THE NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAM

Supplement to the President's Budget

FY 2013

FEBRUARY 2012

National Coordination Office (NCO) for Networking and Information Technology Research and Development (NITRD)

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National Coordination Office for Networking and Information Technology Research and Development

The annual NITRD Supplement to the President's Budget is prepared and published by the National Coordination Office for Networking and Information Technology Research and Development (NCO/NITRD). The NCO/NITRD supports overall planning, budget, and assessment activities for the multiagency NITRD enterprise under the auspices of the NITRD Subcommittee of the National Science and Technology Council's (NSTC) Committee on Technology.

About the Document

This document is a supplement to the President's 2013 Budget Request. It describes the activities underway in 2012 and planned for 2013 by the Federal agencies participating in the NITRD Program, primarily from a programmatic and budgetary perspective. It reports actual investments for 2011, estimated investments for 2012 and requested investments for 2013 by Program Component Area (PCA). It identifies the NITRD Program's strategic priorities by PCA for budgetary requests; strategic priorities underlying the requests; highlights of the requests; planning and coordination activities supporting the request; and 2012 and 2013 activities by agency.

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Supplement to the President's Budget
for Fiscal Year 2013

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 2012

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EXECUTIVE OFFICE OF THE PRESIDENT
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WASHINGTON, D.C. 20502

February 15, 2012

Members of Congress:

I am pleased to transmit with this letter the FY 2013 annual report of the Federal government's multiagency Networking and Information Technology Research and Development (NITRD) Program. The NITRD effort, which today comprises 15 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 as well as business, government, and education. 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 scientific discovery, education, and national security. As the President has made clear, such networking and computing capabilities will also provide critical foundations for a number of specific policy priorities, including 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 today will be crucial to the creation of tomorrow's new industries and workforce opportunities. I look forward to continuing to work with you to support this vital Federal program.

Sincerely,

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

TABLE OF CONTENTS

1 Overview

The Networking and Information Technology Research and Development (NITRD) Program consists of a group of Federal agencies working together to research and develop a broad spectrum of advanced information technology (IT) capabilities to empower Federal missions; support U.S. science, engineering, and technology leadership; and bolster U.S. economic competiveness. The interagency program focuses on identifying research that will help the United States to "out-innovate, out-educate, and out-build the rest of the world."[1] NITRD Program activities are reported under a set of eight Program Component Areas (PCAs), four Senior Steering Groups (SSGs), and a Community of Practice (CoP). The NITRD Subcommittee convenes three times a year and the working groups meet approximately 12 times annually and provide input to the NITRD Supplement to the President's Budget.

1.1 NITRD Program Component Areas (PCAs)

The following is an overview of the eight NITRD PCAs strategic priorities. These PCAs cover the range of Federal networking and information technology R&D. Thus, NITRD working groups are organized around these PCAs, and NITRD investments by agencies are reported by PCA in NITRD Budget Supplements.

1.1.1 Cybersecurity and Information Assurance (CSIA)

CSIA priorities are organized into four thrusts according to the 2011 Federal Cybersecurity R&D Strategic Plan,[2] "Inducing Change, Developing Scientific Foundations, Maximizing Research Impact, and Accelerating Transition to Practice." These thrusts provide a framework for prioritizing cybersecurity research and development that focuses on limiting current cyberspace deficiencies, precluding future problems, and expediting the infusion of research accomplishments into the marketplace. The principal objectives include achieving greater cyberspace resiliency to attacks, and enhancing our capabilities to design software that is resistant to attacks.

- **Inducing Change:** Utilize game-changing themes to analyze the underlying root causes of known current threats to disrupt the status quo with radically different approaches that improve the security of the critical cyber systems and infrastructure that serve society.
- **Developing Scientific Foundations:** Develop an organized, cohesive scientific foundation to serve as the cornerstone for cybersecurity by establishing a systematic, rigorous, and disciplined scientific approach that will promote the discovery of laws, hypothesis testing, repeatable experimental designs, standardized data-gathering methods, metrics, common terminology, and critical analysis that engenders reproducible results and rationally based conclusions.
- **Maximizing Research Impact:** Catalyze integration across the game-changing research and development themes, cooperation between governmental and private-sector communities, collaboration across international borders, and strengthened linkages to other national priorities, such as health IT and Smart Grid.

[1] "A Strategy for American Innovation: Securing Our Economic Growth and Prosperity," President Barack Obama, February 4, 2011 (http://www.whitehouse.gov/innovation/strategy)
[2] Released December 2011 (http://www.whitehouse.gov/sites/default/files/microsites/ostp/fed_cybersecurity_rd_strategic_plan_2011.pdf)

- **Accelerating Transition to Practice:** Implement powerful new technologies and strategies that emerge from the research themes and from the activities to build a scientific foundation so as to create measurable improvements in the cybersecurity landscape.

1.1.2 High-Confidence Software and Systems (HCSS)

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 interested in the Cyber-Physical Systems (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 (CPS):** 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
- **Management of complex and autonomous systems:** Develop measurement and understanding for improved models of complex systems of systems, shared control and authority, levels of autonomy, and human-system interactions, and new integrated analytical, and decision-support tools
- **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" verification and validation [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
- **Translation into mission-oriented research:** Leverage multi-agency research to move theory into practice, for example, through challenge problems
- **CPS education:** Launch an initiative to integrate CPS theory and methodology into education and promote increased understanding of and interest in CPS through the development of new curricula at all levels to break down the silos between physical and cyber disciplines and evolve a new generation of U.S. experts

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

High-fidelity modeling and simulation and large-scale data analysis, enabled by HEC, have become essential and powerful tools for advancing science, technology, and other National priorities and Federal agency missions. The HEC infrastructure enable researchers in academia, Federal laboratories, and industry to model and simulate complex processes in aerospace, astronomy, biology, biomedical science, chemistry, climate and weather, energy and environmental sciences, high energy physics, materials science, nanoscale science and technology, national security, and other areas to address Federal agency mission needs. Priorities include:

- **Advancement of HEC applications:** Support the development of scientific and engineering applications software for current and next-generation HEC platforms; develop mission-responsive computational environments; and lead critical applied mathematics research
- **Leading-edge cyber infrastructure:** Provide efficient access to HEC facilities and resources, enhance infrastructure for computational and data-enabled science, and share best practices for cost-effectively and energy efficiently managing and enhancing HEC resources
- **Leadership-class and production quality HEC systems:** Acquire and operate the highest capability and capacity HEC systems to meet critical agency needs and to support the national science and engineering communities

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

After decades of exponential increase in computing power per dollar, the HEC community faces great challenges in creating the hardware, software, and systems to achieve and exploit the next few orders of magnitude increase in HEC capability expected by 2020. These challenges include developing applications and system architectures that effectively utilize billion-fold concurrency, reducing the energy per computation by orders of magnitude, achieving system resilience at extreme scales, and enabling future revolutions in simulation and big-data-enabled science and technology. To remain leaders in their mission areas, and to maintain U.S. leadership in HEC technology, Federal agencies will lead the R&D to overcome these challenges. In view of these challenges, the HEC R&D agencies see the following as research priorities for FY 2013:

- **Extreme-scale computation:** Integrate computer science and applied mathematical foundations to address the challenges of achieving productive and efficient computation at the exascale level and beyond. Develop innovative systems that combine increased speed, economic viability, high productivity, and robustness to meet future agency needs for systems that manage ultra-large volumes of data and run multi-scale, multidisciplinary science and engineering simulations. Explore new concepts and approaches for solving technical challenges such as power use, thermal management, file system input/output (I/O) latency, resiliency, highly parallel system architectures, and programming language and development environments that can increase the usability of large-scale multiprocessor (including hybrid) systems. Develop, test, and evaluate prototype HEC systems and software to reduce industry and end-user risk and to increase competitiveness.
- **New directions in HEC hardware, software and system architectures:** Develop novel scientific frameworks, system architectures, and prototypes to take computing power and communications "beyond Moore's Law;" advance quantum computing.
- **Productivity:** Continue collaborative development of new metrics of system performance, including benchmarking, lessons learned for acquisition, and total ownership costs of HEC systems; integrate resources for improved productivity. Design and develop requirements for software to enable, support, and increase the productivity of geographically dispersed collaborative teams that develop future HEC applications.

1.1.5 Human-Computer Interaction and Information Management (HCI&IM)

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. Making R&D that is enabled by large data sets a science and technology priority will contribute to U.S. economic growth and technological innovation. New research and advances are needed in:

- **Information integration:**
  - **Standards** provide a way for data to be brought together with shared meaning, providing the basis for interoperability and relationship building which is a basic step of integrating and managing data.

- **Decision-support systems** provide mechanisms for sifting through large, complex data sets to identify alternative strategies from the data that, without computational analysis, would strain human cognitive capabilities.
- **Information management systems** enable individuals and organizations to create, share, and apply information to gain value and achieve specific objectives and priorities.

- **Information infrastructure:** A robust, resilient national digital data framework for long-term preservation and accessibility of electronic records as well as expanding data and records collections
- **Active systems:** This research will provide novel insights into how IT systems can learn, reason, and automatically adapt to new and unforeseen events. Examples include cognitive robotics, in which a mobile manipulator could deploy a specific model of the user's mind to increase the effectiveness of interactions.
- **Multimodal systems:** These systems provide ways for human users to expand their cognitive reach and performance when faced with large, complex data. These can be activated by speech, or other human senses, or movement, sounds, etc. These mechanisms provide different interactions that reflect user requirements.

1.1.6 Large-Scale Networking (LSN)

LSN Federal agencies coordinate networking R&D in future Internet architectures, optical and wired networks, enabling end-to-end applications, network management, R&D for complex networks, identity management, cloud computing, and wireless technology.

- **Measurement, management, and control of large-scale distributed infrastructures:** Including networks, applications, management/control, sensors and their placement, metrics (supported by measurement technologies), and complex systems modeling and analysis in this endeavor.
- **Operational capabilities:** Identify approaches and promote implementation of best practices for identity management, Internet Protocol version 6 (IPv6), cloud computing, and campus interfaces and architectures for large data flows. Promote cooperation among network testbeds including Global Environment for Networking Innovations (GENI) Advanced Networking Initiatives (ANI), Magellan Phase 2 and others
- **Dynamic optical networking:** Identify, in coordination with the research community, the status, technology, research needs, and best practices. Identify next steps for development, and deployment.

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

Research activities funded under the SEW PCA focus on the co-evolution of IT and social, economic, and workforce systems including interactions between people and IT and among people developing and using IT in groups, organizations, and larger social networks. Key focus areas include:

- **Science of collaboration**
  - **IT-enabled innovation ecology:** Shape the creation of IT and research on IT-enabled collaboration in ways that improve the conduct of science and engineering now and in the future and revitalize American leadership in R&D
  - **Integrated multidisciplinary research:** Support research, development, and education that address societal challenges using a systems-based approach to understand, predict, and react to changes in the linked natural, social, and man-made environment – especially in climate change, energy, health, education, and security
  - **Humans in the loop:** Advance understanding of complex and increasingly coupled relationships between people and computing, with an emphasis on IT designed to fit the needs of its users,

and enable explorations of creative ideas, novel theories, and innovative technologies that promise to transform the way humans communicate, work, learn, play, and maintain their health

- **IT and education**
  - **Cyber-learning:** Promote understanding and support for effective IT-enabled learning in all education settings to enhance learning anytime in any location, and provide learning personalized and tailored to the needs of diverse learners; transform science teaching across education and settings
  - **Computational competencies for everyone:** Explore how the nature and meaning of computational competence can be incorporated into K-12, informal, and higher education
  - **IT education and training:** Develop innovative approaches to broadening interest and participation in 21st Century IT careers, including information assurance and computer security

1.1.8 Software Design and Productivity (SDP)

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.). These large-scale systems typically must remain operational, useful, and relevant for decades. The involved agencies are working to identify and define the core elements for a new science of software development that will make engineering decisions and modifications transparent and traceable throughout the software lifecycle (e.g., design, development, evolution, and sustainment). A key goal of this science framework is to enable software engineers to maintain and evolve complex systems cost-effectively and correctly 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:** Develop new computational models and logics, techniques, languages, tools, metrics, and processes for developing and analyzing software for complex software-intensive systems (e.g., a fundamental approach to software engineering that can provide systems that are verifiably correct, assured, efficient, effective, reliable, and sustainable)
  - **Next-generation software concepts, methods, and tools:** Reformulate 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; next-generation software concepts, methods, and tools will be needed for 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:** Explore new means to create, keep current, and use 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 deterministic engineering tasks; scalable analysis, test generation, optimization, and verification with traceability to requirements; related issues:

- **Software application interoperability and usability:** Develop 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

1.2 Senior Steering Groups (SSGs)

The following is an overview of NITRD's established Senior Steering Groups (SSGs). The SSGs are formed to focus on emerging issues and are not required to report budgetary information to the NITRD program. They offer an additional means for agency collaboration for individuals, who because of their level of authority, who typically do not participate in the PCAs.

1.2.1 Big Data Research and Development Senior Steering Group (BD R&D SSG)

The BD R&D SSG was formed in early 2011 to identify current big data research and development activities across the Federal government, offer opportunities for coordination, and identify the goals of a potential national initiative in this area. The BD R&D SSG strategic priorities include the following:

- Promote new science, address key science questions, and accelerate the process of discovery by harnessing the value of large, heterogeneous data
- Exploit the unique value of big data to address areas of national need, agency missions, and societal and economic importance
- Support responsible stewardship and sustainability of data resulting from federally funded research
- Develop and sustain the infrastructure needed to advance data science and broaden the participation in data-enabled inquiry and data-driven action, at all levels

1.2.2 Cybersecurity and Information Assurance Research and Development Senior Steering Group (CSIA R&D SSG)

The purpose of the CSIA R&D SSG is to provide overall leadership for cybersecurity research and development coordination, to address the need for streamlined decision processes and dynamic responsiveness to changing research and budget priorities. The CSIA R&D SG's strategic priorities include:

- Prioritize Federal cybersecurity research and development investments and ensure that the entire spectrum of research and development priorities and technology challenges across the Federal government are being addressed
- Lead strategic research and development coordination efforts in addressing the Administration priorities (such as the President's Cyberspace Policy Review)
- Formulate and evolve a framework for research and development strategies that focuses on game-changing technologies

1.2.3 Health Information Technology Research and Development Senior Steering Group (HIT R&D SSG)

The HIT R&D SSG was established in the fall of 2010 in response to Section 13202(b) of the American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5) which directed the NITRD Program to include Federal research and development programs related to health information technology.

The HIT R&D SSG established the Health Information Technology Innovation and Development Environments (HITIDE) Subgroup. The aim of the HITIDE Subgroup is to advance the development of interoperable health IT

systems by leveraging the existing testbed environments of Federal agency health IT systems for a virtual test, development, and innovation ecosystem.

The HITIDE Subgroup focuses on governance challenges, operational opportunities, and issues relevant to HITIDE projects. Its current interests include interoperability, standards, de-identified test data, and organizational barriers. Briefings held in 2011 on these topics included: lessons learned in establishing development test centers (DoD/Military Health System [MHS]); using synthetic data as test data (DoD/Telemedicine and Advanced Technology Research Center [TATRC]); identifying content resources and tools available to developers (National Library of Medicine [NLM]); identifying issues and challenges with medical device interoperability (NIH Affiliate, ONC Strategic Health IT Advanced Research Projects [SHARP] program); and developing substitutable, modular applications for health IT systems (ONC SHARP program). The strategic priorities of the HIT R&D SSG and the HITIDE Subgroup include the following:

- Address multiagency leadership in health IT interoperability and the development of innovative applications
- Bring together health and research and development IT communities to focus on health IT research and development needs

1.2.4 Wireless Spectrum Research and Development Senior Steering Group (WS R&D SSG)

The WS R&D SSG was established in 2010 in response to the June 28, 2010 *Presidential Memorandum – Unleashing the Wireless Broadband Revolution*.[3] The memorandum calls for NITRD to assist the Secretary of Commerce in creating and implementing a plan to facilitate research, development, experimentation, and testing by researchers to explore innovative spectrum-sharing technologies. The WS R&D SSG priorities are guided by the following strategic objectives:

- Transparency: Communicate to both Federal agencies and the private sector the research and development activities currently being pursued or planned, and help identify areas that still need to be addressed
- Smart investment: Develop strategies that can supplement funding for research and development and/or increase the efficiency of existing investments
- Solicit opportunities: Identify opportunities for spectrum technology transfer between Federal agencies and the private sector

1.3 Community of Practice (CoP)

1.3.1 Faster Administration of Science and Technology Education and Research (FASTER) Community of Practice (CoP)

FASTER, supported by the NITRD NCO, communicates with the White House Office of Management and Budget (OMB) and the Federal Chief Information Officers (CIO) Council concerning IT R&D matters that are of general interest to Federal agencies. FASTER's goal is to enhance collaboration and accelerate agencies' adoption of advanced IT capabilities developed by Government-sponsored IT research. The group is focused on the following strategic themes:

- Cloud computing
- Semantic web and ontology technology
- Open government

[3] http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution, Section 3.

