E^2 through the Cyberlearning Transforming Education program. 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. OCI increases support for the study of virtual organizations to better understand how research communities use cyberinfrastructure to improve collaboration. 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 by Program Component Area

(Dollars in Millions)

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request
Large Scale Networking	$128.14	$121.76	$131.39
Cybersecurity and Information Assurance	76.51	98.49	114.12
High End Computing R&D	103.36	102.98	109.85
High End Computing Infrastructure and Applications	357.00	249.96	255.62
High Confidence Software and Systems	78.01	84.67	97.64
Human-Computer Interaction and Info Management	283.25	291.98	297.24
Software Design and Productivity	54.72	78.26	83.69
Social/Economic/Workforce	108.399	110.17	117.67
Total, NITRD	**$1,189.38**	**$1,138.27**	**$1,207.22**

Totals may not add due to rounding.

[1] FY 2011 Actual includes $90.5 million in funds that were obligated in FY 2010, de-obligated in FY 2011, and then obligated to other projects in the OCI portfolio.

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP)

Climate and global change have pervasive effects on the U.S. through their impacts on the environment, natural resources, and the economy. Global change encompasses a wide range of planetary-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 of the impacts of a changing climate on those systems. The USGCRP involves thirteen U.S. agencies in a concerted interagency program of basic research, comprehensive observations, integrative modeling, and development of products for 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 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 particularly on fundamental Earth system processes and the consequences of change. High priorities for the agency include: data acquisition and information management activities necessary for 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 be key contributions to the National Climate Assessment. A new strategic plan, developed under NSF leadership, will be released in early 2012.

U.S. Global Change Research Program Funding

(Dollars in Millions)

	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request
Biological Sciences	$81.00	$89.00	$91.00
Geosciences	194.00	194.00	194.00
Mathematical and Physical Sciences	3.32	5.03	8.03
Social, Behavioral and Economic Sciences	20.73	22.23	23.23
Office of Polar Programs	18.52	23.10	16.65
Total, U.S. Global Change Research Program	**$317.57**	**$333.36**	**$332.91**

Totals may not add due to rounding.

FY 2013 Areas of Emphasis

NSF's FY 2013 investment in USGCRP decreases by $450,000, or 0.13 percent, relative to the FY 2012 Current Plan. NSF's USGCRP investments continue to reflect two major integrated NSF activities, the Science, Engineering, and Education for Sustainability (SEES) and the Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21). The major USGCRP foci in FY 2013 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 Data and Access to Cyberinfrastructure components.

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 Integrated Science and Engineering thrust.

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 in computational infrastructure.

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. NSF supports the basic research that underpins the National Climate Assessment, including developing models that can be used for these assessments. For example, NSF-supported researchers are developing integrated river-basin models to address often competing water management issues that affect stream flow, such as protecting endangered species, meeting agricultural needs, and honoring transboundary water rights agreements. NSF will support fundamental research regarding the science of adaptation, from developing the theoretical framework for evaluating adaptation options (and avoiding unintended consequences of adaptation choices) to risk assessment and decision making. Under the SEES Integrated Science and Engineering Research on Environmental, Economic, and Engineering systems, NSF will continue interdisciplinary research (including human factors) in water sustainability, biodiversity, and ocean

acidification and initiate new efforts in particularly vulnerable areas such as the Arctic and coastal regions.

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.

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 2011	FY 2011 Actual	FY 2012 Estimate	FY 2013 Request	Change Over FY 2012 Estimate Amount	Change Over FY 2012 Estimate Percent
Centers for Analysis & Synthesis	1995	4	$23.04	$26.32	$26.40	$0.08	0.3%
Centers for Chemical Innovation	1998	14	26.28	24.00	29.25	5.25	21.9%
Engineering Research Centers	1985	17	59.06	70.00	69.00	-1.00	-1.4%
Materials Centers[1]	1994	30	61.33	44.35	51.20	6.85	15.4%
Nanoscale Science & Engineering Centers	2001	19	39.13	31.48	26.50	-4.98	-15.8%
Science & Technology Centers	1987	17	66.10	50.75	74.39	23.64	46.6%
Science of Learning Centers	2003	6	23.08	20.37	20.02	-0.35	-1.7%
Totals		**107**	**$298.02**	**$267.27**	**$296.76**	**$29.49**	**11.0%**

Totals may not add due to rounding.

