FY 2012

Networking and Information Technology Research and Development

Supplement to the President's Budget

February 2011

SUPPLEMENT TO THE PRESIDENT'S BUDGET
FOR FISCAL YEAR 2012

THE
NETWORKING AND INFORMATION TECHNOLOGY
RESEARCH AND DEVELOPMENT
PROGRAM

A Report by the
Subcommittee on Networking and Information Technology
Research and Development

Committee on Technology
National Science and Technology Council

February 2011

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
WASHINGTON, D.C. 20502

February 22, 2011

MEMBERS OF CONGRESS:

I am pleased to transmit with this letter the FY 2012 annual report of the Federal government's multiagency Networking and Information Technology Research and Development (NITRD) Program. The NITRD effort, which today comprises 14 member agencies and many more that participate in NITRD activities, coordinates Federal research and development investments in the advanced digital technologies essential for the Nation's economic growth and prosperity in the 21st century.

In less than a generation, networking and computing technologies have transformed our individual lives and the trajectories of nations around the world, a reality underscored dramatically in recent weeks in Egypt and other nations in the Gulf region. The sustained U.S. commitment to R&D that gave rise to the world's now-indispensable cyber infrastructure will be no less pivotal in enabling our Nation to address the varied challenges sure to arise in the years ahead. The United States needs to accelerate the flow of advances in cutting-edge digital technologies that drive economic innovation and job growth, and provide next-generation capabilities for national security, scientific discovery, and education.

As the President has made clear, such networking and computing capabilities will also provide critical foundations for an improved health care system; more-efficient energy delivery systems and discovery of renewable resources; and a more secure, privacy-protecting Internet. The Federal NITRD investments we make in support of important national policy priorities will generate new industries and workforce opportunities through technological innovation.

I look forward to continuing to work with you to support this vital Federal program.

Sincerely,

John P. Holdren

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

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NITRD Member Agencies

The following Federal agencies, which conduct or support R&D in advanced networking and information technologies, report their IT research budgets in the NITRD crosscut and provide support for program coordination:

Agency for Healthcare Research and Quality (AHRQ)
Defense Advanced Research Projects Agency (DARPA)
Department of Energy/National Nuclear Security Administration (DOE/NNSA)
Department of Energy/Office of Electricity Delivery and Energy Reliability (DOE/OE)
Department of Energy/Office of Science (DOE/SC)
Department of Homeland Security (DHS)
Environmental Protection Agency (EPA)
National Aeronautics and Space Administration (NASA)
National Archives and Records Administration (NARA)
National Institute of Standards and Technology (NIST)
National Institutes of Health (NIH)
National Oceanic and Atmospheric Administration (NOAA)
National Science Foundation (NSF)
National Security Agency (NSA)
Office of the Secretary of Defense (OSD) and Department of Defense (DoD) Service Research Organizations (Air Force, Army, Navy)

NITRD Participating Agencies

Representatives of the following agencies with mission interests involving networking and IT R&D and applications are active participants in NITRD activities:

Defense Information Systems Agency (DISA)
Department of Energy/Office of Electricity Delivery and Energy Reliability (DOE/OE)
Department of Health and Human Services/Office of the National Coordinator for Health Information Technology (HHS/ONC)
Department of State (State)
Department of the Treasury (Treasury)
Department of Transportation (DOT)
Federal Aviation Administration (FAA)
Federal Bureau of Investigation (FBI)
Federal Highway Administration (FHWA)
Food and Drug Administration (FDA)
General Services Administration (GSA)
Intelligence Advanced Research Projects Agency (IARPA)
National Telecommunications and Information Administration (NTIA)
National Transportation Safety Board (NTSB)
Nuclear Regulatory Commission (NRC)
U.S. Department of Agriculture (USDA)
U.S. Geological Survey (USGS)
Veterans Administration (VA)

About the NITRD Program

Since the dawn of the digital age, fundamental research sponsored by the Federal government has supported U.S. leadership in advanced information technologies – from the first supercomputers, to the foundations of high-speed networking, to global positioning and mobile wireless technologies. Today, the Networking and Information Technology Research and Development (NITRD) Program continues that mission.

Now in its 20th year, NITRD is the oldest and largest of the small number of formal Federal programs that engage multiple agencies. As required by the High-Performance Computing Act of 1991 (P.L. 102-194), the Next Generation Internet Research Act of 1998 (P.L. 105-305), and the America COMPETES Act of 2007 (P.L. 110-69), NITRD currently provides a framework and mechanisms for coordination among 14 Federal agencies that support advanced IT R&D and report IT research budgets in the NITRD crosscut. Many other agencies with IT interests also participate informally in NITRD activities. The NITRD member agencies and participating agencies are listed on page vi.

The agencies coordinate their NITRD activities and plans in eight research areas, called Program Component Areas (PCAs), spanning a broad spectrum of IT domains and capabilities, as follows:

High-End Computing Infrastructure and Applications (HEC I&A)
High-End Computing Research and Development (HEC R&D)
Cyber Security and Information Assurance (CSIA)
Human-Computer Interaction and Information Management (HCI&IM)
Large-Scale Networking (LSN)
High-Confidence Software and Systems (HCSS)
Software Design and Productivity (SDP)
Social, Economic, and Workforce Implications of IT and IT Workforce Development (SEW)

In each of these R&D areas, agency program managers meet monthly in an Interagency Working Group (IWG) or Coordinating Group (CG) to exchange information and collaborate on research plans and activities such as testbeds, workshops, and cooperative solicitations. Overall NITRD Program coordination is carried out by the Subcommittee on Networking and Information Technology Research and Development, under the aegis of the National Science and Technology Council's Committee on Technology. The National Coordination Office for NITRD (NCO/NITRD) provides technical, administrative, and logistical support for the activities of the NITRD Program, including publication of the annual *NITRD Supplement to the President's Budget.*

NITRD Program developments over the last 12 months include the establishment of a Senior Steering Group (SSG) for Health IT R&D to coordinate research planning and activities across Federal agencies, as called for by the HITECH Act of 2009; the welcoming of the Department of Homeland Security as a NITRD member agency; and the formation of a multiagency LSN subgroup on Wireless Spectrum R&D (WSRD), pursuant to the Presidential Memorandum "Unleashing the Wireless Broadband Revolution." Responding to the Administration focus on transparent and open government, the NCO/NITRD developed version 1.0 of an IT R&D dashboard – www.nitrd.gov/Open/Index.aspx – that provides the public with 20 years of NITRD budget data in manipulable formats as well as the Program's annual budget documents.

In December 2010, the President's Council of Advisors on Science and Technology (PCAST) – an independent, high-level group of national experts that provides guidance to the President – issued a review of the NITRD Program entitled *Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology*. As a first step in responding to the PCAST's recommendations, the NCO/NITRD solicited comments from the public regarding the major themes of the report. Consideration of the public inputs and possible next steps for NITRD will be a focus of the March 2011 meeting of the NITRD Subcommittee.

For further information about the NITRD Program, please visit the NITRD web site: www.nitrd,gov.

About the NITRD Supplement to the President's Budget

The yearly Supplement to the President's Budget for the NITRD Program is designed to present a succinct technical summary of the research activities planned and coordinated through NITRD in a given Federal budget cycle, as required by law. The Supplement is organized by PCA, to align with the structure of the Program. Every PCA section follows the same format, so that readers can quickly identify:

- The NITRD member agencies and participating agencies active in the PCA
- The definition of the research covered in the PCA
- The interagency strategic priorities in the PCA for the forthcoming fiscal year
- Budget highlights – agencies' key R&D programs and topical emphases in the PCA for the forthcoming year
- Interagency coordination – current and planned activities in which multiple agencies are collaborating
- Ongoing core activities of each agency in the PCA

The NITRD Supplement also includes an annual budget table and budget analysis section, organized by PCA and by agency, to facilitate budgetary and programmatic comparisons from year to year.

The Supplement itself is a product of NITRD coordination: The text is developed, revised, reviewed, and approved by the NITRD agencies in a collaborative process over a six-month period prior to the release of the President's budget. The process begins with an Annual Planning Meeting (APM) in each NITRD PCA. In these day-long gatherings, agency representatives present briefings summarizing their agencies' IT research priorities, program plans, and current activities in the PCA. Following the briefings, the agencies discuss shared research issues and plan cooperative activities.

The Supplement's PCA sections are based on the APM discussions and subsequent refining of the text by the agencies. For example, the IWG and CG members review and update their PCA's definition statement and interagency R&D priorities to reflect evolution of key technologies and associated research challenges that agencies face in common. The agencies report on their collaborative efforts to address such challenges in the PCA subsection called "Planning and Coordination Supporting Request."

NITRD agencies engaged in R&D and coordination activities cited in the Supplement are listed in NITRD budget order, followed by the participating agencies. If there is a lead agency for the activity, that agency is listed first; agencies listed after the word "with" are in-kind contributors rather than funders or performers. Some large-scale activities may be cited in more than one PCA because they involve R&D efforts in a variety of technologies. In such cases, agencies report the portion of program funding in each relevant PCA.

The President's 2012 budget request for the NITRD Program is $3.866 billion; 2010 NITRD actual expenditures totaled $3.793 billion. Details of the budget are presented in the table on page 28 and discussed in the budget analysis section beginning on page 30.

High End Computing (HEC) Infrastructure and Applications (I&A)

NITRD Agencies: NSF, NIH, OSD, DOE/SC, NIST, NASA, NOAA, DOE/NNSA, EPA

HEC I&A agencies coordinate Federal activities to provide advanced computing systems, applications software, data management, and HEC R&D infrastructure to meet agency mission needs and to support national priorities including economic prosperity, national security, science and technology leadership, environmental sustainability, educational excellence, and high quality of life. HEC capabilities enable researchers in academia, Federal laboratories, and industry to model and simulate complex processes in biology, biomedical science, chemistry, climate and weather, energy and environmental sciences, materials science, nanoscale science and technology, aerospace, physics, and other areas to address Federal agency mission needs.

President's 2012 Request

Strategic Priorities Underlying This Request

HEC I&A investments make possible advanced investigations of the world's most complex scientific and technological challenges, and also expand access to Federal computational facilities, scientific applications, and tools so that increasing numbers of U.S. researchers can work on national-priority problems. In addition, these investments support work to improve the capabilities and ease-of-use of HEC software environments and applications. FY12 priorities proposed by the HEC I&A agencies include:

Leadership-class systems: Acquisition and management of highest-capability systems for cutting-edge scientific research including energy, the environment, and national security applications

Production-quality HEC resources: Capacity platforms to expand Federal computing resources for critical agency needs and for the national science and engineering communities

Applications-related advances: Scientific and engineering applications software for current and next-generation HEC platforms; mission-responsive computational environments; applied mathematics research

Leading-edge cyber infrastructure: Access and connections to facilities and resources; infrastructure for computational and data-enabled science; best practices for managing, growing, enhancing HEC resources cost-effectively, energy-efficiently

Highlights of Request

The HEC I&A agencies report the following as highlights of their planned activities for FY 2012 under each of the main HEC I&A priorities:

Acquisition of prototype leadership-class and production HEC systems

NSF: Blue Waters petascale system in initial operation at NCSA; continue multiyear acquisitions of midrange systems exploring innovative solutions to HEC requirements

NIH: Selected acquisition of cluster and midrange compute-intensive systems

OSD (HPCMP)[1]: Provide production-quality HEC resources at supercomputing centers

DOE/SC: Upgrade at least one Leadership Class Facility (LCF) system to 10 PF; continue development of innovative BlueGene-Q ("Mira") LCF system at ANL; full operation of 1 PF Cray XE-6 ("Hopper") at NERSC

NASA: Acquire testbed systems, upgrade production supercomputing and storage resources for next-generation HEC environments at Ames and Goddard

DOE/NNSA: Deployments of next generation of capacity systems across three labs, LANL "Cielo" system (1.37 PF) and LLNL "Sequoia" system (20 PF)

Applications

NSF: Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21), including applications that focus on understanding complexity, grid computing, and data-intensive science; software that integrates computation, data acquisition in heterogeneous, dynamic environments; petascale applications to exploit leading-edge systems for breakthrough science across domains; new data- and visualization-intensive capabilities; Expeditions in Computing program for multiyear investigations addressing national challenges such as energy efficiency, environmental sustainability, advanced communications systems – NSF

[1] In 2012, the OSD HPCMP will transfer to the Army for execution.

NIH: Scientific computing efforts such as biomolecular modeling, computational neuroscience, physiological modeling, and multiscale modeling that now use HEC resources or ultimately will do so; biodata management and analysis; modeling and analysis of biological systems; grid computing

OSD (HPCMP): Continue CREATE program development of highly scalable application codes (aircraft, ships, antennae), CREATE-AV tools; HPC software institutes supporting mission applications

DOE/SC: Recompetition of SciDAC; petascale multiphysics applications; INCITE competition for access to LCF resources by outside researchers; mathematics for analysis of ultra-scale data sets; multiscale mathematics

NIST: Measurement science for HEC applications and visualization (predictive modeling, verification and validation of computational models, uncertainty quantification, computational experiment design, virtual measurements)

NASA: Increase model resolution, complexity, and fidelity in aerospace, Earth science, and astrophysics modeling; enhance analytical capabilities for science research initiatives

NOAA: Accelerate advances in hurricane forecasting, understanding of climate change, ensemble forecasting, ecosystem forecast capabilities, analyses of the historic record, space weather forecasting

DOE/NNSA: Explore code rewrite and portability requirements for exascale computing; investigate embedded uncertainty quantification methodologies

EPA: Applications and analytics required for robust research programs in air quality and climate

HEC infrastructure

NSF: CIF21 effort to provide new infrastructure, access to facilities for data-intensive and computational science for academic research communities; includes XD (successor to TeraGrid), and software development and strategic technologies for cyberinfrastructure

NIH: Grid computing infrastructure and tools for R&D (e.g., BIRN, CaBIG, BISTI, CVRG)

OSD (HPCMP): Operate and sustain supercomputing centers and support services for DoD RDT&E programs

DOE/SC: Continue emphasis on unified approach to software, languages, and tools support to reduce barriers to effective use of complex HEC resources by application developers and users

NIST: Continue development of a measurement infrastructure for HEC software

NASA: Provide full suite of services to maximize mission impact of NASA's HEC resources and users; implement data-management system to facilitate distribution of data sets and access to critical data repositories

NOAA: Integrate new HPC resources and high-speed network (N-Wave) to link HEC centers

DOE/NNSA: Manage common capacity computing environment across three national labs

EPA: Infrastructure to combine existing and future data and model them at various temporal and spatial scales in a meaningful way; build data and information exchange components for R&D

Planning and Coordination Supporting Request

Since 2005, the HEC agencies have provided many billions of compute hours on the Nation's most powerful computing platforms to enable researchers from academia and industry to address ultra-complex scientific challenges; coordinating this activity remains a major focus of collaboration. Another key focus is selecting, evaluating, and procuring Federal high-end platforms – a complicated, labor-intensive process that the HEC agencies work closely together on to streamline. A third major focus of collaborative activities is development of sharable computational approaches for investigation and analysis across the sciences. Cooperative activities include:

