NSF-WIDE INVESTMENTS

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 problem or the resources needed to solve the problem require the advantages of scope, scale, duration, equipment, facilities, and students. Centers are a principal means by which NSF fosters interdisciplinary research.

NSF Centers Funding

(Dollars in Millions)

	Program initiation	Number Centers 2009	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request	Change over FY 2010 Estimate Amount	Change over FY 2010 Estimate Percent
Centers for Analysis & Synthesis	1995	4	$17.41	-	$22.72	$23.25	$0.53	2.3%
Centers for Chemical Innovation	1998	12	15.50	-	24.00	28.00	$4.00	16.7%
Engineering Research Centers	1985	15	61.42	-	54.91	67.50	$12.59	22.9%
Materials Research Science & Engr. Centers	1994	31	60.84	-	56.70	63.00	$6.30	11.1%
Nanoscale Science & Engineering Centers	2001	19	46.97	-	46.26	40.20	-$6.06	-13.1%
Science & Technology Centers	1987	17	62.46	-	57.77	66.03	$8.26	14.3%
Science of Learning Centers	2003	6	12.51	-	25.80	25.80	-	-
Totals			**$277.11**	**-**	**$288.16**	**$313.78**	**$25.62**	**8.9%**

Totals may not add due to rounding.

CENTERS DESCRIPTIONS

Centers for Analysis and Synthesis (BIO)

The Centers for Analysis and Synthesis are designed to continue development of new tools and standards for management of biological information and meta-information, support data analysis capabilities with broad utility across the biological sciences, host workshops that bring together scientists from a variety of disciplines, and begin to host and curate databases. The centers have a critical role in organizing and synthesizing biological knowledge that is useful to researchers, policy makers, government agencies, educators, and society. In FY 2011, four Centers for Analysis and Synthesis are expected to be funded.

The National Center for Ecological Analysis and Synthesis (NCEAS) at the University of California at Santa Barbara promotes integrative studies of complex ecological questions and serves as a locus for the synthesis of large data sets. FY 2010 will be the final year of funding for NCEAS. Given the success of NCEAS in demonstrating the value of synthetic approaches in advancing ecology and the role of ecological synthesis in addressing societal issues, support will be provided in FY 2011 for a new environmental synthesis center to stimulate research, education, and outreach at the interface of the biological, geological, and social sciences. This new center will foster synthetic, collaborative, cross-disciplinary efforts to understand the complex interactions among ecological populations, communities and ecosystems, the geophysical environment, and human actions and decisions that underlie global environmental change.

The National Evolutionary Synthesis Center (NESCent) is a collaborative effort by Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill to foster a greater conceptual synthesis in biological evolution by bringing together researchers and educators, extant data, and information technology resources. In 2009, a five year renewal award of approximately $5.0 million annually was made to NESCent, reflecting increased capacity of activities at the center over the next award period. NESCent will fund graduate students engaged in center activities, support activities to expand the conceptual reach of the center into targeted areas, and initiate a formalized, three-tiered assessment of the center that includes milestones for reporting on the impact of those activities.

The National Institute for Mathematical and Biological Synthesis (NIMBioS), located at the University of Tennessee-Knoxville, fosters cross-disciplinary approaches in mathematics and biology to address fundamental and applied biological questions, including national needs research in modeling of infectious diseases of plants and animals. The center will design 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. Although predominantly supported by BIO, MPS and the Department of Homeland Security also contribute. No major changes are planned for NIMBioS in FY 2011.

iPlant (formerly Plant Science Cyberinfrastructure Collaborative), led by the University of Arizona, uses new computer and information science, and cyberinfrastructure solutions to address an evolving array of grand challenges in the plant sciences. This center is a community-driven effort, involving plant biologists, computer and information scientists and engineers as well as experts from other disciplines, all working in integrated teams. A small increase is provided for iPlant in FY 2011 as part of the existing cooperative agreement for an annual increment.

Centers for Chemical Innovation (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 program is designed as a staged competition, supporting several Phase I centers, which then compete for the larger Phase II awards. The Phase II Center awarded in FY 2007 is developing chemistry needed to transform raw materials, such as plants, into high value organic compounds, such as fuels and chemicals for industry. The Phase II Center awarded in FY 2008 is researching the chemical fundamentals of solar energy capture and conversion to a chemical fuel.

In summer 2009, MPS engaged the Science and Technology Policy Institute (STPI) to assist in establishing a meaningful framework for effective programmatic evaluations in future years. MPS will use this opportunity to carefully consider the Phase I process, specifically whether this developmental grant is meeting objectives and providing a way for the MPS Division of Chemistry to develop a portfolio of research centers effectively targeting high-risk, high-reward science. Based on FY 2010 results, MPS, with STPI's assistance, will revise and finalize the evaluation approach, and any requisite data collection templates to implement beginning in FY 2011.

In FY 2011, four new Phase I and one new Phase II awards are expected. This will bring the total support to $5.0 million for 12 Phase I centers and $23.0 million for six Phase II centers.

Engineering Research Centers (ENG)
NSF's Engineering Research Centers (ERCs) enable innovation, bridging the energy and intellectual curiosity of university research focused on discovery with real-world engineered systems and technology opportunities through partnerships with industry. These centers also are successful in educating a technology-enabled workforce with hands-on, real-world experience. These characteristics create an environment that catalyzes the development of marketable technologies to generate wealth and address engineering grand challenges, many of which intersect the National Academy of Engineering's Grand Challenges. This is particularly evident in ERCs that address the need for intelligent electric power grid systems to integrate the distribution of electricity from a range of variable sources including wind and solar, innovations in healthcare derived from tissue engineering and microelectronics research, sensing systems that improve the prediction of tornados, and intelligent robotic systems to assist the aging and disabled in daily tasks.

ERCs are also devoted to the integration of research and education by creating collaborative environments, and producing curricula and course materials for bioengineering, manufacturing, renewable resource use, optoelectronics, and other fields. Also, all ERCs have active programs that involve pre-college teachers and students to bring engineering concepts to the classroom to stimulate interest in engineering among pre-college students; several have sites at local museums to educate the general public about engineering and technology.

The 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 delivering effectively on those goals, making an impact, and contain challenging future tasks which warrant further support. The ERC program periodically commissions program-level evaluations by external evaluators such as SRI International, STPI, and ABT Associates, to determine the effectiveness of ERC graduates in industry and the benefits of ERC membership to industry and others.

In FY 2011, five additional ERCs are expected to be funded for a total of 18 ERCs. The new Gen-3 ERCs have added goals of speeding innovation through involvement with small firms in translational research and partnerships with state, local, and venture capital organizations devoted to innovations and entrepreneurship.

Materials Research Science and Engineering Centers (MPS)
Materials Research Science and Engineering Centers (MRSECs) address fundamental research problems of intellectual and strategic importance that will advance U.S. competitiveness and the development of future technologies. MRSECs also support shared experimental facilities, place strong emphasis on the integration of research and education at all levels, and provide seed money to stimulate emerging areas of materials research. They support cutting-edge areas such as electronic and photonic materials, polymers, biomimetic and biomolecular materials, magnetic and ferroelectric materials, nanoscale materials, structural materials, and organic systems and colloids. MRSECs have strong links to industry and other sectors, enabling the development of marketable technologies that depend on new classes of materials and the discovery, control, and innovative exploitation of materials phenomena. Areas of potential technological impact include computers and communications, transportation, energy conversion and storage, structural engineering, health, and medicine. MRSECs also foster partnerships among academic institutions in the U.S. as well as internationally. A significant component of new MRSEC awards are expected to tie to cross-Foundation activities, particularly Science and Engineering Beyond Moore's Law (SEBML).

Open competitions for MRSECs are held triennially. The FY 2008 competition yielded five new centers while four others are phasing out with final funding in FY 2009 and FY 2010. To maintain program effectiveness and be consistent with the 2007 report from the MRSEC Impact Assessment Committee convened by the National Research Council, the FY 2011 MRSEC competition will be structured to support small to large-size centers. In FY 2011, 25 MRSECs are expected to be funded, including four to six new centers established as a result of the FY 2011 competition.

Nanoscale Science and Engineering Centers (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; they also address the social and ethical implications of such research. NSEC funding will also support 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 NSECs were evaluated by a Committee of Visitors (COV) in 2004 and SRI International in 2006. Also, NSECs were evaluated as part of the National Nanotechnology Initiative (NNI) flagship activities by the National Research Council (NRC) (2002 and 2006) and President's Council of Advisors on Science and Technology (PCAST) (2005 and 2008). NSECs currently are evaluated by the School of Public Policy, Georgia Institute of Technology for their research, education, and broader outcomes, the specific role of the centers, and recommendations for the future of the program.

The first class of NSECs receives final funding in FY 2010. In FY 2011, 19 NSECs are expected to be funded. Plans for the next round of centers with a nano focus are currently being developed.

Science and Technology Centers: Integrative Partnerships (multi-directorate)
The Science and Technology Centers: Integrative Partnerships (STC) program advances 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 research portfolio reflects the disciplines of science and engineering supported by the NSF. Examples of continuing investment include cyber-security, advanced sensors and embedded networked sensing, revolutionary materials for information technology, advanced nano/microfabrication capabilities, new materials and technologies for monitoring water resources and water quality, modeling and simulation of complex earth environments for improving their sustainability, and weather/climate prediction.

STCs engage the Nation's intellectual talent and robustly draw from its full diversity through partnerships among academia, industry, national laboratories, and government. These partnerships enhance and ensure the timely transfer of knowledge and technology from the laboratory to appropriate industries, the application of patents derived from the work of the STCs, the launching of spin-off companies, and creation of job opportunities. STCs have impressive records of publications and research training of students, postdoctoral fellows, established researchers, and educators as well as strong partnerships with K-12 and informal education communities and industry.

A review of the STC program, organized by the American Association of the Advancement of Science, initiated in FY 2009, will be concluded in early FY 2011. The review will assess outcomes and major impacts of the program since FY 2000 and provide guidance to NSF on future directions.

After ten years of funding, support for five centers from the Class of 2000 ended in FY 2009. A new competition was initiated in FY 2009 to identify and fund up to five new STCs in FY 2010. The FY 2011 Request includes funding for a total of 17 new and continuing STCs. FY 2011 funding includes support for the five new STCs that were partially funded at the 50 percent level in FY 2010 during their start-up phase. Six Class of 2002 STCs will receive their tenth and final year of funding in FY 2011.