[1] In FY 2011, funding includes $2.66 million for Materials Interdisciplinary Research Teams, which are not formal NSF Centers. In FY 2012 and FY 2013, support for these teams is captured in core research programs, outside the NSF Centers portfolio.

Description of Major Changes

Centers for Analysis and Synthesis - BIO

The Socio-Environmental Synthesis Center (SESynC) is the newest (funding initiated in FY 2011) BIO Center for Analysis and Synthesis. SESynC uses a variety of approaches to synthesize scientific information, data, and knowledge to advance the frontiers of scientific understanding of environmental complexity through the active involvement of environmental and social scientists in order to anticipate and manage emerging environmental challenges. These 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. SESynC is expected to be funded at $6.0 million in FY 2013, which is flat with FY 2012.

The iPlant Collaborative provides 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. Pending a successful outcome from the FY 2012 site review, center funding could be renewed or a recompetition held for an additional five years of funding. iPlant is expected to be funded at $12.0 million in FY 2013, which is flat with FY 2012.

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. Support for this Center

decreases by $540,000 to a total of $4.78 in FY 2013 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. NSF support for NIMBioS increases by $1.0 million in FY 2013 to $3.62 million because prior co-funding from the Department of Homeland Security is expected to be withdrawn.

Centers for Chemical Innovation (CCI) – MPS

The Centers for Chemical Innovation (CCI) are designed to support research on strategic, transformative "big questions" in basic chemical research. The program is stimulating the chemical sciences community to perform work that is high-risk and of potential high scientific and societal impact. CCIs promote the integration of research and education through the extensive involvement of students and postdoctoral fellows in all phases of the work. CCIs are expected to be agile, responding to scientific opportunities as they arise, and to creatively engage the public. Grand challenges include emulating and even surpassing the efficiency of the natural process of photosynthesis to capture the sun's energy; activating strong bonds as a means to store and use chemical energy and to lower energy costs in chemical processing; and designing self-assembling, complex structures, such as molecular computers, with emergent and useful functions not yet known or foreseen.

The CCI program is designed as a staged competition. Phase I centers, which are supported for three years, may then compete for larger Phase II awards, which are for five years. Phase I centers initiated in FY 2010 may compete for Phase II awards in FY 2013. In FY 2013, the MPS Division of Chemistry expects to support eight Phase I awards, five continuing and three new, and six Phase II awards, three continuing and three new and/or renewals. Funding levels per center have not changed over FY 2012. However, the requested change (+$5.25 million to a total of $29.25 million) will allow the Division of Chemistry to increase support for renewing Phase I awards, from $1.50 million to $1.75 million per year. The renewal of the Phase II "Center for Enabling Technologies through Catalysis" is currently pending, and the Phase II Center on "POWERING THE PLANET: A Chemical Bonding Center in the Direct Conversion of Sunlight into Chemical Fuel" will be seeking renewal in FY 2013.

The CCI program began collecting qualitative (e.g., list of partnering companies) data and quantitative data (e.g., the amount of funding leveraged from other sources) in FY 2012 to inform an external programmatic evaluation scheduled for FY 2017. A Leadership Network of CCI managing directors and staff has formed to plan meetings to discuss topics of common interest and build collaborations between the CCIs. The first Leadership Network meeting is scheduled for spring 2012.

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 to deliver on ERC program goals, 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.

In FY 2013, funding for ERCs will decrease by $1.0 million, below the FY 2012 Estimate, to a total of $69.0 million. Building on the long-standing ERC program model, NSF will maintain funding for the existing portfolio of ERCs and provide planned growth supplements to the first class of three Nanosystems ERCs (NERCs) funded in FY 2012. This investment will transition the nano-devices created at graduating NSECs to the systems level and commercialization. This will support the first class of three Nanoscale Engineering Research Centers (Nanoscale ERCs) initially funded in FY 2012, maintaining the number of traditional ERCs and Nanoscale ERCs at 17.

Materials Centers - MPS

The Materials Center program is an interdisciplinary vehicle for increasing materials research and educating students, 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.