Access to leadership-class computing: Coordination to make highest-capability HEC resources available to the broad research community – NSF, DOE/SC, NIST, NASA, NOAA, DOE/NNSA

System reviews, benchmarking: Collaborations – NSF, OSD, DOE/SC, NASA, NOAA, DOE/NNSA

Acquisition procedures and analysis: Information sharing, streamlining of processes, and collaborative analysis of total cost of ownership; promote green computing practices – NSF, OSD, DOE/SC, NASA, NOAA, DOE/NNSA, EPA

Best Practices Workshop Series: Annual activity to improve management of HEC infrastructures and applications – DOE/SC, with DOE/NNSA and other HEC I&A agencies

Exascale computing: Collaboration through International Exascale Software Project (IESP) to address issues in extreme-scale HEC software – NSF, DOE/SC, DOE/NNSA

Interagency Modeling and Analysis Group (IMAG): Collaboration to advance modeling of complex living systems – NSF, NIH, OSD, DOE/SC, NASA, USDA, VA

Simulation-based engineering and science: Interagency activity under Administration innovation agenda – DOE/SC, NIST (co-chairs), NSF, NASA, other agencies

National Plan for Aeronautics R&D: Collaboration to drive advances in HEC technologies and applications – OSD, NASA, FAA, other agencies

Life and physical sciences: Joint initiatives at the frontier – NSF, NIH

Infrastructure for climate and weather modeling: Development of interoperable interfaces, software tools, and data standards, Earth System Modeling Framework – NSF (NCAR), DOE/SC, OSD, NASA, NOAA, EPA

Computational toxicology: Integration of HEC technologies with molecular biology to improve methods for risk assessment of chemicals – NIH, OSD, DOE/SC, EPA, FDA

Grid partitioning code: NIST-developed code distributed in SNL's Zoltan Library – NIST, DOE/SC

Open Science Grid: Support for virtual research collaboration community – NSF, DOE/SC

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the HEC I&A PCA:

NSF: CAREER and graduate research awards in computational science; REU sites; exploration of new opportunities in data and software; VOSS program; CI-TEAM; Software Infrastructure for Sustained Innovation (SI^2); cybersecurity for HEC environments

NIH: NIH National Centers for Biomedical Computing (NCBC); Center for Information Technology (CIT) BioWulf cluster with software solutions for NIH intramural research program investigators; Cancer Imaging and Computational Centers; P41 computational centers; bioinformatics centers; proteomics, protein structure initiatives; systems biology centers; Models of Infectious Disease Agent Study (MIDAS); international networks for biomedical data, software sharing

OSD (HPCMP): HEC services for R&D and test communities (e.g., platforms, computational science software support); computational science institutes for DoD priorities (air armament, health force protection, weather prediction, ground sensors, space situational awareness, rotorcraft, networks, microwaves, munitions)

DOE/SC: Manage LCF facilities at ORNL and ANL, support NERSC-6 production system; applied mathematics to prepare for future architectures, huge data sets, multidisciplinary science; computational partnership teams to transform applications for multicore computing at scale; uncertainty quantification at exascale

NIST: Development, analysis of fundamental mathematical algorithms, software, tools; parallel and distributed algorithms in applications (flow of suspensions, nano-magnetic modeling, automated combinatorial software testing); virtual measurements

NASA: Upgrade Pleiades to 1.5 PF; implement concurrent visualization; RFP to select testbeds; upgrade tape archive; explore interface between cloud and HPC computing environments

NOAA: Complete acquisitions, upgrades, interagency agreements for new HPC architecture; conduct solicitation for HPC research grants

High End Computing (HEC) Research and Development (R&D)

NITRD Agencies: NSF, NIH, OSD, AFOSR, ARO, ONR, DOE/SC, DARPA, NIST, NASA, NSA, NOAA, DOE/NNSA

HEC R&D agencies conduct and coordinate hardware and software R&D to enable the use of high-end systems to meet Federal agency mission needs, to address many of society's most challenging problems, and to strengthen the Nation's leadership in science, engineering, and technology. Research areas of interest include hardware (e.g., microarchitecture, large-scale systems architectures, memory subsystems, interconnect, packaging, I/O, and storage), software (e.g., operating systems, languages and compilers, development environments, algorithms), and systems technology (e.g., system architecture, programming models).

President's 2012 Request

Strategic Priorities Underlying This Request

Historically, Federally sponsored HEC R&D has produced cascading innovations (e.g., in memory density and computing speeds) that have fueled the emergence of low-cost personal computers and devices. Today, HEC researchers seek to exploit multicore-processor technologies and to address the growing complexity and costs of emerging platforms and software, the rise of multicore processors, and the constraints of energy consumption and scalability. In view of these challenges, the HEC R&D agencies see the following as key research priorities for FY 2012:

Next-generation HEC systems and architectures: Develop new software frameworks and system architectures; processing "beyond Moore's Law"; innovative systems that combine increased speed, economic viability, high productivity, and robustness to meet agency needs for systems that manage ultra-large volumes of data and support multiscale, multimodal, dynamic data-driven, and multidisciplinary science and engineering simulations; quantum information science. Relevant areas include:

- **New hardware and software directions:** Explore novel concepts and approaches for solving technical challenges such as power use, thermal management, file system and I/O, resiliency, highly parallel system architectures, and programming models and languages, systems software, including new runtime, compiler, and development environments that can increase the usability of large-scale multiprocessor systems including those that incorporate heterogeneity at processing node levels, as well as environments where high-end platforms become integrated with real-time data-acquisition and control systems
- **Performance Engineering:** Develop comprehensive methods for modeling, at the component and system levels, the software and hardware architectural framework to support design, runtime maintenance, upgrade, extensibility, and scalability of the underlying platforms, systems software components, and end-user applications
- **Productivity:** Collaborate in development of new metrics of system performance, including benchmarking, lessons learned for acquisition, total ownership costs of HEC systems; integrate resources for improved productivity
- **Prototypes:** Develop, test, and evaluate prototype HEC systems and software to reduce industry and end-user risk and to increase competitiveness and productivity

Extreme-scale computation: Integrate computer science and applied mathematics foundations with computational science and engineering to address computation at the petascale and exascale levels, and beyond

Software for team/collaborative environment support: Design and develop requirements for software to enable, support, and increase the productivity of multidisciplinary, geographically dispersed, collaborative teams that develop future HEC applications

Highlights of Request

The HEC R&D agencies report the following topical areas as highlights of their planned research investments for FY 2012. Agencies with efforts in a research topic are listed in their NITRD budget order, unless there is a lead agency (listed first) for the effort:

Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21): Long-term, agency-wide effort to develop new data and computational capabilities, including workforce development, for advanced academic research – NSF

Next-generation architectures and programming environments: R&D in advanced architectures for science, highly parallel systems (silicon-based as well as radically new device-based technologies), parallel programming languages and programming environments, programming models, compilers, file systems and I/O, system software, performance engineering frameworks, and other methods and tools; Forum to Address Scalable Technology for runtime and Operating Systems (FAST-OS) – NSF, AFOSR, DOE/SC, DARPA, DOE/NNSA

Petascale computing: R&D in petascale operating, runtime, and file systems; tools, programming models, performance modeling, low-power approaches, software for computation- and data-intensive applications; software effectiveness, systems performance metrics; mathematics and computer science (scalable algorithms, optimization of complex systems, control theory, risk assessment); resource allocation methods – NSF, OSD, DOE/SC, DARPA, DOE/NNSA

Computer science for exascale: Fundamental issues in designing the software stack for extreme computing – DOE/SC, DOE/NNSA, NSF

Advanced computing systems: R&D to improve power efficiency, chip-to-chip I/O, interconnects, productivity, resilience, and file system I/O – NSF, AFOSR, DOE/SC, DARPA, NASA

Expeditions in Computing: Cross-directorate program for multiyear investigations addressing national challenges such as energy efficiency, environmental sustainability, advanced communications systems – NSF

Quantum computing: Quantum information theory; architectures and algorithms; modeling of quantum memory, quantum gates, components, and systems; quantum communications; quantum-based measurements – NSF, DoD Service research organizations, NIST, NSA

Resources for scientific research: Computational concepts, methods, and tools for discovery; centers, institutes, and partnerships for predictive science, applied math/computer science challenges of ultra-large-scale scientific computing, joint mathematics/computer science institutes – NIH, NSF, AFOSR, DOE/SC, DARPA, NASA, DOE/NNSA; recompete SciDAC centers and institutes, continue mathematics/computer science institutes – DOE/SC

Domain-specific software environments: Develop modeling architectures, such as: based on ESMF – NOAA, with NSF (NCAR), DoD Service research organizations, DOE/SC, NASA

Computational neuroscience: Collaborative research projects –NSF, NIH, with international funding agencies

Planning and Coordination Supporting Request

Coordination among the HEC R&D agencies focuses on computer science advancements to improve the performance and efficiency of the current generation of HEC hardware and software as well as on avenues of fundamental research that may lead to revolutionary new architectures and systems. The complexity of high-end hardware, systems software, and supporting technologies is such that Federal program managers and researchers depend on the constant flow of information among colleagues and technical experts to keep current with developments, gain new knowledge, and share best practices and lessons learned. The following are selected examples of the scope of interagency HEC R&D collaboration:

Planning

Technical and planning workshops: Annual File System and I/O Workshop to coordinate HEC-URA effort; Federal Application Benchmark Workshop to plan multiagency benchmarking activity – NSF, OSD, DOE/SC, DARPA, NASA, NSA, DOE/NNSA; Exascale Workshops – DOE/SC, DOE/NNSA, other agencies

Open-source software: Enable HEC users to read, modify, and redistribute source code, fostering more efficient development and collaboration to improve software quality – NSF, DOE/SC, NASA, DOE/NNSA; Next Generation Systems Software – AFOSR, other agencies

Proposal reviews: Multiple HEC agencies

Systems architecture

HEC hardware and software: Facilitate access to and share knowledge gained and lessons learned from HEC hardware and software development efforts – NSF, OSD, DOE/SC, NIST, NASA, NOAA, DOE/NNSA

Institute of Advanced Architectures and Algorithms: Direct and perform R&D in the focus areas that impact the performance and reliability of large-scale systems – DOE/NNSA, DOE/SC

Quantum information science: Study information, communication, and computation based on devices governed by the principles of quantum physics – NSF, DoD Service research organizations, DOE/SC, NIST, NSA

Systems software development

HEC systems software: Coordinate research in operating/runtime systems, languages, compilers, libraries – NSF, DOE/SC, DARPA, AFOSR, NSA, DOE/NNSA

HEC metrics: Coordinate research on effective metrics for application development and execution on high-end systems – NSF, DOE/SC, DARPA, with OSD, NSA, NASA, DOE/NNSA

International Exascale Software Project (IESP): Collaborative effort to explore issues in extreme-scale HEC software – NSF, DOE/SC, DOE/NNSA, international organizations

Benchmarking and performance modeling: Collaborate on developing performance measurement test cases with applications commonly used by Federal HEC community for use in system procurements, evaluation of Federal HEC system productivity – OSD, with NSF, AFOSR, DOE/SC, DARPA, NASA, NSA, DOE/NNSA

File systems and I/O: Coordinate R&D funding based on a national research agenda and update agenda on a recurring basis – NSF, DOE/SC, DARPA, NASA, NSA, DOE/NNSA

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the HEC R&D PCA:

NSF: Science and Engineering Beyond Moore's Law (SEBML) program addressing hardware and software challenges associated with exploiting the performance opportunities of multicore computing technologies; research in novel paradigms such as reconfigurable, evolvable, adaptive hardware architectures, heterogeneous systems that can dynamically change via software mechanisms, and architectures capable of combating error-prone devices at the nano scale; CIF21 support for broad research and innovation needs of the science and engineering communities (software, data modeling, simulation, computation expertise, leading-edge technologies); software development and reuse; SI^2 and CI-TraCS activities; modeling and simulation of complex systems; numerical algorithms; grid and cloud computing experimentation; HEC Taskforce; CAREER, Graduate Research Fellowships

OSD (HPCMP): HEC systems and software R&D, performance metrics in support of DoD mission priorities; modeling and simulation

AFOSR: Systems software; computational math and scalable algorithms; multiscale modeling

DOE/SC: Petascale algorithms; scientific data analysis and management, interoperability at extreme scale; transformation of critical applications for multicore; R&E prototypes; exascale-related R&D

NIST: Techniques and benchmarks to assess performance of quantum computing technologies; develop fault-tolerance, error management for quantum computers; quantum computer simulator

NASA: Advanced HEC technologies for enhanced productivity; software engineering tools for scientific models

NSA: Center for Exceptional Computing;

NOAA: Improved techniques and processes for transitioning of codes from research to operations

DOE/NNSA: Investment in advanced memory technology to prepare for computing beyond petascale

Cyber Security and Information Assurance (CSIA)

NITRD Agencies: NSF, NIH, OSD, AFRL, ARL, ARO, CERDEC, ONR, DOE, DARPA, NIST, NSA, DHS
Other Participants: DISA, DOT, FAA, FBI, IARPA, State, Treasury

CSIA focuses on research and development to prevent, resist, detect, respond to, and recover from actions that compromise or threaten to compromise the availability, integrity, or confidentiality of computer- and network-based systems. These systems provide the foundation in every sector of the economy, including critical infrastructures such as power grids, financial systems, and air-traffic-control networks. These systems also support national defense, national and homeland security, and other vital Federal missions. Broad areas of concern include Internet and network security; security of information and computer-based systems; approaches to achieving hardware and software security; testing and assessment of computer-based systems security; and reconstitution of computer-based systems and data.