Science of Learning Centers (multi-directorate)

The Science of Learning Center (SLC) goals are to advance fundamental knowledge about learning, transform the way people learn and teach, secure the U.S. leadership role in innovation and technology, and prepare the Nation's workforce for the 21st century. The six SLCs will continue to harness and integrate knowledge across multiple disciplines to create a common groundwork of conceptualization, experimentation, and explanation that underlies new lines of thinking and inquiry leading to a deeper understanding of learning. The SLC portfolio represents synergistic, exciting research efforts that address different dimensions of learning, including:

- combined modeling and experimental studies to link brain function and behavior and inform innovations in technology;
- development of learning technologies to study robust learning in classrooms in support of educational data mining, machine learning, and developing principles to inform the use and design of new technologies that enhance learning;
- the processes involved in learning visual languages and how this knowledge can improve language processing and reading in deaf, hearing-impaired, and hearing learners;
- the influence of time and timing on learning across multiple scales and multiple levels of analysis, to inform understanding of learning from the cellular level to social interactivity in classrooms;
- the role of social interaction in learning, including the interplay between learning in informal and formal environments; and
- spatial intelligence and learning, the malleability of the underlying processes and how they can be enhanced to improve learning in STEM domains.

Each SLC award includes funding for an external evaluation of the Center. Annual meetings of the SLC evaluators contribute to consistency of information coming from these evaluations and its usefulness for program managers. An external evaluation of the SLC program is in planning stages.

In FY 2011, $25.80 million will fund six SLCs. This anticipates renewal of five of the centers. The Social, Behavioral, and Economic Sciences Directorate's Office of Multidisciplinary Activities will continue to oversee management of all six centers, with matching co-funding from other NSF directorates.

Estimates of Centers Participation in 2009
(Dollars in Millions)

	Number of Participating Institutions	Number of Partners	Total FY 2009 NSF Support	Total Est. Leveraged Support	Number of Participants
Centers for Analysis & Synthesis	309	102	$17	$7	2,231
Centers for Chemical Innovation	62	47	$16	$3	362
Engineering Research Centers	423	534	$61	$101	4,089
Materials Research Science & Engineering Centers	359	269	$61	$50	3,850
Nanoscale Science & Engineering Centers	522	544	$47	$71	3,754
Science & Technology Centers	140	510	$62	$31	3,140
Science of Learning Centers	33	54	$13	$11	1,137

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 support by NSF.

Centers Supported by NSF in FY 2009

Center	Institution	State
Centers for Analysis and Synthesis		
National Center for Ecological Analysis and Synthesis	U of California-Santa Barbara	CA
National Evolutionary Synthesis Center	Duke, NC State U, U of N. Carolina	NC
National Institute for Mathematical & Biological. Synthesis	U of Tennessee- Knoxville	TN
iPlant (formerly Plant Science Cyberinfrastructure Collaborative)	U of Arizona	AZ
Centers for Chemical Innovation		
Center for Enabling New Technologies through Catalysis (phase II)	U of Washington	WA
Chemistry at the Space-Time Limit (phase II)	U of California-Irvine	CA
Powering the Planet (phase II)	California Institute of Tech	CA
[1]Center for the Chemistry of the Universe (phase I)	U of Virginia	VA
Center for Energetic Non-Equilibrium Chem. at Interfaces (phase I)	U of Chicago	IL
[1]Center for Green Materials Chemistry (phase I)	Oregon State U	OR
[1]Center for Molecular Interfacing (phase I)	Cornell	NY
Center for Molecular Spintronics (phase I)	North Carolina State U	NC
Center for Molecular Tools for Conjugated Polymer Anal. (phase I)	U of Texas Austin	TX
Center for Stereoselective C-H Functionalization (phase I)	Emory U	GA
Fueling the Future (phase I)	U of Massachusetts-Amherst	MA
The Origins Chemical Inventory & Early Metabolism Proj. (phase I)	Georgia Institute of Tech	GA
Engineering Research Centers		
Biomimetic Microelectronic Systems	U of Southern California	CA
Biorenewable Chemicals	Iowa State U	IA
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
Revolutionizing Metallic Biomaterials	North Carolina A&T U	NC
Smart Lighting	Rensselaer Polytechnic Institute	NY
Structured Organic Composites	Rutgers	NJ
Subsurface Sensing and Imaging Systems	Northeastern	MA
Synthetic Biology	U of California-Berkeley	CA
Wireless Integrated MicroSystems	U of Michigan	MI
Materials Research Science and Engineering Centers		
Brandeis Materials Research Science and Engineering Center	Brandeis U	MA
Center for Complex Materials	Princeton	NJ
Center for Emergent Materials	Ohio State U	OH
Center for Materials for Information Technology	U of Alabama	AL
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
Center for Nanomagnetic Structures	U of Nebraska	NE
Center for Nanoscale Science	Pennsylvania State	PA
Center for Nanostructured Interfaces	U of Wisconsin	WI
Center for Nanostructured Materials	Columbia	NY
Center for Polymer Interfaces and Macromolecular Assemblies	Stanford, UC-Davis, IBM	CA
Center for Research on Interface Structures and Phenomena	Yale	CT
Center for Response-Driven Polymeric Films	U of Southern Mississippi	MS
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
Ferroelectric 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 on Polymers	U of Massachusetts	MA
Renewable Energy Materials Research Science and Engineering Center	Colorado School of Mines	CO
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-Santa Barbara	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		
Adaptive Optics	U of California-Santa Cruz	CA
Advanced Materials for Purification of Water Systems	U of Illinois-Urbana Champaign	IL
Behavioral Neuroscience	Georgia State U	GA
Biophotonics Science and Technology	U of California-Davis	CA
Center for Remote Sensing of Ice Sheets	U of Kansas	KS
Coastal Margin Observation and Prediction	Oregon Health and Science U	OR
Earth Surface Dynamics	U of Minnesota-Twin Cities	MN
Embedded Networked Sensing	U of California-Los Angeles	CA
Environmentally Responsible Solvents and Processes	U of North Carolina-Chapel Hill	NC
Integrated Space Weather Modeling	Boston U	MA
Layered Polymeric Systems	Case Western Reserve U	OH
Materials and Devices for Information Technology Research	U of Washington	WA
Microbial Oceanography: Research and Education	U of Hawaii-Manoa	HI
Multi-Scale Modeling of Atmospheric Processes	Colorado State U	CO
Nanobiotechnology	Cornell	NY
Sustainability of Semi-Arid Hydrology and Riparian Areas	U of Arizona	AZ
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

[1] Ongoing centers forward funded in FY 2009 from FY 2008 funds.

CYBERLEARNING TRANSFORMING EDUCATION (CTE)

Goal: Capture the potential of cyber innovations to transform teaching and learning.

Cyberlearning refers to "the use of networked computing and communications technologies to support learning," as discussed in the 2008 report from the NSF Task Force on Cyberlearning, "*Fostering Learning in the Networked World.*" That same report sets the challenge for an NSF cyberlearning agenda:

> *Despite the revolutions wrought by technology in medicine, engineering, communications, and many other fields, the classrooms, textbooks, and lectures of today are little different than those of our parents. Yet today's students use computers, mobile telephones, and other portable technical devices regularly for almost every form of communication except learning. The time is now – if not long overdue – for radical rethinking of learning and of the metrics for success... and a transformation of how STEM is taught in K-12, higher education, and throughout the lifespan. We can anticipate that innovations will continue to be introduced over the coming decade and continually reconfigure the realm of possibilities for learning in a networked world.*

In FY 2011 NSF will establish a new multidisciplinary research program to fully capture the transformative potential of advanced learning technologies across the education enterprise. The Cyberlearning Transforming Education (CTE) program will seek to:

- enable wholly new avenues of science, technology, engineering, and mathematics (STEM) learning for students and for workforce development;
- advance the Nation's ability to study the learning process itself;
- bring advanced technologies to learners at all educational levels;
- identify the innovations that are yielding the most promising evidence of promoting learning, using appropriately rigorous evaluation to identify key features of these innovations and assess their suitability for scale-up; and
- collaborate with the Department of Education and other public and private-sector partners.

Description and Rationale: The education enterprise is at a crossroads. We have made great gains in the design of networked computing and communications technologies that support learning, teaching, and education. Such technologies now allow us to conduct investigations in education and learning with greater scale and in much more complex contexts than was ever previously possible. Technologies are already deeply entwined with our lives, especially so in the lives of young learners. Nonetheless, to date we have not fully embraced them as learning tools in the Nation's classrooms and laboratories, nor have we developed the capacity to integrate current and nascent technologies into our understanding of teaching and learning practices.

NSF's role in STEM education provides a critical focus for its proposed cyberlearning activities. The very nature of how science is conducted has been transformed through the advent of computing. Nonetheless, innovation in STEM teaching has been slow to make its way into formal education settings. The agency will draw upon its established track record in creating and using advanced cybertools, methods, and resources to revolutionize the conduct of scientific inquiry to similarly transform STEM education and learning.

NSF's future investments in CTE will be organized around three interrelated themes:

- **Anytime, Anywhere Learning.** Education today is largely tethered to formal institutions such as schools or colleges and universities, or to informal settings such as museums and afterschool centers. Cyberlearning offers opportunities to redistribute learning throughout the waking hours and throughout a lifetime, provide access to those who might otherwise be barred from valuable learning experiences, and transcend global boundaries.

- **Personalized Learning.** Cyberlearning can support new ways of learning as both a collaborative or social activity and in independent study. In fact, cyberlearning provides opportunities to provide more targeted learning experiences to individuals and to groups with shared characteristics. For example, cyberlearning enables the creation of learning experiences tailored to student traits, such as personality, learning style, motivation, culture, and ability. Similarly, cyberlearning experiences can be tailored to student states, such as affect, level of engagement, and level of understanding.

- **(Cyber)learning about (Cyber)learning.** Our body of knowledge about teaching and learning continues to grow. Cyberlearning allows us to advance fundamental knowledge bases in both technologies and learning sciences (including education and social sciences) in powerful new ways. As cyberlearning grows as a mechanism for learning, we are able to turn our sights to understanding what and why people learn well and don't learn well in both the cyberworld and the classroom. Cyberlearning also opens new doors to assessment, allowing us to embed assessment throughout learning and to use the results to reshape our understanding of how we learn.