- Emerging technologies
- Sharing knowledge, ideas, and best practices

2 Introduction

Now in its 21st 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 (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) Act of 2007 (P.L. 110-69), NITRD currently provides a framework and mechanisms for coordination among 15 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.

2.1 Program Component Areas (PCAs)

The agencies coordinate their NITRD activities and plans in the following Program Component Areas (PCAs). The PCAs are identified as an Interagency Working Group (IWG) or a Coordinating Group (CG) and report their R&D budgets as a crosscut of the NITRD agencies. They are charged with facilitating interagency program planning, developing and periodically updating interagency roadmaps, developing recommendations for establishing Federal policies and priorities, summarizing annual activities for the NITRD program's Supplement to the President's Budget, and identifying potential opportunities for collaboration which has been identified by OMB and the White House Office of Science and Technology Policy (OSTP) as priorities for Federal coordination and collaboration. The PCAs are listed in Table 1.

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

Table 1. PCAs

2.2 The NITRD Program

The Networking and Information Technology Research and Development (NITRD) Program is the Nation's primary source of Federally funded work on advanced information technologies such as computing, networking, and software.

A unique collaboration of Federal research and development agencies, the NITRD Program seeks to:

- 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

2.3 Senior Steering Groups (SSGs)

In addition to the PCAs, NITRD has established several Senior Steering Groups (SSGs). The SSGs allow a more flexible model for NITRD collaboration and are formed to focus on emerging issues as required by a mandate from OSTP. SSGs do not report an R&D budget under NITRD. The following SSG R&D domains are currently under the NITRD umbrella:

Big Data R&D SSG
Cybersecurity and Information Assurance R&D SSG
Health Information Technology R&D SSG
Wireless Spectrum R&D SSG

Table 2. SSGs

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

2.4 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 proportional funding to support the NITRD/NCO operations:

Department of Commerce (DOC) • National Institute of Standards and Technology (NIST) • National Oceanic and Atmospheric Administration (NOAA)
Department of Defense (DoD) • Defense Advanced Research Projects Agency (DARPA) • National Security Agency (NSA) • Office of the Secretary of Defense (OSD) and Service Research Organizations o Air Force Office of Scientific Research (AFOSR) o Air Force Research Laboratory (AFRL) o Army Research Laboratory (ARL) o Office of Naval Research (ONR)
Department of Energy (DOE) • National Nuclear Security Administration (DOE/NNSA) • Office of Science (DOE/SC)
Department of Homeland Security (DHS)
Department of Health and Human Services (HHS) • Agency for Healthcare Research and Quality (AHRQ) • National Institutes of Health (NIH) • Office of the National Coordinator for Health Information Technology (ONC)
Environmental Protection Agency (EPA)
National Aeronautics and Space Administration (NASA)
National Archives and Records Administration (NARA)
National Science Foundation (NSF)

Table 3. NITRD Member Agencies

2.5 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:

Department of Commerce (DOC)
• National Telecommunications and Information Administration (NTIA)
Department of Defense (DoD)
• Defense Information Systems Agency (DISA)
• Intelligence Advanced Research Projects Agency (IARPA)
Department of Energy (DOE)
• Office of Electricity Delivery and Energy Reliability (DOE/OE)
Department of Health and Human Services (HHS)
• Centers for Disease Control and Prevention (CDC)
• Food and Drug Administration (FDA)
• Indian Health Service (IHS)
• Office of the Assistant Secretary for Preparedness and Response (ASPR)
Department of Interior (Interior)
• **U.S. Geological Survey (USGS)**
Department of Justice (DOJ)
• Federal Bureau of Investigation (FBI)
Department of State (State)
Department of Transportation (DOT)
• Federal Aviation Administration (FAA)
• Federal Highway Administration (FHWA)
Department of the Treasury (Treasury)
General Services Administration (GSA)
National Transportation Safety Board (NTSB)
Nuclear Regulatory Commission (NRC)
U.S. Department of Agriculture (USDA)
Department of Veterans Affairs (VA)

Table 4. NITRD Participating Agencies

3 Agency Investments in the NITRD PCAs

The yearly Supplement to the President's Budget for the NITRD Program is designed to present a succinct, high-level summary of the research activities planned and coordinated through NITRD in a given Federal budget cycle, as required by law.

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

NITRD agencies engaged in R&D and coordination activities cited in the Supplement are listed in alphabetic order, followed by the participating agencies. 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.

3.1 FY 2011 Budget Actuals (Dollars in Millions)

Agency	HEC I&A	HEC R&D	CSIA	HCI &IM	LSN	HCSS	SDP	SEW	Total[1]
NSF	357.0	103.4	76.5	283.3	128.1	78.0	54.7	108.4	**1,189.4**
DoD[2]	274.0	32.0	141.4	95.0	142.4	41.8	23.3		**749.9**
NIH	221.0	18.0		215.0	12.0	10.0	53.0	22.0	**551.0**
DOE[3]	310.1	81.5	33.5		49.8	1.3	7.0	6.0	**489.2**
DARPA		80.0	127.0	156.0	73.0				**436.0**
NIST	14.0	7.3	25.7	15.0	5.0	5.5	5.2	0.6	**78.3**
NASA	62.6			14.9	0.8	10.2	5.8		**94.3**
DHS			41.0		3.0		3.0		**47.0**
AHRQ				27.1	0.5				**27.6**
NOAA	20.9	0.2		0.5	4.0		0.7		**26.3**
DOE/NNSA	10.0	15.0			1.0	4.0			**30.0**
EPA	3.0			3.0					**6.0**
NARA				2.0					**2.0**
DOT									**0.0**
Total 2011 Actuals	**1,272.6**	**337.4**	**445.1**	**811.8**	**419.6**	**150.8**	**152.7**	**137.0**	**3,727.0**

Table 5. FY 2011 Budget Actuals

[1] Totals may not sum correctly due to rounding
[2] DoD budget includes funding from OSD, NSA, and the DoD service research organizations
[3] DOE budget includes funding from DOE's Offices of Science, Electricity Delivery and Energy Reliability, and Energy Transformation Acceleration Fund

3.2 FY 2012 Budget Estimates (Dollars in Millions)

Agency	HEC I&A	HEC R&D	CSIA	HCI &IM	LSN	HCSS	SDP	SEW	Total[1]
NSF	250.0	103.0	98.5	292.0	121.8	84.7	78.3	110.2	**1,138.3**
DoD[2]	211.1	49.0	144.6	111.3	111.7	36.4	30.0		**694.1**
NIH	222.0	18.0		215.0	12.0	10.0	54.0	22.0	**553.0**
DOE[3]	316.8	92.4	33.5		73.8	4.0	16.0	6.0	**542.5**
DARPA		75.0	223.0	138.0	53.0				**489.0**
NIST	14.3	5.0	47.2	15.0	8.1	5.8	4.4	0.4	**100.2**
NASA	61.2			13.8	0.8	17.5	9.4		**102.6**
DHS			43.0		1.0		3.0		**47.0**
AHRQ				25.1	0.5				**25.6**
NOAA	19.4				1.9		0.7		**22.0**
DOE/NNSA	9.0	5.0						4.0	**18.0**
EPA	3.0			3.0					**6.0**
NARA				1.0					**1.0**
DOT									**0.0**
Total 2012 Estimates	**1,106.7**	**347.4**	**589.8**	**814.2**	**384.5**	**158.4**	**195.8**	**142.6**	**3,739.4**

Table 6. FY 2012 Budget Estimates

3.3 FY 2013 Budget Requests (Dollars in Millions)

Agency	HEC I&A	HEC R&D	CSIA	HCI &IM	LSN	HCSS	SDP	SEW	Total[1]
NSF	255.6	109.9	114.1	297.2	131.4	97.6	83.7	117.7	**1,207.2**
DoD[2]	196.2	27.4	156.6	107.8	105.3	35.5	25.3		**654.0**
NIH	221.0	18.0		215.0	12.0	10.0	53.0	22.0	**551.0**
DOE[3]	328.3	92.1	33.5		82.6	6.0	20.0	6.0	**568.5**
DARPA		79.0	247.0	87.0	49.0				**462.0**
NIST	16.0	5.0	55.2	15.8	12.1	7.8	4.4	0.4	**116.7**
NASA	60.0			13.0	1.0	16.8	9.6		**100.4**
DHS			61.0		3.0				**64.0**
AHRQ				25.1	0.5				**25.6**
NOAA	20.6	0.2		0.5	3.6		0.7		**25.6**
DOE/NNSA	10.0	11.0						4.0	**25.0**
EPA	3.0			3.0					**6.0**
NARA				1.0					**1.0**
DOT						1.0			**1.0**
Total 2013 Requests	**1,110.7**	**342.5**	**667.4**	**765.4**	**400.5**	**174.7**	**196.6**	**150.1**	**3,807.9**

Table 7. FY 2013 Budget Requests

[1] Totals may not sum correctly due to rounding
[2] DoD budget includes funding from OSD, NSA, and the DoD service research organizations
[3] DOE budget includes funding from DOE's Offices of Science, Electricity Delivery and Energy Reliability, and Energy Transformation Acceleration Fund

3.4 NITRD Program Budget Analysis

Fiscal Year Overview for 2012-2013

Differences between the President's Budget request for a given year and estimated spending for that year reflect revisions to program budgets due to evolving priorities, as well as Congressional actions and appropriations. In addition, the NITRD agencies have continued to work collectively on improving the PCA definitions, as reflected by changes in the definitions outlined in OMB Circular A-11, and individually on improving the classification of investments within the PCAs, resulting in changes in NITRD Program budgets.

Summary

The President's 2013 budget request for the NITRD Program is $3.808 billion, an increase of $69 million, approximately 1.85 percent, more than the $3.739 billion 2012 estimate. The overall change is due to both increases and decreases in individual agency NITRD budgets, which are described below.

3.5 NITRD Program Budget Analysis by Agency

This section describes changes greater than $10 million between 2012 estimated spending and 2013 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.

3.5.1 NSF

Comparison of 2012 estimate ($1,138 million) and 2013 request ($1,207 million): The increase of $69 million is primarily due to $15 million in CSIA for enhanced support for Secure and Trustworthy Cyberspace (SaTC); $9 million in LSN for additional funding for research in new wireless communications and spectrum sharing architectures and services as part of EARS and a slight decrease due to termination of the Network Science and Engineering (NetSE) cross-cutting program; $13 million in HCSS for Cyber-Physical Systems and the National Robotics Initiative, both of which are part of the CEMMSS effort; and smaller increases in other PCAs. CSIA funding includes $57 million for CNCI (CISE, OCI, SBE).

3.5.2 DoD

Comparison of 2012 estimate ($694 million) and 2013 request ($654 million): The $40 million decrease is primarily due to decreases of $15 million in HEC I&A and $22 million in HEC R&D, with smaller decreases in other PCAs, partially offset by $12 million increase in CSIA.

3.5.3 DOE

Comparison of 2012 estimate ($543 million) and 2013 request ($569 million): The $26 million increase results primarily from an $11 million increase in DOE/SC funding in HEC I&A to support new research efforts to address the challenges of data-intensive science with emphasis on the unique needs of the Department of Energy scientific user facilities and large-scale scientific collaborations, with smaller increases and decreases in other PCAs.

3.5.4 DARPA

Comparison of 2012 estimate ($489 million) and 2013 request ($462 million): The $27 million decrease largely results from a $51 million decrease in HCI&IM as Machine Reading and Reasoning programs complete, offset by an increase of $24 million in CSIA programs, a high priority of the DoD, with smaller decreases and increases in other PCAs.

3.5.5 NIST

Comparison of 2012 estimate ($100 million) and 2013 request ($117 million): The increase of $17 million includes $8 million in CSIA for the National Strategy for Trusted Identities in Cyberspace initiative; $4 million in LSN for the Advanced Communications initiative; $2 million in HEC I&A and HCI&IM for the Advanced Materials for Industry initiative; and $2 million in HCSS for the Smart Manufacturing initiative.

3.5.6 DHS

Comparison of 2012 estimate ($47 million) and 2013 request ($64 million): The $17 million increase results primarily from an $18 million increase in CSIA for increased spending across all S&T CSD projects to compensate for the across-the-board cuts necessitated by the FY 2012 decrease, with smaller increases and decreases in other PCAs.

3.6 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 2012 estimated spending and 2013 requests. The changes are described below.

3.6.1 CSIA

Comparison of 2012 estimate ($590 million) and 2013 request ($667 million): The $77 million increase is largely due to increases of $15 million at NSF, $12 million at DoD, $24 million at DARPA, $18 million at DHS, and smaller increases at other agencies.

3.6.2 HCI&IM

Comparison of 2012 estimate ($814 million) and 2013 request ($765 million): The $49 million decrease is largely due to a decrease of $51 million at DARPA, with smaller decreases and increases at other agencies.

3.6.3 HCSS

Comparison of 2012 estimate ($158 million) and 2013 request ($175 million): The $17 million increase is largely due to an increase of $13 million at NSF, with smaller increases and decreases at other agencies.

4 Strategic Priorities for Budget Request by PCA

Section 4 is organized by PCA, to align with the structure of the Program. The PCA sub-sections follow 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

4.1 Cybersecurity and Information Assurance (CSIA)

NITRD Agencies: AFRL, ARL, ARO, CERDEC, DARPA, DHS, DOE, NIST, NSA, NSF, ONR, and OSD
Other Participants: DOT, IARPA, NRC, and Treasury

CSIA focuses on research and development to detect, prevent, resist, 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 IT 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.

4.1.1 President's 2013 Request

4.1.1.1 Strategic Priorities Underlying This Request

The President's *Cyberspace Policy Review* clearly states that the Government has a responsibility to address strategic cyberspace vulnerabilities to protect the Nation and to ensure that the United States and its citizens can realize the full potential of the information technology revolution. In fulfilling this responsibility, Federal research agencies have developed a strategic plan for cybersecurity research and development that confronts underlying and systemic cyberspace vulnerabilities and takes maximum advantage of the Federal government's unique capabilities as a supporter of fundamental research.

The strategic plan, titled *Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program*, builds upon three key principles: First, research must target the underlying cybersecurity deficiencies and focus on the root causes of vulnerabilities, as opposed to treating their symptoms. Second, the execution of the strategic plan must channel expertise and resources from a wide range of disciplines and sectors. Cybersecurity is a multi-dimensional problem, involving both the strength of security technologies and the variability of human behavior. Therefore, solutions will require not only an expertise in mathematics, computer science, and electrical engineering but also in biology, economics, and other social and behavioral sciences. Third, the research must include lasting cybersecurity principles that sustain continuing security despite changes in technologies and in the threat environment.

The priorities are organized into four thrusts: Inducing Change, Developing Scientific Foundations, Maximizing Research Impact, and Accelerating Transition to Practice. The thrusts provide a framework for

prioritizing cybersecurity R&D that focuses on limiting current cyberspace deficiencies, precluding future problems, and expediting the infusion of research accomplishments into the marketplace. The principal objectives include achieving greater cyberspace resiliency, improving attack prevention, developing new defenses, and enhancing our capabilities to design software that is resistant to attacks.