In FY 2011 the Materials Centers program was divided into centers and teams, or Centers for Materials Research and Innovation (CEMRIs) and Materials Interdisciplinary Research Teams (MIRTs). However, based on comments from the Committee of Visitors for the MPS Division of Materials Research in February 2011 and a request from the community, the CEMRIs are reverting to their original name, or Materials Research Science and Engineering Centers (MRSEC). "MRSEC" has been used since 1994 and is a recognized brand of excellence in the materials community. NSF agreed that it would be beneficial to continue using the MRSEC name in place of the newer CEMRI name. This change does not require any programmatic or funding adjustments. The materials teams, or MIRTs, will remain in place as planned. Due to their smaller size, MIRTs do not meet the criteria as formal NSF centers. Therefore, beginning in FY 2012, MIRT funding has been integrated with core research programs. $2.66 million of the funding decrease from FY 2011 to FY 2012 is due to this reallocation of MIRT funding to core programs.

The FY 2013 Request will support 23 MRSECs at $51.20 million (+$6.85 million over the FY 2012 Estimate). The number of centers is equal to FY 2012, with 14 from the 2008 competition and 9 from the 2011 competition. Funding supports continuing grant increments as outlined in existing cooperative agreements. The Materials Centers program holds triennial competitions; the last competition was in FY 2011 and the next is planned for FY 2014.

Nanoscale Science and Engineering Centers (NSEC) - multi-directorate

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 Nanoscale Science and Engineering Centers (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 2013 Request of $26.50 million, representing a decrease of $4.98 million below the FY 2012 Estimate, will support 11 continuing NSECs. The decrease from the FY 2012 Estimate level is primarily associated with two centers receiving final funding in FY 2012. The first class of six NSECs, initiated in 2001, received their final year of support in FY 2010 and completed their associated research programs in FY 2011.

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 investment 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 labs, 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.

A recent review, released in December 2010, by the American Association for the Advancement of Science (AAAS) concluded that the STC program is an effective and distinctive mode of Foundation support for addressing grand challenges and emerging opportunities in science and technology. STCs serve as NSF's major funding instrument for supporting emerging fields of science and technology that do not fit within its existing organizational and programmatic structures – including its other existing center programs. See http://php.aaas.org/programs/centers/capacity/documents/stc_aaas_full_report.pdf.

The FY 2013 Request funding of $74.39 million will support the continuation of 11 existing STCs ($48.09 million), the start up of five new centers ($25.0 million), and the administrative costs ($1.30 million) associated with running the competition and overseeing the program. The change over the FY 2012 Estimate is primarily associated with the funding of five new STCs in FY 2013.

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.

In FY 2013, $20.02 million (-$350,000 below the FY 2012 Estimate) will fund six SLCs. SBE will continue to oversee management of all six centers, with co-funding from the NSF Directorates for Biological Sciences (BIO), Computer and Information Science and Engineering (CISE), and Engineering (ENG).

Four awards for the first cohort of SLCs were made in FY 2004. One center was decommissioned in its second year due to its failure to develop cohesively as a center. The remaining three centers, 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), have been approved for renewal through FY 2014, with a ramp down in funding beginning in FY 2012. Three awards for a second cohort were made in FY 2006 and renewed in February 2011. Two of the three centers in Cohort 2, Temporal Dynamics of Learning Center (TDLC) and the Spatial Intelligence and Learning Center (SILC), were renewed for an additional five years, ending in FY 2015. The third, Visual Language and Visual Learning Center (VL2), was renewed for four years, ending in FY 2014.

Each SLC award requires an annual, external evaluation of the center. Annual meetings of the SLC evaluators contribute to consistency across these evaluations and its usefulness for program managers. A Committee of Visitors (COV) review for the SLCs was held in 2009, and an external, program-level evaluation of the SLC program is being planned for FY 2012.

SBE initiated external discussion on the future of the SLC program and the science it supports at its May 2010 Advisory Committee meeting. The consensus was that NSF should evaluate the program as funding for individual centers comes to a close, with consideration of shifting resources wherever possible to enhance support for the science of learning through non-center mechanisms. In FY 2012 there will be a workshop to explore future directions for the Science of Learning, including diversifying the program's funding mechanisms to include non-center opportunities. NSF started ramping down its funding for the SLC Program in FY 2012.