NSF will establish a suite of Cyberlearning Collaboratoria to explore and assess the efficacy of learning systems that incorporate forward-looking cyberlearning technologies and approaches. The Collaboratoria will include representatives from colleges and universities, school systems, states or urban centers, industry, and/or nonprofits. As with the agency's Math and Science Partnerships, multidisciplinary teams of faculty – in this case with expertise in computing and learning – will play a pivotal role in funded projects; they will provide a tight coupling between state-of-the-art research in computing and related cyberlearning technologies, and rigorous ground-breaking research exploring the effectiveness of cyber-technologies in promoting and advancing learning. Projects funded will encompass school and informal environments, allowing learners and teachers to engage both independently and in virtual informal learning communities. Further, projects will support the effective transition of all stakeholders from highly structured classroom environments to learning models that promote and support anytime, anywhere, and personalized learning. The outcomes of these investments will be model learning tools/resources that have been tested and studied, and whose impacts on learning (or on advancing knowledge about learning) are well understood, as are the critical design and implementation features that led to that impact. CTE basic research outcomes are also expected to ultimately lead to applications which provide greater equity in opportunities to learn and experience authentic participation in STEM – enhancing America's potential to develop the diverse, cyber-savvy workforce of the future. All Cyberlearning Collaboratoria will have built-in evaluation requirements and expertise, while central resource projects will provide program-wide coordination of monitoring, performance measurement, and rigorous evaluation that is appropriate to the development effort.

Potential for Impact, Urgency, and Readiness: This cyberlearning investment is central to addressing significant national challenges. For example, CTE is aimed at improving STEM education and will simultaneously strengthen research and teaching institutions. Both strategies spur the economy and create jobs by producing a creative and innovative STEM workforce.

In the NSF Task Force report cited above and in numerous other reports[1], educators, scholars, and policy makers have showcased the opportunities that technology affords us for transforming how we learn and the consequences for failing to do so. Cyberlearning expands the access to and reach of education and learning. It strengthens established methods and enables new approaches to education and learning. Cyberlearning enables new scholarship about education and learning. It facilitates the scaling of educational innovation quickly and economically. Nonetheless, as indicated in a report recently released by the Department of Education[2], "Educators making decisions about online learning need rigorous research examining the effectiveness of online learning for different types of students and subject matter, as well as studies of the relative effectiveness of different online learning practices" (p. 54). CTE Cyberlearning Collaboratoria will produce just such a body of knowledge.

Leveraging Collaborations: NSF is uniquely positioned to target an ambitious agenda in the national context. Transforming education and learning through technological innovation requires multi-disciplinarity and collaboration. NSF's interdisciplinary research and education programs have already generated productive collaborations among learning scientists, computer scientists, engineers, interaction designers, subject matter experts, social scientists with varied expertise, designers of assessments, and educators. Programs such as the Math and Science Partnership have similarly generated productive collaborations among the various elements of the teaching and learning innovation enterprise, spanning science and technology scholars and educators, local education agencies, higher education enterprises, urban centers, industry, nonprofits, and other stakeholders in teaching and learning innovation. NSF is also this country's leading force in transforming science and engineering, and thus, is well-positioned to maintain timely connections among evolving scientific research and education knowledge, policy, and practice.

NSF has established relationships with key government agencies that have strong interests in transforming education and learning through technological innovations. For example, NSF has a long-standing and productive partnership with the Department of Education; the Department can help disseminate new knowledge about the benefits of cyberlearning in STEM education to the broader education enterprise. NSF also works closely with the Department of Defense, which has a strong track record of supporting advanced learning technology and education innovation in the training of the United States military. In addition, NSF is working with the Federal Communications Commission on its broadband initiative, helping to highlight the importance of universities as community anchors in broadband activities. The broadband initiative is a necessary enabler for cyberlearning activities and has broad reach. The cyberlearning activity is perfectly poised to leverage these efforts and forge partnerships with industry and private foundations.

The CTE and overall STEM education activities in NSF's FY 2011 Request will be part of a coordinated Federal strategy developed in collaboration with the Department of Education and other Federal agencies. The agencies will:

- Clarify and align evidence standards so that recipients of development grants for learning materials understand the type and quality of evidence their research projects must generate to be eligible for U.S. Department of Education validation or scale-up grants; and
- Identify the innovations that are yielding the most promising evidence of producing learning that would merit further Federal investment in development and validation using rigorous evaluation – to assess their suitability for replication, adaptation, and scale-up.

Management and Assessment: Plans for the monitoring and rigorous evaluation of the new multi-faceted cyberlearning program will draw on a variety of practices to ensure the quality and results of the program. External, independent experts will assist NSF and the Department of Education in developing program-wide monitoring systems and rigorous evaluation processes as solicitations are being developed. Core information required for the evaluation processes will be articulated in the solicitations and in award conditions. Plans for ongoing assessment and evaluation will be required as part of proposal submission and a significant consideration in the merit review process.

In addition to project-level evaluation, program level evaluation must assess overall changes in STEM education and learning (e.g., goals, processes, assessments) and include metrics that assess learning outcomes across cyber-enabled environments, the effectiveness of seamless cyber-transitions, and the effectiveness of tools developed through this activity. Innovations which show strong evidence of efficacy will be considered for scale-up by the Department of Education and others further down the development and deployment pipeline.

Funding: The FY 2011 Request is for $41.28 million to support research on innovative cyber-related paradigms in STEM teaching and learning. This investment will permit the launch of 8-15 Cyberlearning Collaboratoria (ranging from $1.0 to $3.0 million each) and integrated data collection and community building efforts through central resource projects.

Cyberlearning Transforming Education Funding

(Dollars in Millions)

	FY 2010 Estimate	FY 2011 Request
Total, CTE	**$25.33**	**$41.28**
Cyberlearning Collaboratoria		*35.00*
Central Resource Projects		*6.28*

[1] See, for example:

- The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy, Carnegie Corporation of New York-Institute for Advanced Study Commission on Mathematics and Science Education, 2009.
- Learning Science in Informal Environments, National Research Council, 2009.
- Learning 2.0: The Impact of Web2.0 Innovation on Education and Training in Europe, European Joint Research Center: Institute for Prospective Technological Studies, 2009
- 2020 Forecast: Creating the Future of Learning, KnowledgeWorks Foundation, 2009
- The Future of ICT and Learning in the Knowledge Society, European Joint Research Center: Institute for Prospective Technological Studies, 2008
- A Review of the Open Educational Resources (OER) Movement: Achievements, Challenges, and New Opportunities, William and Flora Hewlett Foundation, 2007
- Cyberinfrastructure for Education and Learning for the Future, Computing Research Association, 2005
- Planning for Two Transformations in Education and Learning Technology, National Research Council, 2003
- 2020 Visions, Transforming Education and Training Through Advanced Technologies, Department of Education, 2002
- Using Information Technology To Transform the Way We Learn, President's Information Technology Advisory Committee, 2001

[2] Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies, U.S. Department of Education, May 2009

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 individualized pharmaceuticals, new drug delivery systems, more resilient materials and fabrics, catalysts for industry, order-of-magnitude faster computer chips, and sustainable development in using water and energy resources.

NNI by Program Component Area
(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
1. Fundamental Nanoscale Phenomena & Processes	$143.59	$29.91	$152.57	$140.13
2. Nanomaterials	72.35	24.67	78.67	74.30
3. Nanoscale Devices & Systems	54.04	17.61	43.74	40.67
4. Instr. Research, Metrology, & Standards for Nanotech	21.39	4.52	18.34	16.58
5. Nanomanufacturing	27.67	6.05	22.43	32.20
6. Major Research Facilities & Instrumentation Acquisition	31.45	6.52	37.83	35.33
7. Environmental Health & Safety	26.84	3.38	29.82	33.01
8a. Education	26.99	8.04	28.44	23.75
8b. Societal Dimensions (ELSI)	4.31	0.50	5.85	5.28
Total, National Nanotechnology Initiative	**$408.62**	**$101.20**	**$417.69**	**$401.25**

Totals may not add due to rounding.

FY 2011 NNI Funding. NSF supports nanoscale science and engineering in all disciplines throughout all 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 representing more than 10 percent of the NSF portfolio. About 10,000 students and teachers will be educated and trained in nanoscale science and engineering in FY 2011. NSF contributes to the goals and eight program component areas (PCAs) outlined in the NNI Strategic Plan (www.nano.gov). The largest increase in FY 2011 is for nanomanufacturing with a budget of $32.30 million. In FY 2011, funds are transferred from several PCAs to increase funding for the Environmental, Health and Safety (EHS) PCA to a total of $33.01 million. This shift reflects the prioritization of EHS within the overall NNI portfolio. Overall NNI funding in FY 2011 has been reduced by $16.44 million as compared to the FY 2010 Estimate. This reduction is due to decreased support from MPS and GEO based on the research priorities of these directorates.

Fundamental Nanoscale Phenomena and Processes. The FY 2011 Request includes $140.13 million, a reduction of $12.44 million as compared to the FY 2010 Estimate for fundamental research and education. A part of those funds have transitioned to other PCAs, as part of the competitive planning process in each directorate. Special emphasis will be on:

- *Novel phenomena, quantum control, and basic engineering processes* – to discover and understand phenomena and design processes specific at the nanoscale, including new phenomena in materials, mechanics, chemistry, biology, electronics, and optics. A focus will be on the understanding and use of self assembly from basic principles and on multiple scales. Potential applications include quantum information systems, novel products by multiscale self assembling, and new devices and sensors for industry and environmental monitoring. The program on "Macromolecular, Supramolecular and Nanostructures" has been established.

- *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 understanding and simulation of cells, tissues, and nervous systems.
- *Converging science and engineering at the nanoscale* – The convergence of nanotechnology with information technology, modern biology, and social sciences will reinvigorate 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.

Nanomaterials. The FY 2011 Request includes $74.30 million 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 gaining control of nanoscale features and devices with an atomic level of precision. Another 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 beyond Moore's Law, catalysts, energy, healthcare, and manufacturing

Nanoscale Devices and Systems. The FY 2011 Request includes $40.67 million for R&D that applies the principles of nanoscale science and engineering to create novel, or to improve existing, devices and systems. A special 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 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 bio-systems and to regenerate the human body. Another focus will be on nano-informatics for better communication and nanosystem design.