- **Inducing Change:** Utilize game-changing themes to analyze the underlying root causes of known current threats to disrupt the status quo with radically different approaches to improve the security of the critical cyber systems and infrastructure that serve society.
- **Developing Scientific Foundations:** Develop an organized, cohesive scientific foundation to serve as the cornerstone for cybersecurity by establishing a systematic, rigorous, and disciplined scientific approach that will promote the discovery of laws, hypothesis testing, repeatable experimental designs, standardized data-gathering methods, metrics, common terminology, and critical analysis that engenders reproducible results and rationally based conclusions.
- **Maximizing Research Impact:** Catalyze integration across the game-changing R&D themes, cooperation between governmental and private-sector communities, collaboration across international borders, and strengthened linkages to other national priorities, such as health IT and Smart Grid.
- **Accelerating Transition to Practice:** Implement powerful new technologies and strategies that emerge from the research themes and from the activities to build a scientific foundation so as to create measurable improvements in the cybersecurity landscape.

4.1.1.2 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 2013. Agencies are listed in alphabetical order:

- **Inducing change**
  - **Tailored Trustworthy Spaces theme:** Enable flexible, adaptive, distributed trust environments that can support functional and policy requirements arising from a wide spectrum of user activities in the face of an evolving range of threats.
    - Secure and Trustworthy Cyberspace Program – NSF/Computer and Information Science and Engineering (CISE), NSF/Mathematical and Physical Sciences (MPS), NSF/Office of Cyberinfrastructure (OCI), and NSF/Social, Behavioral, and Economic Sciences (SBE) Directorates
    - Trusted foundation for defensive cyberspace operations – AFRL, ARL, ARO, CERDEC, ONR, and OSD
    - Cybersecurity Research and Development Broad Agency Announcement – DHS
    - High assurance security architectures – ONR, NIST, and NSA
    - Security Automation Program – DHS, NIST, and NSA
    - Access Control Policy Machine – NIST
    - Tactical Information Technologies for Assured Network operations (TITAN) – ARL, ARO, and CERDEC
    - Security for cloud-based systems – DARPA, DHS, and NIST
    - Secure wireless networking – ARL, ARO, CERDEC, DARPA, ONR, and NSA
    - Secure Information Exchange Gateway (SIEGate) – DOE
    - Military Networking Protocol (MNP) program – DARPA
  - **Moving Target theme:** Develop capabilities to create, analyze, evaluate, and deploy mechanisms and strategies that are diverse and that continually shift and change over time to

increase complexity and the cost for attackers, limit the exposure of vulnerabilities and malicious opportunities, and increase system resiliency.

- Protected Control Plane for Cyber Command and Control (PCPC3) – AFRL
- Cyber Unification of Security Hardening and Protection of Operational Frameworks (CRUSHPROOF) – ARL, ARO, CERDEC, and OSD
- Morphing Network Assets to Restrict Adversarial Reconnaissance (Morphinator) – ARL, ARO, and CERDEC
- Defensive Enhancements for Information Assurance Technologies (DEFIANT) – ARL, ARO, and CERDEC
- Cybersecurity Research and Development Broad Agency Announcement – DHS
- Proactive & Reactive Adaptive Systems – NSA
- Security Automation and Vulnerability Management – NIST
- Trust Management in Service Oriented Architectures – ONR
- Robust Autonomic Computing System – ONR
- Information Security Automation Program (ISAP) – DHS, NIST, and NSA
- Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) program – DARPA
- Cyber Camouflage, Concealment, and Deception – DARPA

- **Cyber Economic Incentives theme:** Develop effective market-based, legal, regulatory, or institutional incentives to make cybersecurity ubiquitous, including incentives affecting individuals and organizations.
  - Secure and Trustworthy Cyberspace Program – NSF/CISE, NSF/MPS Directorates, NSF/OCI, and NSF/SBE
  - Cybersecurity Research and Development Broad Agency Announcement – DHS
- **Designed-in Security theme:** Develop capabilities to design and evolve high-assurance, software-intensive systems predictably and reliably while effectively managing risk, cost, schedule, quality, and complexity. Create tools and environments that enable the simultaneous development of cyber-secure systems and the associated assurance evidence necessary to prove the system's resistance to vulnerabilities, flaws, and attacks.
  - Survivable Systems Engineering – OSD/Software Engineering Institute (SEI) CERT
  - Trusted Computing – DARPA, NSA, and OSD
  - Software Development Environment for Secure System Software & Applications – ONR
  - Crowd-Sourced Cyber program (approaches for verifying the correctness of software systems) – DARPA
  - META (flows, tools, and processes for correct-by-construction system design) – DARPA
  - Roots of Trust – NIST and NSA
  - Software Assurance Metrics And Tool Evaluation (SAMATE) – DHS and NIST

- **Developing Scientific Foundations**
  - **Science of Security:** In anticipation of the challenges in securing the cyber systems of the future, the research in the areas of science of security aims to develop an organized, scientific foundation that informs the cybersecurity domain, by organizing disparate areas of knowledge, enabling discovery of universal laws, and by applying the rigor of the scientific method.
    - Science for Cybersecurity (S4C) – ARL, ARO, and CERDEC
    - Science of Security MURI – AFOSR

        - Science of Information Assurance – NSA
    - Cross-cutting Foundations:
        - Cryptography – DARPA, NIST, NSA, NSF, and ONR
        - Models, standards, testing, and metrics – ARL, ARO, DHS, DOE, NIST, NSF, and OSD
        - Foundations of Trust – AFRL, ARL, ARO, CERDEC, DOE, NIST, NSF, and OSD
        - Security Management and Assurance Standards – NIST
        - Quantum information science and technology – IARPA, NIST, and ONR
- **Maximizing Research Impact**
    - **Supporting National priorities:** The cybersecurity research themes provide a framework for addressing the cybersecurity R&D requirements associated with national priorities in, for example,
      the healthcare, energy, financial services, and defense sectors.
        - Trustworthy Cyber Infrastructure for the Power Grid (TCIPG) – DHS, and DOE
        - National Strategy for Trusted Identities in Cyberspace (NSTIC) – NIST
- **Accelerating Transition to Practice**
    - **Technology discovery, evaluation, transition, adoption, and commercialization:** Explicit, coordinated processes that transitions the fruits of research into practice to achieve significant and long-lasting impact.
        - Testbeds and infrastructure for R&D – DARPA, DHS, DOE, and NSF
        - Cyber Technology Evaluation and Transition Program (CTET) – DHS
        - Information Technology Security Entrepreneurs' Forum (ITSEF) – DHS
        - Secure and Trustworthy Cyberspace Program – NSF
        - Defense Venture Catalyst Initiative (DeVenCI) – DoD
        - Small Business Innovative Research (SBIR) Conferences – DHS and DoD

4.1.1.3 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. The following is a representative summary of current multiagency collaborations**:**

- **Co-funding:** Trustworthy Cyber Infrastructure for the Power Grid (TCIPG) Center – DHS and DOE; Defense Technology Experimental Research (DETER) testbed – DHS ; Financial Services Sector Coordinating Council (FSSCC) pilot – DHS and NIST; National Centers of Academic Excellence in Information Assurance Education and Research – DHS and NSA; and Process Control System Security – DHS and DOE
- **Workshops:** Cybersecurity Applications and Technology Conference for Homeland Security – DHS; DoD Small Business Innovation Research (SBIR) Conference – DHS and DoD Service research organizations; Annual IT Security Automation Conference – DHS, NIST, and NSA; Assumption Buster Workshops – Office of the Director of National Intelligence (DNI), NIST and NSA, and Treasury; Tailored Trustworthy Spaces for Smart Grid Workshop – DOE and NIST; Workshop on Developing Dependable and Secure Automotive Cyber-Physical Systems from Components – NIST, NSF, and U. S. Consul for Automotive Research (USCAR); Technical Interchange and Roundtable Discussion on Cybersecurity and Electronic Resilience in Automobiles – DoT and NSF; Enabling Distributed Security in Cyberspace – DHS and NSF; Building International Cooperation for Trustworthy ICT workshop session at SysSec workshop – European Union (EU), and NSF; HIPAA Security Rule Conference – HHS

and NIST; National Initiative for Cybersecurity Education Annual Workshop – DHS, NIST, NSA, NSF, and OSD; Cloud Forums – DHS, GSA, and NIST; Mobile Security Forum – NIST and NSA

- **Collaborative deployment:** DNS security (DNSSEC) and routing security – AFRL, DHS, and NIST; NIST App Testing Portal (ATP) – DARPA, NIST; The National Vulnerability Database – DHS and NIST; U.S. Gov't Configuration Baseline (USGCB) – NIST and NSA
- **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 – NIST and NSA; participation in Internet Engineering Task Force (IETF) security groups to develop standard representations and corresponding reference implementations of security-relevant data – NIST, NSA, and OSD
- **Testbeds:** Continued joint development of research testbeds, such as DETER, Protected Repository for the Defense of Infrastructure Against Cyber Threats (PREDICT), Distributed Environment for Critical Infrastructure Decision-making Exercises (DECIDE), Wisconsin Advanced Internet Laboratory (WAIL), National Cyber Range (NCR), Mobile Networks Testbed Emulation – ARL, ARO, CERDEC, DARPA, DHS, NSF, ONR, and Treasury
- **DoD Cyber Science and Technology (S&T) Steering Council:** Oversight and coordination of all defensive cyber S&T programs –OSD and DoD Service research organizations
- **Technical Cooperation Program Communications, Command, Control and Intelligence (C3I) Group:** Information assurance and defensive information warfare – AFRL, ARL, ARO, CERDEC, NSA, ONR, and OSD

4.1.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the CSIA PCA:

- **AFRL:** Building a trusted foundation for cyberspace operations – proactively defending the U.S. Air Force (USAF) and National cyberspace enterprise; assuring USAF missions in cyberspace; designing/developing/building secure cyber assets with agility and resilience; and fully leveraging and shaping cyberspace war fighting domain to U.S. advantage
- **ARL, ARO, and CERDEC:** Mobile security (tactical edge solutions for the dismounted warfighter); cyber maneuver (network & platform agility for mission assurance, cyber deception); cyber frameworks (capabilities built on open, sustainable & well defined specifications and frameworks for defensive & offensive operations); trust research (trust management for optimal network performance, models and analytical tools for social-media-based data sensing and processing); intrusion detection (efficient and secure system for resilient defense, automatic signature generation); secure cross domain information sharing; software/hardware assurance (automated source code analysis, tamper and chip level protections); and cyber threat (novel methods and tools for prompt network protection)
- **DARPA:** Information Assurance and Survivability (core computing and networking technologies to protect DoD's information, information infrastructure, and mission-critical information systems; and cost-effective security and survivability solutions)
- **DHS:** Internet measurement and attack modeling; process control systems security; security for cloud-based systems; secure protocols; cybersecurity assessment and evaluation; cybersecurity experiments and pilots; enterprise level security metrics and usability; Homeland Open Security Technology (HOST); software quality assurance; Secure Protocols for the Routing Infrastructure (SPRI); research infrastructure to support cybersecurity (experimental research testbed, research data

repository, software assurance marketplace); and cybersecurity user protection and education (cybersecurity competitions, cybersecurity forensics, data privacy technologies, identity management)

- **DOE:** Implementing DOE/OE "Roadmap to Achieve Energy Delivery Systems Cybersecurity;" development and deployment of resilient networks and systems for the Smart Grid; vulnerability research for identifying weaknesses and developing mitigations; analysis to assess risks, security posture, and increase ability to mitigate risks; secure sharing of threat information and facilitation of incident response; and basic research in mathematics of cybersecurity and complex interconnected systems
- **IARPA:** Securely Taking on New Executable Software of Uncertain Provenance (STONESOUP); SPAR Program (parsimonious information sharing: minimizing collateral information that must be shared in order to efficiently share a desired piece of information)
- **NIST:** Advanced cryptography (international SHA-3 hash competition, public key, key management; privacy enhanced cryptographic mechanisms, post-quantum); DNSSEC, Border Gateway Protocol Security (BGPSEC); Security Content Automation Protocol (standards development, event management, incident handling, U.S. Government Configuration Baseline (USGCB); standards conformance testing; composable and scalable secure systems; authorization technologies; mitigation of side-channel attacks; ad-hoc networks and wireless security; secure distributed systems; combinatorial testing to automate flaw discovery; Smart Grid cybersecurity; biometrics; identity management, personal identity verification (PIV); security for cloud computing; security for cyber-physical systems; security for electronic voting; security for Health IT; National Initiative for Cybersecurity Education (NICE); National Strategy for Trusted Identities in Cyberspace (NSTIC); usable security; and supply chain risk management; participation in standards development organizations
- **NSA:** High assurance security architectures enabled by virtualization; improved enterprise protection through strong software measurement and reporting; secure enterprise infrastructure required for secure mobility; improved physical protection of mobile assets; location sensitive access control; cost-effective protection of air interface; maximize use of Commercial-off-the-shelf (COTS) hardware, software, and infrastructure; science of information assurance; and proactive and reactive adaptive systems
- **NSF:** Secure and Trustworthy Cyberspace program (build tailored trustworthy spaces with the needed assurances for security and controls for administration; develop the foundations for engineering systems inherently resistant to malicious cyber disruption; protect the cyber infrastructure and deter malicious acts by shifting the computational, economic and social advantage to the defenders; study the trade space among security, privacy, usability; explore legal, social, economic, behavioral and ethical aspects of cybersecurity); NSF/CISE-NSF/ENG CPS; CISE/CNS Future Internet Architecture Program; and CISE Coordinated Core research programs (Computing and Communication Foundations [CCF], Computer and Network Systems [CNS], Information and Intelligent Systems [IIS]) in software/hardware foundations, algorithmic foundations, human centered computing, information integration and informatics
- **ONR:** Software and cyber information assurance; trust management in Service Oriented Architecture; removing the botnet threat; quantum information sciences for future secure computation and secure communication; anti-tamper, security in wireless networks; high assurance in virtualization; coalition networks for secure information sharing; secure distributed collaboration; security management infrastructure and assured information sharing; secure dynamic tactical communications networks; and proactive computer network defense and information assurance
- **OSD:** Cyber resilience (resilient architectures, resilient algorithms and protocols); cyber agility (autonomic cyber agility, cyber maneuver); assuring effective missions (cyber mission control, effects

at scale); foundations of trust (system-level trust, trustworthy components and mechanisms); continue to lead DoD coordination through DoD Cyber S&T Steering Council; cybersecurity metrics; new applied research and advanced development programs in cybersecurity gaps identified in recent studies; and SBIR workshop to facilitate networking with small businesses

4.2 High Confidence Software and Systems (HCSS)

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

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.

