DoD HPC Modernization Program

'05

High Performance Computing Modernization Program

Annual Report

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DoD High Performance Computing Modernization Program
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Cover art:
Hurricane Katrina surge and wind impacts on the Louisiana and Mississippi Gulf Coast. Graphic courtesy of the Interagency Performance Evaluation Team. Background visualization courtesy of the ERDC MSRC.

Department of Defense

High Performance Computing Modernization Program

2005 Annual Report

A report by the Department of Defense
High Performance Computing Modernization Program Office

March 2006

Message from the Director

For more than a decade, the High Performance Computing Modernization Program (HPCMP) has brought to the Department of Defense (DoD) one of the world's top supercomputing infrastructures. In 1993, the Department had just over 180 gigaFLOPS (one thousand million FLoating-point OPerations per Second) of computing capacity. In 2005, the program delivered over 142,000 gigaFLOPS of computing capacity, a factor of over 750 improvement! Today, the Department of Defense has access to some of the world's most powerful supercomputers and to a variety of computing architectures, chosen to best meet the Department's identified requirements. This allows our scientists and engineers to match software applications to supercomputers. In 1994, the program provided wide area networking to 8 sites with connection speeds ranging from 3 to 45 megabits per second. Today, our Defense Research and Engineering Network provides connections to over 135 sites with connection speeds ranging from 45 to 2,400 megabits per second.

Perhaps, most importantly, our program provides key computer and computational science expertise to scientists and engineers across the Department. We successfully completed several software development projects that introduced parallel, scalable production software now in use across the Department and the broader national community. This past year, we delivered 66 training events, attended by 767 people and coordinated technology sharing projects between the defense laboratories and over 2 dozen universities.

These activities and the daily work performed by members of the HPCMP community have a positive impact on our national defense posture. Our scientists and engineers are now in possession of tools once only imagined. They are developing and deploying weather and ocean models that allow our soldiers, sailors, marines and airmen to plan missions more effectively and to navigate adverse environments safely. They are modeling molecular interactions leading to the development of higher energy fuels, munitions, and materials enabling cheaper, more environmentally friendly access to space, more effective weapons, and stronger and longer lasting materials. They are modeling structural responses to different blast environments, guiding improved force protection programs, and designing new guidelines for buildings and structures. Today, we support over 550 individual projects - research, advanced development and applied engineering, test and evaluation - each contributing to our national defense posture.

We are exploring alternative service delivery mechanisms as our users' work processes change. We have evolved our Common High Performance Computing Software Support Initiative to focus on fewer but larger multi-disciplinary software applications now made possible by advances in hardware and software (Integrated Portfolios). We are more tightly coupling our involvement with the Defense Laboratories and Research Centers through the creation of High Performance Computing Software Applications Institutes to infuse computational expertise directly into DoD organizations. We believe the institutes will accelerate a Department-wide shift toward more rigorous computational modeling and simulation. We are also adjusting our approach to assuring a pipeline of future computational scientists and engineers by expanding our intern programs, invigorating our outreach to Historically Black Colleges and Universities and other minority serving institutions, and supporting graduate scholarship assistance through the National Defense Science and Engineering Graduate fellowship program.

As the program completes its twelfth year, we continue to improve the Department's supercomputing environment supported by leading edge networking capabilities. The DoD HPCMP community, working in concert with other Federal Agencies to identify future trends and requirements, anticipates more extensive cooperation with those agencies.

There is still much more to do. Our scientists' and engineers' requirements are growing at rates in excess of our ability to meet them. We are working with several other Federal Agencies to advance both the state of the art and the state of the practice. We are planning an initiative to prepare high performance software to take advantage of the next generation, massively parallel supercomputers such as those resulting from the Defense Advanced Research Projects Agency (DARPA) High Productivity Computing Systems (HPCS) program. Our Department's needs for science and engineering to speed its Transformation Goals continue to accelerate.

These needs are recognized at the highest levels. As President George W. Bush stated in his January 31, 2006 State of the Union message,

> *"… America … must continue to lead the world in human talent and creativity. … I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years. This funding will support the work of America's most creative minds as they explore promising areas such as nanotechnology, supercomputing [emphasis added], and alternative energy sources…"*

The High Performance Computing Modernization Program team is dedicated to deploying and operating superior supercomputing environments and productivity enhancing services allowing DoD's scientists and engineers to develop the best technological solutions for our nation's defense. As President Bush has said, *"science and technology have never been more essential to the defense of the nation…"*

Cray J. Henry
Director
High Performance Computing Modernization Program

Acknowledgements

Many colleagues in the field and in the program office – far too many to acknowledge in this brief section – have contributed to this annual report, as well as to previous ones. I thank them for their hard work and enthusiastic support. All the efforts described in this document were performed using resources provided by the Department of Defense High Performance Computing Modernization Program. Additional sponsorship has come from a variety of research, development, test and evaluation sources, including the Offices of Research, the Defense Laboratories and the Test Centers.

Clifford E. Rhoades, Jr.
High Performance Computing Modernization Program

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Section 1—Overview

Introduction

Today, the Department of Defense (DoD) faces many challenges. We must defend America. We must maintain a military second to none. And we must do so affordably.

The High Performance Computing Modernization Program (HPCMP) provides some of the tools the Department needs to address defense problems. These tools include modern high performance computing hardware and software.

Our military strength depends on many factors. Our people are our greatest asset. Our people include active service members, Reserves, National Guard, civil servants, political appointees, and contractors. High performance computing hardware and software help our people make our military the best in the world.

Many military problems are complicated and require very powerful tools to be solved. Some problems are too expensive for experiment to address. Some problems are too difficult to be solved with paper and pencil. The Department uses high performance computing tools to help address some of these hard problems. These hardware and software tools give us advantage over potential adversaries that don't have them.

Many modern weapons systems present hard problems. Early in system development, we must make trade-offs to balance performance, time and available resources. How do we determine cost, schedule and performance? How do we take into account technical and management risks? High performance computing hardware and software contribute to addressing these questions.

High performance computing hardware and software help us answer other important questions as well. They can be used to address a wide spectrum of issues. Some examples include: protecting our bases of operations through the mitigation of toxic threats; modeling to support certification of new aircraft-store combinations before deployment to conflicts in Afghanistan and Iraq; supporting US supremacy in space operations; conducting climate, weather, and ocean modeling that provides valuable information to countermine warfare operations; preparation for emergency operations, and humanitarian relief operations throughout the world. These are but a few examples.

HPCMP Mission

Accelerate development and transition of advanced Defense technologies into superior war fighting capabilities by exploiting and strengthening US leadership in Supercomputing, Communications and Computational Modeling

HPCMP Vision

A pervasive culture existing among DoD's scientists and engineers where they routinely use advanced computational environments to solve the most demanding problems

Over a decade, the HPCMP has produced an outstanding environment that routinely uses high performance computing resources to solve many of the Department's most challenging scientific and engineering problems. This, in turn, helps the United States ensure military advantage and war-fighting superiority on the 21st century battlefield.

The Program enables scientists and engineers to further the Department's objectives through research, development, test, and evaluation (RDT&E) activities that support science and technology (S&T), and test and evaluation (T&E). These activities focus on the most complex, and highest priority defense challenges. This annual report highlights only a small portion of the work being done to support the Department's Transformation Goals. Defense scientists and engineers, using resources provided by the HPCMP, address multi-disciplinary scientific and engineering challenges. These include problems of interest across the services and to joint force commanders. Improving the accuracy of ocean and weather prediction models, designing materials for specific purposes such as body armor or agile laser eye protection, and modeling complex flow fields around air systems to increase performance are examples. Today's work will:

- Improve detection of targets based on their spectral or spatial/spectral signatures;
- Advance dynamic signal intelligence mission planning;
- Enhance force protection against terrorist threats; and
- Address the critical need to develop new high energy density materials for explosives and rocket fuels.

Congressional investments in and support of the HPCMP since fiscal year 1994 have caused cultural changes in the fundamental way S&T and T&E are pursued. In 1993, the Department had just over 180 gigaFLOPS (FLoating-point OPerations per Second) (or GFs) of computational power to support the S&T community. As Figure 1 illustrates, the HPCMP has expanded those capabilities to over 142 teraFLOPS; this is an increase of a factor of over 750! This was done by applying sound management practices and good investment strategies. Similarly, we transitioned our communications network linking the laboratories from a government-owned, government-operated asset to a commercial environment providing a secure, high bandwidth capability. Our Program is a technology acquisition and service delivery program addressing the needs of Defense scientists and engineers for state-of-the-practice supercomputing environments. The HPCMP achieves the Program's mission and vision (as described on pages 5 and 6) by focusing on five specific goals. Each activity within the program supports one or more of these goals, with progress tracked and successes delineated. These five goals are:

- Acquire, deploy, operate and maintain best-value supercomputers;
- Acquire, develop, deploy and support software applications and computational work environments that enable critical DoD research, development and test challenges to be analyzed and solved;
- Acquire, deploy, operate and maintain a communications network that enables effective access to supercomputers and to distributed S&T/T&E computing environments;

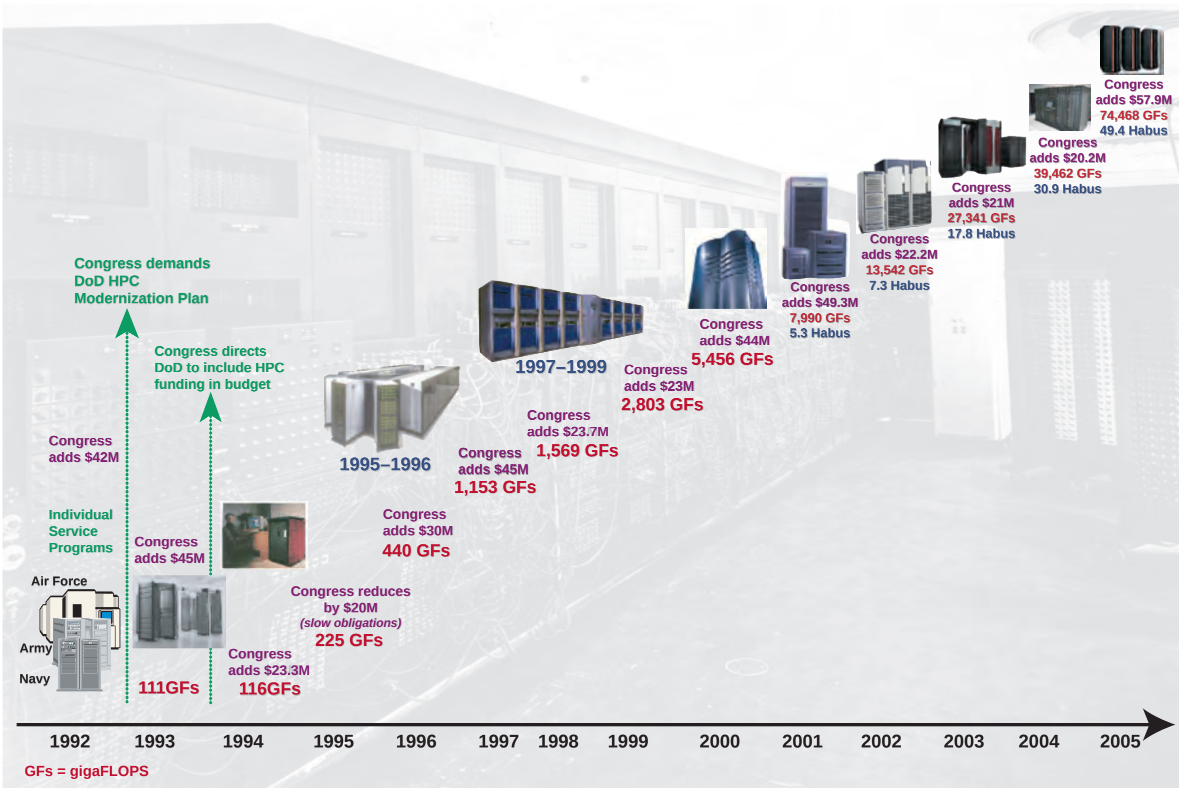


Figure 1. DoD S&T and T&E growth in computational capability

- Promote collaborative relationships among the DoD computational science community, the national computational science community and minority serving institutions; and
- Continuously educate the research, development, test, and evaluation workforce with the knowledge needed to employ computational modeling effectively and efficiently.