Instrumentation Research, Metrology, and Standards for Nanotechnology. The FY 2011 Request includes $16.58 million for R&D to create new tools needed to advance nanotechnology research and commercialization. A special challenge is 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 2011 Request includes an increase of about $10.0 million to $32.20 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 in industry and in the medical field. R&D is aimed at enabling scaled-up, reliable, cost effective manufacturing of nanoscale materials, structures, devices, and systems. A special focus will be creating active nanostructures and complex nanosystems. The investment will emphasize (1) new tools for measuring and restructuring matter for production purposes; (2) hierarchical manufacturing of nanosystems by assembling nanoscale components into new architectures and fundamentally new products; (3) manufacturing by design using new principles, computer simulations, and nanoinformatics; and (4) hybrid nanomanufacturing, including nanobiotechnology and nanostructured catalysts. An overall goal will be advancing nanomanufacturing methods supporting sustainable development. NSF will strengthen the support for the National Nanomanufacturing Network composed of four Nanoscale Science and Engineering Centers in order to advance innovation, partner and implement the research results with industry, medical institutions, and other government agencies.

Major Research Facilities and Instrumentation Acquisition. The FY 2011 Request includes $35.33 million for user facilities, acquisition of major instrumentation, and other activities that develop, support, or enhance the scientific infrastructure 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 are planned to have over 110,000 users in FY 2011. The investment will support facilities for 17 ongoing Nanoscale Science and Engineering Centers (NSEC).

Environmental, Health and Safety. The FY 2011 Request includes $33.01 million, an increase of $3.19 million over the FY 2010 Estimate 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 collaborate on implementation of a joint solicitation for nano EHS. Basic research will support understanding of underlying phenomena and processes. 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. This work will support regulatory and mission agencies in developing science-based standards for risk assessments, such as those needed by the National Institute of Standards and Technology (NIST), EPA, the Food and Drug Administration (FDA) and other agencies to develop standards for and to regulate nano-materials. NSF will provide supplements to NSECs for nano EHS on a competitive basis.

Education and Societal Dimensions. The FY 2011 Request includes $29.03 million for research and other activities that address the broad implications of nanotechnology for society, including education and social aspects, including:

- 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 ($23.75 million). Two networks for nanotechnology education with national outreach will be supported: The Nanotechnology Center for Learning and Teaching (NCLT) and the Network for Nanoscale Informal Science Education (NISE); and
- Research directed at identifying and quantifying the broad implications of nanotechnology for society, including social, economic, workforce, educational, ethical, and legal implications ($5.28 million). The application of nanoscale technologies will stimulate far-reaching changes in the design, production, and use of many goods and services. Factors that stimulate scientific discovery at the nanoscale will be investigated, effective approaches to ensure the safe and responsible development of nanotechnology will be explored and developed, and the potential for converging technologies to improve human performance will be addressed. The Nanotechnology in Society Network will extend its national and international network. NSF will support activities of a new World Technology Evaluation Study to explore the potential of nanotechnology in the long-term.

Coordination with Other Agencies. The NSF program is coordinated with 25 departments and agencies through the National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET). Examples of specific coordination efforts are: Nanomanufacturing (Department of Defense (DOD)/NIST); Environmental issues (EPA/ National Institute of Environmental Health Sciences (NIEHS)/USDA); NSECs, NNIN and Network for Computational Nanotechnology (NCN) centers and networks (DOD/ National Aeronautics and Space Administration (NASA)/ Department of Energy (DOE)/ National Institutes of Health (NIH)); nanoelectronics (NIST, DOD), simulations in nanoelectronics (DOD/NASA); and research and training activities (DOD/NIH).

NNI Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
Biological Sciences	$56.60	-	$56.60	$56.60
Computer and Information Science and Engineering	11.65	1.43	11.00	11.00
Engineering	140.02	35.00	148.00	156.37
Geosciences	0.85	-	6.33	0.85
Mathematical and Physical Sciences	194.27	64.77	190.59	172.26
Social, Behavioral and Economic Sciences	1.73	-	1.67	1.67
Subtotal, Research and Related Activities	405.12	101.20	414.19	398.75
Education and Human Resources	3.50	-	3.50	2.50
Total, National Nanotechnology Initiative	**$408.62**	**$101.20**	**$417.69**	**$401.25**

Totals may not add due to rounding.

NETWORKING AND INFORMATION TECHNOLOGY R&D (NITRD)

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 all of the agency's directorates also contribute. 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. 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.

NSF's FY 2011 Request continues strong support for NITRD at a level of $1.170 billion, a 7.3 percent increase over the FY 2010 Estimate. NITRD activities represent approximately 16 percent of NSF's FY 2011 budget. CISE and OCI's combined support comprises close to 80 percent of NSF's NITRD activities.

Several NSF-wide investments, both new and continuing, are reflected in various NITRD PCAs. 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. NSF's new multidisciplinary research program, Cyberlearning Transforming Education (CTE), will contribute to the Human Computer Interaction and Information Management area. NSF's ongoing Cyber-enabled Discovery and Innovation (CDI) investment is most prominent in the High Confidence Software and Systems and Human Computer Interaction and Information Management areas. NSF's investments in Science and Engineering Beyond Moore's Law (SEBML) are reflected in the High-End Computing R&D program component area.

NITRD by Program Component Area
(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
Large Scale Networking	$79.14	$53.22	$107.18	$113.57
Cybersecurity and Information Assurance	76.30	30.88	71.36	85.16
High End Computing R&D	80.79	39.84	98.54	92.78
High End Computing Infrastructure and Applications	331.77	58.49	310.87	317.83
High Confidence Software and Systems	59.04	33.09	73.08	83.29
Human-Computer Interaction and Info Management	234.11	88.01	280.70	310.43
Software Design and Productivity	48.36	18.08	57.58	73.92
Social/Economic/Workforce	102.11	25.55	91.17	93.09
Total, NITRD	**$1,011.62**	**$347.16**	**$1,090.48**	**$1,170.07**

Totals may not add due to rounding.

Large Scale Networking ($113.57 million): CISE will increase support for core fundamental network research to create new insights into the dynamics of complex networks and explore new architectures for future-generation networks and services. Through the SEES cross-Foundation investment CISE will support research to optimize energy-computation performance in computer and network systems and explore the use of information technology in smart sensing systems that promise to save energy and reduce greenhouse gas emissions.

OCI will continue its International Research Network Connections (IRNC) activity, which will include opportunities to fund experimental networks.

Cybersecurity and Information Assurance ($85.16 million): NSF will continue to fund research on cybersecurity foundations, network security, and systems software that support the objectives of the *Federal Plan for Cyber Security and Information Assurance Research and Development*. CISE will devote $55.0 million to research in usability, theoretical foundations, and privacy to support the Comprehensive National Cybersecurity Initiative. Support will continue for several centers. This includes one devoted to the scientific exploration of new technology that will radically transform the ability of organizations to design, build, and operate trustworthy information systems for critical infrastructure. It also includes one investigating software architectures, tamper-resistant hardware, cryptographic protocols, and verification systems as applied to electronic voting systems.

OCI will fund research and support for cybersecurity approaches and deployment of identity authentication and authorization systems including authorization infrastructure to support science and engineering applications and projects. Efforts include developing scalable cybersecurity approaches and systems for very large, complex, and highly distributed communities, from data integrity and confidence to secure transmission and collaboration technologies.

High-End Computing Research and Development (R&D) ($92.78 million): OCI and CISE will support the development of simulation, optimization, and analysis tools that exploit the potential of petascale computing to advance the frontiers of scientific and engineering research. Included in this PCA are NSF's investments in SEBML that will focus on advancing fundamental science that can revolutionize computing.

High-End Computing Infrastructure and Applications ($317.83 million): OCI will continue acquisition of a high performance computing (HPC) system. OCI is following-up the existing TeraGrid activity with eXtreme Digital (XD). XD will provide computational, storage, networking, and visualization resources to the open science and engineering communities. OCI also will initiate a new software activity in FY 2011, focusing on producing the complex middleware and application codes for new high-end computing architectures. The activity will address not only performance issues but also identification of common software infrastructure and/or approaches that could benefit a broad range of science areas.

CISE will invest in research infrastructure resources to support the acquisition, enhancement, and operation of state-of-the-art infrastructures and facilities that enable high-quality computing research and education in a diverse range of institutions and projects.

Several NSF directorates will continue their investments in this PCA to capitalize on the growing importance of cyberinfrastructure in furthering their research and education goals. For example:

- BIO will invest in activities to broaden access to and usability of high performance computing resources in the biological sciences. Current biology applications claim substantial HPC resources that are narrowly focused in specific areas of biology. With increasing availability of large amounts of diverse data from plant, animal, and microbial genomics to ecosystems modeling, additional areas of biology will likely require expanded access to and development of HPC resources.
- ENG will continue support of virtual organizations to leverage distributed physical experimentation, data collection, modeling, and analysis capabilities using high-end computing and large scale networking infrastructures.

- GEO will continue to support state-of-the-art computing systems and data management services at the National Center for Atmospheric Research (NCAR). Part of this high performance computing environment, the Climate Simulation Laboratory (CSL), helps keep the U.S. at the forefront of 21st century climate science.
- MPS will invest in new computational methods, algorithms, robust software, and other computational tools to support researchers in the mathematical and physical sciences including computational chemistry, materials research, physics, astrophysics, and biological chemistry, physics, and materials with a focus on advancing methods, algorithms, and software that will scale to the petascale and beyond.
- MPS will continue support of research and education activities that contribute to and utilize the Virtual Astronomical Observatory, a federation of astronomical databases. MPS will continue to support remote access to instrumentation and increased connection of institutions that are distant from each other, such as a minority institution and its partner.

High Confidence Software and Systems ($83.29 million): As part of the CDI investment, CISE will support research on software for tomorrow's complex cyber-physical systems, such as smart automobiles, sensor nets for environmental monitoring, and embedded medical devices, and similarly in mobile, portable, and pervasive computing devices, such as cell phones, digital cameras, flexible displays, radio-frequency identification (RFIDs), multi-media multi-modal handhelds, and household robots.

In partnership, CISE and ENG will support advanced manufacturing through research on cyber-physical systems that help better integrate information technology into manufactured goods.

Human Computer Interaction and Information Management ($310.43 million): CISE, in partnership with the EHR and SBE directorates, will establish NSF's new multidisciplinary research program, CTE, which is designed to fully capture the transformative potential of advanced learning technologies across the education enterprise. The CTE program seeks to enable wholly new avenues of science, technology, engineering, and mathematics (STEM) learning for students and for workforce development; advance the Nation's ability to study the learning process itself; and bring proven technologies to learners at all educational levels.

The multidisciplinary CDI emphasis will focus on creation of new knowledge from digital data, including novel algorithms, data mining, and dimension reduction methodologies, new visualization methods to enhance human cognition, and innovative technologies to address data confidentiality, privacy, security, provenance, and regulatory issues.