4.2.1 President's FY 2013 Request

4.2.1.1 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 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
- **Management of complex and autonomous systems:** Develop measurement and understanding for improved models of complex systems of systems, shared control and authority, levels of autonomy, human-system interactions, and new integrated analytical and decision-support tools
- **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); and 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; and component-based accelerated design and verifiable system integration; and predictable, fault-tolerant, distributed software and systems

- **Translation into mission-oriented research:** Leverage multi-agency research to move theory into practice – for example, through challenge problems
- **CPS education:** Launch an initiative to integrate CPS theory and methodology into education and promote increased understanding of and interest in CPS through the development of new curricula at all levels to break down the silos between physical and cyber disciplines and evolve a new generation of U.S. experts

4.2.1.2 Highlights of Request

The HCSS agencies report the following topical areas as highlights of their planned R&D investments for FY 2013. Agencies are listed in alphabetical order:

- **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; and interoperable ("plug-and-play") medical devices – AFRL, ARO, DOE/OE, FDA, NASA, NIH, NIST, NSA, NSF, ONR, OSD, and VA/JIV
- **Complex systems:** Multiyear effort, including focus on software for tomorrow's complex systems such as CPS, to address challenges of interacting systems of systems, including human- system interactions, and investigate their non-linear interactions and aggregate or emergent phenomena to better predict system capabilities and decision-making about complex systems – AFRL, NASA, NIH, NIST, NSF, and OSD
- **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, security, 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; 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 –AFOSR, AFRL, ARO, DOE/OE, FDA, NASA, NIH, NIST, NSA, NSF, ONR, and OSD
- **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 – NSA and ONR; testing infrastructure for health IT standards, specifications, certification (with HHS); and cross-enterprise document sharing in electronic health systems – DOE/OE, NIH, NIST, and NSF
- **Aviation safety:** R&D in transformative V&V methods to rigorously assure the safety of aviation systems. This includes considerations for all classes of aircraft and anticipated future air traffic management capabilities; and develop and demonstrate innovative technologies in the design of architectures with advanced features, focusing on designing for high-confidence certification – AFRL, FAA, Joint Planning and Development Office (JPDO), and NASA

4.2.1.3 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 – FDA, NIST, NSA, and NSF
  - **Future Energy CPS –** DOE/OE**,** NIST, NSA, and NSF
  - **High Confidence Transportation CPS:** Automotive, Aviation, and Rail –AFRL with DOT, FAA, FDA, NASA, NIST, NSA, NSF, and NTSB
  - **CPS Week –** AFRL, NASA, NIST, NSA, NSF, and OSD
  - Verified Software, Theories, Tools, and Experiments (VSTTE) Workshop – NSA and NSF
  - **Static Analysis Tools Exposition (SATE):** Annual summit on software security for vendors, users, and academics – NIST, NSA, and NSF in collaboration with DHS
  - **CPS Education:** NSA, NSF, and ONR
  - CPS Extreme Manufacturing: FDA, NIST, NSF, ONR, and OSD
- **Software Assurance Metrics and Tool Evaluation:** Annual workshop for users and developers to compare efficacy of techniques and tools; develop vulnerability taxonomies – DHS, NIST, and NSA
- **Safe and Secure Software and Systems Symposium (S5):** AFRL, NASA, NSA, and NSF
- **Twelfth Annual HCSS Conference:** Showcasing of promising research to improve system confidence – FAA, NASA, NSA with NSF, ONR, and OSD
- **Software Assurance Forum** – DHS, (DoD) OSD and DoD Service research organizations, NIST, and NSA
- **Safety of flight-critical systems:** Workshops and technical discussion – AFRL, NASA, NSA, NSF, and OSD
- **Future Directions in Cyber-Physical Systems Security:** Joint workshop – DHS, DOE/OE, NIST, NSA, NSF, OSD, and USAF
- **Standards, software assurance metrics for Supervisory Control and Data Acquisition (SCADA), Industrial Control Systems (ICS):** Collaborative development – DOE/OE, NIST, and others
- **Biomedical imagery:** Technical standards for change measurements in patient applications – CMS, FDA, NIH, and NIST
- **Cooperative proposal evaluation** – AFRL, FAA, FDA, NASA, NIST, NRC, NSA, NSF, and OSD
- **FAA National Software and Airborne Electronic Hardware Standardization Conference** – FAA, and NASA

4.2.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the HCSS PCA:

- **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 environment (e.g., Unmanned aerial vehicles [UAVs]); and 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; and reliable and effective mechanisms to monitor and verify software execution status
- **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 cybersecurity; cybersecurity for legacy and next-generation energy delivery systems; and secure cyber-physical interfaces; TCIPG academic consortium for research; and R&D to provide situational awareness that supports NERC-CIP compliance
- **FAA:** Improve and maintain methods for approving digital systems approval methods of digital systems for aircraft and air traffic control (ATC) systems and prepare for the Next Generation Air Transportation System (NextGen) by conducting research in advanced digital (software-based and airborne electronic hardware [AEH]-based airborne systems) technology; keep abreast of and adapt to the rapid, frequent changes and increasing complexity in aircraft and ATC systems; understand and assess safe implementations in fight-essential and flight-critical systems (e.g., fly-by-wire flight controls, navigation and communication equipment, autopilots, and other aircraft and engine functions); and continue work on digital requirements for software-development techniques and tools, airborne electronic hardware design techniques and tools, onboard network security and integrity, and system considerations for complex digitally intensive systems
- **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; and black box/flight-data recording and analysis
- **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; the 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
- **NASA:** Aviation safety R&D with emphasis on enabling technologies for design, V&V of flight-critical systems (argument-based safety assurance, autonomy and authority, integrated distributed systems, software-intensive systems); enabling assurance technologies for NextGen self-separation concepts;

and determining appropriate airworthiness requirements for Unmanned Aircraft Systems (UAS) to help enable routine access to the national airspace

- **NIH:** Translational research in biomedical technology to enhance development, testing, and implementation of diagnostics and therapeutics that require advanced CPS innovations; assurance in medical devices such as pulse oximeters and infusion pumps, cardio-exploratory monitors for neonates; telemedicine; computer-aided detection and diagnosis; computer-aided surgery and treatment; neural interface technologies such as cochlear implants, and brain-computer interfaces. Systematic exploration of the sources and variability introduced during tumor image acquisition and tumor size measurement, for the development of improved algorithms used in assessment of new therapies; and development of new data acquisition and analysis methods to aid in the determination of optimal ultrasound exposure settings to obtain the necessary diagnostic information by using the very lowest total energy for increased patient safety.
- **NIST:** Computer forensics tool testing; National Software Reference Library (funded by DOJ/National Institute for Justice [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; smart manufacturing; and automotive CPS
- **NRC:** Regulatory research to assure safety and security in cyber-physical systems (digital instrumentation and control systems) used in the nuclear energy sector
- **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; and assured cryptographic implementations (software and hardware); domain-specific workbench developments (cryptography, guards, protocols)
- **NSF:** Joint research program of CISE and Engineering (ENG) directorates addressing CPS challenges in three areas (foundations; methods and tools; and components, run-time substrates, and systems); form partnerships to **s**upport 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; Trustworthy Computing (TwC) to ensure security, reliability, privacy and usability; create core disciplinary, exploratory, and educational programs; and the National Robotics Initiative (NRI) to accelerate the development and use of robotics cooperatively with people
- **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; and work in real-time fault-tolerant software, software interoperability, systems for quantum processing
- **OSD:** Improve the DoD's ability to design, build, test, and sustain software-intensive Cyber Physical systems which meet DoD mission critical requirements for embedded and distributed systems, exhibit predictable behavior, and enable affordable evolution and interoperability. Technology thrust areas include specification of complex requirements; "correct-by-construction" software development; scalable composition; high-confidence software and middleware; system architectures for network-centric environments; technologies for system visualization, testing, verification and validation; model- and platform- based design and development approaches; and tools for controlling automated exploration and evaluation of massive trade spaces

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

NITRD Agencies: DoD (OSD and DoD Service research organizations), DOE/NNSA, DOE/SC, EPA, NASA, NIH, NIST, NOAA, and NSF

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. The HEC infrastructure enable researchers in academia, Federal laboratories, and industry to model and simulate complex processes in aerospace, astronomy, biology, biomedical science, chemistry, climate and weather, energy and environmental sciences, high energy physics materials science, nanoscale science and technology, national security, and other areas to address Federal agency mission needs.

4.3.1 President's 2013 Request

4.3.1.1 Strategic Priorities Underlying This Request

Ongoing investments in Federal HEC facilities, advanced applications, and next-generation systems support Federal agencies' science, engineering, and national security missions. Priorities include:

- **Leadership-class and production quality HEC systems:** Acquire HEC systems to meet critical agency needs and to support the national science and engineering communities
- **Advancement of HEC applications:** Support the development of scientific and engineering applications software for current and next-generation HEC platforms; develop mission-responsive computational environments; and lead critical applied mathematics research
- **Leading-edge cyber infrastructure:** Provide efficient access to facilities and resources; enhance infrastructure for computational and data-enabled science; and share best practices for cost-effectively and energy-efficiently managing and enhancing HEC resources

4.3.1.2 Highlights of Request

The following are highlights of planned activities for FY 2013 under each of the main HEC I&A priorities:

- **Leadership-class and production-quality HEC systems**
  - **DoD High Performance Computing Modernization Program (HPCMP):** Continue modernization of HEC platforms and storage subsystems at supercomputing centers; and install cluster and mid-scale systems to support specific mission needs
  - **DOE/NNSA:** Operation of supercomputing platform systems – Cielo 1.37 petaflop (PF) at Los Alamos National Laboratory (LANL) and Sequoia 20 PF at Lawrence Livermore National Lab (LLNL)
  - **DOE/SC:** Oak Ridge National Lab (ORNL) LCF at 10-20 PF; upgrade Argonne National Laboratory (ANL) BlueGene/P (557 TF) to BlueGene/Q (10 PF); National Energy Research Scientific Computing Center (NERSC) operational 1 PF XE6 integrated with a high-performance file system; and develop research and energy efficient computing engineering prototypes and memory technologies
  - **NASA:** Expand Pleiades to 1.75 PF, field testbeds for 10 PF system at NASA Advanced Supercomputing facility (NAS); and upgrade Discover to 500 TF at NASA Center for Climate Simulation (NCCS)
  - **NIH:** Selected acquisition of cluster and mid-scale compute-intensive systems
  - **NOAA:** Acceptance testing of SGI ICE (383 TF) for weather and climate research; and upgrade GAEA climate research system at ORNL to 980 TF
  - **NSF:** Capacity Systems: Track 2 resources Kraken and Ranger lifetimes extended; Gordon, FutureGrid and Keeneland become allocatable resources, for XSEDE (Extreme Science and Engineering Discovery Environment); Stampede operations begin January 2013 (2 PF of Sandy

Bridge CPU, 10-15 PF of Intel Many Integrated Cores (MIC) accelerators); Capability System: Blue Waters system becomes fully operational, providing sustained petascale computational performance across a broad range of science and engineering applications (11.5 petaflops peak performance, 1.5 petabytes aggregate system memory, 25 petabytes user accessible file storage)

- **Advancement of HEC applications**
  - **DoD (HPCMP):** Catalyze the development and modernization of applications that support DoD S&T priorities and operate effectively at extreme scale via: Computational Research for Engineering and Science (CRES) program developing highly scalable engineering application codes for aircraft, ship and antenna design on an annual release cycle; High-performance computing (HPC) Software Applications Institute; and support of specific mission applications
  - **DOE/NNSA:** Code transition to exascale; and investigate uncertainty quantification (UQ) methods for multi-cores
  - **DOE/SC:** Extreme scale multiphysics applications; Innovative and Novel Computational Impact on Theory and Experiment (INCITE) competition for access to LCF resources by outside researchers; applied mathematical research (UQ); exascale co-design centers (LANL, ANL, Sandia National Lab [SNL]; Scientific Discovery through Advanced Computing (SciDAC) application partnerships; mathematics for analysis of ultra-scale data sets; and extreme-scale algorithms
  - **EPA:** Applications and mathematical research for air quality and climate models; and advanced distributed data and modeling capabilities
  - **NASA**: Application enhancement, data analysis, and visualization support for advanced modeling in aerospace, earth science and astrophysics; summer institute to train discipline experts in efficient, scalable parallel programming
  - **NIH:** Scientific computing efforts such as biomolecular modeling, physiological modeling, and multiscale modeling that use HEC resources or are in pre-HEC state; and biodata management and analysis
  - **NIST:** Measurement science for HEC applications and visualization (predictive modeling, V&V, uncertainty quantification, computational experiment design, quantitative methods in visualization), and fundamental mathematical tools
  - **NOAA:** Improve model-based computing of weather forecasting, hurricane forecasting, and climate prediction; and ensemble forecasts, ecosystem forecasting and integration with physics based modules, hybrid architectures
  - **NSF:** eXtreme Digital program goes into full deployment: Two new visualizations resources (RDAV–SGI shared memory at NICS, Longhorn – Cluster with "fat" nodes); A Technical Audit Service (monitor resources and provide XDMoD tool to gather data on all aspects of NSF systems); A Technical Insertion Service (evaluate software for deployment into project); Coordination and Management Service (CMS); Extended Collaborative Support Service (ECSS); and Training, Education and Outreach Service (TEOS)
- **Leading-edge cyber infrastructure**
  - **DoD (HPCMP):** Federated infrastructure to support DoD Research Development Test and Evaluation (RDT&E) applications including network, services, storage, and expertise with a focus on user productivity
  - **DOE/NNSA:** Develop common computing environment across NNSA labs
  - **DOE/SC:** Continue emphasis on unified approaches to software, languages, and tools support to reduce barriers to effective use of complex HEC resources by application developers and users

- **NASA:** Expand NAS archive to 100+ PB and NCCS archives to 10 PB; add key earth science data sets to NASA data services; and demonstrate new approaches for distributed, data-intensive computational science and engineering
- **NOAA:** Implement new tape archive architecture
- **NSF:** Cyber Infrastructure Framework for 21st Century Science & Engineering (CIF21) – Metaprogram to coordinate the full cyber-ecosystem across the entire Foundation; and Software Infrastructure for Sustained Innovation – a three pronged program (single investigator, small teams, large software institutes) to provide funds for researchers to develop, deploy and harden software

4.3.1.3 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 – DOE/NNSA, DOE/SC, NIST, NOAA, and NSF
- **System reviews, benchmarking:** Collaborations – DoD, DOE/NNSA, DOE/SC, NASA, NOAA, NSA, and NSF
- **Multiscale modeling in biomedical, biological, and behavioral systems:** Interagency collaboration to advance modeling of complex living systems – DoD, NIH, and NSF
- **Innovative & Novel Computational Impact on Theory and Experiment (INCITE):** DOE and NIST
- **Quantum Information Theory:** DOE and NIST
- **Computational toxicology:** Integration of HEC technologies with molecular biology to improve methods for risk assessment of chemicals – DoD, DOE/SC, EPA, FDA, and NIH
- **Interagency participation in review panels, Principal investigator (PI) meetings** – HEC IWG: and HEC agencies
- **DOE Best Practices Workshop Series:** Develop and share best practices for HPC operations – DOE/NNSA, DOE/SC, and HEC agencies
- **Competitiveness:** Broaden use of HEC and advanced modeling and simulation by U.S. engineering and manufacturing industry – HEC IWG
- **Education:** Infuse 21st Century curriculum in HEC and computational science into academia – HEC IWG

4.3.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the HEC I&A PCA:

- **DoD (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, and munitions)

- **DOE/SC:** Manage LCF facilities at ORNL and ANL; support computation-intensive and data-intensive applications; programming environment challenges; and mathematics for in complex systems
- **NASA:** Explore distributed, data-intensive, and energy efficient technologies for enhanced user productivity
- **NIH:** International networks for biomedical data, software sharing; NIH Roadmap National Centers for Biomedical Computing (NCBCs); Center for Information Technology (CIT) high-performance, parallel systems with software solutions for NIH intramural research program investigators; Cancer Imaging and Computational Centers; P41 computational centers; bioinformatics centers; proteomics, protein structure initiatives; and systems biology centers
- **NIST:** Development, analysis of fundamental mathematical algorithms, software, tools; and parallel and distributed algorithms in applications (e.g., nano-optics, automated combinatorial software testing, Object-Oriented Micromagnetics Modeling Framework [OOMMF])
- **NOAA:** Detailed design for next-generation NOAA HPC architecture optimizing number, locations of HPC systems; and award systems integration contract for planning and migration to the next-generation architecture
- **NSF:** CIF21, software and data enabled science; CPS; advanced manufacturing; cybersecurity; computing workforce; high performance computing and storage services; extreme digital (XD) remote visualization and data analysis services; technical audit service; technical insertion service; XSEDE integrating services (coordination and management service, extended collaborative support service, training, education and outreach service); Ranger and Kraken extended; and Track 2D (FutureGrid, Keeneland, Gordon) migrate to XSEDE allocatable resources

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

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

HEC R&D agencies conduct and coordinate hardware and software R&D to enable the successful development and effective use of future high-end systems to meet projected Federal agency mission needs, to address many of society's long-term challenges, and to strengthen the Nation's leadership in science, engineering, and technology. Research areas of interest include developing applications and system architectures that effectively utilize billion-fold concurrency, reducing the energy per computation by orders of magnitude, achieving system resilience at extreme scales, and enabling future revolutions in simulation- and big-data-enabled science and technology.

4.4.1 President's 2013 Request

4.4.1.1 Strategic Priorities Underlying This Request

For decades, HEC R&D agencies have led development of increasingly capable computing technologies and environments, which not only enhanced mission success, but also enabled and motivated increased HEC usage by industry and academia, promoting economic competitiveness and scientific leadership. Now, the HEC community faces great challenges in creating the hardware, software, and systems to achieve and exploit the next few orders of magnitude increase in HEC capability expected by 2020. HEC researchers seek to exploit multicore-processor technologies, to address the growing complexity and costs of emerging platforms and software, and to innovate despite the challenges of energy consumption and scalability. In view of these challenges, the HEC R&D agencies see the following as key research priorities for FY 2013:

- **Extreme-scale computation:** Integrate computer science and applied mathematical foundations to address the challenges of productive and efficient computation at the exascale level and beyond. Develop innovative systems that combine increased speed, economic viability, high productivity, and robustness to meet future agency needs for systems that manage ultra-large volumes of data and run multi-scale, multidisciplinary science and engineering simulations. Explore new concepts and approaches for solving technical challenges such as power use, thermal management, file system I/O latency, resiliency, highly parallel system architectures, and programming language and development environments that can increase the usability of large-scale multiprocessor (including hybrid) systems. Develop, test, and evaluate prototype HEC systems and software to reduce industry and end-user risk to increase competitiveness.
- **New directions in HEC hardware, software and system architectures:** Develop novel scientific frameworks, system architectures, and prototypes to take computing power and communications "beyond Moore's Law"; and advance quantum computing.
- **Productivity:** Continue collaborative development of new metrics of system performance, including benchmarking, lessons learned for acquisition, and total ownership costs of HEC systems; integrate resources for improved productivity. Design and develop requirements for software to enable, support, and increase the productivity of geographically dispersed collaborative teams that develop future HEC applications.