President's 2012 Request

Strategic Priorities Underlying This Request
Increasing the security of digital information and of U.S. cyber infrastructures is a high-priority national objective with implications for both national security and economic innovation, as described in the President's 2009 Cyberspace Policy Review. The research challenges of this effort are also called out in the Administration's science and technology budget priorities memorandum for 2012. The CSIA agencies coordinate their ongoing cybersecurity R&D activities and are also leading development of accelerated "game-changing" strategies for securing cyberspace (see page 11 for details). Current R&D priority areas set forth by the CSIA agencies range from fundamental investigation of scientific bases for hardware, software, and system security to applied research in security technologies and methods, approaches to cyber defense and attack mitigation, and infrastructure for realistic experiments and testing. Emphases include:

Inducing change: Coordinated cybersecurity R&D themes to direct efforts toward understanding the root causes of known threats with the goal of disrupting the status quo with radically different approaches to substantially increase the trustworthiness of national digital infrastructure; the initial themes focus on supporting informed trust decisions, enabling risk-aware safe operations in compromised environments, and increasing adversaries' costs and exposure

Foundations: Cybersecurity as a multidisciplinary science; models, logics, algorithms, and theories for analyzing and reasoning about trust, reliability, security, privacy, and usability; assured and trustworthy systems; cyber security metrics; social and technical dimensions of a trustworthy computing future; risk modeling; secure software engineering and development; cryptography and quantum information science for secure computing and communications; science of security

Applied information infrastructure security: Secure virtual platforms; assured information sharing; security for mobile, wireless, and pervasive computing; development of a secure and safe "identity ecosystem," including frameworks, standards, models, and technologies; security automation; secure protocols; vulnerability detection and mitigation; cloud computing; health IT; smart grid

Mission assurance: Activities and processes that ensure an organization's ability to accomplish its mission in an all-hazard cyber environment; cyber conflict defense

Infrastructure for R&D: Testbeds, cyber test ranges, tools, platforms, repositories to support cyber security experimentation and analysis

Highlights of Request
To address these strategic priorities, the CSIA agencies report the following topical areas as highlights of their planned R&D investments for FY 2012. Agencies with efforts in a research area are listed in NITRD budget order, unless there is a lead agency (listed first) for the effort:

Inducing change

Tailored Trustworthy Spaces theme: Enable tailored security environments that can support functional and policy requirements across multiple dimensions of trustworthiness – All CSIA agencies

Moving Target theme: Increase attacker costs via adaptive, diverse, and continually shifting strategies that alter system characteristics to increase complexity for attackers – All CSIA agencies

Cyber Economics and Incentives theme: Frameworks to incentivize security deployment, socially responsible behavior, and deter cyber crimes – All CSIA agencies

Foundations

Research Centers: A Center for Correct, Usable, Reliable, Auditable, & Transparent Elections (ACCURATE) – NSF; Trustworthy Cyber Infrastructure for the Power Grid (TCIPG) – DHS, DOE

Secure software engineering: Metrics for cost-benefit and risk-analysis tools; identification of operational security practices for early phases of systems development life cycle; construction of trustworthy systems from untrustworthy components; formal methods for validation and verification of composable systems; scalable secure systems; lightweight analysis – NSF, OSD, ONR, DARPA, NIST, DHS

Software protection: Function extraction technologies to automate the computation of software behavior; embedded software security technologies; software cross-domain security; malicious code detection, mitigation, and prevention; software anti-tamper – NSF, OSD, AFRL, ARO, CERDEC, ONR, DARPA, NSA, DOE

Hardware and firmware security: Virtualization technologies (e.g., NSA's Secure Virtual Platform); secure OS; encryption of data in memory; security processors; high-performance intrusion-detection technologies and trusted platform modules – NSF, OSD, AFRL, ONR, NSA

Cryptography: Cryptographic algorithms and engineering for increasing network speeds; cryptographic key management; quantum computation-resistant cryptography – NSF, ONR, DARPA, NIST, NSA

Models, standards, testing, and metrics: Quantitative risk-analysis methods and tools; evidence-based security metrics; models and standards for protection, sharing of sensitive information; standards and tests to assess, validate system security; reliable information-assurance metrics; leadership in national and international standards bodies – NSF, OSD, ARL, ARO, DARPA, NIST, DHS, DOE

Applied information infrastructure security

Security management infrastructure: Policy-based access control systems and protocols; principles, frameworks, models, and methods for identity, authentication, privilege management in dynamic environments; management tools (threat analysis, attack- and risk-based decision models; survivability analysis framework; automated and real-time diagnostics for system security-policy flaws, configuration anomalies, vulnerabilities); next-generation biometric standards – NSF, OSD, AFRL, ARO, CERDEC, ONR, DARPA, NIST, NSA

Assured information sharing: DoD-wide priority to enhance technologies and tools to secure communications and data sharing across multiple, heterogeneous networks, platforms, and security levels; demonstrate secure collaboration through cyber sensing station – OSD and DoD Service research organizations, NSA

Strategy for Trusted Identities in Cyberspace: Increase cybersecurity and online privacy so that users can conduct online transactions with higher levels of trust and confidence through development of a secure and safe "identity ecosystem" – NIST

Information Security Automation Program (ISAP): Multiagency program to enable automation and standardization of technical security operations; applying Security Content Automation Protocol (SCAP), a method for using specific standards to enable automated vulnerability management, measurement, and policy compliance evaluation (e.g., FISMA compliance) – NSA, NIST, DHS, DISA

Mobile wireless and sensor networks: Security architectures for airborne/enclave networks, security of classified information on wireless networks; assured access anti-jam communications; geolocation; trustworthy information delivery in mobile tactical systems (including sensor networks); secure handover for roaming between heterogeneous networks – NSF, OSD, AFRL, ARO, CERDEC, ONR, DARPA, NIST, NSA

Expeditions in Computing: Cross-directorate program for multiyear investigations addressing national challenges such as energy efficiency, environmental sustainability, advanced communications systems – NSF

Mission assurance

Network protection and defense: Technologies and tools for situational awareness across organizations; threat anticipation and avoidance; attack sensing, warning, and response; cognitive policy-based intrusion protection and detection; rapid response (containment, adaptation, repair, self-regeneration); behavior-based network monitoring; defense against large-scale attacks (e.g., DDoS, worms, botnets, spyware), real-time forensics – NSF, OSD, AFRL, ARL, ARO, CERDEC, ONR, DARPA, NIST, NSA, DHS

Operating Effectively in DoD Cyberspace: A Key Mission Area identified by the Quadrennial Defense Review (QDR); research focus on dynamically defending DoD cyberspace, detecting and countering insider threats, fighting through any cyber event – OSD, DoD Service research organizations

Infrastructure for R&D

National Cyber Range (NCR): Strengthen the Nation's ability to conduct cyber operations and defend against cyber threats by providing a prototype research cyber testing range – DARPA

Experimental research testbed (DETER): Experimental infrastructure to support next-generation cyber security technologies; allow repeatable medium-scale Internet emulation experiments – NSF, DHS

Information infrastructure security: Secure protocols; Domain Name System Security (DNSSEC); process control systems security; Internet route monitoring; modeling of Internet attacks – NIST, NSA, DHS

Protected Repository for the Defense of Infrastructure Against Cyber Threats (PREDICT): Research data repository to create and develop new models, technologies, and products to assess cyber threats to the country's computing infrastructure and increase cyber security capabilities – DHS

Wisconsin Advanced Internet Laboratory (WAIL): Experimental infrastructure to enable arbitrary interconnections of routing, switching, and host components found along any path in the Internet – NSF

Planning and Coordination Supporting Request

The CSIA agencies engage in a variety of cooperative efforts – from testbeds essential for experimentation with new technologies at realistic scales, to collaborative deployment of prototypes, to common standards. Following is a representative summary of current multiagency collaborations:

Co-funding: Trustworthy Cyber Infrastructure for the Power Grid (TCIPG) Center – NSF, DOE, DHS; DETER testbed – DHS, NSF; Financial Services Sector Coordinating Council (FSSCC) pilot – DHS, NIST; National Centers of Academic Excellence in Information Assurance Education and Research – NSA, DHS

Workshops: Cybersecurity Applications and Technology Conference for Homeland Security – DHS; DoD Small Business Innovation Research (SBIR) Conference – DoD Service research organizations and DHS; Financial Services Workshop – Treasury; 2nd Inco-Trust workshop: International Data Exchange with Security and Privacy – NSF, EU; Workshop on Designing a Secure System Engineering Competition (DESSEC) – IARPA, NSF; Workshop on Cybersecurity Data for Experimentation – NSF, DHS; Science of Cybersecurity study – OSD, NSF, NSA; Workshop on the Future of Trustworthy Computing – NSF; Privilege Management – NIST, NSA; Annual IT Security Automation Conference – NIST, NSA

Collaborative deployment: DNS security (DNSSEC) and routing security – DHS, NIST; deployment of DoD software-protection technologies within the DOE HPC environment – OSD, AFRL, DOE/NNSA

Interagency cooperation: Ongoing information exchanges in support of developing a national cybersecurity R&D agenda – All

Technical standards: Developing, maintaining, and coordinating validation programs for many cryptographic standards – NSA, NIST; participation in IETF security groups to develop standard representations and corresponding reference implementations of security-relevant data – OSD, NSA, NIST

Testbeds: Continued joint development of research testbeds, such as DETER, PREDICT, Web*DECIDE, WAIL, NCR, Mobile Networks Testbed Emulation – NSF, Army, ONR, DARPA, DHS, Treasury

DoD Cyber S&T Steering Council: Expanded role to include oversight and coordination of all defensive cyber S&T programs – OSD and DoD Service research organizations

Technical Cooperation Program C3I Group: Information assurance and defensive information warfare – OSD, AFRL, Army, ONR, NSA

INFOSEC Research Council: Participation in technical forum for coordination of Federal CSIA R&D – All

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the CSIA PCA:

NSF: Trustworthy Computing program (includes support for the multi-agency Comprehensive National Cybersecurity Initiative) seeking new models, logics, algorithms, and theories for analyzing and reasoning about all aspects of trustworthiness (reliability, security, privacy, theoretical foundations, and usability)

OSD: Continue to lead DoD coordination through the expanded DoD Cyber S&T Steering Council; new JASONs report on Science of Cybersecurity; cyber security metrics; new applied research and advanced development programs in cyber security gaps identified in recent studies; SBIR workshop to facilitate networking with small businesses

AFRL: University Center of Excellence for Assured Cloud Computing; integrated cyber defense to ensure continued mission operations

ARO/ARL/CERDEC: Network Science Collaborative Technology Alliance – Trust Cross-Cutting Research Initiative; Army Cryptographic Modernization Office; tactical security tools evaluations; biometric pilot programs; information assurance program support

ONR: Security architecture research for host, network, and application: securing the layers, the components, and interactions for information technologies/infrastructures; secure distributed collaboration; security management infrastructure and assured information sharing; secure dynamic tactical communications networks

DOE: Innovative cybersecurity solutions for smart-grid; basic research in mathematics of cybersecurity and complex interconnected systems

DARPA: New computing and security architectures inspired by biological mechanisms for resilience; information assurance research to protect information infrastructure and systems; trustworthy systems from untrustworthy components; assured Internet communication and computation; and resilient networks

NIST: Federal Computer Security Program Managers' Forums; global electronic ID verification; international SHA-3 hash competition; voting security; Software Analysis Tool Exposition (SATE); key management; multi-factor authentication; Standards Acceleration to Jumpstart Adoption of Cloud Computing (SAJACC); protecting virtualization technologies; Risk Management Framework (RMF); Guidelines for Smart Grid Cyber Security; National Initiative for Cybersecurity Education (NICE); foundations of measurement science for information systems; usability research to determine which factors encourage and which factors discourage the adoption of cybersecurity standards

NSA: Developing low-cost, high-assurance, programmable, "easier" to certify guard (systems to assure separation between information environments with differing security classifications); leveraging commodity hardware, virtualization, measurement, and attestation to develop Secure Virtual Platform

DHS: DHS Secure Wireless Access Pilot (DSWAP); DNSSEC; Secure Protocols for the Routing Infrastructure (SPRI); network data visualization for information assurance; Internet tomography; data anonymization tools, techniques; Homeland Open Security Technology (HOST)

IARPA: Automatic Privacy Protection (APP); Securely Taking on New Executable Software of Uncertain Provenance (STONESOUP)

NITRD Program Defines Key Components of Federal Cybersecurity Research

In realizing the goal of the 2009 President's Cyberspace Policy Review for "a framework for research and development strategies that focus on game-changing technologies," the NITRD Program has led a series of public-private activities to identify promising ideas with the potential to reshape the cybersecurity landscape. These activities culminated in defining initial strategic themes for transforming cybersecurity, which were announced by the NITRD Program in 2010: (a) Tailored Trustworthy Spaces, (b) Moving Target, and (c) Cyber Economics and Incentives.

The themes are among four cornerstones for structured activities and focus areas under a proposed Federal Cybersecurity Research Program, as follows:

- **Research Themes:** Themes provide a focus on underlying causes of cybersecurity vulnerabilities and identify avenues to induce changes that will lead to a more secure cyberspace. The themes compel a new way of operating, draw on a number of sciences and technologies, and present a path to transition, deployment, and cooperation with the private sector. The themes will evolve and new themes will be added as our needs and understanding of the cyberspace mature
- **Scientific Foundations:** The game-change process focuses on near-term threats and current or near-horizon technologies. The Federal Cybersecurity Research Program also establishes the priorities and investments in laying the theoretical, empirical, computational, and analytical foundations needed to meet needs arising from next-generation technologies and to address the threats of the future. Scientific foundations in cybersecurity will provide a formal basis for understanding existing system security properties, developing systems that have desired security properties, supporting quantified tradeoffs between security properties, and providing a scientific basis for the human context in which systems of interest are designed to operate, considering economic, behavioral, social, and organizational factors that influence the deployment and use of cybersecurity technologies
- **Research Integration:** Activities to catalyze integration across themes and cooperation between governmental and private-sector communities, and to strengthen linkages to other national priorities such as health care IT or Smart Grid
- **Transition to Practice:** Focused effort to ensure that powerful new technologies and strategies that emerge through the research themes and from the scientific foundations can be adopted and implemented to create measurable improvements in the cybersecurity landscape

In combination, the four proposed cornerstones will define coordinated directions within the Federal Cybersecurity Research Program. Through their Senior Steering Group for Cybersecurity R&D and the CSIA Interagency Working Group, the NITRD agencies are now in the process of defining the program in the Federal Cybersecurity Research Program Strategic Plan. This plan is expected to be completed in spring 2011.

Human Computer Interaction and Information Management (HCI&IM)

NITRD Agencies: NSF, NIH, OSD and DoD Service research organizations, DARPA, NIST, NASA, DHS, AHRQ, NOAA, EPA, NARA
Other Participants: IARPA, HHS/ONC, USDA, USGS, VA

HCI&IM focuses on R&D to expand human capabilities and knowledge through the use and management of information by computer systems and by humans, facilitated by hardware, software, and systems technologies. These technologies include robotics, multimodal interaction technologies, visualization, agents, cognitive systems, collaborative systems, and information systems that support the organization and refinement of data from discovery to decision and action. HCI&IM outcomes support U.S. national priorities such as scientific research, energy and the environment, climate change and prediction, health care, education and training, protecting our information infrastructure, emergency planning and response, national defense, homeland security, weather forecasting, and space exploration.