The progress the HPCMP has made in meeting these goals is discussed in detail later in Section 2.

The HPCMP Community

The HPCMP community consists of over 4,550 scientists, engineers, computer specialists, networking specialists, and security experts working throughout the United States. All three Military Departments and several Defense Agencies participate in the program. These HPC users execute over 550 projects, validated by the Military Services and Defense Agencies. Figure 2 shows the locations of people using the HPCMP resources. The user base is diverse, drawing from the government workforce, academia, and industry. The demographics by type of workforce as well as by the DoD organizations are shown in Figure 3. Most work, done by the HPCMP community, is in one or more of the ten HPCMP computational technology areas (CTAs) (see Table 1 on page 11).

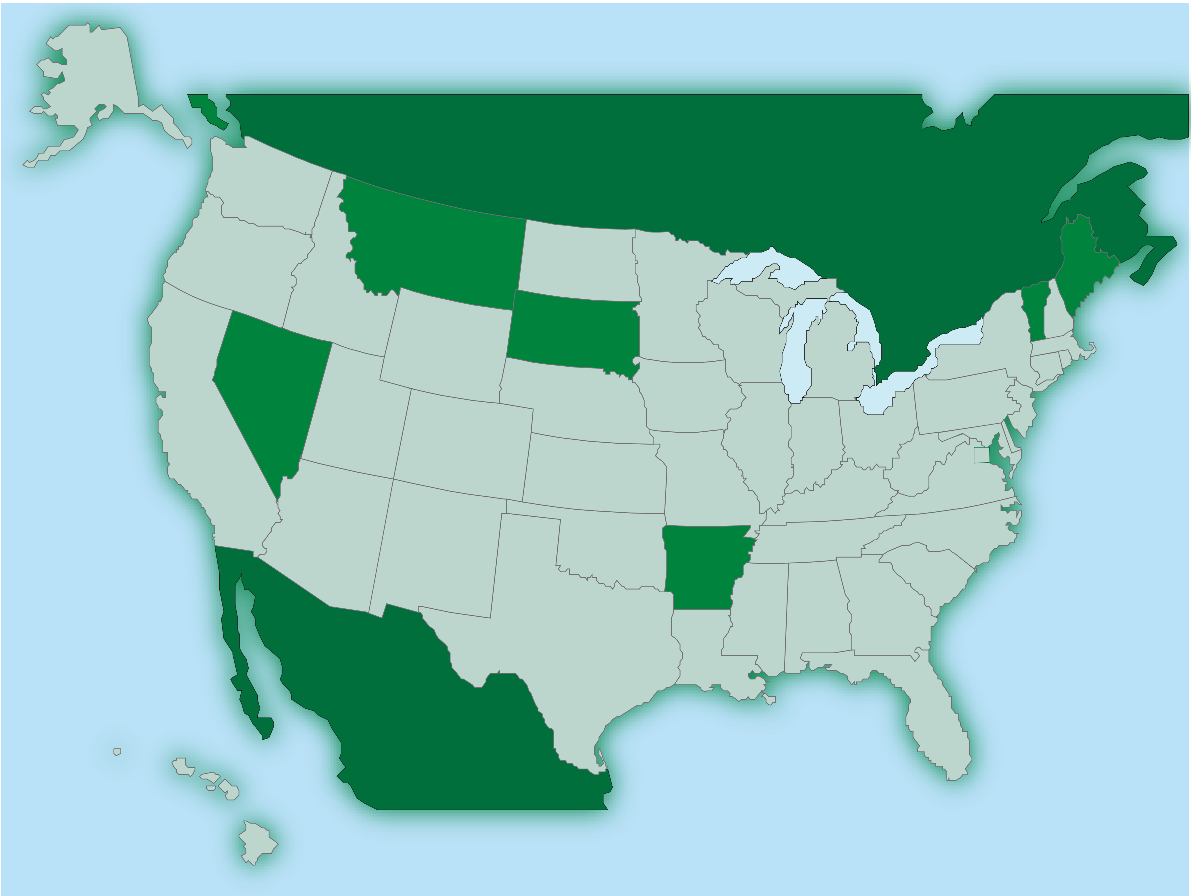
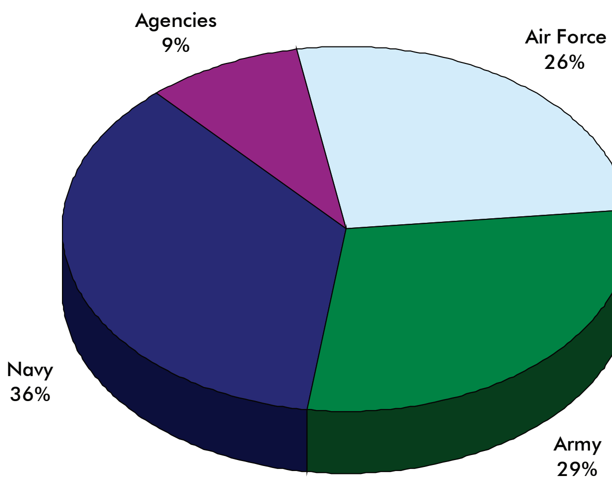


Figure 2. The light green color represents states with people using HPCMP resources

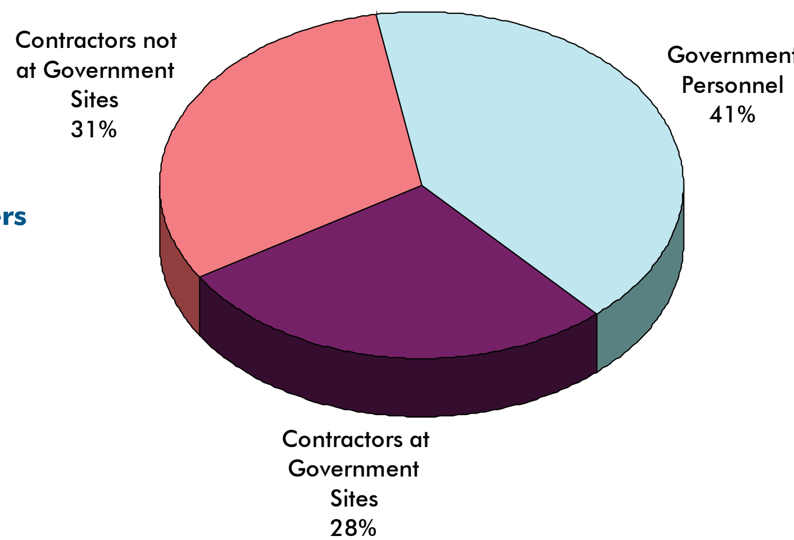
HPCMP Community Computational Requirements

Validated requirements serve as the basis for HPCMP activities and operational decisions. Each year, the HPCMP conducts an exercise to gather, assess, and validate the requirements of its user community. This requirements determination includes all aspects of HPCMP activities and capabilities: system hardware, software, networking, and training. In the past several years, overall requirements increased and are projected to continue to increase at a steady, consistent rate. Total requirements in any given year are approximately two and one-half times total program capability, ramping up from approximately 365 teraFLOPS or 263 Habus in FY 2005 to 1,140 teraFLOPS or 623 Habus in FY 2009 (see Figure 4). [Habus are a measures of computational performance. See callout on page 10 for a definition.] Once collected, the Services' and Agencies' S&T and T&E Executives review, correct, validate, and approve their requirements. HPCMP does requirements analyses as a fundamental part of an overall systems engineering process that collects and analyzes information to make investment decisions.

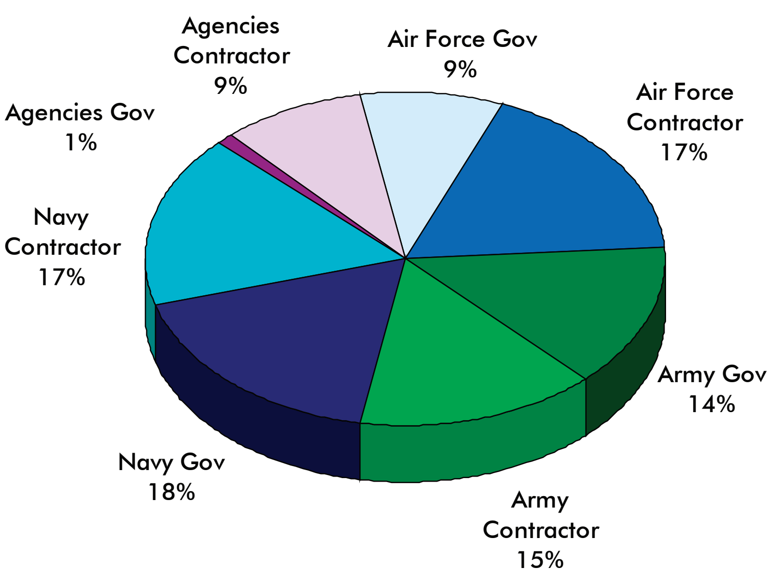
The general conclusion of that requirements analysis is that a complete HPC environment must be provided to support the DoD's S&T and T&E communities. A variety of computational platforms, both at the unclassified and classified