4.4.1.2 Highlights of Request

The HEC R&D agencies report the following topical areas as highlights of their planned research investments for FY 2013. Agencies are listed in alphabetical order:

- **Extreme-scale computation**
  - **Next-generation architectures and programming:** 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 and tools; Forum to Address Scalable Technology for runtime and Operating Systems (FAST-OS) – DOE/NNSA, DOE/SC, and NSF

- **Computing Challenges:** Power efficiency, chip-to-chip I/O, multi-core technology, interconnects, productivity, resilience, and file system I/O – DARPA, DOE/NNSA, DOE/SC, and NSA
- **Pathways to Exascale computing:** Exascale Computing Initiative; and interconnect and memory technologies – DOE/NNSA, and DOE/SC

- **New directions in HEC hardware, software and system architectures**
  - **Quantum computing:** Quantum information theory; architectures and algorithms; modeling of quantum memory, quantum gates, components, and systems – DARPA, NIST, NSA, and NSF
- **Productivity**
  - **Capabilities for scientific research:** Computational concepts, methods, and tools for discovery; centers, institutes, and partnerships for predictive science, applied math/computer science challenges of scientific computing at extreme scale, joint mathematics/computer science institutes – DoD, DOE/NNSA, DOE/SC, and NSF

4.4.1.3 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:

- **Quantum information science:** Study information, communication, and computation based on devices governed by the principles of quantum physics – DARPA, NIST, NSA, and NSF
- **Exascale computing:** Conduct exascale workshops – DOE/NNSA, DOE/SC, and other agencies
- **HEC hardware and software:** Facilitate access to and share knowledge gained and lessons learned from HEC hardware and software development efforts – DoD, DOE/NNSA, DOE/SC, NASA, NIST, NOAA, and NSF
- **HEC tools:** Coordinate research in operating/runtime systems, languages, compilers, libraries – DARPA, DOE/NNSA, DOE/SC, NSA, and NSF
- **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 – DARPA, DoD, DOE/NNSA, DOE/SC, NASA, NSA, and NSF
- **HEC metrics:** Coordinate research on effective metrics for application development and execution on high-end systems – DARPA, DoD, DOE/NNSA, DOE/SC, NASA, NSA, and NSF
- **Technical and planning workshops:** Multiple HEC agencies
- **Proposal reviews:** Multiple HEC agencies

4.4.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the HEC R&D PCA:

- **DARPA:** Develop the technologies and techniques to overcome the power efficiency barriers that currently constrain embedded computing system capabilities.

- **DoD (HPCMP):** HEC systems and software R&D in support of DoD mission priorities; modeling and simulation; user productivity
- **DOE/NNSA:** Invest in R&D partnerships for critical technologies to address Exascale barriers, such as 3-D stacked memory
- **DOE/SC:** SciDAC Institutes for frameworks, algorithms, and scalable technologies, uncertainty quantification at extreme scale computations, co-design centers for next generation applications at exascale, sustained performance, energy and resilience, computer science for architecture, huge data sets, and multidisciplinary science
- **NASA:** Advanced HEC interfaces and technologies
- **NIST:** Quantum information science, (measurements, computing technologies, communications, benchmarks, and modeling)
- **NOAA:** Software R&D (modeling, e.g., Earth System Modeling Framework, large-scale data transfer, optimal configuration for grid computing and meta scheduling, and transition code from research to operations)
- **NSA:** Center for Exceptional Computing (hosts visiting scholars); Advanced Computing Systems (ACS) Research activity: Thrust-centric explorations in power efficiency, and resilience
- **NSF:** CIF21, software and data enabled science, CPS, advanced manufacturing, Virtual Organizations as Sociotechnical Systems (VOSS) activities, robotics, advanced manufacturing, energy dependence, computing workforce, and smart health and wellness

4.5 Human Computer Interaction and Information Management (HCI&IM)

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

4.5.1 President's 2013 Request

4.5.1.1 Strategic Priorities Underlying This Request

HCI&IM research spans both the diverse technologies that enable people to access and use digital information (HCI) and the equally diverse technologies that expand the capabilities of computing systems and devices including the ways people interact with them (IM). In a world annually generating many times more "born-digital" information than in all the books ever written, 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. The rapid rise in the quantity and heterogeneity of data and new data sources fuels discovery, learning, and innovation in new ways, with information acting as both a catalyst and a resource. A number of multiagency initiatives, such as the proposed national Big Data Initiative, are addressing information volume, complexity, and speed of acquisition. Rapid knowledge discovery 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. Such capabilities, essential for U.S. economic growth and technological innovation, make data-related R&D a science and technology priority. New research and advances are needed in:

- **Information integration:**
  - **Standards** provide a way for data to be brought together with shared meaning, providing the basis for interoperability and relationship building which is a basic step of integrating and managing data.
  - **Decision-support systems** provide mechanisms for sifting through large, complex data sets to identify alternative strategies from the data that, without computational analysis, would strain human cognitive capabilities.
  - **Information management systems** enable individuals and organizations to create, share, and apply information to gain value and achieve specific objectives and priorities.
- **Information infrastructure:** A robust, resilient national digital data framework for long-term preservation and accessibility of electronic records as well as expanding data and records collections.

The HCI&IM agencies also support research in new methods and systems technologies that address the key needs of a diverse user community. The systems range from specific sensors and applications to mobile robotic systems to large networks of robots or sensor clouds. The overall goal is to invest in 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 technologies, or enable the devices to perform hazardous tasks in

extreme environments on behalf of people. Advances in these human-centered interactions require research in:

- **Active systems:** This research will provide novel insights into how IT systems can learn, reason, and automatically adapt to new and unforeseen events. Examples include cognitive robotics, in which a mobile manipulator could deploy a specific model of the user's mind to increase the effectiveness of interactions.
- **Multimodal interfaces, capabilities, and data:** These systems provide ways for human users to expand their cognitive reach and performance when faced with large, complex data. These can be activated by speech, human senses, movement, sounds, etc. These mechanisms provide different interactions that reflect user requirements.

4.5.1.2 Highlights of Request

The HCI&IM agencies report the following topical areas as highlights of their planned R&D investments for FY 2013. Agencies are listed in alphabetical order:

- **From data to new knowledge and action:** Analysis research and development require not only new computing research in models, algorithms, and tools to accelerate scientific discovery and productivity from heterogeneous, ultra-scale data stores, but also development of innovative, multidimensional approaches to highly complex data. For complex data, new ways should be developed to enable the intuitive display of complex interactions and mechanisms that enhance both discovery and use of data, as well as effective analytical products for decision makers and the public – AHRQ, DoD/OSD and Service research organizations, DOE/SC, EPA, NARA, NASA, NIH, NIST, NOAA, and NSF
- **Effective stewardship of science and engineering data:** This effort will maximize the value gained from current and previous Federal investments, but will require additional research in providing for life-cycle stewardship over time. Research foci include personalized access to information, as well as federation, preservation, curation, data life-cycle stewardship, and analysis of large, heterogeneous collections of scientific data, information, and records. A persistent issue is the need for fault-tolerant, scalable management of information input and output in light of new system architectures – DOE/SC, EPA, NARA, NASA, NIH, NIST, NOAA, and NSF
- **Information integration, accessibility, and management:** Multiple advances are required in technologies, system architectures, and tools for optimized, scalable ingest and processing for high-capacity data integration (especially of Geographic Information System (GIS) and spatio-temporal data), management, exploitation, modeling, and analysis. In addition, investigation continues in cloud-based infrastructures to efficiently gain distributed access to data resources utilizing new ontologies and metadata formats for discovery – AHRQ, DARPA, EPA, NARA, NASA, NIH, NIST, NOAA, and NSF
- **Earth/space science data and information systems:** These efforts enable multiagency access to and use of Federal scientific data resources through Web-based tools and services (e.g., remote visualization) that exploit advances in computer science and technology – EPA, NASA, NOAA, NSF, and other agencies
- **Health information technologies:** NITRD's new Health IT SSG is developing guidance for R&D in this area. Research needs that have been identified include expansion of clinical decision-support systems, development of more effective use of electronic health records and data, and defining national health information and device interoperability standards – AHRQ, FDA, HHS/Centers for Medicare and Medicaid Services (CMS), NIH, NIST, NSF, and other agencies
- **Information search and retrieval:** New research methods and tools are necessary for evaluation and performance measures of information-discovery technologies, as well as relevance feedback. Current

focus areas include legal discovery, recognition of opinion, and patent search, as well as machine reading of records – DARPA, NARA, NIST, and NSF

- **Cognitive, adaptive, and intelligent systems:** Algorithmic and multidisciplinary research is designed to discover the cognitive, perceptual modeling for joint cognitive systems design; autonomy, trustworthiness, and reliability of automated systems; engineered intelligence and adaptability; robotics, human-robot teaming; affective computing – DARPA, DoD/OSD and Service research organizations, NASA, NIST, and NSF
- **Multimodal language recognition and translation:** Improve multilingual language technology performance in areas of speech-to-text transcription, and text-to-text transcription. A goal is to provide spontaneous two-way communications translation, machine reading, text retrieval, document summarization/distillation, automatic content extraction, and speaker and language recognition through multimodal interfaces – DARPA, DoD/OSD and Service research organizations, NARA, NASA, NIST, and NSF
- **Human engagement and decision:** Design effective HCI and systems integration that provide personalization. This requires human-performance modeling, multimodal interfaces, and mechanisms for distributed collaboration, knowledge management, virtual organizations, and visual environments. There is a crosslink to cognitive and perceptual process modeling and measurement. Expand virtual reality technologies for simulation and training as well as biometric and voting systems – EPA, DoD/OSD and Service research organizations, NASA,NIST, NOAA, and NSF

4.5.1.3 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 and metrics – HCI&IM agencies and others
- **Biodiversity and Ecosystem Informatics Task Group:** The group provides an ongoing Federal point of contact and body for cooperation, with a focus on aspects of environmental, natural resources, and sustainability as outlined in the President's Council of Advisors on Science and Technology (PCAST) July 2011 report *Sustaining Environmental Capital: Protecting Society and the Economy* – DoD, DOE/SC, EPA, Interior, NASA, NIH, NOAA, NSF, and other agencies
- **Earth/space science, climate, and weather:** Agencies focus on cooperative activities in providing interoperable data, multidimensional models, and tools for better understanding and prediction based on the growing corpus of observational and experimental data – DoD/OSD and Service research organizations, EPA, NASA, NOAA, NSF, and other agencies
- **National Robotics Initiative:** Innovative robotics research and applications that emphasize the realization of co-robots acting in direct support of, or in a symbiotic relationship with, human partners – DoD/OSD and Service research organizations, NASA, NIH, NSF, and other agencies.
- **Information access, management, and preservation:** Multiple agencies participate in the IWG on Digital Data and the IWG on Public Access to Scientific Publications. Topics of consideration include new policy development and identification of existing standards for interoperability, such as the Digital Preservation Interoperability Framework International Standard (DPIF) – EPA, NARA, NASA, NIH, NIST, NOAA, NSF, and other agencies
- **Foundations of visualization and analysis:** This provides a multiagency mechanism for coordination of research in feature extraction for anomaly detection, integration of multiple types of

data and records at scale or format, the use of visualization as an interface, and biomedical imaging – AHRQ, EPA, DHS, NARA, NASA, NIH, NIST, NOAA, NSF, and other agencies

- **Usability:** People are the ultimate users of information. Usability research draws input from the social and behavioral sciences and informs the design and evaluation of technical solutions with the goal of ease of use. Research areas include health IT, security, voting, biometrics systems, and decision-support systems – AHRQ, NIST, and NSF

4.5.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the HCI&IM PCA:

- **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; and U.S. Health Information Knowledgebase
- **DARPA:** Autonomous robotic manipulation and machine reading; reasoning, learning across multiple layers of processing, automatic language processing, and visual intelligence
- **EPA:** Databases for computational toxicology; scientific information management (tools, best practices for management, accessibility of complex EPA data sets); and distributed environmental applications
- **NARA:** Global scale capable, open source, "next generation" cloud technologies architectures and services enabling effective sustainable management, intellectual control, and access to nationally distributed billion file and larger scale complex digital object collections
- **NASA:** Human-centered automation concepts for aviation safety; basic and applied research in human performance; decision-support technologies for 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
- **NIH:** Basic research funded under the Biomedical Information Science and Technology Initiative (BISTI)
- **NIST:** Biometrics evaluation, usability, and standards (fingerprint, face, iris, voice/speaker); multimedia evaluation methods (video retrieval, audio and video analysis); measurement, evaluation tools for 3D shape searching; data preservation metrology, standards; usability of voting and security systems; manufacturing, supply chain informatics; standards for manufacturing robots; engineering informatics sustainability; and computational biology; mathematical knowledge management
- **NOAA:** Technologies for real-time weather/climate data in multiple formats for scientists, forecasters, first responders, and citizens; remote visualization via N-Wave, new high-definition devices; and Hurricane Research Division (HRD) Forge centralized database for hurricane data, models; disaster planning, mitigation, response, and recovery
- **NSF:** Through academic R&D, NSF supports Cyberinfrastructure for the 21st Century, as well as programs for support for information privacy; ubiquitous networked data environments; human-computer partnerships; socially intelligent computing; universal access; cognition mechanisms in human learning; and remote access to experimental facilities

4.6 Large Scale Networking (LSN)

NITRD Agencies: AFRL, AHRQ, CERDEC, DARPA, DHS, DOE/SC, NASA, NIH, NIST, NOAA, NSA, NSF, ONR, and OSD

LSN members coordinate Federal agency networking R&D in leading-edge networking technologies, services, and enhanced performance, including programs in future Internet architectures, heterogeneous multimedia community testbeds; middleware, end-to-end performance and performance measurement, network security, networks for disaster response, science and engineering of complex networks; advanced networking components; cloud, grid, and collaboration networking tools and services; education, training, and outreach to support networking services; and engineering, management, and enabling large-scale networks for scientific and applications R&D, including large-scale data transfers and virtual organization functionality. The results of this coordinated R&D, once deployed, can help assure that the next generation of the Internet will be scalable, reliable, and flexible to support user applications.

