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

NITRD Agencies: NSF, DARPA, OSD and DoD Service research organizations, DOE/SC, NSA, NASA, NIST, DOE/NNSA, NOAA

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

President's 2009 Request

Strategic Priorities Underlying This Request

Next-generation HEC systems: Develop new scientific frameworks and system architectures to take computing power and communications "beyond Moore's Law"; innovative systems that combine increased speed, economic viability, high productivity, and robustness to meet Federal agency needs for HEC systems that manage ultra-large volumes of data and run multiscale, multidisciplinary science and engineering simulations

Extreme-scale computation: Integrate computer science and applied mathematics foundations to address computation at the petascale level

New hardware and software directions: Explore novel concepts and approaches for solving technical challenges such as power use, thermal management, file system I/O latency, highly parallel system architectures, and programming language and development environments that can increase the usability of large-scale multiprocessor, including hybrid, systems

Productivity: Continue collaborative development of new metrics of system performance, including benchmarking, lessons learned for acquisition, total ownership costs of HEC systems; integrate resources for improved productivity

Prototypes: Develop, test, and evaluate prototype HEC systems and software to reduce industry and end-user risk and to increase competitiveness

Talent pool: Replenish the workforce with highly skilled researchers who can develop future-generation HEC systems and software

Highlights of Request

High-Productivity Computing Systems (HPCS) Phase III: Design, fabricate, integrate, and demonstrate full-scale prototypes by 2010 for a new generation of petascale, economically viable computing systems to provide leap-ahead advances in performance, robustness, and programmability; develop parallel programming languages and tools to increase user productivity and enable efficient implementation of performance-critical applications – DARPA, DOE/SC, NSA

Next-generation architectures and programming: R&D in highly parallel systems architectures (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) – NSF, DARPA, DOE/SC, DOE/NNSA

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

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

System on a chip: Pursue system-on-a-chip technology, self-monitoring of system processors' health and state; provide PCA technology for a new generation of onboard, embedded processing capabilities – DARPA

Quantum computing: Quantum information theory; architectures and algorithms; modeling of quantum memory, quantum gates – NSF, DARPA, NSA, NIST

Resources 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 – NSF, DARPA, DOE/SC, DOE/NNSA

Computational Research and Engineering Acquisition Tools and Environments (CREATE): Computer science foundations to enhance development of highly scalable application codes – OSD (HPCMP)

Software environments: Develop modeling architecture based on Earth System Modeling Framework (ESMF)
– NOAA with NSF (NCAR), DoD, DOE/SC, NASA

Planning and Coordination Supporting Request

Planning

Technical and planning workshops: Third Storage and I/O Workshop to coordinate HEC-URA effort; Federal Application Benchmark Workshop to plan multiagency benchmarking activity; New Architecture (multithread, cell) Application Workshop; Petascale Tools Workshop; Memory for High-Performance Computing Workshop – NSF, DARPA, OSD, DOE/SC, NSA, NASA, DOE/NNSA

Open-source software: Enable HEC users to read, modify, and redistribute source code, fostering more efficient development and collaboration to improve software quality – NSF, DOE/SC, NASA, DOE/NNSA

Proposal reviews: Multiple HEC agencies

Systems architecture

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

HPCS: Support architecture development – DARPA, DOE/SC, NSA

BlueGene/Q: Assess alternatives for future-generation BlueGene architecture – DOE/NNSA, DOE/SC

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

Systems software development

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

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

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

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

Additional 2008 and 2009 Activities by Agency

NSF: Science and Engineering Beyond Moore's Law (SEBML) emphasis on revolutionary new hardware technologies, related programming models, languages, and tools with promise for computing systems of the future; multidisciplinary CDI emphasis on computational concepts, methods, models, algorithms, and tools to advance science and engineering; complex software and tools for HEC environments; software development and technologies for cyberinfrastructure; modeling and simulation of complex systems; numerical algorithms and software implementations that push the boundaries of computing infrastructure; grid computing

DARPA: Develop a new class of processing approaches, algorithms, and architectures to efficiently enable implementation of cognitive information processing (micro-architecture concepts, framework, and multilevel programming models and implementations for goal-based, resource-constrained cognitive applications)

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

DOE/SC: Joint mathematics/computer science institutes for petascale algorithms; data analysis and management, interoperability; software development environments; support for leading-edge application development to accelerate acceptance of new high-risk, high-payoff algorithms and software

NSA: Complete Eldorado project, with systems available in 2008; Center for Exceptional Computing (hosts visiting scholars); initiate the Integrated High End Computing program

DOE/NNSA: Focus on code validation and verification, uncertainty quantification for predictive simulation