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

NITRD Agencies: NSF, OSD and DoD Service research organizations, DARPA, DOE/SC, NIH, NSA, 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 2008 Request

Strategic Priorities Underlying This Request

Next-generation HEC leadership: Develop innovative computing systems that combine increased speed, economic viability, high productivity, and robustness to meet Federal agency needs for HEC systems that can manage ultra-scale volumes of data and run multiscale, multidisciplinary scientific simulations

Petascale computing environments: Develop understanding of the architecture-application relationship in petascale applications on leadership systems, and of the mathematical and computer science foundations for petascale systems

New hardware and software directions: Explore novel approaches to solving technical challenges such as power use, thermal management, file system I/O latency; scalable runtime and operating system architectures, and language and development environments that increase the usability of large-scale multiprocessor systems

Productivity: Continue collaborative development of new metrics of system performance, 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

HEC-URA: University-based R&D in file systems and I/O, system software and tools for complex systems; Forum to Address Scalable Technology for runtime and Operating Systems (FAST-OS) recompetition – NSF, DARPA, DOE/NNSA, DOE/SC, NSA

Next-generation programming: R&D in parallel programming languages and programming environments for next-generation high-end systems – NSF, DARPA, NSA

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, DOE/NNSA, NSA

System on a chip: Pursue system-on-a-chip technology and self-monitoring of system processors' health and state; provide PCA technology for a new generation of onboard, embedded computing processing capabilities that will be mission- and technology-independent and able to adapt for optimal performance – DARPA

Expanded resources for scientific research: Expand SciDAC-enabling organizational resources including centers, institutes, and partnerships through conducting R&D to optimize the performance of HEC systems used for scientific research – DOE/SC, DOE/NNSA

Petascale systems and computational science: R&D in operating and runtime systems, programming models, file systems, performance modeling and optimization, software component architectures; mathematics and computer science (scalable algorithms, petascale infrastructure, optimization of complex systems, control theory, risk assessment) – DOE/SC, DOE/NNSA, NSF

Advanced computing systems: New effort to include research to improve power efficiency, chip-to-chip I/O, interconnects, productivity, resilience, and file system I/O – NSA

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

Software environments: Develop common system software and tools for high-end systems – DOE/NNSA, DOE/SC, NSF, OSD

System software: Sustain advanced systems initiative to meet requirements for nuclear weapons simulations – DOE/NNSA

Planning and Coordination Supporting Request

Planning

Technical and planning workshops: HPCS Productivity Workshops, second Storage and I/O Workshop to coordinate HEC-URA effort – DARPA, DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD

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

Systems architecture

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

HPCS: Support architecture development in Phase III of HPCS Program – DARPA, DOE/SC, DOE/NNSA, NSA

BlueGene/Q: Assess architectural 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 – DARPA, NIST, NSA, NSF

Systems software development

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

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

Benchmarking and performance modeling: Collaborate on developing measurement tools to help improve the assessment and productivity of HEC systems – DARPA, DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD

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

Additional 2007 and 2008 Activities by Agency

NSF: Support innovative research in complex software and tools for HEC environments; formal and mathematical foundations (algorithmic and computational science); foundations of computing processes and artifacts (software, architecture, design); emerging models for technology and computation (biologically motivated, quantum, and nanotechnology-based computing and design); distributed systems; create, test, and harden next-generation systems and software

OSD (HPCMP): Support HEC R&D activities (e.g., metrics development, benchmarking, performance modeling, file system and I/O subsystem modeling, testbeds) that are directly relevant to ongoing computer center operations or commercial supercomputer acquisitions

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)

DOE/SC: Investigate programming models, performance modeling and optimization, software component architectures; development time and execution time productivity (with HPCS); data analysis and management, interoperability, software development environments

NSA: Complete Black Widow and Eldorado projects, with systems available in 2007

DOE/NNSA: Pursue R&D in platforms, problem-solving environments, numerical methods, and user-productivity baseline in context of weapons simulations