4.6.1 President's 2013 Request

4.6.1.1 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 2013 will focus on:

- **Measurement, management, and control of large-scale distributed infrastructures:** Including networks, applications, management/control, sensors and their placement, metrics (supported by measurement technologies), and complex systems modeling and analysis
- **Operational capabilities:** Identify approaches and best practices for identity management, spectrum management, information assurance, energy-efficient radios/apertures, tactical communications and network technologies (e.g., dynamic ad-hoc, multi-hop wireless networks), IPv6, cloud computing, and campus interfaces and architectures for large data flows. Promote cooperation among network R&D testbeds including GENI, ANI, and others
- **Dynamic optical networking:** Coordinate the development and deployment of dynamic optical networking to support leading-edge science applications and Internet adoption (e.g., architecture and user interfaces)

4.6.1.2 Highlights of Request

The LSN agencies report the following topical areas as highlights of their planned networking R&D investments for FY 2013. Agencies are listed in alphabetical order:

- **Network architectures and protocols for future networks:** Develop network architecture concepts to enable reliable, secure, flexible, dynamic, heterogeneous networking and hybrid networking capabilities, and support sustainable environments, energy-efficient networking, and virtualization at scale – AFRL, CERDEC, DARPA, DOE/SC, Defense Research and Engineering Network (DREN), NASA, NIST, NSF, and OSD

- **Experimental network facilities:** Provide at differing scales and promote cooperation among DOE/SC's 100 Gigabit (Gb) ANI, NSF's GENI and other R&D testbeds, to support experimentation at scale in new architectures and protocols – DOE/SC, NASA, NIST, NOAA, and NSF
- **Strategic technologies for networking:** Research, develop, demonstrate new technologies for robust, secure, reliable networking for autonomous cars, intelligent (efficient) buildings, medical devices, assistive technologies, and ad-hoc IP routing infrastructure – CERDEC, DOE/SC, NIST, NSA, and NSF
- **Large-scale data flows:** Develop and test terabit-plus transport protocols and capabilities (e.g., Coronet, Online Representations and Certifications Application (ORCA), SATCOM-CX, InfiniBand single-stream flows over wide area networks [WANs]) – DOE/SC, NASA, NOAA, NSF, and OSD
- **Cloud and grid computing:** 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 – DOE/SC, NASA, NIH, NIST, NOAA, and NSF
- **Networking for health science research, clinical needs:** NIH, NIST, and NSF
- **End-to-end network management, performance measurement:** Enable cross-domain end-to-end performance measurement for advanced networking; autonomous secure management; provide tools for and implement Performance Services-Oriented Network Architecture (PerfSONAR), fault tolerance – CERDEC, DOE/SC, NASA, NIST, and NSF
- **Computational research infrastructure:** Provide networking to support U.S. and international research communities for networking research, large-scale data flows, and applications across all science disciplines – DoD, DOE/SC, NASA, NIST, NOAA, and NSF
- **Security implementation (IPv6, DNSSec, and Trusted Internet Connections [TICs]**): Develop and implement near-term mandated capabilities – DOE/SC, NASA, NIH, NIST, NSA, NSF, and OSD
- **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 – DARPA, DOE/SC, NASA, NIH, NIST, NSF, and OSD
- **Network science and engineering:** Develop concepts, methods, architectures, protocols, and measurement for modeling networks as complex, autonomous, and dynamic systems – DARPA, DOE/SC, NIST, and NSF
- **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; and sensing and control systems – CERDEC, DARPA, NASA, NIST, NSF, ONR, and OSD
- **Public-safety networking, disaster recovery, and crisis management:** Disaster Information Management Research Center (DIMRC), public-safety communications, implant communication system – NIH (NLM), and NIST

4.6.1.3 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:** Workshops on networking for extreme-scale science and data flows; experimentation, network management, smart grid, DETER, PerfSONAR deployability; experimental design for complex systems; and network performance measurement – LSN agencies
- **Infrastructure cooperation:** National and international connectivity – DoD, DOE/SC, NASA, NOAA, and NSF
- **Multiagency workshops:** Modeling and mathematics of complex distributed systems; leveraging PerfSONAR and implications for Internet instrumentation research; semantically rich descriptions of networked systems – Multiple agencies
- **Trans-Oceanic Networking for Science** – DOE/SC and NSF
- **Inter-service collaboration**: Services for federation, management, information, discovery, and delivery – AFRL, CERDEC, and ONR
- **Digital policy management** – CERDEC and NSA
- **Coordination by LSN Teams**
  - **Joint Engineering Team (JET):** DOE/SC, NASA, NIH, NOAA, NSA, NIST, NSF, Naval Research Laboratory (NRL), and USGS, with DOD (HPCMP), participation by national laboratories (ANL, and Brookhaven National Laboratory (BNL), academic organizations (Corporation for Network Initiatives in California [CENIC], Global Ring Network for Advanced Applications Development [GLORIAD], Internet2, ISI, Mid-Atlantic Exchange [MAX], National Laboratory for Applied Network Research [NLANR], PNW-GigaPoP, StarLight), supercomputing centers (Artic Region Supercomputing Center [ARSC], Microelectronics Center of North Carolina [MCNC], and Pittsburgh Supercomputing Center [PSC]), universities (Florida International University [FIU], Indiana University [IU], Massachusetts Institute of Technology [MIT], Northwestern, Texas A&M University [TAMU], University of Delaware [UDel], University of Illinois-Chicago [UIC], University of Maryland [UMd], University of North Carolina [UNC], University of Southern California (USC), University of Utah [UU], University of Washington [UW], and Yale), and vendors – Advanced testbeds, coordination of end-user requirements, engineering of research networks and testbeds (JETnets); security best practices, applications testbeds (DNSSec, IPv6, performance measurement); TICs coordination; interdomain and end-to-end metrics, monitoring; tool sharing and exchange; international coordination; and transit and services cooperation
  - **Middleware And Grid Infrastructure Coordination (MAGIC) team:** AFOSR, DOE/SC, NASA, NIH, NIST, NOAA, and NSF with participation by academic organizations (EDUCAUSE, Internet2, Information Sciences Institute [ISI], National Center for Supercomputing Applications [NCSA], Renaissance Computing Institute [RENCI], Southeastern Universities Research Association [SURA], and University Corporation for Atmospheric Research [UCAR]), National labs (ANL, LANL, Lawrence-Berkeley National Laboratory [LBNL], Pacific Northwest National Laboratory [PNNL]), universities (California Institute of Technology [CalTech], IU, Louisiana State University [LSU], Texas Tech University [TTU], UDel, University of Chicago [UChi], University of Illinois-Urbana-Champaign [UIUC], UMd, UNC, University of Wisconsin [UWisc], and University of Virginia [UVa]) and vendors – Cloud computing services, grid computing services, middleware; cloud and grid standards and implementation status (TeraGrid, Open Science Grid [OSG], Earth Systems Grid (ESG), Center for Enabling Distributed Petascale Science [CEDPS], cancer Biomedical Information Grid [caBIG], and Biomedical Informatics Research Network [BIRN]), security and privacy (e.g., identity management); and international coordination

- **Information exchange:** Multiagency participation in review panels, informational meetings, principal investigator (PI) meetings; coordination among program managers; and joint JET, DOE Energy Sciences network Steering Committee (ESSC) and Internet2 Joint Techs Meetings – AFRL, DARPA, DHS, NASA, NIST, NSA, and NSF
- **Partnerships for research connectivity** – DOE/SC, DREN, NASA, NOAA, and NSF

4.6.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the LSN PCA:

- **AFRL:** Low-observable communications, aerial vehicle optical communications
- **AHRQ:** With ONC, health care IT (develop, evaluate IT tools to improve quality of care and patient safety; demo statewide, regional information networks; and integrate with Nationwide Health Information Network data standards)
- **CERDEC:** Spectrum management, internetwork policy negotiations, and joint common operational picture
- **DARPA:** Mobile wireless communication systems and networks; increased network capacity and scaling; spectrum efficiency in congested spectrum; tolerate network degradation; electromagnetic interference mitigation; counter network reconnaissance and surveillance; and counter DNS and other cybersecurity threats
- **DOE/SC:** ANI-100 Gb networking (technology, infrastructure, testbed, scaling middleware, coupled applications, data movement); hybrid technology for dynamic network allocation, research for Tbps networking, collaboration systems and scalable workflows for distributed intensive science, middleware for distributed science, distributed resource ensembles for petascale science collaboration; and systems for remote visualization and operations, real-time collaboration, scalable performance measurement; and federated network joint engineering taskforce
- **NASA:** 40-100 Gb access to unrestricted (non-TIC) science data, network access control, and IT Infrastructure Integration Program (security, emerging technology, strategic and innovation planning), and IPv6 transition
- **NIH:** Health care IT, infrastructure creation; and applications (Web, wireless, grid-based, distributed databases and repositories, and TeraGrid)
- **NIST:** Measurement science for complex systems; Internet infrastructure protection, public safety communications; personal and medical devices models and standards, smart grid, and seamless cloud computing
- **NOAA:** Integration of and access to HPC and data centers, support to remote users; test, measurement and analysis tools; improved security, and science DMZ protocol
- **NSA:** Delay-tolerant and ad hoc networking, and wireless testbeds
- **NSF:** Core and Strategic Networking Research (NeTS); Computing Research Infrastructure (CRI) for science; trustworthy network architecture, understanding complexity, robust socio-technological networking; Future Internet Architectures (FIA); reconfigurable network architectures at scale (GENI); wireless, mobile, and sensor systems; cyber-physical systems networking; social-computational systems; education and outreach; middleware; and performance-monitoring capabilities, international infrastructure (International Research Network Connections [IRNC]), software and strategic technologies for cyberinfrastructure
- **ONR:** Social networking analysis, layerless networking (wireless), and interference alignment for tactical networks

- **DoD (HPCMP):** Multidomain performance measurement; security (IPsec, Virtual private network [VPN] portals, security assessment script, Kerberos development, filters, encryption, data attribution); and network high-speed access to DOJ, Hawaii, and Alaska

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

NITRD Agencies: DOE/NNSA, DOE/SC, NIH, NIST, and NSF
Other Participants: ONR and OSD

Research activities funded under the SEW PCA focus on the co-evolution of IT and social, economic, and workforce systems including interactions between people and IT and among people developing and using IT in groups, organizations, and larger social networks. Collaborative science concerns are addressed including improving the effectiveness of teams and enhancing geographically distributed, interdisciplinary R&D to engage societal concerns, such as competitiveness, security, economic development, and well-being. Workforce concerns are addressed by leveraging interagency efforts to improve education outcomes through the use of learning technologies that anticipate the educational needs of individuals and society. SEW also supports efforts to speed the transfer of R&D results to the policymaker, practitioner, and IT user communities in all sectors.

4.7.1 President's 2013 Request

4.7.1.1 Strategic Priorities Underlying This Request

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 e-science to cyber-learning, 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 writing open-source software, classifying galaxies, and identifying words in non-machine-readable text. Global multidisciplinary teams connected through cyberinfrastructure play a central role in addressing societal needs, such as developing economical solar power, mitigating environmental disasters, delivering new medical interventions, and maintaining our national security. 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 action. In this new era, developing cyber-capable citizens is also critical – from the ability to use digital capabilities wisely and effectively, to the IT skills and knowledge needed in the advanced technical workforce of tomorrow. It is imperative that the general populous be able to understand the challenges in complex systems, such as health care information infrastructures, e-commerce, and cyber-learning as well as appreciate the trade-offs among privacy, security, and reliability. SEW priorities exemplify the scope of these concerns among the NITRD agencies. Many SEW activities involve extending understanding and applications of IT to help people learn, conduct research, and innovate more effectively. Key focus areas include:

- **Science of collaboration**
  - **IT-enabled innovation ecology:** Shape the creation of IT and research on IT-enabled collaboration in ways that improve the conduct of science and engineering now and in the future
  - **Integrated multidisciplinary research:** Support research, development, and education that address societal challenges using a systems-based approach to understand, predict, and react to changes in the linked natural, social, and man-made environment – especially in climate change, energy, health, education, and security
  - **Humans in the loop:** Advance our understanding of the complex and increasingly coupled relationships between people and computing, with an emphasis on IT designed to fit the needs of its users, and enable explorations of creative ideas, novel theories, and innovative technologies that promise to transform the way humans communicate, work, learn, play, and maintain their health

- **IT and education**
  - **Cyber-learning:** Promote understanding and support for effective IT-enabled learning in all education settings to enhance learning anytime in any location, and provide learning personalized and tailored to the needs of diverse learners; and transform science teaching across education and settings
  - **Computational competencies for everyone:** Explore how the nature and meaning of computational competence can be incorporated into K-12, informal, and higher education
  - **IT education and training:** Develop innovative approaches to broadening interest and participation in 21st Century IT careers, including information assurance and computer security

4.7.1.2 Highlights of Request

The SEW agencies report the following areas as highlights of their planned R&D investments for FY 2013. Agencies are listed in alphabetical order:

- **Science of collaboration**
  - **Multidisciplinary centers, institutes, and communities:** Support collaborative activities to advance a field or create new directions in research or education by enabling coordination of research, training and educational activities across disciplinary, organizational, geographic, and international boundaries. Create centers to coordinate multi-year activities addressing national challenges such as translational sciences, energy efficiency, environmental sustainability, advanced communication, transportation, learning, and health care systems – DOE/NNSA, NIH, and NSF
  - **Geographically distributed organizations as socio-technical systems:** Advance understanding of how to develop effective distributed organizations and how they can enhance collaborative scientific, engineering, and education research production and innovation – NSF and other agencies
  - **Social computational systems:** Develop new understandings of social computing (i.e., integrated systems of people and computers) and develop practical understandings of the purposeful design of such systems including robotics, cyber-physical systems, and handling big data – NIH and NSF
  - **Human-centered computing:** Focus on the co-evolution of social and technical systems to create new knowledge about human-machine partnerships – NIH and NSF
  - **Improving health and wellbeing:** Leverage the scientific methods and knowledge bases of a broad range of computing and communication research perspectives to facilitate long-term, transformative change regarding how we treat illness and maintain our health; and improve safe, effective, efficient, equitable, and patient-centered health and wellness services – NIH and NSF
  - **Sustainability science, engineering, and education:** Generate the discoveries and capabilities in climate and energy science and engineering needed to inform societal actions that lead to environmental and economic sustainability; and support interdisciplinary communities focused on sustainability science – NSF
- **IT and education**
  - **Advanced learning technologies:** Understand advanced learning technologies that have demonstrated potential to transform science, technology, engineering, and mathematics (STEM) teaching and learning at all levels across all societal settings; understand technologies that can contribute to a highly interdisciplinary technical STEM workforce; enable new avenues of STEM learning with novel, collaborative, and global learning experiences for students, the general public, and the emerging IT workforce; advance the Nation's ability to more discretely study the learning process and rapidly deploy new understandings and adaptive and assistive resources in

education to broaden participation of all Americans in STEM R&D, including returning disabled veterans – NSF and ONR

- **Cybersecurity education:** Bolster formal education programs to focus on cybersecurity and STEM – NIST and NSF
- **Cybersecurity workforce training and professional development:** Intensify training and professional development programs for existing cybersecurity workforce – DHS, DoD, NIST, and other agencies

4.7.1.3 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-Ed agenda. SEW also continues to support interactions between IT researchers, practitioners, and government policymakers. Forthcoming activities include:

- **Articulate program and priority similarities across agencies:** Develop coordination plans for sharing robust practices; identify gaps and develop plans to prioritize and address them; incorporate input from a broad cross-section of stakeholders; and prepare a comprehensive strategic plan document – SEW agencies and others

4.7.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the SEW PCA:

- **DoD:** Develop world-class science, technology, engineering, and mathematics capabilities for DoD and the Nation; inventory of DoD educational programs; and complete DoD-wide STEM Strategic Plan and begin implementation phase including communications, marketing of programs and opportunities
- **DOE/NNSA:** Critical-skills development program for university participants in the Advanced Simulation and Computing (ASC) Alliance Program
- **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; and 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 citizens
- **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; Cyberinfrastructure Training, Education, Advancement and Mentoring (CI-TEAM) for Our 21st Century Workforce program to prepare the next generation of scientists, engineers, and educators able to exploit and promote cyberinfrastructure in science and engineering research and education; Transformative Computational Science using CyberInstrastructure (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, and junior faculty; and promote digital gaming in education

- **ONR:** The Information Dominance and Cybersecurity program seeks to advance the science of security through interdisciplinary research to ensure safe and secure operations in cyberspace; the Naval Research Enterprise Summer Intern Program (NREIP) allows students to participate in naval research; Mission Ocean allows fifth-through eighth-grade level students to gain hands-on experience operating a simulated submarine; and the SeaPerch Program provides students with the opportunity to learn about robotics, engineering, science, and mathematics while building an underwater remotely operated vehicle (ROV) as part of a science and engineering curriculum

4.8 Software Design and Productivity (SDP)

NITRD Agencies: AFOSR, DHS, NASA, NIH, NIST, NOAA, NSF, ONR, and OSD
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, and tools) 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. The core SDP R&D activities are software productivity, software cost, responsiveness to change, and sustainment. The success of these activities will have a major beneficial effect on high-confidence systems because they are critically dependent upon the quality of the software and on the many companies producing software reliant products.