NSF will focus increased attention on the issues of federation, preservation, curation, and access to large, heterogeneous collections of scientific data and information. High capacity data management and high capacity computing are increasing challenges for a growing number of research communities. OCI will develop activities for a robust and resilient national and global digital data framework for preservation and access to the resources and products of the digital age. OCI will invest in data, modeling paradigm, and software interoperability in the area of virtual organizations.

Several other NSF directorates will continue their investments in this PCA, for example:

- BIO's investments 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 that provide an intuitive display of the complex networks of interactions among organisms and their environments, and make it practical for scientists to search vast collections of biological images simply and quickly.

- ENG's investment in this area will focus on creating new pathways to connect researchers with each other and with state-of-the-art experimental facilities.
- MPS continues to invest in new and fundamental methods for analysis and computation with large data sets. These investments will be of value to all science and engineering disciplines.
- SBE and CISE will continue to support research on Socio-Computational Systems, encouraging the study of the interaction between people and machines.

Software Design and Productivity ($73.92 million): CISE will support research on the scientific and engineering principles for developing software for tomorrow's complex cyber-based systems. Advances in software foundations, including new computational models, techniques, languages, tools, metrics, and processes for developing and analyzing software for these complex systems, will be pursued. Through the SEES cross-Foundation investment, CISE will support research on the software advances needed to meet the energy requirements inherent in computation and communication.

As part of OCI's new software activity (also described under HEC I&A), research on topics such as software production, hardening, collaboration, and sustainability will be supported.

BIO, through its Biological Databases and Informatics program, will promote new ways of enabling science through the use of cyberinfrastructure, including new visual programming environments and integrated information systems that allow an entire community of experts to contribute simultaneously to understanding genome dynamics.

ENG will invest in developing new algorithms and software that can efficiently scale to the petascale level. ENG will also invest in virtual organizations to enhance the productivity of researchers by providing them access to computational tools, specialized facilities, and observational data from anywhere in the world.

Social, Economic and Workforce ($93.09 million): Through CDI, NSF will support investments that infuse computational thinking into computing education at all levels and in all fields of science and engineering.

CISE education and workforce activities, such as the Broadening Participation in Computing (BPC) and CISE Pathways to Revitalized Undergraduate Computing Education (CPATH) programs, are aimed at significantly increasing the number of students who are U.S. citizens and permanent residents receiving post secondary degrees in the computing disciplines. CISE will continue to support and refine these activities to help create and sustain a U.S. workforce with the computing competencies and computational thinking skills imperative to the Nation's health, security, and prosperity in the 21st century.

In collaboration with partners across NSF, OCI will support creative explorations and demonstrations of the use of cyberinfrastructure to integrate research with education, the development of innovative technologies that will facilitate the integration of research and education, and research on how educators and students interact with cyberinfrastructure along with exploring novel uses of cyberinfrastructure.

Activities in other directorates include:

- BIO investments to strengthen IT capabilities in all biological sub-disciplines through support for postdoctoral fellowships in bioinformatics; integrative graduate programs that combine training in biology and computer sciences (via the NSF-wide Integrative Graduate Education and Research Traineeship (IGERT) program); undergraduate summer institutes in bioinformatics through the interagency Bioengineering and Bioinformatics Summer Institutes program; and other mechanisms.

- 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 on learning, and efforts that advance teaching and learning opportunities utilizing cyberinfrastructure. In FY 2011, EHR will fund research that highlights the educational use of information tools that operate seamlessly across formal and informal learning environments and across traditional computers, mobile devices, and newly emerging information and communications.
- SBE will continue to study the impact of IT 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 on learning, and efforts that advance teaching and learning opportunities in nanotechnology and/or cyberinfrastructure through the Science of Learning Centers (SLC) program.

NITRD Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
Biological Sciences	$86.15	-	$93.00	$93.00
Computer and Information Science and Engineering	574.50	235.00	618.83	684.51
Engineering	20.75	3.30	23.70	23.70
Geosciences	18.98	-	22.98	22.98
Mathematical and Physical Sciences	85.01	24.24	85.39	84.51
Social, Behavioral and Economic Sciences	17.50	4.62	22.80	23.80
Office of Cyberinfrastructure	199.23	80.00	214.28	228.07
Subtotal, Research and Related Activities	1,002.12	347.16	1,080.98	1,160.57
Education and Human Resources	9.50	-	9.50	9.50
Total, NITRD	**$1,011.62**	**$347.16**	**$1,090.48**	**$1,170.07**

Totals may not add due to rounding.

RE-ENERGYSE: A DOE–NSF Partnership in Research and Education on Renewable Energy and a Sustainable Environment

RE-ENERGYSE (REgaining our ENERGY Science and Engineering Edge) is a developing partnership between the Department of Energy (DOE) and NSF that will inspire more young people to pursue careers in renewable energy and related environmental areas. Its goals are to address what President Obama has identified as the "generational challenge" of clean energy and to secure U.S. leadership in sustainable energy by building the clean energy workforce of the future. This partnership will build on: the scientific and engineering expertise of both agencies in the energy field, NSF's successful track record of integrating research with education using proven programs developed over the past two decades, and NSF's experience in linking research on energy, technology, and the environment with social, behavioral and economic research.

NSF and DOE will explore additional planning workshops that focus on identifying educational opportunities for sparking interest in careers related to sustainable energy and the environment, and identifying future workforce needs in these areas. NSF and DOE also have a continuing partnership in public awareness and outreach activities that support the goals of RE-ENERGYSE.

In FY 2011, NSF will invest roughly $19.0 million in RE-ENERGYSE through five existing research and education programs that help develop the future STEM workforce. These programs provide fellowships, traineeships, and research opportunities for undergraduate and graduate students, as well as build collaboration between academia and industry. NSF will contribute at least 5 percent of its support for the following programs towards specific, energy-related awards:

- Graduate Research Fellowship (GRF);
- Graduate STEM Fellows in K–12 Education (GK–12);
- Integrative Graduate Education and Research Traineeship (IGERT);
- Support for community colleges through Advanced Technological Education (ATE); and
- Research Experiences for Undergraduates (REU) sites.

Through these investments, the Nation will prepare a generation of young people to meet the clean energy challenge.

SCIENCE AND ENGINEERING BEYOND MOORE'S LAW (SEBML)

Goal: Position the U.S. at the forefront of communications and computation capability beyond the physical and conceptual limitations of current technologies.

Description and Rationale: The transistor was demonstrated in 1947, and once multiple devices were simultaneously fabricated, the packing density of devices on a chip began to increase. Moore's Law is the empirical observation, made in 1965, by the co-founder of Intel, Gordon E. Moore, that semiconductor device density, and therefore computer processing power, doubles about every 18 months. Currently, many innovations are being pursued to prolong the scalability of computer processing power, but with silicon technology the fundamental physical and conceptual limits of Moore's Law are likely to be reached in 10 to 20 years.

To take computation *beyond* Moore's Law requires new scientific, mathematical, engineering, and conceptual frameworks. Fundamental research across many disciplines will lead to the new hardware and architectures needed to address challenges such as efficient input and output, data storage and communication, and reduction of energy consumption, as well as sheer computing power. Further, there are also great potential increases in speed of basic computations due to innovative new algorithms and software, and new mathematical frameworks for computation. In the near term, massively parallel machines require a fundamental shift from the traditional sequential model of computation in order to utilize distributed paradigms such as grid and cloud computing. In the longer term, a completely new physical and conceptual foundation of computing will be needed.

Science and Engineering Beyond Moore's Law (SEBML) is a multidisciplinary research investment with strong ties to economic competitiveness and potential for transformation. Tied to nanotechnology, computer science, chemistry, mathematics, materials science, and physics, it builds on past NSF investments in these areas and energizes them with new directions and challenges. Connections to the communications and computer industries ensure that SEBML will directly address economic benefits to the Nation. SEBML research will also enhance NSF investments in both the National Nanotechnology Initiative (NNI) and Networking and Information Technology Research and Development (NITRD).

Potential for Impact, Urgency, and Readiness: The U.S. has fundamental strengths in computers and information systems. In today's globalized enterprise, however, many other countries dominate parts of the hardware and software markets. The areas where the U.S. currently excels are in innovative state-of-the-art components, which require a continual investment in research and development. The reward of this approach has been continual leadership in the areas of the largest economic return. To continue U.S. leadership, a paradigm shift is required in the physical foundations of computing.

Fundamental research will focus on a number of areas, including:

- *New materials, devices, and processes* that exploit the capability to create and manipulate specific quantum states. Some possible candidates include optical and photonic systems, spin-based or single electron transistors, atom condensates, ions, non-equilibrium devices, and molecular-based approaches including biologically inspired systems.
- *New architectures*, particularly multi-core processors, with new control principles, massive parallelism, and designed asynchronicity and indeterminacy. Advances here may be applicable to other kinds of communication, distribution, and computing systems, leading to truly transformational outcomes.
- *New algorithms* that exploit hardware and architecture characteristics to optimize computing power, including those that exploit quantum behavior. The consideration of biological and social systems may lead to new approaches.

- *New software* that allows the effective use of new devices. New programming models will be needed, along with languages and compilers to support them. Tools for analyzing, monitoring, debugging, and documenting software on these parallel and distributed systems will be essential.
- *New paradigms* that take us from bits (binary logic) to quantum bits or qubits (non-binary logic). These programming models are shifts in our thinking that will change the conceptual foundations of computing.
- *New awareness* of power and energy considerations throughout the "computation stack" from physical devices to architectures to software and applications.

Integration of Research and Education: SEBML has the potential to take computing and communications to new levels of capability, making the development of a workforce trained in these new areas particularly important. All activities will seek creative ways to engage students and, as appropriate, take new ideas into formal and informal learning environments.

Leveraging Collaborations: NSF has in place proven partnerships among its directorates, connections with other communities (notably other governmental funding organizations and industry), and collaborations with international partners. Strong potential exists for interagency partnering with organizations such as the Department of Defense, Department of Energy, National Aeronautics and Space Administration (NASA), National Institutes of Science and Technology and the intelligence community. NSF, in particular the Mathematical and Physical Sciences (MPS), Engineering (ENG), and Computer and Information Science and Engineering (CISE) Directorates, and the Office of Cyberinfrastructure (OCI) has the broad responsibility for support of fundamental research needed to have a significant technological impact.