NSF Estimates for Centers Participation in 2011

(Dollars in Millions)

	Number of Participating Institutions	Number of Partners	Total FY 2011 NSF Support	Total Leveraged Support	Number of Participants
Centers for Analysis & Synthesis	385	62	$23	$8	2,369
Centers for Chemical Innovation	74	62	$26	$3	505
Engineering Research Centers	472	299	$59	$101	2,720
Materials Centers	388	344	$61	$54	4,000
Nanoscale Science & Engineering Centers	648	622	$39	$47	6,553
Science & Technology Centers	177	460	$66	$46	3,129
Science of Learning Centers	44	73	$23	$17	1,120

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.

No. of Participants: The total number of people who use center facilities, not just persons directly supported by NSF.

Centers Supported by NSF in FY 2011

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 Energetic Non-Equilibrium Chem. at Interfaces (phase I)	U of Chicago	IL
Center for Molecular Spintronics (phase I)	North Carolina State U	NC
Center for Molecular Optimization of Electronic Plastics (phase I)	U of Texas Austin	TX
Center for Multiscale Theory and Simulation (phase I)	U Chicago	IL
Center for Nanostructured Electronic Materials (phase I)	University of Florida	FL
Center for Stereoselective C-H Functionalization (phase I)	Emory U	GA
Center for Sustainable Materials Chemistry (phase II)	Oregon State U	OH
Center for Sustainable Polymers (phase I)	U of Minnesota-Twin Cities	MN
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
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 Micro- and Nanomechanics of Materials	Brown	RI
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
Center for Semiconductor Physics in Nanostructures	U of Oklahoma, U of Arkansas	OK, AR
Liquid Crystals Materials Research Center	U of Colorado-Boulder	CO
Genetically Engineered Materials Science and Engineering Center	U of Washington	WA
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	Carnegie Mellon	PA
Materials Research Science and Engineering Center	Johns Hopkins	MD
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 Maryland	MD
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 U.	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
Directed Assembly of Nanostructures	Rensselaer Polytechnic Institute	NY
Electronic Transport in Molecular Nanostructures	Columbia	NY
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
Integrated Nanopatterning and Detection Technologies	Northwestern	IL
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
Nanoscale Systems in Information Technologies	Cornell	NY
Nanoscience in Biological and Environmental Engineering	Rice	TX
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
Science of Nanoscale Systems and their Device Applications	Harvard	MA
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	U of Illinois-Urbana Champaign	IL
Center for Biophotonics Science and Technology	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	U of California-Los Angeles	CA
Center for Integrated Space Weather Modeling	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	U of Minnesota-Twin Cities	MN
Center on Materials and Devices for Info. Technology Research	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 with Learning Experiments in Real Classrooms	Carnegie Mellon	PA
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

SELECTED CROSSCUTTING PROGRAMS

NSF crosscutting programs include interdisciplinary programs and programs that are supported by multiple directorates. Examples of major crosscutting activities include the following:

ADVANCE

In FY 2013, 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 $17.06 million, a decrease of $890,000 below the FY 2012 Estimate of $17.95. This decrease reflects a reprioritization of funding pending the results of an evaluation currently underway. A major focus will be broadening the spectrum of institutions participating in the program. The IT-Catalyst program component, which provides support to institutions to undertake institutional self-assessment activities, will be used to support predominantly undergraduate institutions, teaching-intensive colleges, community colleges, minority-serving institutions, and women's colleges. The funding will also support new awards under the Institutional Transformation (IT) program component as well as data collection to capture the impact of prior ADVANCE awards and as part of an overall program evaluation.

ADVANCE is in the process of completing a retrospective evaluation of the first two cohorts of the program. The evaluation is examining such questions as:

- What is the impact of ADVANCE on institutional transformation?
- What is the impact of ADVANCE beyond the initially funded institutions (e.g., publications, new collaborations)?
- How and why have successful programs worked in specific institutional contexts?

The evaluation methodology includes an analysis of project documents and data, survey results, interviews, and comparative data from the Survey of Earned Doctorates (SED). The evaluation will be completed in early FY 2013. Results are expected to inform future program budgets.