President's 2012 Request

Strategic Priorities Underlying This Request

As noted in the agencies' definition above, HCI&IM research spans both the diverse technologies that enable people to access and use digital information and the equally diverse technologies that expand the capabilities of computing systems and devices and the ways people interact with them. For example, in a world now annually generating many times more "born-digital" information than in all the books ever written, new transformative approaches for accessing and extracting meaning from vast quantities and forms of data have become a critical need. The Federal government generates and maintains the world's largest digital collections of science and engineering data, historical records, health information, and scientific and other types of archival literature. Rapid knowledge discovery to address national grand challenges requires next-generation methods, technologies, and tools that integrate and efficiently manage massive stores of distributed, heterogeneous information while integrating the human in the discovery process. Deeming such capabilities essential for U.S. economic growth and technological innovation, the Administration has cited NITRD data-related R&D as a science and technology budget priority for 2012. The following are key elements of the HCI&IM R&D agenda:

Information integration: To support complex human, societal, and organizational ideas, analysis, and timely decision-making, large amounts of multisource forms of raw information (e.g., sensors) must be managed, assimilated, and accessible in formats responsive to user needs and expertise. Advances are needed in:

- **Information standards:** Data interoperability, integration of distributed data; generalizable ontologies; data format description language (DFDL) for electronic records and data; data structure research for complex digital objects; interoperability standards for semantically understood ubiquitous health information exchanges; information services for cloud-based systems
- **Decision support:** Portals and frameworks for data and processes; user-oriented techniques and tools for thematic discovery, synthesis, analysis, and visualization for decision making; mobile, distributed information for emergency personnel; management of human responses to data; information triage; portfolio analysis; development of data corpora for impact assessment and other metrics of scientific R&D
- **Information management:** Intelligent rule-based data management; increasing access to and cost-effective integration, maintenance of complex collections of heterogeneous data; innovative architectures for data-intensive and power-aware computing; scalable technologies; integration of policies (differential sensitivity, security, user authentication) with data; integrated data repositories, computing grids; testbeds; sustainability, validation of complex models; grid-enabled visualization for petascale collections

Information infrastructure: Technical challenges in building a robust, resilient national and global digital data framework; management of the Federal government's electronic records; technologies (data transfer, mass storage) and tools for long-term preservation, curation, federation, sustainability, accessibility, and survivability of vital electronic records, data collections, and health records; multidisciplinary R&D in ways to convert data into knowledge and discovery; social-computational systems; digitization of scientific collections

The HCI&IM agencies also pursue research in technologies that imbue digital systems and devices with human-like attributes and capabilities designed to assist people, make it easier for people to interact with and benefit from computing, or enable the devices to perform hazardous tasks in extreme environments on behalf of people.

Strategic R&D areas include:

Active systems: Systems that learn, reason, and automatically adapt to new and unforeseen events; onboard autonomy; performance evaluation of intelligent sensing and control systems; robotic devices for emergency response, urban search and rescue, bomb disposal, advanced manufacturing, and exploration

Multimodal interfaces, capabilities, and data: Systems that are activated by and/or demonstrate speech, hearing, vision, touch, movement, sensing, etc; language recognition and translation; transformative cyber-learning technologies; improved understanding of human-computer interactions to advance human performance

Highlights of Request

The HCI&IM agencies report the following topical areas as highlights of their planned R&D investments for FY 2012. Agencies are listed in NITRD budget order, unless there is a lead agency (listed first) for the effort:

From data to new knowledge: Computational concepts, methods, models, algorithms, and tools to accelerate scientific discovery and productivity from heterogeneous, ultra-scale data stores; innovative, multidimensional approaches to identifying, processing, retrieving, exploring, analyzing, describing, and visualizing highly complex data; intuitive display for complex interactions; enhanced discoverability, availability, interoperability, usability of data and analysis tools; effective analytical products for decision makers and the public – NSF, NIH, DoD Service research organizations, NIST, NASA, AHRQ, NOAA, EPA, NARA

Effective stewardship of science and engineering data: Issues in access to and federation, preservation, curation, data life-cycle stewardship, and analysis of large, heterogeneous collections of scientific data, information, and records; fault-tolerant, scalable I/O – NSF, NIH, NIST, NASA, NOAA, EPA, NARA; new program for digitization of scientific collections – NSF

Information integration, accessibility, and management: Advanced technologies, system architectures, and tools for optimizable, scalable ingest and processing; high-capacity data integration, management, exploitation, modeling, analysis, and tools; virtualization, infrastructures for efficient distributed access to data resources; video understanding; ontologies and metadata; integration of GIS, spatial-temporal data –NSF, NIH, DARPA, NIST, NASA, AHRQ, NOAA, EPA, NARA

Earth science data and information: Development of collaborative connections, including Web-based SOA tools and services (e.g., remote visualization), that exploit advances in computer science and technology to expand access to, use of Federal scientific data resources – NASA, NOAA, EPA with other agencies

Expeditions in Computing: Cross-directorate program for multiyear investigations addressing national challenges such as energy efficiency, environmental sustainability, advanced communications systems – NSF

Health information technologies: Clinical decision-support systems, evidence-based standards and tools; physician/personal electronic health records; preventable adverse drug effects, national health information interoperability standards; smart health and wellness; usability of health IT systems; biomedical imaging – HHS/CMS, HHS/ONC, NSF, NIH, NIST, AHRQ, FDA, other agencies

Text Retrieval and Text Analysis Conferences: Evaluation of information-discovery technologies; relevance feedback; legal discovery; recognition of opinion in blogs; entity, web, chemical patent search; machine reading – NIST, NSF, DARPA, NARA, IARPA

Cognitive, adaptive, and intelligent systems: Cognitive, perceptual modeling for joint cognitive systems design; decision-support tools; autonomy, trustworthiness, reliability of automated systems; engineered intelligence, adaptability; robotics, human-robot teaming; affective computing – NSF, DoD Service research organizations, DARPA, NIST, NASA

Multimodal language recognition and translation: Improve multilingual language technology performance in areas of speech-to-text transcription, spontaneous two-way communications translation, machine reading, text retrieval, document summarization/distillation, automatic content extraction, speaker and language recognition, multimodal interfaces, usability, language understanding – NSF, DoD Service research organizations, DARPA, NIST, NASA, NARA, IARPA

Human-in-the-loop: HCI and systems integration; personalization in design; human performance modeling; decision-support systems and tools; multimodal interfaces and data; distributed collaboration, knowledge management, virtual organizations and visual environments; cognitive and perceptual process modeling and measurement; virtual reality technologies for simulation and training; user-controlled data abstraction; biometric and voting systems – NSF, DoD Service research organizations, DARPA, NIST, NASA, NOAA, EPA

Planning and Coordination Supporting Request

Although the HCI&IM portfolio includes a broad range of enabling technologies, the current focus of coordination among the agencies is the overriding challenge of ultra-scale, heterogeneous data: how to manage it, enable interoperability and usability, and develop new infrastructures and tools that broaden access and exploration to a wider range of end users. The following HCI&IM collaborations seek to forward this agenda:

Science and Science Innovation Policy Interagency Task Group: Coordination on Federal science policy issues, including data aspects – HCI&IM agencies, others

Health IT: Coordination on research needs in data management, technology interfaces – NIH, NSF, NIST, AHRQ, HHS/CMS, HHS/ONC, other agencies

Biodiversity and Ecosystem Informatics Task Group: Ongoing forum for cooperation – NSF, NIH, DOE/SC, NASA, NOAA, USGS, Interior, other agencies

Earth science, climate, and weather: Continuing cooperative activities in interoperable data, multidimensional models, and tools for better understanding and prediction based on the growing corpus of observational and experimental data – NASA, NOAA, DoD Service research orgs., NSF, EPA, other agencies

Information access, management, and preservation: Collaborations in IWG on Digital Data; workshop on science data management; scalable repository architectures; data management and decision-support technologies; data grids; data-intensive computing; Digital Preservation Interoperability Framework International Standard (DPIF) –NSF, NIH, NIST, NASA, EPA, NARA, other agencies

Foundations of visualization and analysis: Coordination to consider feature extraction for anomaly detection; integration of multiple types of data and records at scale or format; use of visualization as an interface; biomedical imaging –NSF, NIH, NIST, NASA, NOAA, EPA, DHS, AHRQ, NARA, other agencies

Usability: Issues in health IT, biometrics systems, clinical decision support – NIST, AHRQ

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the HCI&IM PCA:

NSF: Through academic R&D, support for information privacy; integrative intelligence (agents, modalities, domains); ubiquitous networked data environments; human-computer partnerships; socially intelligent computing; universal access; cognition mechanisms in human learning; remote access to experimental facilities

NIH: Basic research funded under the Biomedical Information Science and Technology Initiative (BISTI)

DARPA: Autonomous robotic manipulation and machine reading; reasoning, learning, and visual intelligence

NIST: Biometrics evaluation, usability, and standards (fingerprint, face, iris, voice/speaker); multimedia evaluation methods (video retrieval, audio and video analysis, smart-space technologies); measurement, evaluation tools for 3D shape searching; data preservation metrology, standards; usability of voting systems; manufacturing, supply chain informatics; standards for manufacturing robots; engineering informatics sustainability; computational biology; mathematical knowledge management

NASA: Human-centered automation concepts for aviation safety; basic and applied research in human performance; decision-support technologies for Next Generation Air Transportation System (NextGen); multimodal interface research; applied information systems research to help increase productivity of scientific research; research on advanced tools for discovering tools and services, and developing as well as preserving provenance of data products and associated information

AHRQ: Patient safety, quality improvement program in ambulatory care; maintaining a Health IT Research Center (with ONC); health care decision making; patient-centered care; evidence-based practice center; U.S. Health Information Knowledgebase

NOAA: Technologies for real-time weather/climate data in multiple formats for scientists, forecasters, first responders, citizens; remote visualization via N-Wave, new high-definition devices; HRD Forge centralized database for hurricane data, models; disaster planning, mitigation, response, and recovery

EPA: Databases for computational toxicology; scientific information management (tools, best practices for management, accessibility of complex EPA data sets); distributed environmental applications

NARA: Testbed investigations of: advanced decision-support technologies for ultra-high-confidence processing of very large Presidential electronic records collections (with ARL support); open source-based access and digital preservation infrastructure; technology-independent access to, preservation of complex digital objects, including engineering and science data

Large Scale Networking (LSN)

NITRD Agencies: NSF, NIH, OSD and DoD Service research organizations, DOE/SC, DARPA, NIST, NASA, NSA, DHS, AHRQ, NOAA, DOE/NNSA
Other Participants: USGS

LSN members coordinate Federal agency networking R&D in leading-edge networking technologies, services, and enhanced performance, including programs in network security, future trustworthy Internet design, technology for enterprise, core and optical networks, wireless, mobile, sensor peer-to-peer, delay-tolerant, and application-level networks, advanced network testbeds (100 G end-to-end, GENI); cloud computing testbeds, end-to-end performance measurement (e.g., perfSONAR), networks for public safety communications and Smart Grid, network science and engineering of complex networks; and engineering, management, and enabling large-scale networks for scientific and applications R&D including large-scale data transfers, and virtual organization functionality (e.g., BIRN, caBIG). The results of this coordinated R&D, once deployed, can help assure that the next generation of the Internet will be scalable, trustworthy, and flexible to support user applications.

President's 2012 Request

Strategic Priorities Underlying This Request

The missions of the LSN agencies, though varied, all require ultra-high-speed communications and ultra-scale data-transfer capabilities with demanding constraints of security, reliability, and availability. The advanced Federal research networks support national security needs as well as transport data among the world's leading science discipline centers and observational systems on the ground, on the seas, in the air, and in space. Each year, the LSN agencies agree upon a small number of priority areas in which focused research collaboration will promote advances in networking that address these needs and benefit all. The performance measurement activity, for example, is enabling Federal researchers to monitor and improve end-to-end performance across multiple network domains, and also providing innovative capabilities being adopted in the marketplace. LSN collaborative activities for 2012 will focus on:

Understanding large-scale network complexity: deriving fundamental insights, and measuring performance to enable trustworthy, economically viable networks that preserve our social values

Technology for advanced networking: Trustworthy, scalable Internet architecture, 100 G end-to-end networking testbeds, heterogeneous dynamic networking, and sensor networking to provide infrastructure for scientific research and social interactions

Cloud computing research: Research to enable secure cloud computing and virtualization at scale to improve basic science transparency, collaboration, efficiency across science domains, and network management; implementation of large-scale testbeds to explore cloud computing technologies

Performance measurement over federated, multidomain networks: Hold a continuing series of workshops to promote development and use of performance measurement capabilities based on the perfSONAR infrastructure

Highlights of Request

The LSN agencies report the following topical areas as highlights of their planned networking R&D investments for FY 2012. Agencies with efforts in a research topic are listed in their NITRD budget order:

Networking for health science research, clinical needs, and disaster management – NIH, NSF, NIST

Network architectures and protocols for future networks: Develop network architecture concepts to enable robust, secure, flexible, dynamic, heterogeneous networking capabilities and support sustainable environments, energy-efficient computing, and virtualization at scale – NSF, OSD, DOE/SC, DARPA, NIST, NASA

Experimental network facilities: Provide at differing scales, including DOE/SC's 100 G network to support experimentation at scale in new architecture and protocols and the NSF GENI virtual laboratory project for exploring future Internets at scale – NSF, DOE/SC, NIST, NASA, NOAA

Large-scale data flows: Develop, test terabit-plus transport protocols, capabilities (e.g., InfiniBand single-stream flows over WANs) – NSF, OSD, DOE/SC, DARPA, NASA, NOAA

Cloud computing, distributed computing, and collaboration: Secure federated software tools and cloud services for data distribution and management, visualization, software stack for large-scale scientific collaborations, high-bandwidth implementation, interoperable smart grid standards and testbeds, Open Science Grid, Worldwide Large Hadron Collider Computational Grid, Earth System Grid – NSF, NIH, DOE/SC, NIST, NASA, NOAA

End-to-end performance measurement: Enable federated, end-to-end performance measurement for advanced networking; provide tools for and implement perfSONAR – NSF, DOE/SC, NIST, NASA

Security implementation (IPv6, DNSSEC, and Trusted Internet Connections [TICs]): Develop and implement near-term mandated capabilities –NSF, NIH, OSD, DOE/SC, NIST, NASA, NSA

Network security research: Technologies for detection of anomalous behavior, quarantines; standards, modeling, and measurement to achieve end-to-end security over heterogeneous, multidomain networks and infrastructure; critical-infrastructure protection; trustworthy networking; privacy, confidentiality, authentication, policy, cryptography, and quantum communication –NSF, NIH, OSD, DOE/SC, NIST, NASA

Network science and engineering: Develop concepts, methods, architectures, protocols, and measurement for modeling networks as complex, autonomous, and dynamic systems – NSF, OSD, DOE/SC, DARPA, NIST

Mobile and sensor networking: Standards, tools to allow for better interconnectivity, seamless interoperability, management (e.g., power, data fusion, heterogeneous interfaces, spectrum constraints) for robust, secure, dynamic, mobile networks (wireless, radio, sensor) and interoperability with heterogeneous networks; sensing, control systems – NSF, OSD, DARPA, NIST, NASA

Public-safety networking, disaster recovery, and crisis management: Disaster Information Management Research Center (DIMRC), public-safety communications, implant communication system – NIH (NLM), NIST

Expeditions in Computing: Cross-directorate program for multiyear investigations addressing national challenges such as energy efficiency, environmental sustainability, advanced communications systems – NSF

Planning and Coordination Supporting Request

The LSN agencies have long worked through interagency and private-sector partnerships, both formal and informal, to interconnect and extend the capabilities of Federally supported research networks. By engaging participants from academia, industry, national labs, and international networking groups, for example, LSN's Joint Engineering Team is able to coordinate efforts to resolve technical networking issues at the global level and to develop collaborative testbeds for exploring advanced technologies at scale. In summary, the following are ongoing LSN coordination activities:

Interagency research agenda: PerfSONAR development testing and deployment, complexity of networking and cloud computing testbeds – LSN agencies

Cooperative R&D efforts: Smart Grid, DETER, networking research projects – NSF, DOE/SC; Internet Infrastructure Protection Program – NIST, other agencies; perfSONAR deployment and cooperation – DOE/SC, NIST, NASA

Workshops: DOE/SC workshops on Biological and Environmental Research and Basic Energy Sciences network requirements, OSCARS and DOE Grid CA services; NSF workshops on perfSONAR and Highly Controllable Dynamic Heterogeneous Networking

Trans-Oceanic Networking for Science: NSF, DOE/SC

Coordination by LSN Teams

- **Joint Engineering Team (JET): NSF, NIH, OSD (HPCMP), DOE/SC, NIST, NASA, NSA, NOAA, USGS, FAA, with participation by academic organizations (CAIDA, CENIC, Internet2, ISI, MAX, NLANR, StarLight), ANL, PNNL, supercomputing centers (ARSC, NERSC, MCNC, PSC), universities (FIU, IU, UIC, UMd, UNC, UU, UW), and vendors** – Advanced testbeds, coordination of end-user requirements, engineering of research networks and testbeds (JETnets); security best practices, applications testbeds (DNSSEC, IPv6, IPv6 multicast, performance measurement); TICs coordination; interdomain and end-to-end metrics, monitoring; tool sharing and exchange; international coordination; transit and services cooperation
- **Middleware And Grid Infrastructure Coordination (MAGIC) team: NSF, NIH, DOE/SC, NIST, NASA, NOAA, with participation by academic organizations (EDUCAUSE, Internet2, ISI, UCAR), national labs (ANL, LANL, LBNL, PNNL), universities (UIUC, UMd, UNC, UWisc), vendors** – Cloud

computing, middleware and grid tools, services; grid standards and implementation status (TeraGrid, OSG, ESG, CEDPS, CDIGS, Nebula, caBIG, CVRG, biomedical research grids such as BIRN), identity management (e.g., coordinated certificate authorities); international coordination

Information exchange: Multiagency participation in review panels, informational meetings, principal investigator (PI) meetings; coordination among program managers; joint JET, DOE ESSC and Internet2 Joint Techs Meetings – NSF, AFRL, DARPA, NIST, NASA, NSA, DHS

Partnerships for research connectivity – NSF, DREN, DOE/SC, NASA, NOAA

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the LSN PCA:

NSF: Core networking research; network experimental infrastructure; SEES efforts to optimize energy-computation performance; IRNC; focus on theory of network architecture, understanding complexity, robust socio-technological networking; collaboratories; data-intensive computing; Expeditions in Computing center-scale activities

NIH: Health care IT, infrastructure creation; applications (Web, wireless, grid-based, distributed databases and repositories, TeraGrid)

OSD (HPCMP): Multidomain performance measurement; security (IPsec, VPN portals, security assessment script, Kerberos development, filters, encryption, data attribution); high-speed access to DOJ, Hawaii, and Alaska

DOE/SC: 100 G networking (technology, infrastructure, testbed, scaling middleware, coupled applications); cloud computing testbed; distributed systems software implementations; hybrid networking; scalable performance measurement; on-demand bandwidth services

DARPA: Radio networking in challenging environments for mobile tactical applications; power and spectrum management, interface multiple access, brood of spectrum supremacy, wireless electronic protect/attack; data fusion and management; collective technology for dynamic teams, software agents, and sensors

NIST: Smart Grid standards; Internet infrastructure protection; seamless, secure mobility standards and tools; complex systems; quantum communications technology; cloud-computing security

NASA: 40-100 G testbed, high-performance encrypted Infiniband and file transfers, performance measurement, firewalls; innovative architectures; network security research and implementation; mobile and sensor networking; TIC development

NSA: Delay-tolerant and ad hoc networking; open-source compressed sensing

AHRQ: With ONC, health care IT (develop, evaluate IT tools to improve quality of care and patient safety; demo statewide, regional information networks; integrate with Nationwide Health Information Network data standards)

NOAA: Integration of and access to HPC centers; support to remote users, test, measurement and analysis tools, improved security

High Confidence Software and Systems (HCSS)

NITRD Agencies: NSF, NIH, OSD, AFRL, AFOSR, ARO, ONR, DARPA, NIST, NASA, NSA, DHS
Other Participants: DOE (OE), DOT, FAA, FDA, FHWA, NRC, NTSB

HCSS R&D supports development of scientific foundations and innovative and enabling software and hardware technologies for the engineering, verification and validation, assurance, and certification of complex, networked, distributed computing systems and cyber-physical (IT-enabled) systems (CPS). The goal is to enable seamless, fully synergistic integration of computational intelligence, communication, control, sensing, actuation, and adaptation with physical devices and information processes to routinely realize high-confidence, optimally performing systems that are essential for effectively operating life-, safety-, security-, and mission-critical applications. These systems must be capable of interacting correctly, safely, and securely with humans and the physical world in changing environments and unforeseen conditions. In many cases, they must be certifiably dependable. The vision is to realize dependable systems that are more precise and highly efficient; respond more quickly; work in dangerous or inaccessible environments; provide large-scale, distributed coordination; augment human capabilities; and enhance societal quality of life. New science and technology are needed to build these systems with computing, communication, information, and control pervasively embedded at all levels, thus enabling entirely new generations of engineering designs that can enhance U.S, competitiveness across economic and industrial sectors.

President's FY 2012 Request

Strategic Priorities Underlying This Request
In recent years, the HCSS agencies have engaged in a sustained effort to foster a new multidisciplinary research agenda that will enable the United States to lead in the development of next-generation engineered systems that depend on ubiquitous cyber control and require very high levels of system assurance. Through a variety of ongoing activities, the HCSS effort is forging a nationwide community of parties interested in the CPS research challenges faced in common across such economic sectors as medicine and health care, energy, transportation, manufacturing, and agriculture, and across such agency missions as national security, environmental protection, and space exploration. The HCSS agencies have set the following priorities for research coordination:

Science and technology for building cyber-physical systems: Develop a new systems science providing unified foundations, models and tools, system capabilities, and architectures that enable innovation in highly dependable cyber-enabled engineered and natural systems

Assurance technology: Develop a sound scientific and technological basis, including formal methods and computational frameworks, for assured design, construction, analysis, evaluation, and implementation of reliable, robust, safe, secure, stable, and certifiably dependable systems regardless of size, scale, complexity, and heterogeneity; develop software and system engineering tool capabilities to achieve application and problem domain-based assurance, and broadly embed these capabilities within the system engineering process; reduce the effort, time, and cost of assurance ("affordable" V&V/certification); provide a technology base of advanced-prototype implementations of high-confidence technologies to spur adoption

High-confidence real-time software and systems: Pursue innovative design, development, and engineering approaches to ensure the dependability, safety, security, performance, and evolution of software-intensive, dynamic, networked control systems in life- and safety-critical infrastructure domains, including "systems-of-systems" environments; real-time embedded applications and systems software; component-based accelerated design and verifiable system integration; predictable, fault-tolerant, distributed software and systems

CPS innovation challenges: Collaborate in problem-driven research and development of transition platforms for innovation in mission systems

Advances to enhance understanding and management of complex systems: Develop improved models of complex systems, software, human cognition, and human-system interactions; new integrated analytical and decision-support tools

Integration of research and education: Foster the research community's commitment to integrating CPS theory and methodology in education and promoting increased understanding of and interest in CPS systems through the development of new curricula at all levels

Highlights of Request

The HCSS agencies report the following topical areas as highlights of their planned R&D investments for FY 2012. Agencies with efforts in a research area are listed in their NITRD budget order, unless there is a lead agency (listed first) for the effort:

Cyber-physical systems: Continuing support for research to enable physical, biological, and engineered systems whose operations are integrated, monitored, and/or controlled by a computational core and interact with the physical world, with components networked at every scale and computing deeply embedded in every physical component, possibly even in materials; real-time embedded, distributed systems and software; interoperable ("plug-and-play") medical devices – NSF, AFRL, ARO, ONR, NIST, NASA, NSA, FAA, FDA

Large-scale complex systems: Multiyear effort, including focus on software for tomorrow's complex systems such as CPS, to address challenges of large-scale interacting systems and investigate their non-linear interactions and aggregate or emergent phenomena to better predict system capabilities and decision-making about complex systems – NSF

High-confidence systems and foundations of assured computing: Formal methods and tools for modeling, designing, measuring, analyzing, evaluating, and predicting performance, correctness, efficiency, dependability, scalability, safety, and usability of complex, real-time, distributed, and mobile software and systems; high-assurance environments from COTs; high-assurance virtualization and measurement; architectures, components, composition, and configuration; systems-of-systems governance, engineering, analysis, and testing of software and hardware; cost-effective V&V; verification techniques for separation assurance algorithms; safety cases, standards, and metrics; quantum information processing – NSF, OSD, AFRL, AFOSR, ARO, ONR, NIST, NASA, NSA, FDA

Information assurance requirements: Methods and tools for constructing, analyzing security structures (management architectures and protocols, etc.); assurance technologies for cross-domain creation, editing, sharing of sensitive information in collaboration environments that span multiple security levels; cryptographic algorithms and engineering; assured compilation of cryptographic designs, specifications to platforms of interest – ONR, NSA; testing infrastructure for health IT standards, specifications, certification (with HHS); cross-enterprise document sharing in electronic health systems – NSF, NIST

Standards and test methods for intelligent industrial control systems security (ICS) and networks: Approaches to balancing safety, security, reliability, and performance in SCADA and other ICS used in manufacturing and other critical infrastructure industries (e.g., water, electric power, oil and gas, chemicals, pharmaceuticals, food and beverage, materials processing) and building security into next-generation systems – DHS, NIST; ensuring performance, interoperability of factory floor network communication devices and systems; leading Smart Grid Industrial-to-Grid Domain Expert Working Group on interoperability – NIST

Aviation safety: R&D in transformative, cost-effective V&V methods to rigorously assure the safety of the NextGen Air Transportation System – NASA; Flight Critical Systems & Software Initiative (FCSSI) to develop and demonstrate innovative technologies in the design of mixed-critical architectures with advanced features, focusing on designing for high-confidence certification and developing in-house capability – AFRL, NASA

Expeditions in Computing: Support for far-reaching research explorations motivated by deep scientific questions or hard problems in the computing and information fields, and/or by compelling applications that promise significant societal benefits – NSF

Planning and Coordination Supporting Request

To build multidisciplinary communities of interest both within and across sectors, the HCSS agencies have developed a busy annual schedule of workshops and other research meetings that bring a broad mix of stakeholders together who might not otherwise cross paths. The HCSS workshops on high-confidence medical devices, for example, draw medical researchers, medical practitioners and caregivers, device developers and vendors, care facility administrators, academic computer scientists and engineers, and Federal government regulators. These first-of-their-kind gatherings are forging wider understanding of critical issues and developing consensus around promising research directions in high-confidence CPS. Similarly, HCSS-sponsored workshops on transportation CPS are developing agreement on R&D needs that span multiple transportation sectors. In summary, the following are ongoing HCSS coordination activities:

National Research Workshop Series: Academic, industry, and government stakeholder workshops to identify new R&D for building 21st century CPS for life-, safety-, and mission-critical applications; topics include:

- **High Confidence Medical Device CPS** – NSF, NIST, NSA, FDA
- **Future Energy CPS** – NSF, NIST, NSA, ARPA-E
- **High Confidence Transportation CPS: Automotive, Aviation, and Rail –** NSF, NIST, NASA, NSA, AFRL with DOT, FAA, FDA, NTSB
- **CPS Week** – NSF, AFRL, NIST, NASA, NSA
- **Verified Software, Theories, Tools, and Experiments (VSTTE) Workshop** – NSA, NSF
- **Static Analysis Tools Exposition (SATE):** Annual summit on software security for vendors, users, and academics **–** NIST, NSA, NSF with DHS
- **CPS Education:** NSF, ONR, NSA
- **CPS Extreme Manufacturing:** NIST, NSF, DARPA, ONR, FDA

Software Assurance Metrics and Tool Evaluation: Annual workshop for users and developers to compare efficacy of techniques and tools; develop vulnerability taxonomies – NIST, NSA, DHS

Eleventh Annual HCSS Conference: Showcasing of promising research to improve system confidence – NSA with NSF, ONR, NASA, FAA

Software Assurance Forum – OSD and DoD Service research organizations, NIST, NSA, DHS

Safety of flight-critical systems: HCSS agencies are collaborating on workshops and technical discussions on this topic in which multiple agencies have ongoing activities – OSD, AFRL, NASA, NSA, NSF

Future Directions in Cyber-Physical Systems Security: Joint workshop – DHS, NIST, NSA, NSF, DOE (OE), OSD, USAF

Standards, software assurance metrics for SCADA, ICS: Collaborative development – NIST, DOE (OE), others

Biomedical imagery: Technical standards for change measurements in patient applications – NIH, NIST, FDA, CMS

Cooperative proposal evaluation – NSF, AFRL, NIST, NASA, NSA, FAA, FDA, NRC

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the HCSS PCA:

NSF: Joint research program of CISE and ENG directorates addressing CPS challenges in three areas (foundations; methods and tools; and components, run-time substrates, and systems); partnership to support advanced manufacturing through CPS research that helps better integrate IT into manufactured goods; core research in software and information foundations, communications, and computer systems; Expeditions projects in next-generation approaches to software and system assurance and CPS

NIH: Assurance in medical devices such as pulse oximeters, cardio-exploratory monitors for neonates; telemedicine; computer-aided detection and diagnosis; computer-aided surgery and treatment; neural interface technologies such as cochlear implants, brain-computer interfaces

AFOSR: Theoretical foundations for specification, design, analysis, verification, use, and continued evolution of systems and software, including formal models for complex software-intensive systems and their environments, modeling of human-machine systems, and new development approaches

AFRL: R&D in improved system design methodologies and enhanced V&V techniques supporting safety and security airworthiness certification of onboard embedded, flight-critical aircraft systems operating in a system-of-systems (SoS) environment (e.g., UAVs); emphasis on mixed-criticality (i.e., air safety combined with security) interdependencies requiring deep interaction and integration of hardware and software components

ARO: Software/system prototyping, development, documentation, and evolution; virtual parts engineering research; reliable and secure networked embedded systems; reliable and effective mechanisms to monitor and verify software execution status

ONR: R&D in fundamental principles to understand, design, analyze, build software systems that are correct, assured, efficient, effective, predictable, verifiable, and extendable to emerging quantum information processing; includes work in real-time fault-tolerant software, software interoperability, systems for quantum processing

NIST: Computer forensics tool testing; National Software Reference Library (funded by DOJ/NIJ); National Vulnerability Database; Internet infrastructure protection (with DHS funding); seamless mobility; trustworthy information systems; information security automation, Security Content Automation Protocol (SCAP); combinatorial testing; next-generation access control; extreme manufacturing; automotive CPS