Evaluation and Management: While it may be 10 to 20 years before the full impact of the investment is known, indicators of success will be developed and monitored along the way. Indicators of a growing capability to conduct research in SEBML include: increased numbers of students involved in SEBML projects and related data on breadth/diversity of participation, degree completion, opportunities to participate in interdisciplinary teaming, and progression to higher levels of education or first professional jobs; increased numbers of researchers involved in SEBML projects; numbers of collaborative projects that span disciplines or institutions; increased partnerships with national laboratories and private sector organizations; and the development of curricular materials or informal education activities that convey aspects of SEBML research. Indicators of research progress include highlights demonstrating progress from NSF awards; publications and patents resulting from NSF awards in SEBML; and public or private sector adoption of ideas from NSF awards in developing new technologies that stimulate innovation.

Committees of Visitors and other external review panels involving all sectors of the economy will be involved in evaluating progress on SEBML research and education.

SEBML Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
CISE	$4.00	-	$15.00	$15.00
ENG	3.00	-	10.00	20.00
MPS	36.53	9.82	18.68	32.18
OCI	-	-	3.00	3.00
Total, NSF	**$43.53**	**$9.82**	**$46.68**	**$70.18**

Totals may not add due to rounding.

SCIENCE, ENGINEERING, AND EDUCATION FOR SUSTAINABILITY (SEES)

<u>Goal:</u> To generate the discoveries and capabilities in climate and energy science and engineering needed to inform societal actions that lead to environmental and economic sustainability.

<u>Description and Rationale:</u> Major drivers for establishing the NSF SEES portfolio are the August 2009 report from the *National Science Board: Building A Sustainable Energy Future* and the *IPCC Fourth Assessment Report: Climate Change 2007.*

- The scope of the SEES portfolio parallels the NSB's call for integrated approaches that "increase U.S. energy independence, enhance environmental stewardship and reduce energy and carbon intensity, and generate continued economic growth." The NSB provided specific guidance to NSF that emphasized systems approaches to research programs, education and workforce development, public awareness and outreach, and the importance of partnerships with other agencies, states, universities, industry, and international organizations.
- The IPCC Synthesis Report presented a number of key scientific uncertainties that if resolved would improve our ability to predict future climate change, its consequences, and the potential success of mitigation and adaptation strategies.

The two-way interaction of human activity with environmental processes now defines the challenges to human survival and wellbeing. Human activity is changing the climate and the ecosystems that support human life and livelihoods. Reliable and affordable energy is essential to meet basic human needs and to fuel economic growth, but many environmental problems arise from the harvesting, generation, transport, processing, conversion, and storage of energy. Climate change is a pressing anthropogenic stressor, but it is not the only one. The growing challenges associated with climate change, water and energy availability, emerging infectious diseases, invasive species, and other effects linked to anthropogenic change are causing increasing hardship and instability in natural and social ecologies throughout the world.

Solutions to these emergent, coupled problems will have to be based on sound multi-disciplinary and quantitative principles derived from science, engineering, and technology. It is not only urgent, but also timely and achievable to generate understanding of the links between energy sources and systems, climate forcings and feedbacks of the Earth system, and social, educational, and policy responses. This research will lay the foundation for technologies to mitigate against, and adapt to, environmental change that threatens sustainability. By informing policy, education, and management decisions, we will address the major challenge of ensuring human wellbeing over the long term.

<u>Integrated Science and Engineering Research in Climate Change and Energy:</u> NSF has broad and long-standing investments in environment, energy, climate, social sciences, mathematics, and many other areas of research and education that provide insight into the challenges to sustainable well-being in the 21st century. Fundamental research that underpins the development of innovative solutions to pressing problems in sustainability will continue to be supported and emphasized across NSF. This research – in such areas as complex environmental and climate-system responses and pathways – will be complemented by activities focused on sustainable and renewable energy technologies.

NSF's unique mandate to support all areas of science, engineering, and science education allows it to now identify SEES research aimed at tackling the complex system level problems of sustainability. SEES research will investigate the fundamental role that social, economic, and political systems play in creating and addressing major issues in sustainability. It will include conceptual, theoretical, empirical, and computational research needed to further develop the basic science, engineering, education, and policy knowledge base, as well as address the multifaceted challenges of sustainability (energy-economy-environment) at both individual and systems levels.

The NSB report outlined a range of SEES research investments in the area of sustainable energy: novel energy storage schemas; ecosystem impacts of energy technologies; improving the efficiency and yield of established sustainable energy systems, e.g. wind, solar; and the discovery and development of novel energy sources, e.g. biofuels, ocean/kinetic power. Energy-intelligent computational performance in computer and network systems will be explored as well as the use of information technology in smart sensing systems that have promise to save energy. Energy efficiency in manufacturing and materials will be stressed.

Some key scientific uncertainties identified in the IPCC report that SEES research will address include: interactions between the climate, human and natural systems; feedbacks in the climate and especially carbon cycles; impacts of ice sheets dynamics on climate change and sea level rise; regional climate change and causes; the difference between low probability/high impact vs. high probability/low impact events on risk-based approaches to decision making; interactions between socio-economic factors and the evolution and utilization of adaptive and mitigating strategies; barriers, limits and costs of adaptation; effects of lifestyle and behavioral changes on energy consumption and climate.

Scientific and engineering research in SEES will benefit from creative mathematical, statistical and computational methods for analysis and simulation. Supercomputing capability will be enhanced in support of improved predictability and communication at the climate-energy-society nexus. Many efforts will build on the climate research emphasis initiated in FY 2010, including research on regions highly susceptible to the impacts of environmental changes, such as coastal areas subject to sea-level rise, the Arctic where permafrost is changing rapidly, and the Antarctic where sub-ice sheet conditions are being explored and modeled.

In addition to advances in research, these awards will_include activities that help prepare an informed, solutions-oriented citizenry and future work force to address the complex problems and decisions associated with sustainability. Experiences for undergraduate, doctoral and postdoctoral students will complement those supported by the Climate Change Education program.

Management and Assessment: As an investment portfolio, SEES will support research and education that span ten NSF directorates and offices. Because it will build on and initiate activities that are dispersed, there is a need to create an integrated management framework for the complex, highly interdisciplinary, yet integrated activities that will be effective in addressing the challenge of sustainability. For example, additional planning will occur during FY 2010 in order to consult with a wide spectrum of disciplinary communities, form partnerships, and identify shared priorities. Specific measures will therefore be established to provide coordination and guidance across this portfolio.

The organizational structure will include:

- A senior leadership committee composed of Assistant Directors/Office Heads to provide long-term planning and provide overall guidance;
- 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; and
- Interagency working groups to coordinate interagency activities, which may require establishment of MOUs/MOAs and joint solicitations between the collaborating agencies.

Specific outcomes will include:

- Emergence of new areas of research, identified in FY 2010 and FY 2011, that help close key gaps in the knowledge base;
- Development of new models for the conduct of research, specifically employing integrative, systemic approaches. These will be used by investigators and evaluated between FY 2014 and FY 2016; and
- Generation of new integrated understanding of the interplay of environment, energy, and the economy. Communication and publication of results is expected primarily after awards conclude, beginning as early as FY 2014.

To develop the evaluation framework necessary to monitor progress toward these outcomes, the senior leadership committee will consider a matrix of assessment methods and measures that captures a range of outcomes and impacts. These outcome metrics and targets will be developed during FY 2010. The Advisory Committee for Environmental Research and Education, in addition to other existing NSF advisory committees, will provide input to the senior leadership committee and establish, as appropriate and timely, Committees of Visitors to assess outcomes of programs. NSF will engage the community through workshops in FY 2010 to gather input and explore potential approaches, including those emerging from NSF-funded work in the Science of Science and Innovation Policy program.

Funding: SEES is constructed as a portfolio of investments (e.g., individual investigators, small interdisciplinary teams, and larger groups) that include new as well as augmented ongoing activities in climate and energy research and education that are directly relevant to the SEES goal of informing societal actions needed for a sustainable Earth. This portfolio-based approach is intended to facilitate coordination, monitoring and impact across the major NSF investments.

Activities in FY 2011 include refreshing and integrating ongoing programs and issuing new solicitations for SEES. Identification of needs for further coordination and integration to address key science and engineering challenges will be an ongoing high priority.

SEES Portfolio Funding Levels

(Dollars in Millions)

	FY 2010 Estimate	FY 2011 Request
Biological Sciences	$121.00	$126.00
Computer and Information Science and Engineering	17.00	29.36
Engineering	108.20	120.00
Geosciences	195.50	230.70
Mathematical and Physical Sciences	87.00	110.50
Social, Behavioral and Economic Sciences	20.78	27.98
Office of Cyberinfrastructure	5.50	5.00
Office of International Science and Engineering	2.50	8.20
Office of Polar Programs	65.26	69.26
Office of Integrative Activities	26.50	26.50
Total, R&RA	**$649.24**	**$753.50**
Education and Human Resources	$11.50	$12.00
Total, NSF	**$660.74**	**$765.50**

Totals may not add due to rounding.

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP)

Climate has a pervasive effect on the U.S. through its impact on the environment, natural resources, and the economy. The U.S. Global Change Research Program (USGCRP) is providing the Nation and the world with the science-based knowledge to predict climate change and environmental responses, manage risk, and take advantage of opportunities resulting from climate change 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 natural factors and human activities affects the climate system. The USGCRP engages 13 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 between and among the atmosphere, hydrosphere, cryosphere, geosphere, and biosphere – all significantly influenced by human activities. NSF programs address these components by investing in fundamental discovery, utilizing the full range of intellectual resources of the scientific community; research infrastructure that provides advanced capabilities; and innovative educational activities. As a key participating agency in the USGCRP, NSF encourages interdisciplinary activities and focuses particularly on 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 the feedbacks that link ecosystems and the physical climate; the development of new, innovative Earth observing instruments and platforms; and the development of advanced analytic research methods. NSF also supports fundamental research on the general processes used by organizations to identify and evaluate policies for mitigation, adaptation, and other responses to varying environmental conditions. NSF will be actively involved in the development of a new strategic plan for the USGCRP.

U.S. Global Change Research Program Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
Biological Sciences	$61.00	$20.00	$81.00	$89.00
Engineering	$1.00	-	-	-
Geosciences	160.00	50.00	194.00	225.00
Mathematical and Physical Sciences	13.48	2.75	7.28	7.63
Social, Behavioral and Economic Sciences	15.48	3.00	18.48	25.98
Office of Polar Programs	18.30	44.79	18.30	22.30
Total, U.S. Global Change Research Program	**$269.26**	**$120.54**	**$319.06**	**$369.91**

Totals may not add due to rounding.