Climate Change Education Program

The FY 2013 Request provides $6.26 million for the Climate Change Education (CCE) program, a decrease of $3.74 million below the FY 2012 Estimate level of $10.00 million. The Directorates for Education and Human Resources, and Geosciences, will continue to support this activity. In FY 2013, CCE, formerly part of the Science, Engineering, and Education for Sustainability (SEES) portfolio, is refocused to support the Learning and Understanding Sustainability focus area of the Expeditions in Education (E^2) activity. The Directorate of Biological Sciences and the Office of Polar Program concludes its participation in CCE in FY 2013 as a result of this refocusing of activities. CCE is a multi-disciplinary, multi-faceted climate change education program that is enabling a variety of partnerships within formal and informal settings, including partnerships among K-12 education, higher education, the private sector, related non-profit organizations, and relevant education and/or climate-related policymakers. It will support individual investigators and multidisciplinary teams of STEM researchers and educators in a range of activities, including those with a local, regional, and/or global scope.

FY 2013 investments continue support for Phase II Climate Change Education Partnership (CCEP-II) projects initiated in FY 2012. Climate scientists, learning scientists, and education practitioners from formal or informal settings are engaged in efforts to foster a deeper understanding of, and engagement with, the complex processes of the climate system and the potential impacts of a changing climate, through activities that lead to development, evaluation, dissemination, and increased adoption of effective, high quality educational programs and resources. Development and implementation of a strategy for program-wide evaluation of the combined CCEP-II projects is a priority for FY 2013. In addition, NSF continues collaboration with NASA and NOAA to support annual tri-agency principal

investigator meetings for climate change-education related awards and to develop common evaluation approaches. CCE program activities continue to be informed by discussions with the National Research Council, through the auspices of its Climate Change Education Roundtable.

Enhancing Access to the Radio Spectrum (EARS)
NSF's FY 2013 Request provides $50.50 million for EARS, an increase of $35.50 million above the FY 2012 Estimate level of $15.0 million. 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 2013 is consistent with the recent 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), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE). It will fund innovative collaborative research that transcends the traditional boundaries of existing disciplinary programs.

Faculty Early Career Development (CAREER)
The FY 2013 Request provides $216.49 million for the CAREER program, an increase of $10.14 million over the FY 2012 Estimate level of $206.35 million. This will result in approximately 40 more CAREER awards than in FY 2012. CAREER awards 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. A Committee of Visitors will review the CAREER program in 2012, and its report is expected to be available in 2013.

Graduate Fellowships and Traineeships
The FY 2013 Request provides $321.67 million for NSF's flagship graduate fellowship and traineeship programs. This funding will enable NSF to support an estimated 6,950 graduate students, including 2,000 new Graduate Research Fellows in FY 2013.

- $242.98 million for the Graduate Research Fellowship (GRF) program, an increase of $44.84 million over the FY 2012 Estimate of $198.14 million. As indicated below, the Budget Request increase is needed primarily to support the increased number of fellows, and also the proposed increases in the cost of education allowance and stipend. The fellowship provides up to 3 years of support over a 5-year period to graduate students in all STEM fields. In FY 2013, 2,000 new fellows will be supported maintaining the doubling of new fellowships awarded as achieved in FY 2010. In order to maintain the competitiveness and appeal of the GRF program, NSF increased the cost of education (COE) allowance in FY 2012 from $10,500 to $12,000. The COE allowance level is consistent with the America COMPETES Reauthorization Act of 2010. NSF will address inflationary pressures on the long-stagnant GRF stipend level implementing a stipend increase to $32,000 in FY 2013. In FY 2013, GRF funding will be drawn equally between the R&RA and Education and Human Resources (EHR) accounts. In FY 2012, GRF is initiating and conducting a phase-one evaluation framing study. In FY 2013, a GRF full-scale longitudinal study will be initiated.

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

NSF Graduate Research Fellowship Program

	Total Number of Fellows	Number of New Fellows	Projected Fellows on Tenure[1]
FY 2012 Estimate	7,800	2,000	4,200
FY 2013 Estimate	8,900	2,000	4,900

[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 the National Science Foundation.

- $51.69 million for the Integrative Graduate Education and Research Traineeship (IGERT) program, a decrease of $8.13 million from the FY 2012 Estimate of $59.82 million. CISE and EHR have reduced funding support of IGERT to direct resources to other activities in FY 2013. IGERT will support comprehensive Ph.D. programs that are innovative models for interdisciplinary education and research and that prepare students for academic and non-academic careers. This reduced funding will support approximately 1,250 IGERT trainees, which is about 200 less than the number in FY 2012.
- $27.00 million for the NSF Graduate STEM Fellows in K-12 Education (GK-12) program, an increase of $50,000 from the FY 2012 Estimate of $26.95 million. The GK-12 program was initiated in 1999, and during the subsequent years more than 300 projects have been funded throughout the Nation. The GK-12 program did not hold a new competition in FY 2011 and will not hold future competitions because it has been terminated. The program has achieved its goal of providing models for other organizations to consider, along with evaluation data, in developing their efforts. The FY 2013 amount will be used to cover commitments to grants made in prior years, and it will support an estimated 800 GK-12 graduate fellows.