4.8.1 President's 2013 Request

4.8.1.1 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.). These large-scale systems typically must remain operational, useful, and relevant for decades. The involved agencies are working to identify and define the core elements for a new science of software development that will make engineering decisions and modifications transparent and traceable throughout the software lifecycle (e.g., design, development, evolution, and sustainment). A key goal of this science framework is to enable software engineers to maintain and evolve complex systems cost-effectively and correctly long after the original developers have departed. This new science of software development will also benefit the many companies producing software-reliant products that comprise an increasing portion of the economy. 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:** Develop new computational models and logics, techniques, languages, tools, metrics, and processes for developing and analyzing software for complex software-intensive systems (e.g., a fundamental approach to software engineering that can provide systems that are verifiably correct, assured, efficient, effective, reliable, and sustainable).
  - **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; and next-generation software concepts, methods, and tools will be needed for emerging technologies such as multicore, software-as-a-service, cloud computing, end-user programming, quantum information processing; and 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 engineering artifacts to support long-lived software-intensive systems; new approaches to reliably meet changing requirements and

assure security and safety; and 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 deterministic engineering tasks; and scalable analysis, test generation, optimization, and verification with traceability to requirements; related issues include:
  - **Software application interoperability and usability:** Develop interface and integration standards, representation methods to enable software interoperability, data exchanges, interoperable databases; supply-chain system integration; and 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

4.8.1.2 Highlights of Request

The SDP agencies report the following topical areas as highlights of their planned R&D investments for FY 2013. Agencies are listed in alphabetical order:

- **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; V&V tools for sound development of reliable and assured software; formal definitions of weaknesses; standards for certification; and techniques that enable prediction of cost and schedule for large-scale software projects – AFOSR, NASA, NIST, NOAA, NSF, ONR, and OSD
- **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 – AFOSR, NASA, NSF, ONR, and OSD
- **Intelligent software design:** Investigate approaches to design 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; and languages and modeling tools that support interoperability, data exchange among engineering tools, large-scale simulations, federated information systems – AFOSR, NASA, NIST, NOAA, NSF, ONR, and OSD
- **Interoperability standards, knowledge capture processes:** Develop representation schemes 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; and infrastructure for capture, reuse of domain expertise – NOAA, ONR, and OSD

4.8.1.3 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.

- **Software verification and validation:** Ongoing collaboration to develop effective approaches for next-generation air transportation – FAA and NASA
- **SDP Cross Agency and National Needs Summit:** Provided a focus for the results from the Future of Software Engineering Research (FoSER) Workshop Report; established a Wiki to discuss and formulate software and productivity research goals and priorities – 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 (National Center for Atmospheric Research [NCAR]), DOE/SC, and DoD/OSD and Service research organizations
- **Next-generation aircraft:** Collaboration on concepts, modeling and simulation tools – DoD/OSD and Service research organizations, and NASA

4.8.2 Additional 2012 and 2013 Activities by Agency

The following list provides a summary of individual agencies' ongoing programmatic interests for 2012 and 2013 under the SDP PCA:

- **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, and synthesis; modeling of human-machine interaction; advanced algorithms for real-time and distributed systems; and language-based assurance; and formal analysis and verification
- **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; and physics-based multidisciplinary analysis optimization framework (MDAO) for cost-effective advanced modeling in development of next-generation aircraft and spacecraft
- **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; precisely and accurately define classes of software weaknesses which will serve as a basis for tool interoperability and proofs that a tool or technique precludes certain classes of weaknesses; run SATE to understand the contribution of such tools to assurance; and convene Software Testing Metrics and Standards workshop to document state of the art in testing and to map gaps and needed research
- **NOAA:** Standard and consistent software development practices for environmental modeling; continue adoption of Earth System Modeling Framework (ESMF) as part of overall modeling activities; and computer science aspects of software development, including collaboration with universities on programming model for fine-grain parallel architectures
- **NSF:** Advance core research on the science of software development and software evolution including formal and automated development methods, programming languages and methodologies, software testing and analysis, empirical software research, and human-centered computing. Coordinate SDP-related areas (e.g., productivity, cost, responsiveness of software, and evolution) crosscutting topics and programs, including Software Infrastructure for Sustained

Innovation in Science, Secure and Trustworthy Cyberspaces, and effective software design for real-world systems in health care, manufacturing, etc.; and Science, Engineering, and Education for Sustainability (SEES) research on software advances to meet energy requirements in computation and communication

- **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; and software for quantum processing
- **OSD:** Technologies with defense-wide applications for producing more efficient software that maximizes the computing power of multi-core processors and for the design and production of mission and safety-critical software for cyber-physical systems. This includes tools and techniques to improve the efficiency of software production such as: correct-by-construction methods; model-driven development; validation and verification of large-scale, complex systems (greater than 20 million lines of code); software visualization; static and dynamic analysis; deterministic behavior in software; interoperable multi-scale, multi-domain models; efficient execution and coordination of distributed and multi-core processing; and quantitative representations of risk and uncertainty in software development

5 Senior Steering Groups (SSGs)

5.1 Big Data Research and Development Senior Steering Group (BD R&D SSG)

Participating Agencies: DARPA, DoD/OSD and Service Research Organizations, DOE/SC, NASA, NIH, NIST, NOAA, NSA, and NSF

5.1.1 Mandate/Mission

The BD R&D SSG was formed in early 2011 to identify current big data research and development activities across the Federal government, offer opportunities for coordination, and identify the goals of a potential national initiative in this area. The science of data includes the process of turning data into knowledge, data mining and visualization, interoperability, search and discovery, and semantics. As data volumes grow exponentially, so does the concern regarding data preservation, access, dissemination, and usability. Research such as automated analysis techniques, data mining, machine learning, privacy, and database interoperability will help identify how Big Data can advance science in futuristic ways and inspire revolutionary research techniques.

5.1.2 Strategic Priorities

The BD R&D SSG defines its vision as a future in which the ability to analyze and extract information from large, diverse, and disparate data sets accelerates the process of scientific discovery and innovation; promotes new economic growth; and leads to new fields of research and new areas of inquiry that would otherwise be impossible. The BD R&D SSG strategic priorities include:

- Promoting new science, addressing key science questions, and accelerating the process of discovery by harnessing the value of large, heterogeneous data
- Exploiting the unique value of big data to address areas of national need, agency missions, and societal and economic importance to all parts of society
- Supporting responsible stewardship and sustainability of data resulting from Federally funded research.
- Developing and sustaining the infrastructure needed to advance data science and broaden the participation in data-enabled inquiry and data-driven action, at all levels

5.1.3 Deliverables and Planned Activities

The BD R&D SSG has exceeded their goals for year one with the following deliverables and activities:

- *Big Data – Near-term Opportunities Report*: A multi-agency assessment of current projects that exist within the Federal Government
- *Vision and Goals Statements for a Big Data Initiative Report*: Developed with input from nine agencies.
- Established four working groups in the areas of core technologies, domain research projects, education and training, and competitions and challenges to help identify and further develop "building block" programs that can be launched or expanded
- Organized "Toward Innovative Spectrum-Sharing Technologies: A Technical Workshop on Coordinating Federal Government/Private Sector R&D Investments" to analyze and categorize the challenges pertaining to big data as either a traditional grant-funded research project or a challenge/competition opportunity
- Published a core technology joint agency solicitation
- Developed a framework for a prize competition
- Future workshops will focus on education and establishing domain research centers

5.2 Cybersecurity and Information Assurance Research and Development Senior Steering Group (CSIA R&D SSG)

Participating Agencies – DHS, DNI, DoD/OSD and Service Research Organizations, NIST, NSA, and NSF

5.2.1 Mandate/Mission

The CSIA R&D SSG was formed in response to the January 2008 Comprehensive National Cybersecurity Initiative (CNCI) – National Security Presidential Directive 54/Homeland Security Presidential Directive 23. This initiative called for the Director of the Office of Science and Technology to "develop a detailed plan to coordinate classified and unclassified cyber research." The purpose of the CSIA R&D SSG is to provide overall leadership for cybersecurity research and development coordination, to address the need for streamlined decision processes and dynamic responsiveness to changing research and budget priorities. The CSIA R&D SSG is composed of senior representatives of agencies with national cybersecurity leadership positions.

5.2.2 Strategic Priorities

The CSIA R&D SSG seeks principally to streamline the communication between research planning among agencies' technical managers and budgetary decision making to accelerate advances in transformative research and deployable technologies. The CSIA R&D SSG is therefore positioned to communicate research needs and proposed budget priorities to policy makers and budget officials. Similarly, the CSIA R&D SSG relays priorities and other pertinent information from higher Federal policy levels to inform research and development coordination activities. The CSIA R&D SSG's strategic priorities include:

- Prioritizing Federal cybersecurity research and development investments and ensuring that the entire spectrum of research and development priorities and key technology challenges across the Federal government are being addressed
- Leading strategic research and development coordination efforts in addressing the Administration priorities (such as the President's Cyberspace Policy Review)
- Formulating and evolving a framework for research and development strategies that focuses on game-changing technologies

5.2.3 Deliverables and Planned Activities

The CSIA R&D SSG has been a driving force in the development and delivery of the first Federal cybersecurity research and development strategic plan (*Trustworthy Cyberspace: Strategic Plan for the Federal Cybersecurity Research and Development Program)*. The CSIA R&D planned activities include:

- Coordinating the development of agency programs to include strategic research and development objectives and the allocation of Federal budgets to support them
- Developing and sponsoring events, such as workshops, to advance the national research agenda necessary to fulfill key objectives of the strategic plan
- Publicizing and promoting the strategic plan within the technical research community, in academia, industry, and government
- Continuing to focus on effective Federal cybersecurity research and development coordination among government agencies and with academia and industry by prioritizing research needs and determining appropriate investment strategies, enabling broad multidisciplinary and multisector efforts, enabling agencies to leverage resources, and improving synergy between classified and unclassified Federal research
- Exploring the strategic plan's research themes and how they can drive better security solutions in sectors such as the Smart Grid, health IT, and transportation, with an emphasis on the most recently introduced Designed-In Security theme

- Cultivating and supporting a research community in the area of the science of security
- Developing focused activities to help accelerate the transition of research into practice

5.3 Health Information Technology Research and Development Senior Steering Group (HIT R&D SSG)

Participating Agencies – AHRQ, ASPR, CDC, DoD, FDA, IHS, NIH, NIST, NSF, ONC, and VA

5.3.1 Mandate/Mission

The HIT R&D SSG was established in the fall of 2010 in response to Section 13202(b) of the American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5) which directed the NITRD Program to include Federal research and development programs related to health information technology.

The HIT R&D SSG established the Health Information Technology Innovation and Development Environments (HITIDE) Subgroup. The aim of the HITIDE Subgroup is to advance the development of interoperable health IT systems by leveraging the existing testbed environments of Federal agency health IT systems for a virtual test, development, and innovation ecosystem.

The HITIDE Subgroup participants are working collaboratively, and with OSTP support, to solve the issues identified and move forward on interagency opportunities to advance interoperable health IT systems and health data exchange. Under HITIDE, the DoD and VA are currently cooperating on interconnecting agency testbeds to advance interoperability for the DoD/VA integrated Electronic Health Record (iEHR) project. Other agencies under HITIDE are collaborating to broaden interoperability among a wider range of electronic health records (EHRs) and health IT systems.

5.3.2 Strategic Priorities

The HITIDE Subgroup focuses on governance challenges, operational opportunities, and issues relevant to HITIDE projects. Its current interests include interoperability, standards, de-identified test data, and organizational barriers. Briefings held in 2011 on these topics included: lessons learned in establishing development test centers (DoD/ MHS); using synthetic data as test data (DoD/ TATRC); identifying content resources and tools available to developers (NLM); identifying issues and challenges with medical device interoperability (NIH Affiliate, ONC SHARP program); and developing substitutable, modular applications for health IT systems (ONC SHARP program). The strategic priorities of the HIT R&D SSG and the HITIDE Subgroup include:

- Addressing multiagency leadership in health IT interoperability and the development of innovative applications
- Bringing together health and research and development IT communities to focus on health IT research and development needs

5.3.3 Deliverables and Planned Activities

The HIT R&D SSG is developing a report on the research and development needs in health IT. The report, which is currently under review, presents research and development themes for planned activities and programs that include:

- Health information infrastructure and exchange: Research and develop a Universal Exchange Language and knowledge representation models for EHRs; provide testbeds for interoperability testing and IT innovations; promote an open platform architecture that allows modular, substitutable biomedical applications for use in health IT systems; and develop strong security and privacy mechanisms to protect patient health data from misuse
- Decision support in traditional and emerging healthcare areas: Accelerate the transformation from data-to-knowledge-to-decision for improved health outcomes. The goal is to connect measurable improvements in health outcomes to actionable decision support systems that are kept current with the latest evidence-based guidelines. Research and development will enable the development of

decision support systems for clinicians and patients, systematic uses of data aggregated from EHRs, integration of health IT for disaster preparedness and response, and clinical trials re-engineering.

- Assistive systems, devices, and robotics for clinical and consumer use: Research and develop standards for interoperable devices, medical alarms, and alerts; assistive systems, devices, and robotic aids; and modeling and simulation for medical device design
- Empower patients: Research and develop user interfaces that support new modes of care and care relationships, collaboration technologies and social computing, and health data collection and intervention technologies

5.4 Wireless Spectrum Research and Development Senior Steering Group (WS R&D SSG)

Participating Agencies – DARPA, DHS, DoD/OSD and Service Research Organizations, DOE/INL, DOE/Oak Ridge, DOJ, FAA, FCC, NASA, NEC, NIST, NSA, NSF, and NTIA

5.4.1 Mandate/Mission

The WS R&D SSG was established in 2010 in response to the June 28, 2010 *Presidential Memorandum – Unleashing the Wireless Broadband Revolution*.[4] The memorandum calls for NITRD to assist the Secretary of Commerce in creating and implementing a plan to facilitate research, development, experimentation, and testing by researchers to explore innovative spectrum-sharing technologies.

5.4.2 Strategic Priorities

WS R&D SSG members, such as DARPA and NSF, are working alongside academic and private-sector researchers and have been funding research and development techniques that could potentially enable many different wireless devices to use congested airwaves without disrupting high-priority uses (e.g., disaster response and national security communications). Working within the requirements of the Presidential Memorandum and with guidance from the President's Chief Technology Officer, the WS R&D SSG has established a set of objectives and a schedule of near-term actions and deliverables to facilitate collaboration in research and development to drive these new technologies. The WS R&D SSG priorities are guided by the following strategic objectives:

- Transparency: Communicate to both Federal agencies and the private sector the research and development activities currently being pursued or planned, and help identify areas that still need to be addressed.
- Smart investment: Develop strategies that can supplement funding for research and development and/or increase the efficiency of existing investments.
- Solicit opportunities: Identify opportunities for spectrum technology transfer between Federal agencies and the private sector.

5.4.3 Deliverables and Planned Activities

The WS R&D SSG is working with NTIA and NSF, in developing a series of reports based upon findings gathered by the WS R&D SSG. The group is using informational meetings and public-private workshops to compile and analyze the required information for these documents. The WS R&D SSG has exceeded their goals for year one with the following deliverables and planned activities:

- Delivered first interim report: This initial report drew from data provided by WS R&D members on their current and planned research and development activities. Based on that inventory of more than 670 individual projects across 12 agencies, the report presented a preliminary analysis of research and development needs and a long term plan. A copy of the report and inventory was made available online.
- Held first industry/academia workshop: The group presented its initial findings to a panel of 28 industry and academic researchers, with discussion focused on three major areas: identifying what spectrum-sharing activities are currently feasible; what technological gaps exist in current research; and what specific research the Federal government should invest in to help promote innovation in

[4] http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution, Section 3.

spectrum-sharing technologies and to make a shared environment practicable for both the public and private sectors.

- Delivered second interim report: This report described and summarized the results of the first industry/academia workshop.
- Held a second industry/academia workshop: This workshop focused on the expressed need for improved access to testbeds that can simulate the requirements for spectrum-sharing technologies operating across multiple systems. In preparation for the workshop, the WS R&D SSG developed an inventory of existing Federal wireless testbeds, including their capabilities and limitations. The information was presented at the workshop with the goal of better leveraging existing capabilities and identifying additional testbed requirements necessary to attract government, industry, and academic researchers.
- A third interim report is scheduled for delivery in the spring of 2012. This report will summarize the findings from the workshop held on improving access to testbeds.
- A third industry/academia workshop is scheduled for the summer of 2012. The goal of this workshop will be to develop a set of recommendations to direct future Federal research and development on spectrum-sharing technologies toward achieving a wireless environment that promotes and facilitates spectrum-sharing activities.
- A fourth interim report is scheduled for the fall of 2012. This report will deliver the recommendations developed as a result of the preceding workshops and inventories. The recommendations will strive to propose concrete, short-term projects to help stimulate innovation in this area, as well as propose a timeline consistent with the goals stated in the Presidential Memorandum.