FY 2011 Areas of Emphasis:

NSF's FY 2011 investment in USGCRP increases by $50.85 million, or 15.9 percent, over the FY 2010 Estimate of $319.06 million. The Directorates for Biological Sciences and Geosciences together contribute the largest portion of this increase, a total of $39.0 million totaling $314.0 million in FY 2011. Other contributions come from the Directorate for Social, Behavioral and Economic Sciences, the Office of Polar Programs, the Directorate for Engineering, and the Directorate for Mathematical and Physical Sciences. Specific foci include:

- Supporting a broad research portfolio in carbon cycling, biodiversity, and ecological systems including major themes such as abrupt environmental changes; balancing the carbon budget; water, ice, and ecosystems; and the impact of ocean acidification;
- Enhancing scalability of climate and ecosystem models to move climate modeling from the global to regional and decadal scales; move ecological modeling from the local to the regional scale; and improve predictability at multiple scales to inform decision makers;
- Expanding research efforts on human, social, and economic dimensions of climate change, with particular attention to implications for government agencies, private organizations, and individuals faced with the need to make decisions regarding adaptation and mitigation in a new climatic environment;
- Improving, upgrading and deploying critical environmental observing platforms and systems; and
- Expanding the Nation's workforce trained to address complex environmental challenges.

The overarching themes of the USGCRP program in FY 2011 are as follows:

U.S. Global Change Research Program Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request
Atmospheric Composition	$30.67	$10.56	$28.90	$28.90
Climate Variability & Change	91.39	53.18	95.96	123.31
Water Cycle	27.18	9.93	40.18	42.18
Carbon Cycle	42.73	11.99	55.73	57.73
Land Use/Land Cover	8.30	-	8.30	8.30
Terrestrial & Marine Ecosystems	49.67	30.71	66.67	75.67
Human Contributions & Responses to Climate Change	18.32	4.17	23.32	33.82
Total, U.S. Global Change Research Program	**$268.26**	**$120.54**	**$319.06**	**$369.91**

Totals may not add due to rounding.

Atmospheric Composition – NSF programs in tropospheric and stratospheric chemistry will continue in FY 2011 to address the composition of the atmosphere and its relation to climate variability and change, and linkages between the atmosphere and the biosphere, land surface, oceans, and cryosphere. Studies of the transport and transformation of gaseous constituents and aerosols provide insights into the radiative and cloud nucleating properties of the atmosphere. Greenhouse gases are particularly important since they are the principal absorbers and re-radiators of heat. Results of these studies serve as important inputs for the assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

Climate Variability and Change – In FY 2011, NSF programs will continue to emphasize climate variability and change across temporal and spatial scales, supporting observational campaigns, use of paleoclimate proxy information, and numerous analytical and modeling activities. These activities will improve parameterizations of unresolved dynamics and address biases in global climate models, including those related to the role of human activities. A continuing and important focus is on changes in the Atlantic Meridional Overturning Circulation and its interactions with the atmosphere to improve understanding of the processes and explore possible future changes, particularly those that may happen abruptly. The Community Climate System Model will continue to improve through incorporation of small-scale ocean processes, aerosol radiative forcing, stratospheric dynamics, interactive chemistry, and biogeochemical cycles. Coupled climate model studies on decadal predictability at regional scales will be initiated and will include exploratory research on initialized climate modeling. Significant new resources will be devoted to the intellectually challenging task of advancing climate modeling capabilities from global and centennial scales to decadal and regional scales. Analyses of model output will focus on extreme climate events, such as hurricanes, droughts, and major ecological disturbances, in order to determine the mechanisms responsible and to evaluate their representation in models. Studies of paleoclimatology will continue to be supported as a means to provide baseline data on natural climate variability from the past and from key climatic regions. These studies improve our understanding of the natural variability of the climate system and will enable reconstructions and evaluations of past environmental change as inputs for model validations.

Water Cycle – NSF supports research to understand all aspects of the global water cycle. Relevant programs will continue to explore ways to utilize more effectively the wide range of hydrologic data types – continuous and discrete information from a variety of platforms – for research purposes. A community-initiated Hydrologic Information System, which provides data access and analysis tools, continues to expand, serving both research and operational communities, and is considered a model to be emulated internationally. Data from process studies will be used to refine models through parameterizations of sub-grid processes, particularly the fluxes of water through the Earth system, including human-managed systems. High resolution cloud system models are being refined to address the persistent problems of moist convection and cloud processes – two of the more challenging and uncertain components in climate change calculations. Our ability to study integration and coupling of Earth surface processes as mediated by the presence and flux of fresh water has been greatly expanded with six Critical Zone Observatories.

Carbon Cycle – NSF provides support for a wide variety of carbon cycle research activities, from the underlying biological and geophysical processes to critical long-running oceanic time series stations and atmospheric records as well as planning and data management. FY 2011 investigations will continue to examine a wide range of topics in terrestrial and marine ecosystems and their relations to the carbon cycle. Research in terrestrial settings will explore, for example, carbon storage, delivery of carbon by rivers, carbon fluxes from wetlands and high-latitude soils, the role of microbial processes, and submarine groundwater discharge in the oceans, ocean acidification, and remineralization in mesopelagic zones. Studies on the role of ocean acidification and the capacity of the oceans to absorb carbon will be highlighted, as will research on the coupling of nitrogen and carbon cycles – both are critical to improvement of ocean and global carbon models. Carbon cycle studies will integrate observational data into models to provide insights for understanding key aspects of the global carbon cycle and feedbacks on the climate system and on strategies to investigate and adapt to climate change through CO_2 sequestration.

Land-Use and Land-Cover – Several NSF programs continue to address key aspects of land-use and land-cover change through studies in ecological rates of change and related aspects of biodiversity, Arctic systems, temporal variability, biophysical feedbacks to the climate system, water and energy influences on vegetative systems, and human influences on land use.

Terrestrial and Marine Ecosystems – Several NSF programs address terrestrial and marine ecosystems through observational, experimental, modeling, and laboratory studies. The Long Term Ecological Research (LTER) program supports the collection of time-series data on key ecosystem processes and funds research on the drivers of ecosystem change in terrestrial and marine systems. The Global Ocean Ecosystem Dynamics program and follow-on activities will continue studies on the impact of global ocean changes on marine ecosystems through specific syntheses focused on the North Atlantic, the North Pacific and the Southern Ocean. Research will continue to focus on understanding the impact of increasing carbon dioxide on ocean pH levels (ocean acidification) and the impacts on marine organisms, ecosystems, and chemistry from tropical coral reefs to polar regions. New efforts focused on the coastal ecosystem processes and macrosystems biology at regional to continental scales.

Human Contributions and Responses to Climate Change – NSF supports basic research on the processes through which people (individually or through organizations) interact with environmental systems. FY 2011 funding supports collaborative teams that focus on decision making under uncertainty associated with climate change. These teams are expected to produce new knowledge and tools that should facilitate improved decision making related to climate variability and change. In addition, climate studies will be a major theme in NSF's cross directorate program, Dynamics of Coupled Human and Natural Systems, which examines the complex interactions and feedbacks between these systems. Finally, NSF will fund basic research on climate-related decision support for government agencies, private organizations, and individuals facing a changing environment in which making decisions based on past climatic averages is no longer prudent.

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: A budget of $21.65 million for ADVANCE in FY 2011, an increase of $630,000 above the FY 2010 Estimate of $21.02 million, will fund transformative efforts to address the systemic barriers to women's full participation in academic science, technology, engineering, and mathematics (STEM). ADVANCE will broaden the spectrum of institutions participating in the program. Predominantly undergraduate institutions, teaching intensive colleges, community colleges, minority-serving institutions, and women's colleges will be reached through the IT-Catalyst program component, which provides support to institutions to undertake institutional self-assessment activities. The funding will also support new awards under the Institutional Transformation (IT) program component as well as an overall program evaluation and data collection to capture the impact of prior ADVANCE awards. To this end, ADVANCE has initiated the process for an evaluation of its program, focusing primarily on awards that have completed their funding cycles. The two organizations leading this effort include Urban Institute and Westat. The Urban Institute will qualitatively evaluate awards from several components of the ADVANCE program including the Partnerships for Adaptation, Implementation and Dissemination (PAID), IT and Leadership awards. This evaluation component will highlight models of implementation through carefully designed case studies. It is expected that case studies will provide the ADVANCE program with valuable information on mechanisms of intervention implementation at a range of institutions, as well as an understanding of institutional barriers that promote the underrepresentation of women in the academic STEM disciplines and how these barriers can successfully be addressed. As a result, conclusive theories will be produced that can serve to guide future program directions. Secondly, Westat will provide a quantitative analysis of the ADVANCE program, focusing on both institutional transformation and fellows awards. To achieve this goal, this organization will not only conduct in-depth surveys of initial cohort institutions, but will also use national data sets to draw conclusions about program effectiveness. As a result, Westat's findings will inform the ADVANCE program of specific outcome measures for institutional transformation at the institutional and individual levels. The dissemination and adaptation of models and strategies that have demonstrated effectiveness, as well as research on gender in academics, will continue to be supported through the PAID program component.

Climate Change Education Program: The FY 2011 Request provides $10.0 million for the Climate Change Education (CCE) program, equal to the FY 2010 Estimate. The Directorates for Education and Human Resources, Geosciences, Biological Sciences, and the Office of Polar Programs will support this Administration priority program. CCE is a multi-disciplinary, multi-faceted climate change education program that will enable a variety of partnerships, including those among K-12 education, higher education, the private sector, and related non-profit organizations, in formal and informal settings, as well as 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 local, regional, and/or global in scope.

NSF has made an award to the National Research Council to implement an 18-month roundtable process that will examine key issues and needs inherent to climate change education. The roundtable is bringing together federal and state policymakers, educators, communications and media experts, and members from the business and scientific community. Insights gained through the roundtable are providing NSF with important foundational knowledge related to key aspects of CCE and learning, such as the nature and scope of existing efforts, achievable and measurable goals, challenges and opportunities inherent in developing a national level CCE initiative, and areas where investments in FY 2011 may provide the greatest leverage.

Faculty Early Career Development (CAREER): The FY 2011 Request provides $209.16 million for the CAREER program, which is a continuing Administration priority program. This is an increase of $12.77 million over the FY 2010 Estimate of $196.39 million. This will result in approximately 60 more CAREER awards than in FY 2010. 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 academic leaders of the 21st century.

Graduate Fellowships and Traineeships: The FY 2011 Request provides $272.89 million for NSF's three flagship graduate fellowship and traineeship programs. This funding will enable NSF to support an estimated 5,775 graduate students.