Breakdown of HPCMP Users by Service/ Agency



Overall Breakdown of HPCMP Users



Distribution of HPC Users

Figure 3. FY 2005 HPCMP user demographics

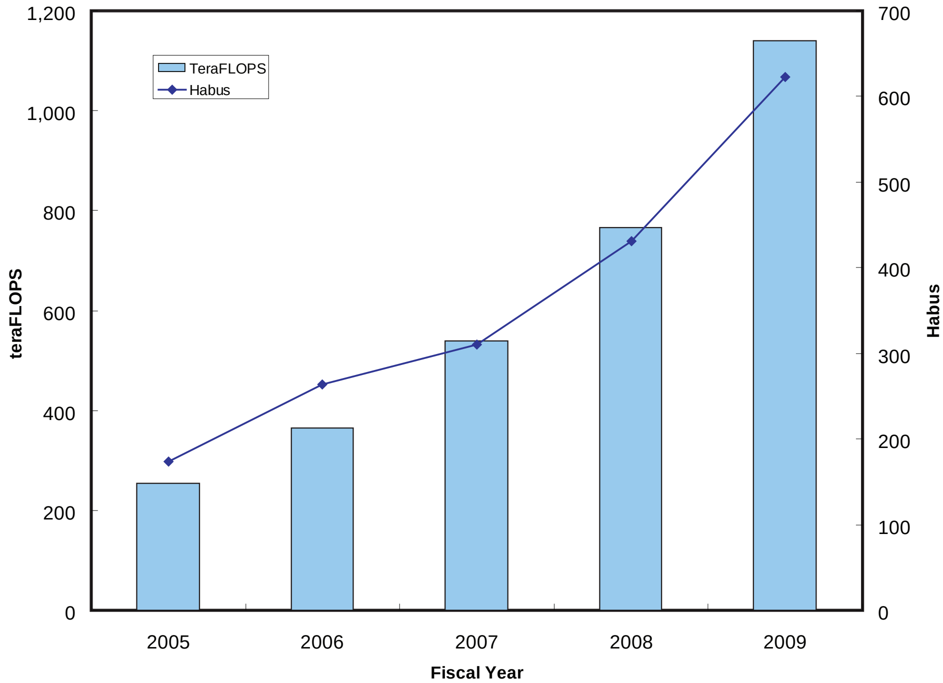


Figure 4. Total computational requirements of the HPCMP community

level, must be provided so that a wide range of DoD applications may be efficiently supported. These platforms must be balanced with respect to computational power, central memory, and file storage capabilities. A variety of systems and applications software that enable DoD computational scientists and engineers to perform their mission are required. A reliable high-speed network that connects the users to these resources and to each other is required, as is the continuation of an aggressive training program that broadens and educates DoD's HPC users. Progress must be balanced across all program activities to optimize the impact of HPC on the DoD S&T and T&E programs' support of the war fighting mission.

Habu—a Measure of Computational Performance

The HPCMP rates computer systems in terms of the speed with which DoD computational applications run on the systems. For the past half decade, the HPCMP has run a suite of applications on existing and new systems to obtain performance comparisons. By comparing the timing results for these applications, the HPCMP is able to compare the performance of any system, relative to the others. In 2002, a large IBM system located at the NAVO MSRC named Habu was designated the baseline system. Hence, performance measures are all in "Habu" equivalent units. For example, if a new system is rated at 2 Habus, that system is roughly two times more capable than a system rated at 1 Habu. That is, the new system executes the suite of applications at roughly twice the performance of the old. Of course, any individual application may run faster or slower. The line in Figure 8 shows the growth in computational capability in Habu units of system performance.

Table 1. Computational Technology Areas (CTAs)

Computational Technology Area	Acronym	Description
Computational Structural Mechanics	CSM	Covers the high resolution, multi-dimensional modeling of materials and structures subjected to a broad range of loading conditions such as quasi-static, dynamic, electro-magnetic, shock, penetrations, and blast.
Computational Fluid Dynamics	CFD	Provides accurate numerical solution of the equations describing fluid and gas motion.
Computational Chemistry, Biology, and Materials Science	CCM	Predicts properties, and simulates the behavior, of chemicals and materials for DoD applications. Methods ranging from quantum mechanical, atomistic, and mesoscale modeling, to multiscale theories that address challenges of length- and time-scale integration, are being developed and applied. Of recent emerging interest in the CCM CTA are methodologies that cover bioinformatics tools, computational biology, and related areas, such as cellular modeling.
Computational Electromagnetics and Acoustics	CEA	Provides high-resolution multidimensional solutions of electromagnetic and acoustic wave propagation and their interaction with surrounding media.
Climate/Weather/Ocean Modeling and Simulation	CWO	Involves accurate numerical simulation and forecast of the Earth's atmosphere and oceans on those space and time scales important for both scientific understanding and DoD operational use.
Signal/Image Processing	SIP	Extracts and analyzes key information from various sensor outputs in real-time; sensor types include sonar, radar, visible and infrared images, signal intelligences, and navigation assets.
Forces Modeling and Simulation	FMS	Focuses on the research and development of HPC-based physical, logical, and behavioral models and simulations of battlespace phenomenology in the correlation of forces.
Environmental Quality Modeling and Simulation	EQM	Involves the high-resolution modeling of hydrodynamics, geophysics, and multi-constituent fate/transport through the coupled atmospheric/land surface/subsurface environment, and their interconnections with numerous biological species and anthropogenic activities.
Electronics, Networking, and Systems/C4I	ENS	Focuses on the use of computational science in support of analysis, design, modeling, and simulation of electronics from the most basic fundamental, first principles physical level to its use for communications, sensing, and information systems engineering; activity ranges from the analysis and design of nano-devices to C4ISR systems-of-systems.
Integrated Modeling and Test Environments	IMT	Addresses the application of integrated modeling and simulation tools and techniques with live tests and hardware-in-the-loop simulations for the testing and evaluation of DoD weapon components, subsystems, and systems in virtual and composite virtual-real environments.

HPCMP Organization

The HPCMP is comprised of three major components: HPC Centers, Networking and Information Assurance, and Software Applications Support. These areas provide the base of the integrated program strategy (see Figure 5) to provide a technologically advanced computational environment to support the ongoing and emerging needs of the Department's laboratories and test centers. These components are interdependent, with distinct business practices and community relationships.

The HPC Centers component includes four major shared resource centers (MSRCs) and four allocated distributed centers (ADCs). These computer centers provide DoD scientists and engineers with the resources necessary to solve the most demanding computational problems. Additional computational resources are provided to support specific projects if those projects can not be easily addressed at the HPC Centers in a shared resource environment. These resources are termed dedicated HPC project investments (DHPIs). Figure 6 shows the MSRCs, ADCs and DHPIs.

The Networking component includes the Defense Research and Engineering Network (DREN), which provides advanced capabilities to a greater user base at faster communication speeds than previously available on a wide basis and addresses the security requirements of the program's environment.

The Software Applications Support (SAS) component provides expert services to assist

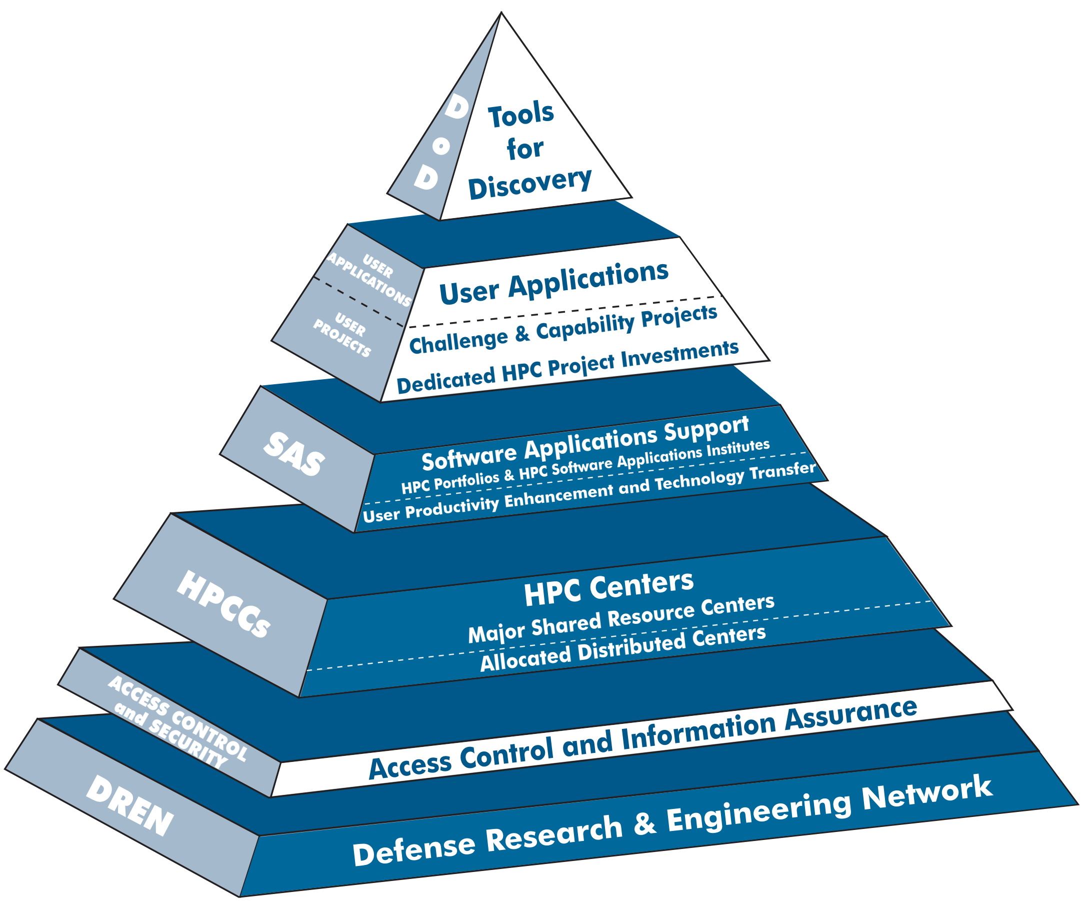


Figure 5. HPCMP integrated program strategy

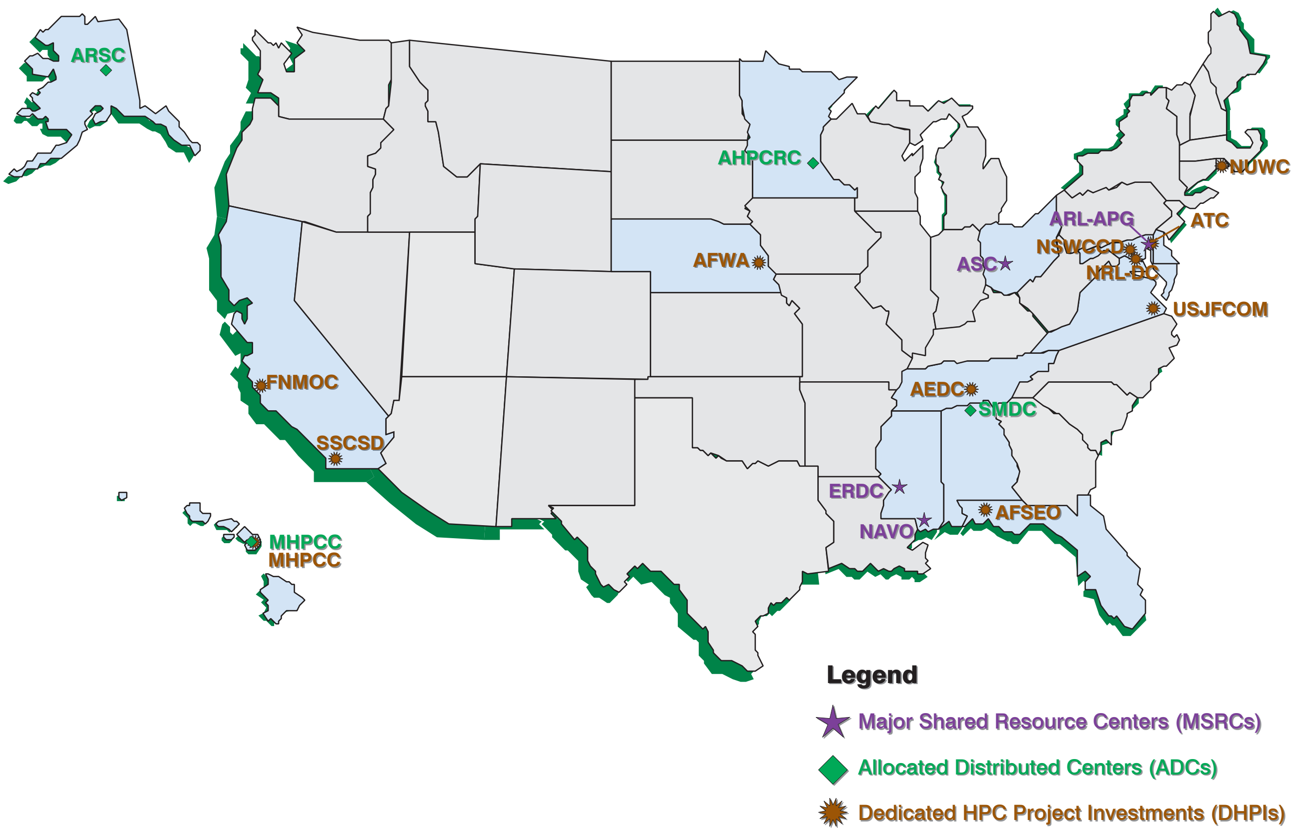


Figure 6. Location of HPCMP resources (MSRCs, ADCs, and DHPis)