6 Community of Practice (CoP)

6.1 Faster Administration of Science and Technology Education and Research (FASTER) Community of Practice (CoP)

NITRD Agencies: DARPA, DoD/OSD and Service Research Organizations, DOE/SC/ ASCR, DHS, NASA, NIST, NARA, NIH, and NOAA
Other Participants: VA

The Federal CIO Council, under the leadership of OMB, coordinates the use of IT systems by Federal agencies and NITRD coordinates the federally supported IT research under the leadership of OSTP. FASTER is a Community of Practice (CoP) of science agency CIOs and/or their advanced technology specialists whose mission is to improve the communication and coordination between these two inter-agencies. FASTER is organized under the interagency NSTC Subcommittee on Networking and IT Research and Development to focus on the IT challenges specific to supporting the Federal scientific research enterprise.

6.1.1 Strategic Priorities

The CoP has identified several themes to promote the use of advanced IT systems to support the science agency research and development missions. Through coordination and collaboration it seeks to share information on protocols, standards, and best practices, technology assessments, testbeds, and accelerate deployment of promising research technology. Consensus among the participants determines the focused theme activities that are coordinated with the CIO Council, and OSTP, among others. The group's activities are focused on the following strategic themes:

- Cloud computing
- Semantic web and ontology technology
- Open government
- Emerging technologies
- Sharing knowledge, ideas, and best practices

6.1.2 Deliverables and Planned Activities

FASTER's goal is to enhance collaboration and accelerate agencies' adoption of advanced IT capabilities developed by Government-sponsored IT research. FASTER hosts Expedition and Emerging Technology workshops as well as monthly meetings with invited guest speakers to achieve this goal, including:

- Cloud computing: FASTER supported a Cloud Computing Forum & Workshop IV offered by NIST under the U.S. Government Cloud Computing Technology Roadmap initiative to develop a NIST Cloud Computing Standards & Technology Roadmap concerning interoperability, portability and security.
- Semantic web and ontology: The NCO is working with the FASTER's Semantic Web Ontology Team (SWOT) to understand the potential of semantic technologies for data representation and analysis.
- Open government: Government innovators, academia, and industry discussed openness in the context of education, health, and economic policy, including the international arena, at the Open Government Research & Development Summit which was cosponsored in conjunction with NARA and with support from the MacArthur Foundation.
- Emerging technologies: FASTER supports the Emerging Technologies Subcommittee of the CIO Council's Architecture and Infrastructure Committee (AIC) with Expedition and Emerging Technology

Workshops that provide coordination opportunities among government agencies, academia, and industry.

- Sharing knowledge, ideas and best practices: FASTER plans to broaden its coordination efforts by addressing ways to improve the consumerization of IT and exploit innovative ways to advance the explosion of mobile applications that will serve to expedite the translation of research results. Currently it is exploring the use of challenges rewarded by prizes to bring the public and government together to solve problems.

7 Membership in the NITRD Program

The NITRD Program was established by the High Performance Computing Act of 1991 and provides a framework and mechanism for coordination that support advanced Networking IT R&D. The benefits and responsibilities of NITRD membership are outlined below.

7.1 Benefits of NITRD Membership

- Participate in a multi-agency coordination program that seeks to ensure U.S. Networking Information Technology (NIT) R&D leadership and accelerate deployment of advanced and experimental information technologies
- Synergistically share NIT research program information to advance new technologies more rapidly, innovate more effectively to improve economic competiveness, be better informed about the overall Federal investment in the NIT R&D portfolio, leverage the work of other agencies, avoid duplicative efforts, and develop collaborative multi-agency research activities
- Interface with NITRD members representing diverse mission agencies to identify the national and global cross-sectional NIT research priorities
- Participate in workshops involving the public, academic, and private sectors to ensure that the Nation leverages its strengths and increases interoperability in critical NIT areas

7.2 Responsibilities of NITRD Membership

- Provide request for membership from a policy-level authority
- Assign a representative and one or more alternates to serve on the NITRD Subcommittee
- Assign a representative(s) to actively participate in the PCA's where funding is reported in the NITRD Budget crosscut
- Provide inputs to NITRD's Annual Supplement to the President's Budget
- Provide proportional funding to support the NITRD/NCO operations

8 NITRD Program Component Area (PCA) Co-Chairs

Cybersecurity and Information Assurance (CSIA) Interagency Working Group

Co-Chairs

- Douglas Maughan, DHS
- William D. Newhouse, NIST

High Confidence Software and Systems (HCSS) Coordinating Group

Co-Chairs

- Helen D. Gill, NSF
- William Bradley Martin, NSA
- Albert J. Wavering, NIST

High End Computing (HEC) Interagency Working Group

Chair

- Bryan Biegel, NASA

Vice-Chair

- Barry Schneider, NSF

Human-Computer Interaction and Information Management (HCI&IM) Coordinating Group

Co-Chairs

- Leslie A. Collica, NIST
- Sylvia Spengler, NSF

Large Scale Networking (LSN) Coordinating Group

Co-Chairs

- Robert J. Bonneau, AFOSR
- Daniel A. Hitchcock, DOE/SC
- Bryan Lyles, NSF

LSN Teams:
Joint Engineering Team (JET)

Co-Chairs

- Vince Dattoria, DOE/SC
- Kevin Thompson, NSF

Middleware and Grid Infrastructure Coordination (MAGIC) Team

Co-Chairs

- Gabrielle Allen, NSF
- Richard Carlson, DOE/SC

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

Co-Chairs

- C. Suzanne Iacono, NSF
- Susan Winter, NSF

SEW-Education Team

Co-Chairs

- Arlene de Strulle, NSF
- Ernest McDuffie, NIST

Software Design and Productivity (SDP) Coordinating Group

Co-Chairs

- Simon P. Frechette, NIST
- Sol Greenspan, NSF
- James Kirby, NRL

Table 8. NITRD PCA Co-Chairs

9 NITRD Senior Steering Group (SSG) and Community of Practice (CoP) Co-Chairs

Big Data SSG
Co-Chairs • C. Suzanne Iacono, NSF • Karin Remington, NIH • George O. Strawn, NCO
Cybersecurity and Information Assurance R&D SSG
Co-Chairs • Keith Marzullo, NSF • Mark A. Luker, NCO
Health Information Technology R&D SSG
Co-Chairs • Douglas Fridsma, HHS/ONC • Donald A.B. Lindberg, NIH/NLM • Howard D. Wactlar, NSF • George O. Strawn, NCO
Wireless Spectrum R&D SSG
Co-Chairs • Byron Barker, NTIA • Andrew Clegg, NSF • Mark A. Luker, NCO

Table 9. NITRD SSG Co-Chairs

Faster Administration of Science and Technology Education and Research (FASTER) Community of Practice (CoP)
Co-Chairs • Robert Bohn, NIST • Robert Chadduck, NARA

Table 10. NITRD CoP Co-Chairs

Abbreviations and Acronyms

ACS – Advanced Computing Systems
AEH – Airborne electronic hardware
AFOSR – Air Force Office of Scientific Research
AFRL – Air Force Research Laboratory
AHRQ – HHS's Agency for Healthcare Research and Quality
AIC – Architecture and Infrastructure Committee
ANI – Advanced Networking Initiative
ANL – DOE's Argonne National Laboratory
ARL – Army Research Laboratory
ARO – Army Research Office
ARSC – Arctic Region Supercomputing Center
ASC – DOE/NNSA's Advanced Simulation and Computing program
ASPR – Office of the Assistant Secretary for Preparedness and Response
ATC – Air traffic control
ATP – App Testing Portal
BD – Big Data, one of NITRD's Senior Steering Groups
BGPSEC – Border Gateway Protocol Security
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
CalTech – California Institute of Technology
CCF – Computing and Communication Foundations
CDC – Centers for Disease Control and Prevention
CEDPS – DOE/SC's Center for Enabling Distributed Petascale Science
CEMMSS – Cyber-enabled Manufacturing, Materials, and Smart Systems
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
CIO – Chief Information Officers
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 – Coordination and Management Service
CNCI – Comprehensive National Cybersecurity Initiative
CNS – Computer and Network Systems
COMPETES – Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science
CoP – Community of Practice
COTs – Commercial off the shelf technologies
CPS – Cyber-physical system(s)
CRASH – Clean-slate design of Resilient, Adaptive, Secure Hosts
CRES – Computational Research for Engineering and Science program
CRI – Computing Research Infrastructure
CRUSHPROOF – Cyber Unification of Security Hardening and Protection of Operational Frameworks
CSD – DHS's Cybersecurity Devision
CSIA – Cybersecurity and Information Assurance, one of NITRD's eight Program Component Areas
CTET – Cyber Technology Evaluation and Transition program
DARPA – Defense Advanced Research Projects Agency
DECIDE – Distributed Environment for Critical Infrastructure Decision-making Exercises
DEFIANT – Defensive Enhancements for Information Assurance Technologies
DETER – NSF- and DHS-initiated cyber DEfense Technology Experimental Research network
DeVenCI – Defense Venture Catalyst Initiative
DHS – Department of Homeland Security
DIMRC – NIH's Disaster Information Management Research Center
DISA – Defense Information Systems Agency
DNI – Office of the Director of National Intelligence
DNSSEC – Domain Name System Security protocol
DOC – Department of Commerce
DoD – Department of Defense
DoD (HPCMP) – DoD's High Performance Computing Modernization Program
DoD/MHS – DoD's Military Health System
DoD/TATRC – DoD's Telemedicine and Advanced Technology Research Center
DOE – Department of Energy
DOE/INL – DOE's Idaho National Laboratory
DOE/NNSA – DOE/National Nuclear Security Administration
DOE/Oak Ridge – DOE's Oak Ridge National Laboratory
DOE /OE – DOE's Office of Electricity Delivery and Energy Reliability
DOE/SC – DOE's Office of Science
DOE/SC/ASCR – DOE/SC's Advanced Scientific Computing Research
DOJ – Department of Justice
DOT – Department of Transportation
DPIF – Digital Preservation Interoperability Framework International Standard
DREN – DoD's Defense Research and Engineering Network
EARS – Enhanced Access to the Radio Spectrum Program
ECSS – Extended Collaborative Support Service
EDUCAUSE – Nonprofit organization promoting advancement of IT in higher education
EHRs – Electronic health records
ENG – NSF's Engineering directorate
EPA – Environmental Protection Agency
ESG – Earth Systems Grid
ESMF – Earth System Modeling Framework
ESSC – DOE/SC's Energy Sciences network (ESnet) Steering Committee
EU – European Union

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
FCC – Federal Communications Commission
FDA – Food and Drug Administration
FHWA – Federal Highway Administration
FIA – Future Internet Architectures
FIU – Florida International University
FoSER – Future of Software Engineering Research
FSSCC – Financial Services Sector Coordinating Council
FY – Fiscal Year
Gb – Gigabit
GENI – NSF's Global Environment for Networking Innovations program
GIS – Geographic Information System
GLORIAD – Global Ring Network for Advanced Applications Development
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
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
HIT – Health Information Technology, one of NITRD's Senior Steering Groups
HITIDE – HIT R&D SSG's Health Information Technology Innovation and Development Environments subgroup
HOST – Homeland Open Security Technology
HPC – High-performance computing
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
iEHR – DoD/VA integrated Electronic Health Record
IETF – Internet Engineering Task Force
IHS – Indian Health Services
IIS – Information and Intelligent Systems
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
Interior – Department of Interior
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
ITSEF – Information Technology Security Entrepreneurs' Forum
IU – Indiana University
IWG – Interagency Working Group
JET – LSN's Joint Engineering Team
JETnets – Federal research networks supporting networking researchers and advanced applications development
JPDO – Joint Planning and Development Office
K-12 – Kindergarten through 12th 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
LSU – Louisiana State University
MAGIC – LSN's Middleware and Grid Infrastructure Coordination team
MAX – Mid-Atlantic eXchange
MCNC – Microelectronics Center of North Carolina
MIC – Many integrated cores
MDAO – Multidisciplinary analysis optimization
MIT – Massachusetts Institute of Technology
MNP – Military Networking Protocol
Morphinator – Morphing Network Assets to Restrict Adversarial Reconnaissance
NARA – National Archives and Records Administration
NAS – NASA Advanced Supercomputing facility
NASA – National Aeronautics and Space Administration
NCAR – NSF-supported National Center for Atmospheric Research
NCBC – NIH's National Centers for Biomedical Computing
NCCS – NASA Center for Climate Simulation
NCO – National Coordination Office for NITRD
NCR – DARPA's National Cyber Range program
NCSA – National Center for Supercomputing Applications
NEC – National Economic Council, White House
NERSC – DOE/SC's National Energy Research Scientific Computing Center
NeTS - Core and strategic networking research
NetSE – NSF's Network Science and Engineering Program
NextGen – Next Generation Air Transportation System
NICE – National Initiative for Cybersecurity Education
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
NREIP – Naval Research Enterprise Summer Intern Program
NRI – National Robotics Initiative
NRL – Naval Research Laboratory
NSA – National Security Agency
NSF – National Science Foundation

NSF/MPS – NSF's Directorate for Mathematical and Physical Sciences
NSF/OCI – NSF's Office of Cyberinfrastructure
NSF/SBE – NSF's Directorate for Social, Behavioral, and Economic Sciences
NSTC – National Science and Technology Council
NSTIC – National Strategy for Trusted Identities in Cyberspace
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
ONC SHARP – ONC's Strategic Health IT Advanced Research Projects
ONR – Office of Naval Research
OOMMF – Object-Oriented Micromagnetics Modeling Framework
ORCA – Online Representations and Certifications Application
ORNL – DOE's Oak Ridge National Laboratory
OS – Operating system
OSD – Office of the Secretary of Defense
OSD/SEI CERT – Carnegie Mellon's Software Engineering Institute CERT program
OSG – Open Science Grid
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
PCPC3 – Protected Control Plane for Cyber Command and Control
PerfSONAR – performance Services-Oriented Network Architecture
PF – Petaflop(s), a thousand teraflops
PI – Principal investigator
PIV – Personal identity verification
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
R&D – Research and development
RDT&E – DoD's Research Development Test & Evaluation programs
RENCI – Renaissance Computing Institute
ROV – Remotely operated vehicle
S&T – Science and technology
S4C – Science for Cybersecurity
S5 – Safe and Secure Software and Systems Symposium
SaTC – Secure and Trustworthy Cyberspace
SAMATE – Software Assurance Metrics and Tool Evaluation
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
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
SIEGate – Secure Information Exchange Gateway
SNL – Sandia National Laboratories
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
SURA – Southeastern Universities Research Association
SWOT – Semantic Web Ontology Team
TAMU – Texas A&M University
TCIPG – DHS- and DOE-supported Trustworthy Cyber Infrastructure Protection for the Power Grid program, with initial funding also from NSF
TEOS – Training, Education, and Outreach Service
TeraGrid – NSF terascale computing grid, now succeeded by eXtreme Digital (XD) program
TIC – Trusted Internet Connection
TITAN – Tactical Information Technologies for Assured Network operations
Treasury – Department of the Treasury
TTU – Texas Tech University
TwC – NSF's Trustworthy Computing program
UAS – Unmanned Aircraft Systems
UAV – Unmanned aerial vehicle
UCAR – University Corporation for Atmospheric Research
UChi – University of Chicago
UDel – University of Delaware
UIC – University of Illinois at Chicago
UIUC – University of Illinois at Urbana-Champaign
UMd – University of Maryland
UNC – University of North Carolina
UQ – Uncertainty quantification
USAF – United States Air Force
USC – University of Southern California
USCAR – U.S. Consul for Automotive Research
USDA – U.S. Department of Agriculture
USGCB – U.S. Government Configuration Baseline
USGS – U.S. Geological Survey
UU – University of Utah
UVa – University of Virginia
UW – University of Washington
UWisc – University of Wisconsin
VA – Department of Veterans Affairs
VA/JIV – VA's Joint Interoperability Ventures directorate
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
WS – Wireless Spectrum, one of NITRD's Senior Steering Groups
XD – NSF's eXtreme Digital program
XSEDE – Extreme Science and Engineering Discovery Environment

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