- $158.24 million for the Graduate Research Fellowship (GRF) program, an increase of $22.32 million over the FY 2010 Estimate of $135.92 million, will provide up to 3 years of support over a 5-year period to graduate students in all STEM fields. The GRF program is widely recognized as a unique fellowship grant program because it supports the broad array of science and engineering disciplines across all fields as well as international research activity. In FY 2010 NSF received thousands of applications for these highly prestigious and competitive awards, resulting in 2,000 new fellows. The GRF program expects to award 2,000 new fellows in FY 2011 as well. The table below contains the total number of fellows, number of new fellows, and number of fellows on tenure in FYs 2010 and 2011. The FY 2011 Request for GRF program is increased to provide funding for more U.S. citizens, nationals, and permanent resident aliens. As an Administration priority program, NSF has committed to tripling the number of new fellowships awarded over the FY 2008 level by FY 2013.

NSF Graduate Research Fellowship Program

	Total Number of Fellows	Number of New Fellows	Projected Fellows on Tenure
FY 2010 Estimate	5,600	2,000	2,500
FY 2011 Request	6,700	2,000	3,400

- $61.80 million for the Integrative Graduate Education and Research Traineeship (IGERT) program, a decrease of $7.43 million below the FY 2010 Estimate of $69.23 million. The decrease in funding reflects a reallocation of support to other activities, primarily within the Mathematical and Physical Sciences and Biological Science directorates. 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. Funding will support an estimated 1,500 IGERT trainees. Funds for this program are well justified. In 2009 Abt Associates, Inc. completed a survey of over 800 IGERT graduates in order to investigate the short-term professional outcomes of IGERT graduates and assess whether the IGERT program has prepared funded graduate students for successful STEM-related careers and developed their capacity for research, teaching, and leadership. Preliminary results show that IGERT graduates overwhelmingly reported that their graduate preparation gave them a competitive edge when applying for positions in the workforce and that their IGERT experience specifically helped them obtain a position. In addition, IGERT graduates credited their interdisciplinary experiences as influential in securing employment.

- $52.85 million for the NSF Graduate STEM Fellows in K-12 Education (GK-12) program, a decrease of $1.46 million below the FY 2010 Estimate of $54.31 million, will provide support to higher education institutions. This support will be used to transform their existing graduate training programs through strong partnerships with local school districts by innovative integration of leading STEM research findings and practices with K-12 education in a manner that benefits graduate fellows, teachers, and students. The GK-12 program provides value-added experiences to graduate fellows to improve their leadership, communication, teamwork, and teaching skills while providing professional opportunities for teachers and enriching STEM learning in K-12 schools. Preliminary evaluative findings conducted in 2005 by AIR Associates indicate that GK-12 is meeting its goal of enabling graduate students in STEM disciplines to acquire additional skills that will prepare them for professional and scientific careers. In 2007, the program engaged Abt Associates, Inc. in the development of a thorough evaluation of the program to provide data related to the success of GK-12. The first draft of the results is expected in early calendar year 2010. FY 2011 funding will support an estimated 875 graduate fellows.

Long-Term Ecological Research (LTER): The FY 2011 Request provides $28.10 million, an increase of $160,000 above the FY 2010 Estimate of $27.94 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. The National Ecological Observatory Network (NEON) will begin construction in FY 2011, the first year of a six-year construction project. NEON infrastructure will be co-located at eleven LTER sites. This co-location will permit the integration of the historic long-term LTER research into NEON and allow scientists to scale the site based research to regional and continental scales. Increased support in FY 2011 covers planned periodic increases to cover higher costs as sites are renewed.

Research Experiences for Teachers (RET): The FY 2011 Request for NSF's RET program totals $5.52 million, a decrease of $120,000 below the FY 2010 Estimate of $5.64 million. Funding will provide pre-service and in-service K-12 teachers with discovery-based learning experiences.

Research Experiences for Undergraduates (REU): The FY 2011 Request for NSF's REU program totals $67.27 million, an increase of $610,000 above the FY 2010 Estimate of $66.66 million. The increase proposed for FY 2011 is consistent with the recent (July 2006) external evaluation of REU by SRI International. It found that undergraduate students who participate in hands-on research are more likely to pursue advanced degrees and careers in STEM fields. REU supplements support active research participation by undergraduate students in any area of research funded by the NSF by providing supplements to research grants. REU sites involve students in research who might not otherwise have the opportunity, particularly those from institutions where research programs are limited. A significant fraction of the student participants come from outside the host institutions. Some REU grants have been extended to the freshman and sophomore levels to enhance retention and graduation rates. Beginning in FY 2009, efforts have been made to create partnerships between community colleges and baccalaureate degree granting institutions to provide research opportunities for community college STEM students and faculty. This will continue to be a focus in FY 2011.

Research in Undergraduate Institutions (RUI): The FY 2011 Request for NSF's RUI program totals $37.45 million, an increase of $130,000 million above the FY 2010 Estimate of $37.32 million. The RUI activity supports research by faculty members of predominantly undergraduate institutions through the funding of (1) individual and collaborative research projects, (2) the purchase of shared-use research instrumentation, and (3) Research Opportunity Awards for work with NSF-supported investigators at other institutions.

Science and Technology Centers (STCs): The FY 2011 Request for the Science and Technology Centers program totals $66.03 million, an increase of $8.26 million above the FY 2010 Estimate of $57.77 million. For additional information, see the NSF Centers Programs section of this chapter.

FY 2010 SUPPORT FOR POTENTIALLY TRANSFORMATIVE RESEARCH

In FY 2010, each R&RA directorate has allocated a minimum of $2.0 million per research division ($94.0 million Foundation-wide) to explore methodologies that help support potentially transformative research (PTR). NSF identifies PTR as work that may lead to:

- Dramatically new ways of conceptualizing or addressing major scientific and technological challenges.
- New methods or analytical techniques that could put a discipline on a new scientific pathway, provide tools that allow unprecedented insights, or radically increase the rate of data collection.

A set of Foundation-wide processes and methods is in place and available to all directorates and offices to encourage innovation and identify potentially transformative research. Primarily, specialized solicitations, competitions, and funding mechanisms such as EAGER (EArly-concept Grants for Exploratory Research) are used. Some directorates have specialized activities, described below.

Approaches being explored at NSF in FY 2010 fall into several categories:

- Alterations to the merit review process
  - Training of reviewers to recognize PTR as a review criterion (CISE, BIO, GEO);
  - Creativity training for program managers (BIO); and
  - "Re-review": Use of secondary or shadow panels to focus on PTR (SBE/SES) and use of a second-dimension approach for rating proposals (CISE, ENG).

- Greater use of specialized award mechanisms
  - Venture funds for EAGER mechanisms (all DIRs and offices);
  - Creativity extensions/program officer challenges (incentivized by BIO); and
  - Seed grants (OCI).

- Novel uses of solicitations, competitions, and workshops to create change in the external community
  - "Emerging Frontiers" solicitation development model, wherein the science and engineering community is engaged in the development of solicitations over time (e.g. ENG/EFRI);
  - Radically new mechanisms such as the "sandpit" process for intense, rapid development of collaborative proposals (BIO/MPS/SBE, with the Engineering and Physical Sciences Research Council of the United Kingdom) and the crowd sourcing, clean slate, or prediction market paradigms (pioneered by BIO); and
  - Solicitations designed to bridge diverse topics and fields (SBE, CISE).

Below is more specific information on the planned approaches of NSF directorates for these funds.

BIO: $20.0 million
Anticipated Approaches: Efforts in BIO will be conducted through the Office of Emerging Frontiers (EF), which will lead efforts to:
- Identify and implement thematic research areas that transcend scientific disciplines and/or advance the conceptual foundations of biology; and
- Provide up to $2 million in matching funds to each of the four BIO divisions to develop one or more emerging thematic research areas that cross at least two divisions within BIO or elsewhere in NSF. It

is expected that, in addition to supporting innovative research, these activities will incorporate innovative processes, such as:

- Developing and implementing new forms of peer review; and
- Testing new mechanisms to support transformative research and stimulate creativity, such as crowd sourcing, clean slate, sandpits, or prediction markets.

CISE: $8.0 million
Anticipated Approaches: as noted above, CISE will rely principally on specific activities within the merit review process (such as special instructions to reviewers and the "re-review" of proposals), as well as special solicitations that bring diverse topics and fields (such as CreativeIT).

ENG: $37.0 million
Anticipated Approaches: The ENG directorate has a number of programs focusing on potentially transformative research, which facilitate the transfer of knowledge creation and discovery to products and processes of societal benefit. Two examples of such programs include:

- The Office of Emerging Frontiers in Research and Innovation, which evaluates, recommends, and funds interdisciplinary initiatives at the emerging frontiers of engineering research and innovation; and
- The Engineering Interdisciplinary Research (IDR) program supports potentially transformative, interdisciplinary research proposals which span the boundaries of traditional disciplines and engineering Divisions.

GEO: $8.0 million
Anticipated Approaches: As noted above, GEO will rely principally on specific activities within the merit review process (such as special instructions to reviewers). It also intends to support projects of a size and complexity that makes them difficult to support within existing programs, but that possess a potential for transformation and impact that makes the investment compelling.

MPS: $10.0 million
Anticipated Approaches:

- Support for new research networks that will provide new models for research collaboration;
- Approvals for two-year Creativity Extensions for high-risk, high-reward research that has already shown promising results;
- Support for EAGER proposals, especially in the area of untested approaches to MPS sciences;
- Additional funding for Centers conducting high-risk, high-reward research; and
- Investments in individual investigator proposals deemed by review panels to be the most innovative.

OCI: $2.0 million
Anticipated Approaches: As noted above, OCI will rely principally on specialized award mechanisms, such as seed grants, to leverage and foster PTR in FY 2010.

OPP: $4.0 million
Anticipated Approaches: OPP will focus on activities through the merit review process for identifying potentially transformative research, with follow-up assessment activities to compare the different approaches.

SBE: $5.0 million
Anticipated Approaches: Investments will draw from themes that are emerging in the social and behavioral sciences as these fields incorporate theoretical approaches, analytical techniques, models and innovative methodologies. These include development of enabling infrastructure and support of large-scale interdisciplinary work conjoining the human sciences with other disciplines in novel combinations. Challenge program officers and panels to articulate clearly the criteria by which they designate research as transformative.

Following this FY 2010 investment, NSF will engage in a number of activities to compare the different approaches, to determine the most effective approaches to employ in future years. These assessment will include traditional means, such as the use of Committees of Visitors, plus the development of tools particular to solicitations as they are developed.