our customers in most effectively using the HPC systems, provides investments in human capital across the DoD to facilitate the application of HPC tools, and supports a modest investment in a few high need HPC software applications.

DoD Challenge Projects

The HPCMP recognizes and supports high priority computational work conducted within DoD that can be done at its shared resource centers through its implementation of Challenge Projects. These projects represent the DoD's highest-priority, highest-impact computational work, both from technical and mission-relevance standpoints. The modeling and simulations conducted in these projects account for 30% of the allocations of resources at the HPC centers. These projects range from discovering new materials using quantum chemical simulations to studying the impact of new physics in the prediction of weather. There were 36 active DoD Challenge Projects in FY 2005 including 21 continuing projects and 15 new projects. The 15 new projects were selected from 32 proposals submitted by the Services and Agencies in response to the HPCMP's annual call for Challenge Project proposals. Selections are made by peer review with a panel consisting of service, agency, DoD, and external reviewers. Table 2 lists the FY 2005 DoD Challenge Projects. Almost all Challenge Project Leaders presented the results of their work at the annual Users Group Conference held in Nashville, TN in June 2005.

Table 2. FY 2005 DoD Challenge Projects

Project Title	Project Leader/Organization
3-D Modeling of the Chemical Oxygen-Iodine Laser II	Timothy Madden, Air Force Research Laboratory, Kirtland AFB, NM
Applications of Time-Accurate CFD in Order to Account for Blade-Row Interactions and Distortion Transfer in the Design of High Performance Military Fans and Compressors	Steven E. Gorrell, Air Force Research Laboratory, Wright-Patterson AFB, OH
Applied Computational Fluid Dynamics (A CFD) in Support of Aircraft-Store Compatibility and Weapons Integration	Jacob Freeman, Air Force SEEK EAGLE Office, Eglin AFB, FL
Characterization and Prediction of Stratospheric Optical Turbulence for DoD Directed Energy Platforms	Frank H. Ruggiero, Air Force Research Laboratory, Hanscom AFB, MA
Computational Fluid Dynamics (CFD) in Support of Wind Tunnel Testing for Aircraft/Weapons Integration	William Sickles, Arnold Engineering Development Center, Arnold AFB, TN
Computational Simulations of Combustion Chamber Dynamics and Hypergolic Gel Propellant Chemistry for Selectable Thrust Engines in Next Generation Guided Missiles	Michael Nusca and Michael McQuaid, Army Research Laboratory, Aberdeen Proving Ground, MD
Computer Design and Simulation of Molecular Devices and Energy Sources for Naval Applications	Mark R. Pederson, Naval Research Laboratory, Washington, DC
Defense against Chemical Warfare Agents (CWAs) and Toxic Industrial Chemicals (TICs): Filtration, Prophylaxis and Therapeutics	Margaret Hurley, Jeffrey Wright, and Alex Balboa, Army Research Laboratory, Aberdeen Proving Ground, MD
Distributed Pump Jet Propulsion (DPJP) for Submarines	Joseph Gorski, Naval Surface Warfare Center, Carderock Division, West Bethesda, MD, and Robert Kunz, Pennsylvania State University, State College, PA (Office of Naval Research)
Dynamic Rotorcraft Simulations for Accurate Interactional Aerodynamics and Performance Prediction	Mark Potsdam, US Army Aviation and Missile Command, Moffett Field, CA
Evaluation and Retrofit for Blast Protection in Urban Terrain	James Baylot, Engineering Research and Development Center, Vicksburg, MS
Explosive Structure Interaction Effects in Urban Terrain	James T. Baylot, Army Engineer Research and Development Center, Vicksburg, MS
Global Ocean Prediction with HYCOM	Alan Wallcraft, Naval Research Laboratory, Stennis Space Center, MS
High Accuracy DNS and LES of High Reynolds Number, Supersonic Base Flows, and Passive Control of the Near Wake	Hermann Fasel, University of Arizona, Tucson, AZ (Army Research Office)
Hybrid RANS-LES for High Fidelity Simulation of Circulation Control Schemes for Navy Applications	Eric Paterson, Robert Kunz, and Leonard Peltier, Pennsylvania State University, State College, PA (Office of Naval Research)
Hypersonic Scramjet Technology Enhancements for Long Range Interceptor Missile	Kevin Kennedy, US Army Aviation and Missile Command, Redstone Arsenal, AL and CRAFT Tech, Pipersville, PA
Large-Eddy Simulation of Tip-Clearance Flow in a Stator-Rotor Combination	Parviz Moin, Stanford University, Stanford, CA (Office of Naval Research)
Millimeter-Wave Radar Signature Prediction Improvements for Ground Vehicles	William Coburn, Army Research Laboratory, Aberdeen Proving Ground, MD

Table 2. FY 2005 DoD Challenge Projects—continued

Project Title	Project Leader/Organization
Modeling Breaking Ship Waves for Design and Analysis of Naval Vessels	Dick K.P. Yue, Massachusetts Institute of Technology, Cambridge, MA (Office of Naval Research)
Modeling Complex Projectile-Target Interactions II	Kent Kimsey, Army Research Laboratory
Molecular Rotors for Nanotechnology	Josef Michl, University of Colorado, Boulder, CO (ARO)
Multidisciplinary Applications of Detached-Eddy Simulation to Separated Flows at High Reynolds Numbers	Scott Morton, US Air Force Academy, Colorado Springs, CO
Multiscale Simulations of Quantum Structures	Jerry Bernholc, North Carolina State University, Raleigh, NC (Office of Naval Research)
Numerical Simulation of Submarine Late Wakes in Stratified and Sheared Flows	Joseph Werne, NorthWest Research Associates (Office of Naval Research)
Scalable Multiscale Simulations of Material Behavior at the Nanoscale	Rajiv K. Kalia, Aiichiro Nakano, and Priya Vashishta, University of Southern California, Los Angeles, CA (Army Research Office)
Seismic Signature Simulations for Tactical Ground Sensor Systems	Mark Moran, Cold Regions Research and Engineering Laboratory, Hanover, NH
Simulation of a Dynamically Maneuvering Unmanned Combat Air Vehicle	Raymond Gordnier, Air Force Research Laboratory, Wright-Patterson AFB, OH
Simulation of Enhanced Explosive Devices in Chambers	John B. Bell, Lawrence Berkeley National Laboratory, Berkeley, CA (Defense Threat Reduction Agency)
Simulations for Microbubble Drag Reduction at High Reynolds Number	Martin Maxey, Brown University, Providence, RI (DARPA)
Three-Dimensional Modeling and Simulation of Weapons Effects for Obstacle Clearance	Amos Dare, Naval Surface Warfare Center, Indian Head, MD
Time Accurate Unsteady Simulation of the Stall Inception Process in the Compression System of a US Army Helicopter Gas Turbine Engine	Michael Hathaway, Army Research Laboratory, Cleveland, OH
Time-Accurate Coupled CFD/RBD Simulations of Free Flight Aerodymanics of Guided Weapons	Jubaraj Sahu, Army Research Laboratory, Aberdeen Proving Ground, MD
Tip-to-Tail Turbulent Scramjet Flowpath Simulation with MHD Energy Bypass	Datta Gaitonde, Air Force Research Laboratory, Wright-Patterson AFB, OH
Towards a High-Resolution Global Coupled Navy Prediction System	Julie McClean, Naval Postgraduate School, Monterey, CA
Towards Predicting Scenarios of Environmental Arctic Change (TOPSEARCH)	Wieslaw Maslowski, Naval Postgraduate School, Monterey, CA
Virtual Prototyping of Directed Energy Weapons	Keith Cartwright, Air Force Research Laboratory, Kirtland AFB, NM

Dedicated HPC Project Investments

The HPCMP also recognizes and supports high priority computational work conducted within DoD that requires dedicated HPC resources. These projects typically have a need for quick turnaround of the computational work, either actual real-time or near-real-time calculations often in support of a specific test event. Such dedicated HPC requirements are met through the HPCMP's implementation of dedicated HPC project investments (DHPIs). Typically these small to medium-sized projects require HPC resources that have one or more of the following attributes:

- Require access to data or computational resources under time critical constraints that can not tolerate network latency or shared computing;
- Require special operational considerations that have security requirements or have unconventional operating considerations.

Acquisitions of the HPC investments are made either through the annual technology insertion process (TI-XX) that acquires new computational capability at HPCMP centers or by providing procurement funding for the dedicated HPC computational capability directly to the user site that proposed the dedicated HPC project.

Five such investments were made in FY 2005; these included a joint project between the Arnold Engineering Development Center and the Seek Eagle Office at Eglin AFB for computational fluid dynamics in support of aircraft-store certification, the Naval Undersea Warfare Center for torpedo hardware in-the-loop simulation, the Naval Surface Warfare Center to create a concurrent computation and visualization environment, and the Maui High Performance Computing Center for support of a space situational awareness project. User organizations that were awarded HPC resources to support their projects in prior years and reached milestone completion presented reports at the annual Users Group Conference in June 2005.

A typical DHPI has a life-cycle of two to three years. In FY 2005, four (Naval Air Warfare Center, White Sands Missile Range, Redstone Technical Test Center, and Simulations and Analysis Facility) were transitioned from HPCMP oversight. The following DHPIs are currently under HPCMP oversight:

- Aberdeen Test Center (ATC), Aberdeen Proving Ground, MD;
- Air Force Weather Agency (AFWA), Offutt AFB, NE;
- Air Force Seek Eagle Office (AFSEO), Eglin AFB, FL;
- Arnold Engineering Development Center (AEDC), Arnold AFB, TN;
- Fleet Numerical Meteorology and Oceanography Center (FNMOC), Monterey, CA;
- Joint Forces Command (JFC/J9), Suffolk, VA;
- Maui High Performance Computing Center (MHPCC), Kihei, HI;
- Naval Research Laboratory (NRL-DC), Washington, DC;
- Naval Surface Warfare Center (NSWCCD), Carderock Division, Bethesda, MD;
- Naval Undersea Warfare Center (NUWC), Newport, RI; and
- Space and Naval Warfare Systems Center, San Diego (SSCSD), San Diego, CA.