NASA: Aeronautics safety R&D with emphasis on technologies for software health management, integrated vehicle health management; enabling technologies for design, V&V of flight-critical systems (safety assurance, autonomy and authority, integrated distributed systems, software-intensive systems); enabling V&V technologies for NextGen airspace systems for separation assurance and super-density programs

NSA: High-assurance system construction (correct-by-construction methods, model-driven development, programming languages) and analysis (concolic execution, multi-tool analysis, separation/matching logic, static/dynamic analysis); assured implementation, execution of critical platform components and functionality; assured cryptographic implementations (software and hardware); domain-specific workbench developments (cryptography, guards, protocols, policies)

DHS: Security of cyber-physical systems in critical infrastructures; modeling, simulation, and analysis for decision making in the context of infrastructure protection

DOE (OE): Next Generation Control Systems (scalable, cost-effective methods for secure communication between remote devices and control centers; cost-effective security solutions for new architecture designs and communication methods; risk analysis; National SCADA Test Bed; secure SCADA communications protocol; middleware for inter-utility communications and cyber security; cybersecurity for legacy and next-generation energy delivery systems; secure cyber-physical interfaces; TCIPG academic consortium for frontier research and workforce development; R&D to provide situational awareness that supports NERC-CIP compliance

FAA: Evaluate COTS technology and V&V techniques in complex and safety-critical systems for regulatory compliance and intended performance (e.g., software development techniques and tools; airborne electronic hardware design assurance; onboard network and hardware security, integrity, and reliability)

FDA: Formal methods-based design (assured verification, device software and system safety modeling and certification, component composition, forensics analysis, engineering tool foundations); architecture, platform, middleware, resource management for interoperable medical devices (plug-and-play, vigilance and trending systems); infrastructure for medical-device integration, interoperation; patient modeling, simulation; adaptive patient-specific algorithm; black box/flight-data recording; generic insulin infusion pump safety model

FHWA: Apply concept of cyber-enabled discovery and innovation to develop new transportation paradigm for an Integrated Active Transportation System (IATS) focused on three major technical areas: autonomous transportation system, beyond-autonomous vehicle system; real-time response (prediction, prevention, control); and advanced emergency response; goals are to develop new energy sources and reduce emissions, reduce accident frequency and achieve zero fatality, increase mobility and reduce congestion, improve national productivity and economy, and drive national competitiveness in science and technology.

NRC: Regulatory research to assure safety and security in cyber-physical systems (digital instrumentation and control systems) used in the nuclear energy sector

Software Design and Productivity (SDP)

NITRD Agencies: NSF, NIH, OSD, AFOSR, ONR, NIST, NASA, DHS, NOAA
Other Participants: DISA

The SDP R&D agenda spans both the science and the technology of software creation and sustainment (e.g., development methods and environments, V&V technologies, component technologies, languages, tools, and system software) and software project management in diverse domains. R&D will advance software engineering concepts, methods, techniques, and tools that result in more usable, dependable, cost-effective, evolvable, and sustainable software-intensive systems. The domains cut across information technology, industrial production, evolving areas such as the Internet and the World Wide Web, and highly complex, interconnected software-intensive systems.

President's 2012 Request

Strategic Priorities Underlying This Request
Complex software-based systems today power the Nation's most advanced defense, security, and economic capabilities. Such systems also play central roles in science and engineering discovery, and thus are essential in addressing this century's grand challenges (e.g., low-cost, carbon-neutral, and renewable energy; clean water; next-generation health care; extreme manufacturing; space exploration, etc.) Unlike commodity software, these large-scale systems typically must remain operational, useful, and relevant for decades. The SDP agencies are working to identify and define the core elements for a new science of software development that will make design and engineering decisions and modifications transparent and traceable throughout the software lifecycle. A key goal of this science framework is to enable software engineers to maintain and evolve complex systems cost-effectively long after the original developers have departed. The following areas are research priorities:

Research to rethink software design: From the basic concepts of design, evolution, and adaptation to advanced systems that seamlessly integrate human and computational capabilities, including:
- **Foundational/core research on science and engineering of software:** New computational models and logics, techniques, languages, tools, metrics, and processes for developing and analyzing software for complex software-intensive systems (e.g., a principled approach to software engineering that can provide systems that are verifiably correct, assured, efficient, effective, and reliable)
- **Next-generation software concepts, methods, and tools:** Reformulation of the development process, the tool chain, the partitioning of tasks and resources; open technology development (open-source and open-systems methods); technology from nontraditional sources; multidisciplinary and cross-cutting concepts and approaches; emerging technologies such as multicore, software-as-a-service, cloud computing, end-user programming, quantum information processing; modeling of human-machine systems
- **Capabilities for building evolvable, sustainable, long-lived software-intensive systems:** Exploration of new means to create, keep current, and use design and engineering artifacts to support long-lived software-intensive systems; new approaches to reliably meet changing requirements and assure security and safety; long-term retention and archiving of software-development data and institutional knowledge

Predictable, timely, cost-effective development of software-intensive systems: Disciplined methods, technologies, and tools for systems and software engineering, rapidly evaluating alternative solutions to address evolving needs; measuring, predicting, and controlling software properties and tradeoffs; virtualized and model-based development environments; automation of engineering tasks; scalable analysis, test generation, optimization, and verification with traceability to requirements; related issues:
- **Software application interoperability and usability:** Interface and integration standards, representation methods to enable software interoperability, data exchanges, interoperable databases; supply-chain system integration; standardized software engineering practices for model development
- **Cost and productivity issues in development of safety-critical, embedded, and autonomous systems:** Research on composition, reuse, power tools, training, and education to address systems that can be inaccessible after deployment (e.g., spacecraft) and need to operate autonomously

Highlights of Request

The SDP agencies report the following topical areas as highlights of their planned R&D investments for FY 2012. Agencies with efforts in a research topic are listed in their NITRD budget order, unless there is a lead agency (listed first) for the effort:

Software Infrastructure for Sustained Innovation (SI^2): Agency-wide program for development and integration of next-generation software infrastructure to advance scientific discovery and education at all levels in the sciences, mathematics, and engineering – NSF

Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21): Development of new algorithms, tools, and other applications to support innovation – NSF

Software and hardware foundations: Scientific and engineering principles and new logics, languages, architectures, and tools for specifying, designing, programming, analyzing, and verifying software and software-intensive systems; verification and validation (V&V) tools for sound development of reliable software, standards for certification; techniques that enable prediction of cost and schedule for large-scale software projects – NSF, AFOSR, ONR, NIST, NASA, NOAA

Computer systems research: Rethink and transform the software stack for computer systems in different application domains (e.g., new reference architectures for embedded systems); investigate systems that involve computational and human/social, and physical elements – NSF, AFOSR, ONR, NASA

Intelligent software design: Investigate approaches to design of software-intensive systems that operate in complex, real-time, distributed, and unpredictable environments; invariant refinement of software properties; automation and scaling of testing, validation, and system-level verification; automated analysis of model-based software development; transformational approaches to drastically reduce software life-cycle costs, complexity and extend life span; languages and modeling tools that support interoperability, data exchange among engineering tools, large-scale simulations, federated information systems – NSF, AFOSR, ONR, NIST, NASA, NOAA

Interoperability standards, knowledge capture processes: Representation scheme for interoperability among computer-aided engineering systems; standards for instrument, mathematical, and measurement data; ontological approaches to facilitate integrating supply-chain systems; interoperability of databases; interoperability testing tools – NIST; infrastructure for capture, reuse of domain expertise – ONR, NOAA

Planning and Coordination Supporting Request

The SDP agencies' current collaboration activities focus on domain areas in which large-scale software-intensive systems predominate – such as in aviation, air-traffic control, and global climate and weather modeling – and on building a forward-looking research agenda to improve the engineering and evolvability of such systems.

Critical Code: Software Producibility for Defense: Contributed information for National Academies study published in November 2010 – OSD and DoD Service research organizations

Software verification and validation: Ongoing collaboration to develop effective approaches for next-generation air transportation – NASA, FAA

Workshop on the Future of Software Engineering Research: November 2010 international workshop co-sponsored by SDP and ACM SIGSOFT/FSE; research needs report now under development – SDP agencies

Earth System Modeling Framework, weather research, and forecasting: Long-term multiagency efforts to build, use common software toolset, data standards; visualization for weather and climate applications – NASA, NOAA, NSF (NCAR), DOE/SC, OSD and DoD Service research organizations

Next-generation aircraft: Collaboration on concepts, modeling and simulation tools – NASA, DoD Service research organizations

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the SDP PCA:

NSF: SEES research on software advances to meet energy requirements in computation and communication; SDP-related areas in cross-cutting topics and programs (Trustworthy Computing, Social Computational Systems); software for real-world systems in health care, manufacturing, other sectors (micro- and nano-scale embedded devices, global-scale critical infrastructures, cyber-physical systems, robotics, networked and distributed systems); tools, documentation to support formal methods research; software support for human-centered computing

AFOSR: Research in new methods, tools for developing reliable, sustainable software-intensive systems for complex real-world environments with human-machine interactions; focus areas include model-based analysis, synthesis; modeling of human-machine interaction; advanced algorithms for real-time and distributed systems; language-based assurance; formal analysis and verification

ONR: Technologies for real-time control of distributed and embedded systems; methods for intelligent orchestration of Web services; language and system for building secure, federated, distributed information systems; analysis tools for modeling, testing software component interactions; software for quantum processing

NIST: Standards development and testing tools supporting interoperability such as schema validation, automated test generation (conformance testing), naming and design rules; product data models and modeling tools; methods to facilitate 3D shape search; Units Markup Language

NASA: Architecture for SensorWeb for Earth sciences; integrated vehicle health management tools and techniques to enable automated detection, diagnosis, prognosis, and mitigation of adverse events during flight; integrated aircraft control design tools and techniques; physics-based multidisciplinary analysis optimization framework (MDAO) for cost-effective advanced modeling in development of next-generation aircraft and spacecraft

NOAA: Standard and consistent software development practices for environmental modeling; continue adoption of ESMF as part of overall modeling activities; computer science aspects of software development, including collaboration with universities on programming model for GPUs

DISA: Coordination with universities and others on development of research, development, and training aspects of the DISA-developed Open Source Corporate Management Information System (OSCMIS), a Web-based suite of applications including a learning management system, a balanced scorecard system, a telework management application, emergency notification and response products, and about 50 other office productivity tools

Social, Economic, and Workforce Implications of IT and IT Workforce Development (SEW)

NITRD Agencies: NSF, NIH, DOE/SC, NIST, DOE/NNSA
Other Participants: DoD

Research activities funded under the SEW PCA focus on the co-evolution of IT and social and economic systems, including interactions among people, organizations, and cyber infrastructure. Workforce development concerns must also be addressed to meet the growing demand for workers who are highly skilled in information technology, requiring innovative IT applications in education and training. A related goal of SEW research and dissemination activities is to enable individuals and society to better understand and anticipate the uses and consequences of IT. To advance this aim, SEW actively seeks opportunities to help speed the transfer of R&D results to the policymaker, practitioner, and IT user communities in all sectors.

President's 2012 Request

Strategic Priorities Underlying This Request

Agency priorities in SEW reflect the sweeping socio-technical transformations occurring as a result of 21st century life in an increasingly networked society. From crowdsourcing to smart health to cyberlearning, new forms of social collaboration and problem-solving are taking place in networked, online environments. In cyberspace, thousands voluntarily contribute time and intellectual resources for collective tasks such as adding information to Wikipedia, classifying galaxies, and identifying words in non-machine-readable text and scripts. A new era of human-machine partnerships is emerging, but we do not yet understand how to most effectively harness these novel forms of collective intelligence. In this new era, development of cyber-capable citizens is also critical – from the ability to use digital capabilities wisely and effectively, to the IT skills and knowledge levels needed in the advanced technical workforce of tomorrow, to the understanding of trade-offs among privacy, security, reliability and other challenges in complex systems, such as health care information infrastructures, e-commerce, and cyberlearning. SEW priorities exemplify the scope of these concerns at NSF, which alone among the NITRD agencies carries out a broad mission to advance U.S. research and education at all levels across the sciences, technology, engineering, and mathematics (STEM). Many NSF activities involve extending understanding and applications of IT to help people learn, conduct research, and innovate more effectively. Key focus areas include:

IT-enabled innovation ecology: Shape the creation of and research on collaboration in ways that improve the conduct of science and engineering now and in the future and revitalize American leadership in R&D

IT education and training: Support innovative approaches to broaden interest and participation in IT careers; provide advanced training and fellowship programs to develop new generations of IT technical leaders and researchers

Human-centered computing: R&D to advance our understanding of the complex and increasingly coupled relationships between people and computing with explorations of creative ideas, novel theories, and innovative technologies that promise to transform the way humans communicate, work, learn, play, and take care of their health needs

Integrated research in climate change and energy: R&D to address challenges in climate and energy research and education using a systems-based approach to understanding, predicting, and reacting to change in the linked natural, social, and built environment

Cyber-learning: Anytime, anywhere learning; personalized learning; cyberSTEM (use of computing to transform science teaching); (cyber)learning about (cyber)learning

Computational competencies for everyone: Increase computational competencies for all students by exploring the nature and meaning of computational competence with emphasis on how it might be incorporated into K-12 education

Highlights of Request

The SEW agencies report the following topical areas as highlights of their planned R&D investments for FY 2012. Agencies with efforts in a research topic are listed in their NITRD budget order, unless there is a lead agency (listed first) for the effort:

Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21) Community Research Networks: Development of virtual organizations, collaboration tools, shared tools to create secure research environments – NSF

Virtual Organizations as Socio-technical Systems (VOSS): Advance understanding of how to develop effective virtual organizations and how they can enhance collaborative scientific, engineering, and education research production and innovation – NSF

Human-centered computing: Focus on co-evolution of social and technical systems to create new knowledge about human-machine partnerships – NSF

Social Computational Systems (SoCS): Reveal new understandings of social computing (i.e., the properties that systems of people and computers together possess) and develop a practical understanding of the purposeful design of systems to facilitate socially intelligent computing – NSF

Smart Health and Wellbeing: Facilitate long-term, transformative impact in how we treat illness and maintain our health; improve safe, effective, efficient, equitable, and patient-centered health and wellness services by leveraging the scientific methods and knowledge bases of a broad range of computing and communication research perspectives – NSF

Research Coordination Networks (RCN): Advance a field or create new directions in research or education by supporting coordination of research, training and educational activities across disciplinary, organizational, geographic, and international boundaries – NSF

Expeditions in Computing: Center-scale program for multi-year investigations addressing national challenges such as energy efficiency, environmental sustainability, advanced communication, transportation, learning, and health care systems – NSF

Science, Engineering, and Education for Sustainability (SEES): Generate the discoveries and capabilities in climate and energy science and engineering needed to inform societal actions that lead to environmental and economic sustainability; expand interdisciplinary communities focused on sustainability science topics – NSF

