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

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

HEC R&D members coordinate research and development activities to optimize the performance of today's high-end computing systems and to develop future generations of high-end computing systems necessary for meeting critical Federal agency mission and scientific and engineering needs, addressing many of society's most challenging large-scale computational problems, and strengthening the Nation's global leadership in science, engineering, and technology.

**President's 2006 Request**

***Strategic Priorities Underlying This Request***

- User requirements for HEC technology in the 2010 timeframe, as documented in the HECRTF report, include achieving high sustained application performance, building and maintaining complex software, managing dramatically increasing volumes of data, and integrating multiscale – in space and time – multidisciplinary simulations. The report laid out a broad R&D agenda and roadmap in hardware (including components and subsystems), software (including tools and languages), and systems (including architectures and programming models), and a set of R&D roadmaps that inform the HEC R&D strategy, priorities, and interagency coordination activities.
- Government, academic, and industry participants in the HECRTF activity highlighted the need for Federal HEC R&D as the essential underpinning for continued U.S. leadership in high-end computing. The report concluded that a revitalized R&D effort is necessary to:
  - *Refill the research pipeline with new ideas and the next generations of highly trained computer scientists.* DARPA, NSF, and DOE/SC have funded HEC University Research Activity (HEC-URA) to support R&D in software for high-end systems.
  - *Preserve U.S. leadership in the development of the world's most robust and innovative high-end systems, with the goals of orders of magnitude increases in U.S. computational capabilities and significantly improved cost-to-performance metrics.* The DARPA High Productivity Computing Systems (HPCS) program is funding research that will enable the next generation of high-end computing systems envisioned in 2010. These will be systems capable of petaflops of sustained operations.
  - *Reduce industry and end-user risk by undertaking the testing and evaluation of early prototype HEC systems and software.* The DARPA HPCS program seeks to minimize the risk to industry by funding research activities leading to next-generation capability systems and by working with the HPCS mission partners to acquire early versions of these systems. NSA's continuing HEC efforts in collaboration with other agencies in development of the Red Storm, X1e, and Black Widow supercomputers helps ensure that these systems also will be available for acquisition by other agencies and companies.
  - *Strengthen R&D in HEC component and software technologies to make HEC systems easier to use.* An HPCS-associated activity is the HPCS productivity effort, which is exploring language and development environments geared to workflows producing high-end applications.
- The HECRTF R&D strategy advances the development of robust and innovative systems and reduces industry and end-user risk by supporting the test and evaluation of HEC systems and software technologies. It calls for integrating hardware and software innovations to enable rapid advances in end-user applications. This approach is key to current and future HEC R&D priorities and activities.

***Highlights of Request***

- **DOE/SC:** Re-competition of the SciDAC program, which has been successful in establishing multidisciplinary, multi-institutional teams in applied mathematics and computer science that are developing advanced software and computational tools for the physical and biological sciences
- **DOE/SC:** New competitive program to support next generation of Research and Evaluation Testbeds that enable SciDAC teams to evaluate the promise of future computer architectures for their applications
- **DARPA, DOE/SC, NSF:** HEC-URA to fund university research in software specifically for high-end computing (NSA helped plan the activity)

- **DARPA, with DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD:** HPCS Phase III – final, full-scale development phase of DARPA's HPCS program
- **NSA, DOE/SC (SNL and ORNL):** Continue cooperative development of Black Widow and Red Storm systems, leading to introduction in 2006 of a new generation of these systems

***Planning and Coordination Supporting Request***
- **DARPA, DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD:** Technical and planning workshops
- **DARPA, DOE/NNSA, DOE/SC, NSA, OSD:** Joint planning memorandum of understanding (MOU)
- **DOE/NNSA, DOE/SC:** NA/CSTB study, "Getting Up to Speed: The Future of Supercomputing"
- **DOE/NNSA, DOE/SC:** Open-source software

*Systems architecture activities*
- **DOE/SC, NASA, NIST, NOAA, NSF, OSD:** Testbeds
- **DARPA, with DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD:** HPCS Phase II
- **DARPA, DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD:** Blue Gene/L, Red Storm, Black Widow reviews
- **DARPA, NIST, NSA, NSF:** Quantum information science

*Systems software development*
- **DARPA, DOE/NNSA, DOE/SC, NSA, NSF (DOE/NNSA participates in proposal reviews):** HEC-URA
- **DARPA, with DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD:** HPCS productivity metrics
- **DARPA, DOE/NNSA, DOE/SC, NASA, NSA, NSF, OSD:** Benchmarking and performance modeling
- **DARPA, DOE/NNSA, DOE/SC:** Scalable visualization and file system

**2005 and 2006 Activities by Agency**

**NSF:** Supports university-based research on 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 and next-generation software systems; data-driven science including bioinformatics, geoinformatics, cognitive neuroscience; infrastructure development (create, test, harden next-generation systems); and software and tools for high-end computing
**DOE/SC:** SciDAC Integrated Software Infrastructure Centers in applied mathematics (applied partial differential equations and terascale tools) and computer science (component technology, scalable systems, engineering of system performance, scientific data management); operating/runtime systems for extreme-scale scientific computation; advanced computing research testbeds (ORNL X1e system)
**DARPA:** HPCS program – Phase II ends mid-2006 when full-scale development (Phase III) begins; Council on Competitiveness HPC Initiative (with DOE/SC, DOE/NNSA) to promote industry involvement; Polymorphous Computing Architectures program (agile, reconfigurable systems); HEC-URA support (with DOE/SC, NSF)
**NSA:** Architectures and systems; high-speed switches and interconnects; programming environments; quantum information sciences; vendor partnerships; X1e/Black Widow (extend development of the NSA/OSD X1 system to hundreds of teraflops)
**NASA:** Multiagency coordination activities in architectures, testbeds, and system performance assessment
**NIST:** Research in quantum computing and secure quantum communications
**NOAA:** Development of skills, algorithms, and techniques to fully utilize scalable computing for improved environmental understanding and prediction
**DOE/NNSA:** Software quality engineering for longevity of codes; verification to ensure accuracy, validation of the problem solution, certification methodology; capability computing, capacity computing; problem solving environments; industry collaboration; tracking requirements