Examples of the types of projects supported by DHPI resources include:

- Real-time analytic and decision support in test and evaluation of land combat systems;
- Platform for conducting operational tests of weather research and forecast models;
- Real-time global-scale computer-generated forces experimentation;

- Real-time hardware-in-the-loop avionics and weapon systems simulations for test and evaluation;
- Modeling and simulation of command, control, communication, computers, intelligence, surveillance and reconnaissance (C4ISR) electronic systems under realistic tactical conditions; and
- Real-time test and evaluation of data imaging for aerial objects.

Capability Applications Projects

For the first time in FY 2005, the HPCMP made available newly acquired systems for capability applications projects (CAP), designed to test key DoD application codes on a substantial portion of entire HPC systems and solve large problems in a relatively short time. Thus, the goals of capability applications projects are:

- To quantify the degree to which important application codes scale to thousands of processors;
- To enable new science and technology by applying these codes in dedicated, high-end, capability environments.

The process is in some sense an extension of pioneer usage of new HPC systems, but it focuses much more heavily on true capability use for a short time before those systems are put into allocated operational use. It is implemented in two phases: Phase I, which focuses on scalability testing of applications codes proposed for CAPs, and Phase II, during which a subset of successfully tested codes and projects have dedicated access to substantial fractions of newly acquired systems for production work designed to solve a large, significant problem. The period of time dedicated to this capability workload lasted from one to three months.

Table 3. FY 2005 Capability Applications Projects

Project Title	Project Leader/Organization
HYCOM TI-04 CAP: 1/25° Atlantic	Alan Wallcraft, Naval Research Laboratory, Stennis Space Center, MS
Prediction of Aircraft Dynamic Motions (Abrupt Wing Stall and Spin)	James R Forsythe, Kenneth E. Wurtzler, Scott A. Morton, US Air Force Academy, Colorado Springs, CO
Statistical Fatigue and Residual Strength Analysis of New and Aging Aircraft Structure	Scott A. Fawaz, US Air Force Academy, Colorado Springs, CO
Direct Simulation of Nano-scale Plasticity	Chris Woodward, Air Force Research Laboratory, Wright-Patterson AFB, OH
Terminal Weapons Effects Analysis	Stephen J. Schraml, Army Research Laboratory, Aberdeen Proving Ground, MD
HPC Simulations of Army Special Structural Defeat Charges	Kent T. Danielson, Engineering Research and Development Center, Vicksburg, MS
Computational Support for Airblast and Thermal Nuclear Weapons Effects	Joseph Crepeau, ARA, Phoenix, AZ (Defense Threat Reduction Agency)
Stratospheric Turbulence: Stratified Shear Flow	Joseph Werne, NorthWest Research Associates, Boulder, CO (Air Force Research Laboratory)

Table 3 lists the Phase II CAPs that were executed during FY 2005. Several were executed on systems acquired during TI-04, including the NAVO IBM P4+ and the ARL IBM Opteron cluster, and several were executed on the ASC SGI Altix, one of the systems acquired during TI-05. Together this set of capability applications projects validated extensive scalability of several important DoD applications codes and accomplished significant capability work in a short period of time.

Highlights of Impact in FY 2005

The High Performance Computing Modernization Program provides some of the tools the Department needs to address defense problems. These tools include modern high performance computing hardware, software and networking. Our scientists and engineers use these tools to solve many critical problems faced by the Military Departments and Defense Agencies.

Some problems are of immediate concern, while others are of longer-term interest. Thus, program investments impact both short-term and long-term issues. The following vignettes serve as brief overviews of some highlights that occurred in FY 2005.

Characterizing High Altitude Turbulence for Theater Ballistic Missile Defense

The Airborne Laser (ABL) is a Major Defense Acquisition Program to provide defense against theater ballistic missiles. ABL consists of a high-energy laser fired from the nose-mounted turret of a modified Boeing 747-400 freighter aircraft. Loitering at ~40,000 feet, ABL will scan the horizon for the plume of a rising missile, acquire and track, then attack the missile with a megawatt-class chemical oxygen iodine laser (COIL), destroying it and scattering debris over the launch area, i.e., over enemy territory.

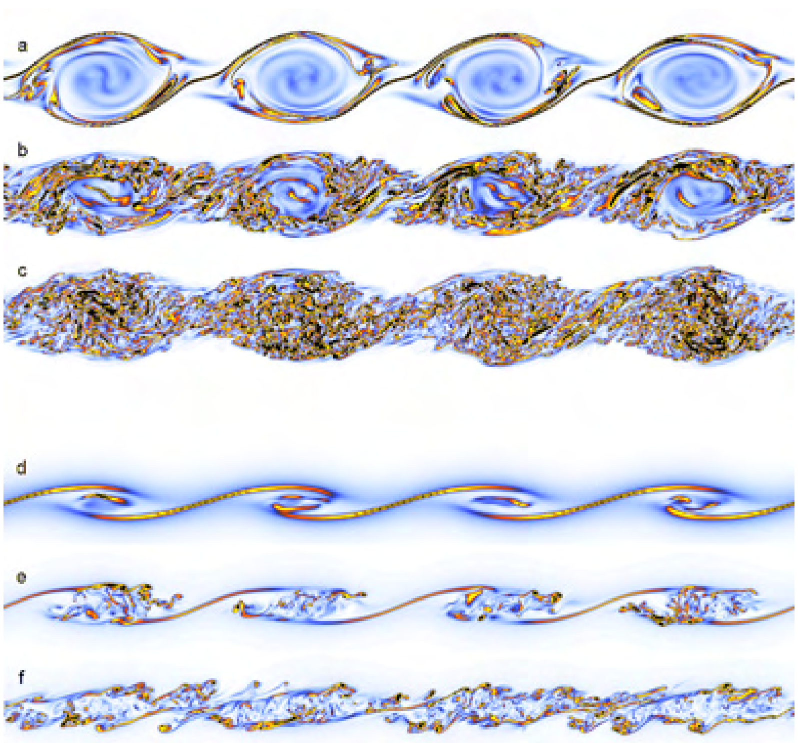
Because atmospheric turbulence can weaken and scatter the laser beam, and thereby reduce its effectiveness against a target missile, it is necessary to choose flight paths that minimize turbulence effects. To help guide such flight-path selection, an atmospheric decision aid (ADA) is being developed to provide critical optical turbulence nowcasting and forecasting information and products to theater decision makers.

To support ADA development, detailed simulations of atmospheric turbulence were conducted early in 2005 as part of the first DoD capability applications projects (CAP) program. The CAP program is designed to enable new science and technology by applying important and highly efficient application codes in dedicated high-end capability environments. The solutions computed under this program are helping the creation and refinement of atmospheric turbulence models that will allow the ADA to operate much more accurately and efficiently than is currently possible.

Both direct-numerical and large-eddy simulations (DNS and LES) were conducted during the CAP campaign. The solutions are being used to both refine the subgrid-scale (SGS) turbulence model used in the LES code and to construct sophisticated statistical models for enabling turbulence prediction under stably stratified conditions based, in part, on output from the Air Force Weather Agency (AFWA) forecast model.

The largest of the computed stratified turbulence solutions was 24 times larger than the largest that have ever been run before. They required 3000 × 1500 × 1500 spectral modes, consumed nearly 1,000,000 hours of computer time, generated more than 80 terabytes (TB) of stratified turbulence data, and achieved a 99.98% parallel execution efficiency.

While helping refine the DNS/LES comparisons and pin-point issues for further model improvement, these simulations produced three new scientific discoveries that contribute significantly to our basic understanding of stratified shear turbulence in the upper troposphere and stratosphere. (The troposphere is the portion of the atmosphere near the ground and in which most of the Earth's weather occurs. Above the troposphere is the stratosphere, where the ABL flies.) First, a fundamental difference was discovered between strong and weak stratification distinguished by the stabilizing influence of nearly solid-body rotation of overturning Kelvin-Helmholtz billows (see figure below). The transition between the strong- and weak-stratification regimes is characterized by a Richardson number of Ri≈0.15. The Richardson number quantifies the competing influences of stable density stratification and wind shear. Second, by comparing with recent aircraft data, the computed solutions were able to explain the "cliff-ramp" structures recently observed in measurement data, and they also allowed us to estimate the likely minimum initial Richardson number for the observed atmospheric events. Third, the final state of the flow subsequent to turbulent mixing was discovered to exhibit nearly identical stability profiles and shear/buoyancy timescale ratios, independent of the initial value of Ri, even for cases in either the weak or strong stratification regimes. This last result implies that we can reasonably predict the end state in the middle of a previously turbulent layer, even when we have little knowledge of the conditions that triggered the turbulence in the first place. This is an important and unexpected result that will improve the decision aid element of the ABL, especially in situations where there is minimal observational turbulence data available to support targeting



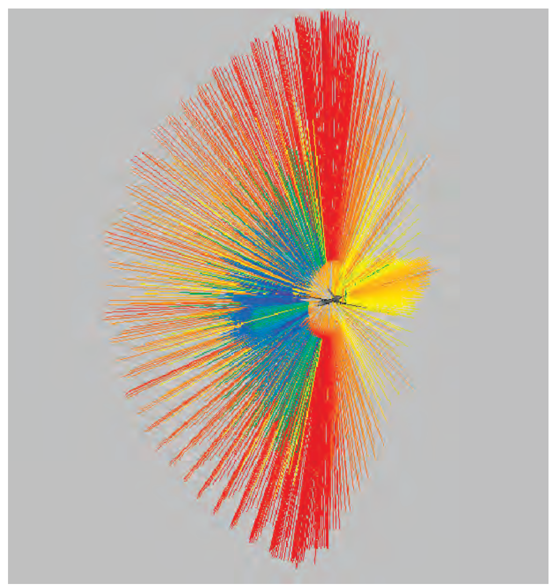
Flow morphology for stratified wind shear turbulence. Panels a-c show slices for Richardson number Ri=0.05 at time 54, 68 and 85. Panels e-f show slices for Ri=0.20 at time 54, 75 and 86. Weak vorticity is shown in blue, while yellow, red, and black indicate successively higher vorticity levels. The solutions at the two different values of Ri show marked differences in their transitions to turbulence. The low-Ri solution exhibits a three-stage transition in which billow edges first become unstable, followed by the braids between billows, then finally the billow cores. In contrast, the high Richardson-number solution becomes unstable in the cores first, followed by the braids. The different morphologies and dynamics leave signatures that can be observed in aircraft measurements.

HPC Supports the Predator System Program Office

The unmanned aerial vehicle (UAV) has quickly become a cutting edge Air Force technology with a variety of current and future applications. Improved UAV tactical performance, in the areas of radar signatures, could ultimately expand the range and use of such vehicles. Precise and timely modeling and testing in the radio frequency (RF) area is of vital importance to both predicting performance and improving the manufacture of UAVs.