Long-Term Ecological Research (LTER)

The FY 2013 Request provides $27.97 million, an increase of $570,000 above the FY 2012 Estimate level of $27.40 million. LTER supports fundamental ecological research that requires long time periods and large spatial scales. This program supports a 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 and documented ecological experiments; 3) conducting major syntheses and theoretical efforts; and 4) providing information necessary for the identification and solution of environmental problems. LTER field sites represent a diversity of habitats in continental North America, the Caribbean, Pacific Ocean, and the Antarctic, including coral reefs, deserts, estuaries, lakes, prairies, various forests, alpine and Arctic tundra, urban areas, and production agriculture. Beginning in FY 2012, NEON infrastructure will be co-located at eleven LTER sites, as the LTER network and NEON are complementary networks that enhance ecological research in different ways. 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 processes in a wide range of ecosystems. The co-location of NEON infrastructure at LTER sites will enable innovative research building on the long history of LTER research with the new capabilities to quantitatively scale the site-based knowledge to regional and continental scales. The increased support for LTER in FY 2013 covers planned periodic increases to cover higher costs as sites are renewed.

Research at the Interface of the Biological, Mathematical, and Physical Sciences (BioMaPS)

The FY 2013 Request provides $30.17 million, an increase of $10.17 million above the FY 2012 Estimate of $20.00 million for the BioMaPS program, an interdisciplinary partnership between the Directorates for Biological Sciences, Mathematical and Physical Sciences, and Engineering. Support for BioMaPS is

consistent with the recommendations of the National Academies of Science study, Research at the Intersection of the Physical and Life Sciences.[2] BioMaPS seeks to discover fundamental new knowledge at the intersections of the biological, mathematical and physical sciences, and engineering in order to enable innovation in national priorities such as clean energy, climate science, and advanced manufacturing that are essential to the Nation's prosperity, economic competitiveness, and quality of life. The increases funding in FY 2013 reflects the overall alignment with these funding priorities.

Research Experiences for Teachers (RET)
The FY 2013 Request for NSF's RET program totals $5.47 million, a decrease of $1.51 million below the FY 2012 Estimate 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 toward engineering. A formal evaluation by SRI International was completed in 2007, which documented achievements of the RET program from 2001 to 2006.[3] As a result, some minor adjustments were made to the program, for example, extending the minimum duration of the program from four weeks to six weeks.

Research in Undergraduate Institutions (RUI)
The FY 2013 Request for NSF's RUI program totals $40.15 million, equal to the FY 2012 Estimate. 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.

Research Experiences for Undergraduates (REU)
The FY 2013 Request for NSF's REU program totals $68.40 million, an increase of $2.41 million from the FY 2012 Estimate of $65.99 million. The request for FY 2013 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. The increase is consistent with the external evaluation of REU conducted between 2003 and 2006, and also with a survey of former REU participants conducted in 2009 by SRI International, which found that undergraduate students who participate in hands-on research are more likely to pursue advanced degrees and careers in STEM. 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. This emphasis will continue in FY 2013 as a means of broadening participation in STEM and fostering educational pathways and transfer opportunities for students in STEM programs. In FY 2012, EHR's evaluation group is exploring the feasibility of how best to evaluate themes, such as research experience that cross NSF's STEM education programs. REU is included in the FY 2012-FY 2013 Agency Priority Goal focusing on undergraduate programs.

[2] www.nap.edu/catalog.php?record_id=12809
[3] http://csted.sri.com/content/evaluation-national-science-foundations-research-experiences-teachers-ret-program-2001-2006

Science and Technology Centers (STCs)

The FY 2013 Request for the Science and Technology Centers program totals $74.39 million, an increase of $23.64 million over the FY 2012 Estimate level of $50.75 million. The funding increase in FY 2013 includes support for a new class of STCs. For additional information, see the NSF Centers Programs section of this chapter.