Cyberlearning Transforming Education (CTE): Multidisciplinary effort to fully capture the transformative potential of advanced learning technologies in education, enable new avenues of STEM learning for students and workforce members, advance the Nation's ability to study the learning process itself, and bring advances in technology to learners at all educational levels – NSF

Transforming Undergraduate Education in STEM (TUES): Improve undergraduate STEM education; create, adapt, and disseminate new learning materials and teaching strategies to reflect advances in STEM disciplines and in what is known about teaching and learning – NSF

Computing Education for the 21st Century (CE 21): Engage larger numbers of students, teachers, and educators in computing education at earlier stages in the pipeline, focusing on middle school through early undergraduate to increase interest in computing as a field and to better prepare students for careers in other computing-intensive fields – NSF

Bioinformatics fellowships and training: University-based graduate and post-doctoral programs to expand the ranks of professionals trained in both IT and applications of IT in biomedical research and health care systems – NIH (NLM)

Computational Science Graduate Fellowship Program: Graduate program to build the community of computational scientists through advanced training that includes a three-month practicum at the national laboratories – DOE/SC, DOE/NNSA

Planning and Coordination Supporting Request

In 2010, the SEW agencies established a new SEW-Education team (SEW-Ed) to pursue opportunities for expanded interagency collaborations addressing ways to improve IT education and workforce training. Preliminary steps have included outreach to non-NITRD agencies and workshop discussions on possible elements of the SEW-Education agenda. SEW also continues to support interactions between IT researchers, practitioners, and government policymakers. Forthcoming activities include:

Strategic leadership for IT education: Identify overlaps, gaps, and points of agreement across agencies on education goals, works in progress, and visions for their efforts; develop initial rough set of priorities and shared vision; request input from broader cross-section of stakeholders via social networking; and use responses to prepare a concise SEW-Ed vision document – SEW agencies and others

Leadership in collaboration and innovation: Continue to encourage/support collaboration among government implementers of IT and demonstrate promising IT capabilities emerging from Federal research (e.g., through Collaborative Expedition Workshop series co-sponsored by SEW and the FASTER Community of Practice); continue to work with IWGs/CGs to host joint workshops focusing on high-priority NITRD interests and interagency R&D topics – SEW, NITRD agencies, and others

Additional 2011 and 2012 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2011 and 2012 under the SEW PCA:

NSF: Advance new modes of collective intelligence (e.g., social, participatory, and intelligent computing) while also ensuring that human values are embedded in these emerging systems and infrastructures; support the human capital essential for advances across all disciplines by linking key areas of educational investments in HEC, data, education, software, virtual organizations, networking, and campus bridging; CI-TEAM program to prepare the next generation of scientists, engineers, and educators able to exploit and promote cyberinfrastructure in science and engineering research and education; CI TRaCS effort to support outstanding scientists and engineers who have recently completed doctoral studies and are interested in pursuing postdoctoral activities in computational science; broaden participation in computing by underrepresented minorities; faculty, graduate, and undergraduate fellowships, traineeships; digital gaming in education

NIST: Designated lead agency for the National Initiative for Cybersecurity Education (NICE) to promote coordination of existing and future activities in cybersecurity education, training, and awareness to enhance effectiveness; strengthen the overall cybersecurity posture of the United States by accelerating the availability of educational and training resources designed to improve the cyber behavior, skills, and knowledge of every segment of the population, enabling a safer cyberspace for all

DOE/NNSA: Critical-skills development program for university participants in the Advanced Simulation and Computing (ASC) Alliance

DoD: Develop world-class science, technology, engineering, and mathematics capabilities for DoD and the Nation; inventory of DoD educational programs; complete DoD-wide STEM Strategic Plan and begin implementation phase including communications, marketing of programs and opportunities

Agency NITRD Budgets by Program Component Area

FY 2010 Budget Actuals, *FY 2011 CR Levels*, and **FY 2012 Budget Requests**

(Dollars in Millions) *[Footnotes on next page]*

Agency		High End Computing Infrastructure & Applications (HEC I&A)	High End Computing Research & Development (HEC R&D)	Cyber Security & Information Assurance (CSIA)	Human-Computer Interaction & Information Management (HCI &IM)	Large Scale Networking (LSN)	High Confidence Software & Systems (HCSS)	Software Design & Productivity (SDP)	Social, Economic, & Workforce Implications of IT (SEW)	Total [1]
NSF	2010 Actual	325.2	89.1	72.7	269.8	121.0	74.3	54.4	99.2	1,105.6
	2011 CR Level [2]	*310.9*	*98.5*	*71.4*	*280.7*	*107.2*	*73.1*	*57.6*	*91.2*	*1,090.5*
	2012 Request	**308.1**	**123.8**	**94.7**	**330.0**	**132.6**	**91.8**	**78.8**	**98.0**	**1,257.7**
NIH [3]		309.0	18.0	0.1	213.0	17.0	8.0	46.0	35.0	646.1
		309.0	*18.0*	*0.1*	*213.0*	*17.0*	*8.0*	*46.0*	*35.0*	*646.1*
		316.0	**18.0**	**0.1**	**213.0**	**17.0**	**8.0**	**46.0**	**35.0**	**653.1**
OSD and DoD Service research orgs. [4]		257.6	19.4	89.5	99.5	105.8	34.3	19.6		625.8
		251.2	*21.3*	*85.6*	*93.8*	*110.3*	*24.3*	*19.4*		*605.8*
		189.9	**9.4**	**72.3**	**103.4**	**95.4**	**23.8**	**17.7**		**511.8**
DOE [5]		276.7	87.8	3.5		44.4			6.0	418.4
		282.5	*81.6*	*33.5*		*53.6*			*6.0*	*457.2*
		332.6	**98.2**	**33.5**		**59.6**			**6.0**	**529.9**
DARPA			116.0	144.7	173.9	96.3				531.0
			121.2	*119.1*	*150.8*	*75.1*	*5.0*			*471.3*
			56.9	**222.4**	**136.7**	**54.2**	**10.0**			**480.2**
NIST		17.0	3.6	29.6	14.1	6.2	4.7	5.5	0.3	81.0
		17.0	*3.6*	*29.6*	*14.1*	*6.2*	*4.7*	*5.5*	*0.3*	*81.0*
		17.0	**4.4**	**54.7**	**18.8**	**14.2**	**10.4**	**10.1**	**4.3**	**133.9**
NASA		59.4	0.8		16.0	0.8	5.8	2.5		85.3
		61.4	*0.5*		*12.5*	*0.8*	*4.8*	*2.4*		*82.3*
		62.2	**0.5**		**10.0**	**0.8**	**13.2**	**8.0**		**94.7**
NSA			118.4	29.0		2.8	5.6			155.8
			31.0	*30.0*		*3.5*	*7.6*			*72.1*
			19.5	**29.2**		**4.2**	**6.8**			**59.7**
DHS				38.0	3.9	8.0				49.9
				37.0	*4.2*	*9.0*				*50.2*
				41.0	**5.4**	**10.0**		**0.7**		**57.1**
AHRQ					27.1	0.5				27.6
					27.1	*0.5*				*27.6*
					27.1	**0.5**				**27.6**
NOAA		23.4	0.2		0.5	1.5		0.7		26.3
		20.9	*0.2*		*0.5*	*4.0*		*0.7*		*26.3*
		20.9	**0.2**		**0.5**	**4.0**		**0.7**		**26.3**
DOE/NNSA		8.9	16.1			0.9			3.7	29.6
		10.3	*14.7*			*1.2*			*4.1*	*30.3*
		9.5	**11.5**			**0.9**			**4.0**	**25.9**
EPA		3.3			3.0					6.3
		3.3			*3.0*					*6.3*
		2.9			**3.0**					**5.9**
NARA					4.5					4.5
					4.5					4.5
					2.5					**2.5**
TOTAL (2010 Actual) [1]		1,280.5	469.4	407.1	825.4	405.2	132.7	128.7	144.2	3,793
TOTAL (2011 CR Level) [1]		***1,266.4***	***390.6***	***406.3***	***804.2***	***388.3***	***127.5***	***131.6***	***136.6***	***3,652***
TOTAL (2012 Request) [1]		**1,259.1**	**342.3**	**547.9**	**850.4**	**393.4**	**163.9**	**161.9**	**147.3**	**3,866**

NITRD Budget Table Footnotes

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[1] Totals may not sum correctly due to rounding.

[2] The 2011 levels reflect the annualized amounts provided by the continuing resolution that extends through March 4, 2011.

[3] The estimated expenditures reported by NIH in the NITRD Budget Supplement have varied substantially in recent years, rising by $425 million in FY2009 and falling by $555 million (estimated to actual) in FY 2010. These changes reflect the results of a new way used by NIH to calculate its annual expenditures by NITRD categories, and do not indicate any deliberate change in NIH research emphasis or interest in its NITRD programs. In particular, the increase reported in FY 2009 expenditures resulted from the adoption by NIH of a new Research, Condition, and Disease Categorization (RCDC) system, which uses an automated text data mining system to assign research project descriptions to reporting categories based on a list of terms and concepts selected by NIH scientific experts to define each category. Based on recognized issues in the initial RCDC results, NIH has implemented an ongoing process of reviewing and refining the RCDC terms and categories to improve accuracy. The decrease reported for FY 2010 actual vs. estimated expenditures reflects the results of such refinements in the RCDC and includes, for example, the reassignment of nearly $250 million for the National Library of Medicine's biomedical information services, which earlier had been miscategorized as a NITRD expenditure.

[4] The budget for OSD and the DoD service research organizations includes the High Performance Computing Modernization Program.

[5] The DOE budget includes funding from DOE's Office of Electricity Delivery and Energy Efficiency.

NITRD Program Budget Analysis

Fiscal Year Overview for 2010-2012

In the following analysis, the President's FY 2012 Budget request for the NITRD Program is compared with FY 2010 actual NITRD spending, since FY 2011 spending levels remain uncertain. Changes in NITRD Program budgets reported in the budget analysis reflect revisions to program budgets due to evolving priorities; the agencies' ongoing collaborative efforts to improve the PCA definitions, as outlined in OMB Circular A-11; and individual agencies' efforts to improve the classification of their NITRD investments across the PCAs.

The 2011 levels reported in the budget table on page 28 reflect the annualized amounts provided by the Continuing Resolution that currently is scheduled to extend through March 4, 2011.

2010 Summary

Actual NITRD spending in 2010 totaled $3.793 billion, $0.133 billion below the 2010 budget request of $3.926 billion.

2012 Summary

The President's 2012 budget request for the NITRD Program is $3.866 billion, an increase of $0.073 billion, approximately 1.92 percent, above 2010 actual expenditures. The overall change is due to both decreases and increases in individual agency NITRD budgets, which are described below.

NITRD Program Budget Analysis by Agency

This section describes changes greater than $10 million between 2010 actual spending and 2012 requests. Smaller changes are discussed only if they represent shifts in funding focus. Budget numbers in these descriptions are rounded from initial agency numbers with three decimals to the nearest whole number.

NSF

Comparison of 2010 actual ($1,106 million) and 2012 request ($1,258 million): The $152 million increase includes $35 million in HEC R&D for additional support for nanotechnology research and the SEES effort, and investment in CIF21; $22 million in CSIA for development of a science of cybersecurity, R&D in the new CSIA research themes, and early deployment and testing of cybersecurity prototypes and experimental approaches; $60 million in HCI&IM, primarily to support the new National Robotics Initiative (NRI), but also for CIF21 and the agency's Smart Health and Wellbeing effort; $12 million in LSN for basic research in radio spectrum technologies and networking aspects of CIF21; $18 million in HCSS for the NRI and research in cyber-physical systems in such areas as advanced manufacturing, smart infrastructures, and health care; and $24 million in SDP for new software centers, CIF21, and increased SEES investment. The decrease of $17 million in HEC I&A reflects a reduction in Track 1 and Track 2 high-performance computing activities, partially offset by support for CIF21 and increased investments in innovative partnerships and collaborations between universities and industries, including the Industry/University Cooperative Research program.

OSD and DoD Service Research Organizations

Comparison of 2010 actual ($626 million) and 2012 request ($512 million): The $114 million decrease is primarily due to decreases of $68 million in HEC I&A, $10 million in HEC R&D, $18 million in CSIA, $11 million in LSN, and $10 million in HCSS. This budget reduction will be used to meet the DoD Efficiency Initiatives.

DOE

Comparison of 2010 actual ($418 million) and 2012 request ($530 million): The $112 million increase results from increases of $56 million in HEC I&A for research and new co-design partnerships to address the challenges of emerging disruptive computing technologies from the private sector; $10 million in HEC R&D for research and new partnerships with industry to address the challenges of emerging disruptive computing technologies from the private sector, with a goal to bring exascale science capabilities within reach in terms of cost, feasibility, and energy utilization, $30 million in CSIA for advanced critical-infrastructure security research, and $16 million in LSN for installation and operation of an ESnet dedicated optical network to meet the growing requirements for DOE applications and facilities.

DARPA

Comparison of 2010 actual ($531 million) and 2012 request ($480 million): The $51 million decrease is due to decreases of $59 million in HEC R&D, reflecting the transition of high-productivity computing and architecture research efforts, while research in novel design flow, tools, and processes grows; $37 million in HCI&IM, reflecting a reduction in robotics and cognitive computing efforts as these technologies mature and machine reading, learning, and reasoning expand; and $42 million in LSN, resulting from the transition of research in cognitive networking and core optical network and RF communication. The overall decrease is partially offset by an increase of $77 million in CSIA, reflecting expanded efforts in information assurance, survivability, clean-state design of secure systems, and insider-threat research, and an investment of $10 million in HCSS.

NIST

Comparison of 2010 actual ($81 million) and 2012 request ($134 million): The $53 million increase is primarily due to an increase of $25 million in CSIA to support new cybersecurity initiatives and smaller increases in other PCAs for interoperability in emerging technologies activities.

NSA

Comparison of 2010 actual ($156 million) and 2012 request ($60 million): The $96 million decrease results from a decrease of $98 million in HEC R&D, largely due to non-sustainment of 2010 Congressional add-ons and the completion of the DARPA HPCS program, offset by small increases in other PCAs.

NITRD Program Budget Analysis by PCA

Using the information presented above, this section provides an analysis of the NITRD Program budget by PCA, summarizing the more substantial differences between 2010 actual spending and 2012 requests. The changes are described below.

HEC I&A

Comparison of 2010 actual ($1,281 million) and 2012 request ($1,259 million): The $22 million decrease is largely due to decreases of $17 million at NSF and $68 million at OSD and Service research organizations, partially offset by an increase of $56 million at DOE and smaller increases at other agencies.

HEC R&D

Comparison of 2010 actual ($469 million) and 2012 request ($342 million): The $127 million decrease is largely due to decreases of $10 million at OSD and Service research organizations, $59 million at DARPA, and $98 million at NSA, partially offset by increases of $35 million at NSF and $10 million at DOE, with smaller increases and decreases at other agencies.

CSIA

Comparison of 2010 actual ($407 million) and 2012 request ($548 million): The $141 million increase is largely due to increases of $22 million at NSF, $30 million at DOE, $77 million at DARPA, and $25 million at NIST, partially offset by a decrease of $18 million at OSD and Service research organizations.