The Predator System Program Office (SPO) needed to evaluate proposed design changes to the airframe, and as a result approached the US Air Force Simulation and Analysis Facility (SIMAF) to get the necessary engineering and analysis support. The complete evaluation that SIMAF provided the SPO included the prediction of performance against a range of enemy threats in multiple roles.

To assist in improving UAV designs, calculations of high resolution Radar Cross Section (RCS) required computational resources that exceeded SIMAF computing capabilities. For RCS prediction the team used Xpatch® which is a set of prediction codes and analysis tools that use the shooting-and-bounding ray method to predict realistic far-field and near-field radar signatures for 3-D target models. Using such existing configurations can take 12 months or more. Technical staff from our university affiliates were chartered with assisting SIMAF to significantly reduce these cycle times, while maintaining accuracy and efficacy of output.



Radar cross section predictions
(Representative data – not actual)

The numerous aspect angles required for a detailed RCS were partitioned. These angles ordinarily number in the thousands per frequency. The calculations for these smaller groups of aspect angles were then performed in parallel, using the serial code Xpatch® running on HPC platforms. To facilitate the partitioning and scheduling of these calculations, a Perl script was written for job controls and submissions. This script was developed and debugged at the ASC MSRC and the final calculations were performed at the ARL MSRC. The Perl script has proven so useful it has been transitioned to other users for their projects.

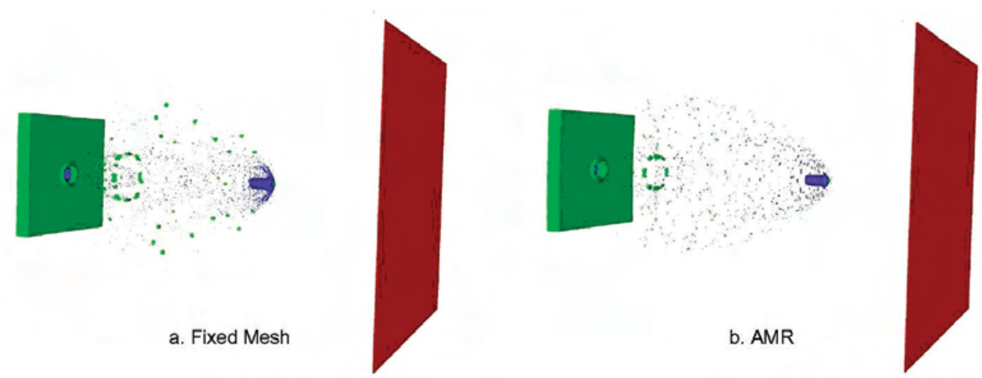
By exploiting the inherent parallelism in the study and using HPC resources, the cycle time to conduct studies of such high resolutions was dramatically reduced. From an original SIMAF estimate of 12-plus months for accurate computation, performance time with equivalent data accuracy was reduced to 2 months.

According to Richard Graeff of SIMAF, "The HPCMP and PET involvement are allowing a much higher fidelity and more timely RF signature prediction for the Predator … Without the support of the HPCMPO compute power, it would take us months, if not years, to provide such a detailed signature prediction to the Predator Program Office. … These results help the Predator Program Office ensure that the Predator will be properly employed in operational support of the warfighter."

Evaluating Armor Designs with High Performance Computing

We constantly seek to improve protection for our soldiers in the field by assessing and upgrading armors on combat vehicles such as the Abrams family of battle tanks, the Bradley Fighting Vehicle and the lightly armored High Mobility Multipurpose Wheeled Vehicle (HMMVVV) (also known as a "humvee" or "hummer"). Behind armor debris is a major cause of casualties and damage in military vehicles that have been perforated by a penetrator, bullet or fragment. The ability to predict the debris field resulting from attack by such a threat is critical to assessing and improving the survivability of ground combat systems. Modeling of the debris field has historically been done by statistically analyzing data from carefully controlled experiments. The difficulty of collecting this information makes it an expensive and lengthy process. Supplementing these experiments with numerical simulations is a natural synergy, but to date has not yet been successfully exploited because legacy computer systems were unable to cope with the daunting size of the simulations.

Recent advances in computer hardware and software allow us to numerically model these experiments. The Figure shows an experiment modeled as a demonstration. It consists of a 30 mm armor piercing discarding sabot round perforating a 1 inch thick steel armor plate. The resulting behind armor debris cloud impacts a large (610 mm × 610 mm) [2ft × 2ft], thin (0.8 mm) [1/32 inch], mild steel witness plate placed 610 mm behind the armor. Perforations made in the witness plate by the debris are measured, and conclusions are drawn about the size, mass, spatial distribution and velocity of the debris field. This is painstaking work, but it results in a reasonably accurate characterization of the debris field.



Simulations of armor penetration and debris field, 600 μs after impact: a. fixed mesh, b. AMR.

The difficulty in modeling such an experiment arises primarily from the fact that the problem is inherently three dimensional in nature, requires a very fine computational mesh, and consequently a small integration time step to model accurately the physical phenomena. The recent hardware and software advances also allow one to reduce the size of this simulation by employing an automatic mesh refinement (AMR) technique. When AMR is employed, the mesh is refined only in regions of interest allowing for an optimal simulation which can then be completed in a reasonable time frame.

We can now simulate complex armor configurations, with complex geometries and multiple materials. The resultant improvements in armor technology are directly linked to advanced computing platforms and enhanced software that translates into a lifesaving asset in the field.

SECTION 2

PERFORMANCE RESULTS

Section 2— Performance Results

FY 2005 Activities

The activities of fiscal year 2005 continued our forward progression in assisting the Department of Defense (DoD) science and technology (S&T) and test and evaluation (T&E) community in providing support to the warfighter, both near-term within FY 2005 and what will be of benefit in years to come.

This section is separated by the goals of the High Performance Computing Modernization Program (HPCMP) as we work toward making the vision a reality.

Goal 1: Acquire, deploy, operate and maintain best-value supercomputers

The HPCMP provides high performance computing capabilities to the DoD S&T and T&E communities via three modes of delivering HPC computational capability:

- Major Shared Resource Centers (MSRCs);
- Allocated Distributed Centers (ADCs); and
- Dedicated HPC Project Investments (DHPIs).

Major Shared Resource Centers

Major Shared Resource Centers are very large high performance computing (HPC) computational centers that provide leading-edge, high performance computational resources, data storage, data interpretation and HPC technical expertise to the defense community. These Centers are "purple" in that they serve all DoD Services and Agencies without regard to their location or supporting organization. They are located at four government installations listed and highlighted in Figure 7:

- US Army Research Laboratory (ARL), Aberdeen Proving Ground, MD;
- Aeronautical Systems Center (ASC), Wright-Patterson AFB, Dayton, OH;
- US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), Vicksburg, MS; and
- Naval Oceanographic Office (NAVO), Stennis Space Center, MS.

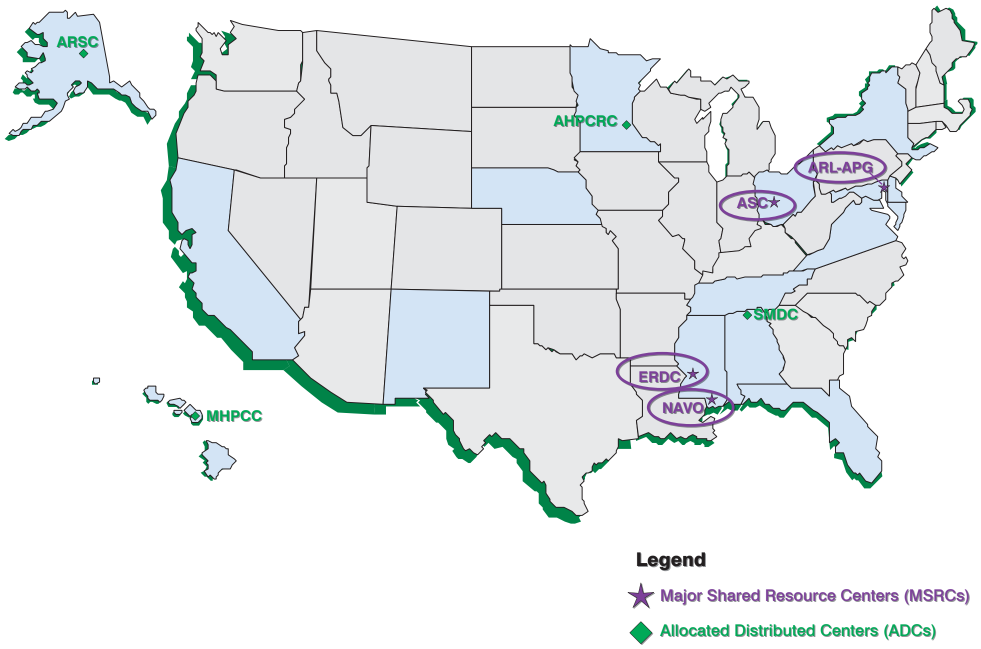


Figure 7. Location of major shared resource centers

At the beginning of FY 2005, the HPC systems at the four MSRCs had a total computational capability of 77.2 teraFLOPS (i.e., the capability to perform 77.2 trillion mathematical operations per second). During FY 2005, the HPCMP procured three very large systems for deployment at two of the MSRCs (ASC and ERDC). These new systems have a computational capability of 44.6 teraFLOPS. At the end of FY 2005, the total capability of the HPC systems at the four MSRCs stands at 114.9 teraFLOPS. The bars in Figure 8 show the computational growth in teraFLOPS as well as Habus at the four centers over the past 10 years. [See callout on page 10 for a definition of a Habu.]

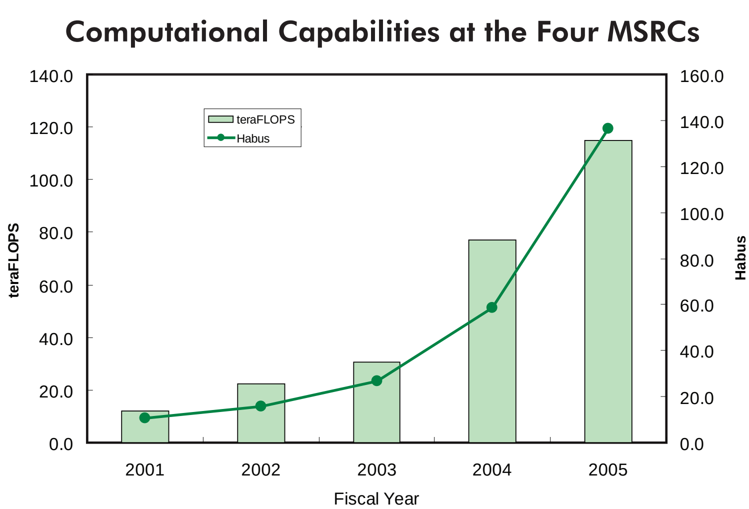


Figure 8. Growth in capability of the MSRCs

Allocated Distributed Centers

To complement the computational capacity of the four MSRCs, the HPCMP also supports four "mid-sized" centers that provide additional computational resources to DoD researchers. These centers are identified as allocated distributed centers (ADCs). From the DoD's perspective, ADCs function like smaller scale MSRCs but have a role of serving the DoD as well as other customers. The four centers are listed below and highlighted in Figure 9:

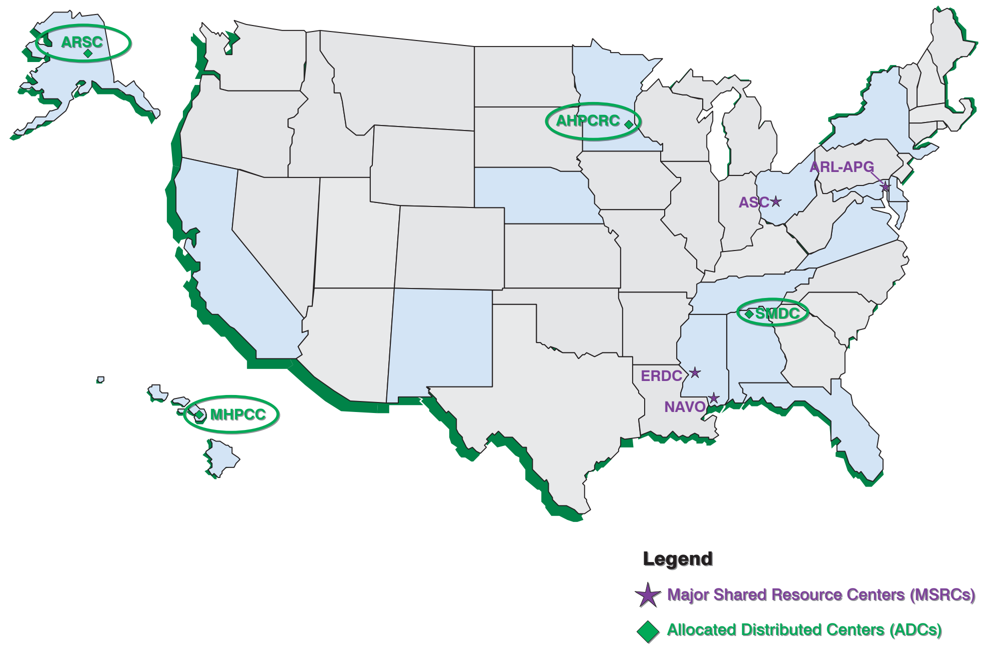


Figure 9. Location of allocated distributed centers

- Arctic Region Supercomputing Center (ARSC), Fairbanks, AK;
- Maui High Performance Computing Center (MHPCC), Kihei, HI;
- Army High Performance Computing Research Center (AHPCRC), Minneapolis, MN; and
- Army Space and Missile Defense Command (SMDC), Huntsville, AL.

In FY 2005 the ARSC ADC continued to support open literature, DoD basic research. The academic community of users, whose research is supported by the Offices of Research in the Defense Services, were otherwise challenged to acquire the proper access clearances required to use the systems located at the MSRCs. This operational model allows the ARSC to mix non-DoD university related work and DoD open literature work on the same systems; a win-win example of how the DoD leverages the use of ADCs.

Collectively, the ADCs have a number of large HPC systems which provide a total of 15.8 teraFLOPS of computational capability to the HPCMP. Adding this computational power to the capability located at the MSRCs, the HPCMP total capability increases from 114.9 teraFLOPS to 130.7 teraFLOPS.

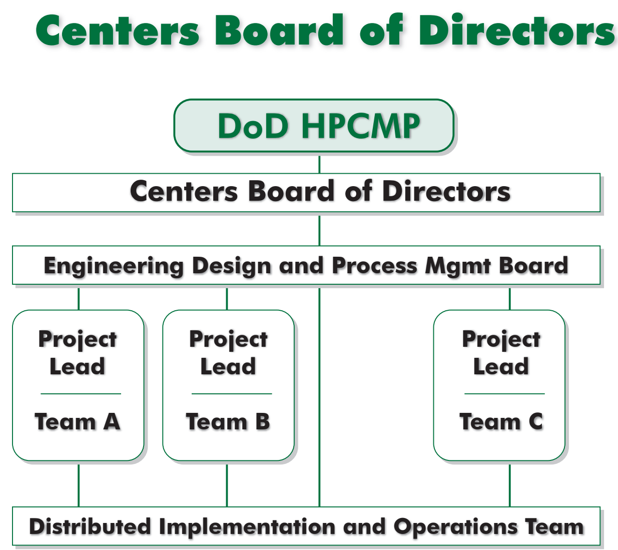
Summary

The hardware and software acquisition budget for the MSRCs over the last six years has had, for all practical purposes, zero growth. However, in FY 2001, the HPCMP implemented a consolidated acquisition process whereby all HPCMP hardware and software is acquired via consolidated large contracts with competitively selected HPC offerings. The leveraging of volume purchasing power combined with technology advances commensurate with Moore's law (a prediction made by the former CEO of Intel Corporation that the number of transistors contained on a silicon chip will double every 18 months) has provided the HPCMP with computational capabilities that exceed traditional growth curves.

Overarching Governing Infrastructure for Centers

The HPCMP is a geographically distributed community with a valuable diversity of local skills and capabilities that must be captured in support of community ends. To achieve this transfer of best practices and innovations, an overarching centers' governing infrastructure was created:

- The center directors of the four MSRCs, plus ARSC, and MHPCC are members of the Centers Board of Directors (CBoD) for the HPCMP Centers capability;
- The technical specialists that design, build, and implement the solutions comprise the Engineering Design and Process Management Board (ED&PMB); and
- The Distributed Implementation and Operations Team (DIOT), a group of individuals at each of the centers are positioned to sustain the capability.



This governing infrastructure was formulated in early FY 2004 and chartered in March of 2004. The adjoining figure shows the organization of the CBoD. The CBoD has met several times and has initiated three new investigations. The other two teams have begun to address the initiatives. Early indications are that the unified direction from the CBoD has helped to keep the ED&PMB and the DIOT on focus.

Goal 2: Acquire, develop, deploy and support software applications and computational work environments that enable critical DoD research, development and test challenges to be analyzed and solved

The DoD Software Applications Support component activities align with the goal above. This component consists of three major areas: HPC Portfolios, HPC Software Applications Institutes, and User Productivity Enhancement and Technology Transfer (PET), formerly known as Programming Environment and Training. The ultimate aim is to provide DoD scientists and engineers with the capability for modeling and simulating the physical world to facilitate the design, development, test, and acquisition of superior weapons systems, thereby allowing our soldiers, sailors, marines, and airmen to be prepared better through training, tactics, and support systems.

HPC Portfolios

The trend in research, development, test, and evaluation (RDT&E) clearly indicates that multi-disciplinary problems will further challenge DoD scientists and engineers and require upscale HPC resources. This implies that many of tomorrow's applications will incorporate multiple computational disciplines, defined in this program by the computational technology areas (CTAs). CTAs are listed in Table 1 on page 11. The portfolio effort within the HPCMP has embraced these needs. Portfolios provide efficient, scalable, portable software codes, algorithms, tools, and models and simulations that run on a variety of HPC platforms and are needed by a large number of S&T and T&E scientists and engineers to execute their missions. Portfolio development teams span DoD Services and Agencies and include algorithm developers, applications specialists, computational scientists, computer scientists and engineers, and end users.

Developing software for scalable HPC systems remains technically challenging and labor intensive. The HPCMP helps the DoD take advantage of existing and future computing and communications capabilities by building software with an emphasis on reusability, scalability, portability, and maintainability. In addition, this initiative is producing a new generation of world-class scientists and engineers trained in scalable software techniques to reduce the future costs of doing business and increase our defense capabilities. HPC portfolios, shown in Figure 10, focus on specific themes that encompass multiple CTAs and cross Service and Agency boundaries.

The portfolios, described in the following five paragraphs, address critical needs in S&T and T&E. The resultant software codes completed in these efforts provide DoD scientists and engineers with applications software that efficiently and effectively exploits the latest generation of scalable high performance computing systems. These applications affect the design, acquisition, and utilization of military technologies that will aid in the development of improved military capability for the 21st century.

Sensor/Scene Processing and Generation (SPG)

The Sensor/Scene Processing and Generation portfolio developed scalable HPC software that will assist research and development, and virtual testing of sensors including multi-function sensors, algorithms, and techniques in weapon models, hardware-in-the-loop, installed systems, and concept systems. Application areas and computational techniques include (1) single or multi-spectral target and background signature modeling and scene generation, (2) scene generation validation, verification, and accreditation (VV&A) software tools, (3) signal and image processing, (4) image cueing and automatic target recognition, (5) low-observables/counter low-observables, and (6) unified problem solving environment for sensor/scene processing and generation. This effort was completed in FY 2005.

System-of-Systems (SOS) Simulation

The System-of-Systems (SOS) Simulation portfolio built a set of tools designed to assist in the testing of integrated, autonomously operating weapons systems into dynamically controlled information networks or SOS. In recent years, the DoD has recognized that weapons systems operating autonomously provide a less than optimal solution to our national security problems. Information processing nodes in the network fuse information from other nodes to provide a relevant battle-space view to friendly participants. The testing of future System-of-Systems will require simulations more complex than any developed to date. This portfolio assisted in the tracking of interaction among hundreds of thousands of players, complex weapons systems, and environmental models while merging physics with information theory. This effort was completed in FY 2005.

Materials by Design (MBD)

The first phase of the Materials by Design portfolio developed codes that address the design of a wide-range of materials, including metals, molecular and nanoscale materials, high energy density materials, optical materials, nanowire materials for spin quantum computing devices, polymer nanocomposites, and functional surfaces. Codes developed coupled structural mechanics approaches to achieve a microscopic-to-macroscopic algorithmic parallelization link. Some of these projects completed activities in FY 2005, half of this portfolio continues through FY 2006.

Chemical/Biological Defense (CBD)

The activities within this portfolio are coming to fruition in FY 2006, and address a nationally recognized need to become better prepared in the event of attacks which incorporate biological agents or toxic chemicals. This portfolio was established to provide scalable software for military applications focused on chemical and biological threats and corresponding Defense Technology Objectives (DTO). This portfolio is a multi-disciplinary effort encompassing computational themes in the fields of chemistry and materials science, fluid dynamics, electronics, and nanoelectronics. The goal of the CBD portfolio is to provide high performance scalable software to support the soldier in the areas of chemical and biological agent detection, identification, transport, controls, and countermeasures.

Virtual Electromagnetics Design (VED)

The overall goal of the VED portfolio is to provide the DoD with the ability both to virtually design wide-band, multi-functional antennas and to compute rough surface scattering solutions for a wide range of DoD activities including communication, acquisition, target identification, surveillance, and electronic attack. The specific goal is to develop a tightly integrated enabling set of tools for rapid analysis and design of large antenna aperatures and arrays in air, sea, and ground environments. The tools will be further integrated with DoD Laboratories HPC codes to enable the tri-services to solve previously unattainable DoD challenge problems.

HPC Software Applications Institutes

Institutes address Service/Agency high priority, high value technology or materiel RDT&E mission priorities and augment traditional processes with computational insight by utilizing legacy or newly-developed computational techniques. Additional information about the six institutes is contained in Figure 11 on page 32.