HCI&IM

Comparison of 2010 actual ($825 million) and 2012 request ($850 million): The $25 million increase is largely due to an increase of $60 million at NSF, partially offset by a decrease of $37 million at DARPA.

LSN

Comparison of 2010 actual ($405 million) and 2012 request ($393 million): The $12 million decrease is largely due to decreases of $11 million at OSD and Service research organizations and $42 million at DARPA, partially offset by increases of $12 million at NSF and $16 million at DOE.

HCSS

Comparison of 2010 actual ($133 million) and 2012 request ($164 million): The $31 million increase is largely due to increases of $18 million at NSF, $10 million at DARPA, and smaller increases at other agencies, partially offset by a $10 million decrease at OSD and Service research organizations.

SDP

Comparison of 2010 actual ($129 million) and 2012 request ($162 million): The $33 million increase is largely due to an increase of $24 million at NSF and small increases at other agencies.

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Participation in the NITRD Program

The following goals and criteria developed by the NITRD Program are intended to enable agencies considering participation to assess whether their research and development activities fit the NITRD framework.

NITRD Goals

- Provide research and development foundations for assuring continued U.S. technological leadership in advanced networking, computing systems, software, and associated information technologies
- Provide research and development foundations for meeting the needs of the Federal government for advanced networking, computing systems, software, and associated information technologies
- Accelerate development and deployment of these technologies in order to maintain world leadership in science and engineering; enhance national defense and national and homeland security; improve U.S. productivity and competitiveness and promote long-term economic growth; improve the health of the U.S. citizenry; protect the environment; improve education, training, and lifelong learning; and improve the quality of life.

Evaluation Criteria for Participation

Relevance of Contribution
The research must significantly contribute to the overall goals of the NITRD Program and to the goals of one or more of the Program's eight Program Component Areas (PCAs) – High End Computing Infrastructure and Applications (HEC I&A), High End Computing Research and Development (HEC R&D), Cyber Security and Information Assurance (CSIA), Human-Computer Interaction and Information Management (HCI&IM), Large Scale Networking (LSN), High Confidence Software and Systems (HCSS), Software Design and Productivity (SDP), and Social, Economic, and Workforce Implications of Information Technology (IT) and IT Workforce Development (SEW) – in order to enable the solution of applications and problems that address agency mission needs and that place significant demands on the technologies being developed by the Program.

Technical/Scientific Merit
The proposed agency program must be technically and/or scientifically sound, of high quality, and the product of a documented technical and/or scientific planning and review process.

Readiness
A clear agency planning process must be evident, and the organization must have demonstrated capability to carry out the program.

Timeliness
The proposed work must be technically and/or scientifically timely for one or more of the PCAs.

Linkages
The responsible organization must have established policies, programs, and activities promoting effective technical and scientific connections among government, industry, and academic sectors.

Costs
The identified resources must be adequate to conduct the proposed work, promote prospects for coordinated or joint funding, and address long-term resource implications.

Agency Approval
The proposed program or activity must have policy-level approval by the submitting agency.

Glossary

ACCURATE - NSF-funded A Center for Correct, Usable, Reliable, Auditable, and Transparent Elections
ACM SIGSOFT/FSE - Association of Computing Machinery's Special Interest Group on Software Engineering/ Foundations of Software Engineering conference
AFOSR - Air Force Office of Scientific Research
AFRL - Air Force Research Laboratory
AHRQ - HHS's Agency for Healthcare Research and Quality
ANL - DOE's Argonne National Laboratory
APM - Annual Planning Meeting
APP - IARPA's Automatic Privacy Protection effort
ARPA-E - DOE's Advanced Research Projects Agency-Energy
ARL - Army Research Laboratory
ARO - Army Research Office
ARSC - Arctic Region Supercomputing Center
ASC - DOE/NNSA's Advanced Simulation and Computing program
BIRN - NIH's Biomedical Informatics Research Network
BISTI - NIH's Biomedical Information Science and Technology Initiative
BlueGene - A vendor supercomputing project dedicated to building a new family of supercomputers
BlueGene-Q - Latest-generation BlueGene architecture
C3I - Communications, Command, Control, and Intelligence
CaBIG - NIH's cancer Biomedical Informatics Grid
CAIDA - Cooperative Association for Internet Data Analysis
CAREER - NSF's early-career development grants program
CDIGS - NSF grant program for Community Development and Improvement of Globus Software
CE 21 - NSF's Computing Education for the 21st Century program
CEDPS - DOE/SC's Center for Enabling Distributed Petascale Science
CENIC - Corporation for Network Initiatives in California
CERDEC - U.S. Army's Communications-Electronics Research, Development, and Engineering Center
CG - Coordinating Group
CIF21 - NSF's Cyberinfrastructure Framework for the 21st Century program
CISE - NSF's Computer and Information Science and Engineering directorate
CIT - NIH's Center for Information Technology
CI-TEAM - NSF's Cyber Infrastructure Training, Education, Advancement, and Mentoring for our 21st Century Workforce activity
CI-TraCS - NSF's Fellowships for Transformative Computational Science using CyberInfrastructure activity
CMS - HHS's Centers for Medicare and Medicaid Services
COMPETES - Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science
COTs - Commercial off the shelf technologies
CPS - Cyber-physical system(s)
CREATE - OSD's Computational Research and Engineering Acquisition Tools and Environments program
CREATE-AV - OSD's Computational Research and Engineering Acquisition Tools and Environments program for Air Vehicles
CTE - NSF's Cyberlearning Transforming Education program
CSIA - Cyber Security and Information Assurance, one of NITRD's eight Program Component Areas
CVRG - NIH's CardioVascular Research Grid
CyberSTEM - Use of computing to transform science teaching
DARPA - Defense Advanced Research Projects Agency
DDoS - Distributed denial of service
DETER - NSF- and DHS-initiated cyber DEfense Technology Experimental Research network
DFDL - Data Format Description Language
DHS - Department of Homeland Security
DIMRC - NIH's Disaster Information Management Research Center
DISA - Defense Information Systems Agency
DNSSEC- Domain Name System Security protocol
DoD - Department of Defense
DOE - Department of Energy
DOE/NNSA - DOE/National Nuclear Security Administration
DOE (OE) - DOE's Office of Electricity Delivery and Energy Reliability
DOE/SC - DOE's Office of Science
DOJ - Department of Justice
DPIF - Digital Preservation Interoperability Framework International Standard
DREN - DoD's Defense Research and Engineering Network
DSWAP - DHS Secure Wireless Access Pilot
EDUCAUSE - Nonprofit organization promoting advancement of IT in higher education
ENG - NSF's Engineering directorate
EPA - Environmental Protection Agency
ESMF - Earth System Modeling Framework
ESSC - DOE/SC's Energy Sciences network (ESnet) Steering Committee
FAA - Federal Aviation Administration
FASTER - NITRD's Faster Administration of Science and Technology Education and Research community of practice
FAST-OS - Forum to Address Scalable Technology for runtime and Operating Systems
FBI - Federal Bureau of Investigation
FCSSI - Flight Critical Systems Software Initiative
FDA - Food and Drug Administration
FHWA - Federal Highway Administration
FISMA - Federal Information Security Management Act
FIU - Florida International University
FY - Fiscal Year
G - Gigabit
GENI - NSF's Global Environment for Networking Innovations program
GEOSS - Global Earth Observation System of Systems, a cooperative effort of 34 nations, including the U.S., and 25 international organizations to develop a comprehensive, coordinated, and sustained Earth observation system
GIS - Geographic Information System
GPU - Graphics Processing Unit
GSA - General Services Administration
HCI&IM - Human-Computer Interaction and Information Management, one of NITRD's eight Program Component Areas
HCSS - High Confidence Software and Systems, one of NITRD's eight Program Component Areas
HEC - High-end computing
HEC I&A - HEC Infrastructure and Applications, one of NITRD's eight Program Component Areas
HEC R&D - HEC Research and Development, one of NITRD's eight Program Component Areas
HEC-URA - HEC University Research Activity, jointly funded by multiple NITRD agencies
HHS - Department of Health and Human Services
HHS/CMS - Department of Health and Human Services/Centers for Medicare & Medicaid Services

HHS/ONC - Department of Health and Human Services/Office of the National Coordinator for Health Information Technology
HOST - Homeland Open Security Technology
HPC - High-performance computing
HPCMP - OSD's High Performance Computing Modernization Program
HRD - NOAA's Hurricane Research Division
I/O - Input/output
IARPA - Intelligence Advanced Research Projects Activity
IATS - FHWA'S Integrated Active Transportation System
ICS - Industrial control systems
IESP - International Exascale Software Program
IETF - Internet Engineering Task Force
IMAG - Interagency Modeling and Analysis Group
INCITE - DOE/SC's Innovative and Novel Computational Impact on Theory and Experiment program
InfiniBand - A switched fabric communications link used in high-performance computing and enterprise data centers
INFOSEC - Information security
Internet2 - Higher-education consortium for advanced networking and applications deployment in academic institutions
IPsec - IP security protocol
IPv6 - Internet Protocol, version 6
IRNC - NSF's International Research Network Connections Program
ISAP - Multiagency Information Security Automation Program
ISI - Information Sciences Institute
IT - Information technology
IU - Indiana University
IWG - Interagency Working Group
JASONs - Independent scientific advisory group that provides consulting services to the U.S. government on matters of defense science and technology
JET - LSN's Joint Engineering Team
JETnets - Federal research networks supporting networking researchers and advanced applications development
K-12 - Kindergarten through 12^{th} grade
LANL - DOE's Los Alamos National Laboratory
LBNL - DOE's Lawrence-Berkeley National Laboratory
LCF - DOE's Leadership Computing Facility
LLNL - DOE's Lawrence-Livermore National Laboratory
LSN - Large Scale Networking, one of NITRD's eight Program Component Areas
MAGIC - LSN's Middleware and Grid Infrastructure Coordination team
MANET - Mobile ad hoc network
MAX - Mid-Atlantic eXchange
MCNC - Microelectronics Center of North Carolina
MDAO - multidisciplinary analysis optimization
MIDAS - NIH's Modeling of Infectious Disease Agents Study
NARA - National Archives and Records Administration
NASA - National Aeronautics and Space Administration
NCAR - NSF-supported National Center for Atmospheric Research
NCBC - NIH's National Centers for Biomedical Computing
NCO - National Coordination Office for NITRD
NCR - DARPA's National Cyber Range program
Nebula - NASA's experimental cloud computing project
NERSC - DOE/SC's National Energy Research Scientific Computing Center
NextGen - Next Generation Air Transportation System
NIH - National Institutes of Health
NIJ - DOJ's National Institute for Justice
NIST - National Institute of Standards and Technology
NITRD - Networking and Information Technology Research and Development
NLANR - NSF-supported National Laboratory for Applied Network Research
NLM - NIH's National Library of Medicine
NOAA - National Oceanic and Atmospheric Administration
NRC - Nuclear Regulatory Commission
NRL - Naval Research Laboratory
NSA - National Security Agency
NSF - National Science Foundation
NSTC - National Science and Technology Council
NTIA - National Telecommunications and Information Administration
NTSB - National Transportation Safety Board
N-Wave - NOAA's high speed network
OMB - White House Office of Management and Budget
ONC - HHS's Office of the National Coordinator for Health IT
ONR - Office of Naval Research
ORCA - Online Representations and Certifications Application
ORNL - DOE's Oak Ridge National Laboratory
OS - Operating system
OSCARS - DOE/SC ESnet's On-Demand Secure Circuits and Advance Reservation System
OSD - Office of the Secretary of Defense
OSD (HPCMP) - OSD's High Performance Computing Modernization Program
OSG - Open Science Grid
OSCMIS - DISA's Open Source Corporate Management Information System
OSTP - White House Office of Science and Technology Policy
P41 - NIH computational centers
PCA - Program Component Area
PCAST - President's Council of Advisors on Science and Technology
perfSONAR - performance Services-Oriented Network ARchitecture
PF - Petaflop(s), a thousand teraflops
PI - Principal investigator
PNNL - DOE's Pacific Northwest National Laboratory
PREDICT - DHS's Protected Repository for the Defense of Infrastructure Against Cyber Threats
PSC - NSF-supported Pittsburgh Supercomputing Center
QDR - OSD**'s** Quadrennial Defense Review
R&D - Research and development
R&E - Research and evaluation
RCN - NSF's Research Coordination Networks program
RDT&E - DoD's Research Development Test &Evaluation programs
RFP - Request for proposal
S&T - Science and technology
SATE - NIST's Software Analysis Tool Exposition
SBIR - Small Business Innovation Research, a Federal grant program
SCADA - Supervisory control and data acquisition
SCAP - Security Content Automation Protocol
SciDAC - DOE/SC's Scientific Discovery through Advanced Computing program
SDP - Software Design and Productivity, one of NITRD's eight Program Component Areas
SEBML - NSF's Science, and Engineering Beyond Moore's Law program
SEES - NSF's Science, Engineering, and Education for Sustainability program
SensorWeb - NASA infrastructure of linked ground and space-based instruments to enable autonomous collaborative observation
SEW - Social, Economic, and Workforce Implications of IT and IT Workforce Development, one of NITRD's eight Program Component Areas
SEW-Ed - SEW's Education team
SI2 - NSF's Software Infrastructure for Sustained Innovation
SNL - Sandia National Laboratories

SoCS - NSF's Social Computational Systems program
SoS - System-of-systems
SP/IA - DoD's Software Protection/Information Assurance effort
SPRI - DHS's Secure Protocols for the Routing Infrastructure activity
SSG - Senior Steering Group
StarLight - NSF-supported international optical network peering point in Chicago
State - Department of State
STEM - Science, technology, engineering, and mathematics
STONESOUP - IARPA's Security Taking on New Executable Software of Uncertain Provenance activity
TCIPG - DHS- and DOE-supported Trustworthy Cyber Infrastructure Protection for the Power Grid program, with initial funding also from NSF
TeraGrid - NSF terascale computing grid, now succeeded by eXtreme Digital (XD) program
TIC - Trusted Internet Connection
Treasury - Department of the Treasury
TUES - NSF's Transforming Undergraduate Education in STEM program
TwC - NSF's Trustworthy Computing program
UAV - Unmanned aerial vehicle
UCAR - University Corporation for Atmospheric Research
UIC - University of Illinois at Chicago
UIUC - University of Illinois at Urbana-Champaign
UMd - University of Maryland
UNC - University of North Carolina
USAF - United States Air Force
USDA - U.S. Department of Agriculture
USGS - U.S. Geological Survey
UU - University of Utah
UW - University of Washington
UWisc - University of Wisconsin
VA - U.S. Veterans Administration
V&V - Verification and validation
VOSS - NSF's Virtual Organizations as Sociotechnical Systems program
VPN - Virtual private network
VSTTE - Verified software, theories, tools, and experiments
WAIL - NSF's Wisconsin Advanced Internet Laboratory
WAN - Wide area network
XD - NSF's eXtreme Digital program

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