During FY 2005, a significant effort was spent in starting up the five HPC Software Applications Institutes selected in FY 2004. Each of the five institutes had a Board of Directors meeting during the winter as part of the organizing efforts. These progress reviews were accomplished in the summer and concluded that the institutes were on the proper course in accordance with their strategic and first annual plans.

At the request of the Office of the Director, Defense Research and Engineering, the Program Office worked to solicit, and evaluate a proposal for a sixth HPC Software Applications Institute. The Deputy Undersecretary of Defense for Science and Technology selected the proposal for the HPC Institute for Advanced Rotorcraft Modeling and Simulation (HI-ARMS). This institute is centered at the Army's Research, Development and Engineering Command (RDECOM), Aeroflightdynamics Directorate at Ames Research Center, Moffett Field, CA. Its mission is to transform the analysis-test paradigm that currently exists within the rotorcraft industry and government laboratories in the United States into one built around high performance computing.

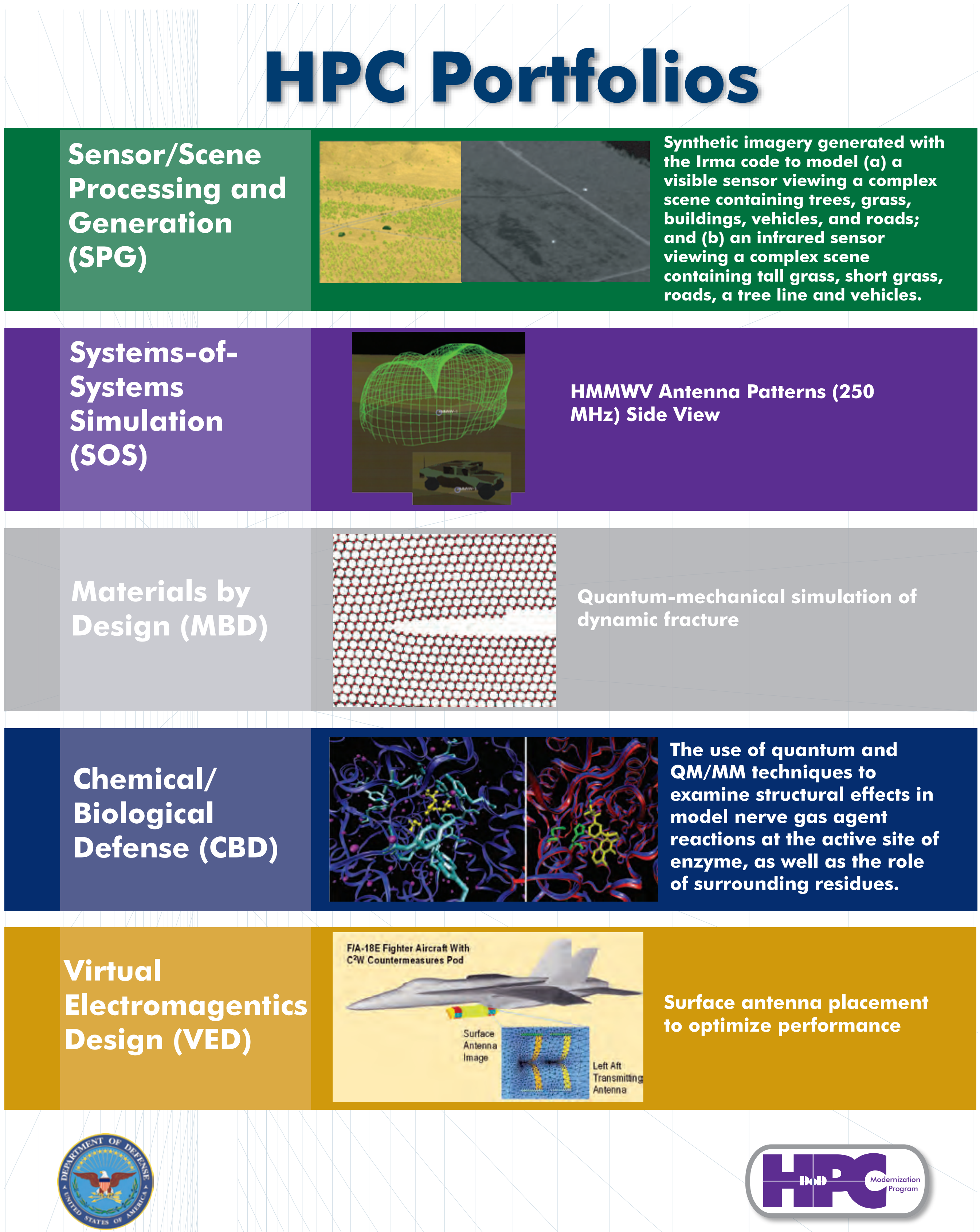
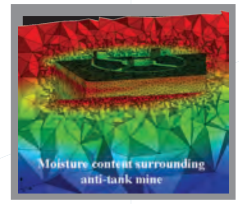


Figure 10. Examples of HPC portfolio research

HPC Software Applications Institutes

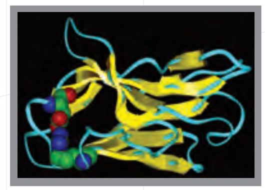
Institute for Maneuverability and Terrain Physics Simulation (IMTPS)

The institute focuses on simulating near-surface environmental processes to support: detection of landmines, improvised explosive devices, and unexploded ordnance; the use of unattended ground sensor networks; analysis of maneuver and traffic-ability; and remote sensing of denied areas.



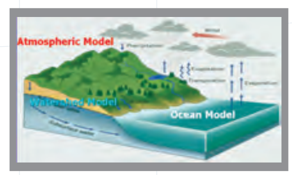
Biotechnology HPC Software Applications Institute for Force Health Protection (BHSAI)

The institute builds HPC experience and expertise within the DoD to deliver the best medical and non-medical biotechnology solutions to protect and treat our warfighters.



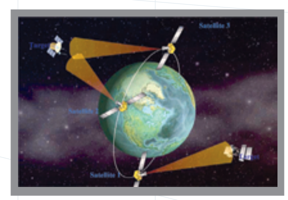
Battlespace Environments Institute (BEI)

This institute migrates existing DoD climate/weather/ocean modeling and simulation, environmental quality modeling and simulation, and space weather applications to the Earth System Modeling Framework (ESMF) and assists in transitioning non-DoD ESMF applications to DoD.



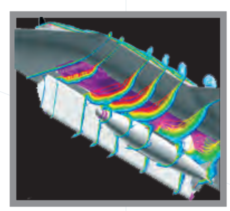
HPC Software Applications Institute for Space Situational Awareness (ISSA)

The institute addresses two top priority capability shortfalls in the SSA community: space object characterization/change detection and knowledge fusion/knowledge repository. The institute applies the power of HPC and advanced algorithms to identify the functionality, capability, mission, status, and health of space objects.



Institute for HPC Applications to Air Armament (IHAAA)

This institute identifies and integrates new technologies, and rebuilds and restructures existing Service-generated software, using formal software engineering procedures that will build acquisition community confidence. Greater accuracy and rapid production of HPC solutions will enable early detection of problem areas in new systems and provide quicker reaction to warfighter needs.



HPC Institute for Advanced Rotorcraft Modeling and Simulation (HI-ARMS)

This institute significantly increases domestic capability to analyze and design future rotorcraft systems to meet heavy-lift requirements of the Department of Defense. Institute software products are built according to the physical accuracy, solution throughput and cost, and solution quality priorities necessary to build a rotorcraft design process around HPC.

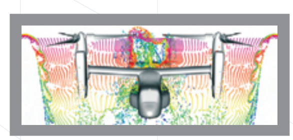
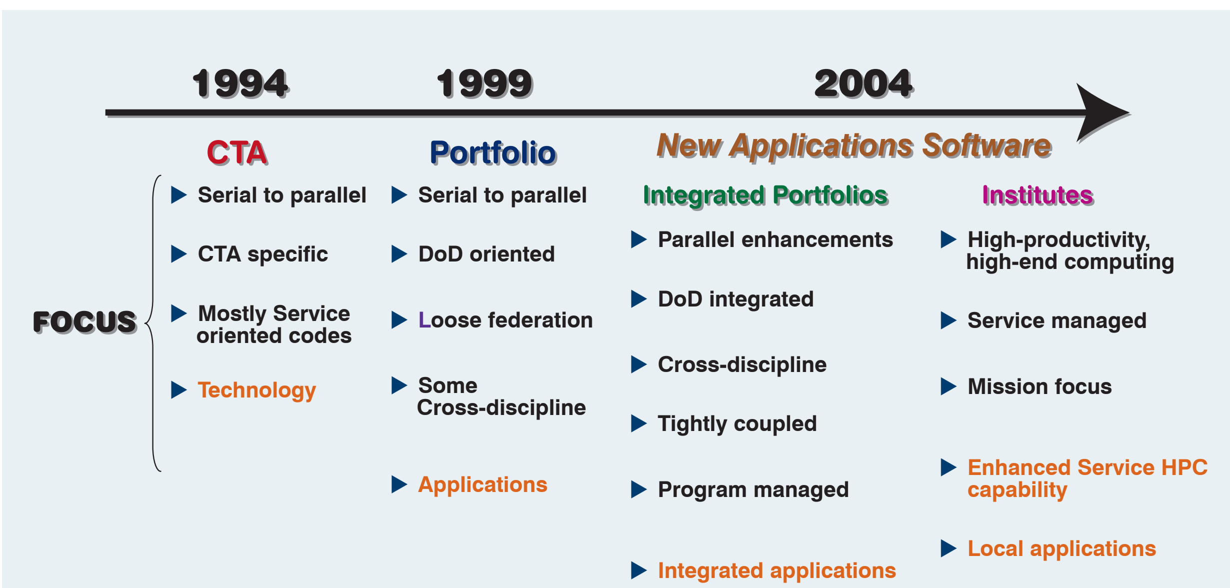


Figure 11. The missions of the HPC software application institutes

Evolution of Software Applications Support within the HPCMP

An evolutionary timeline is shown below which graphically depicts how the DoD software applications programs are transitioning from CTA focused activities to ones that will lead to tightly integrated, multidisciplinary codes that tackle some of the most comprehensive and complex problems facing the DoD warfighters today. Both paradigms have evolved from individual software projects for applications codes from the mid-nineties, where the efforts focused on enhancing DoD applications codes originating up to several decades earlier. These codes were enhanced to become more robust and execute efficiently on scalable hardware coming on line in the mid-to-late nineties. From the beginning of the software applications efforts since 1998 until today, the DoD has completed over 100 projects involving many hundreds of codes; this was a great boon to the weapons development, testing, and warfighting communities. These efforts improved the speed, complexity, and accuracy of military simulations in - materials for combat platforms, space and earth weather prediction, littoral environments, weapons systems, and simulations for the battlefield. Codes released within the last few years: predict the weather with forecasting and nowcasting; model radar-based sensing of surface and subsurface targets, including land mines, unexploded ordnance, and vehicles; model 3-D rectangular arrangements such as the pulsed plasma micro-thruster for microsatellite propulsion; model and simulate large-scale military communications and tactical signal intelligence platforms, weather forecasting model improvements; and simulate large scale, heterogeneous, communication networks.

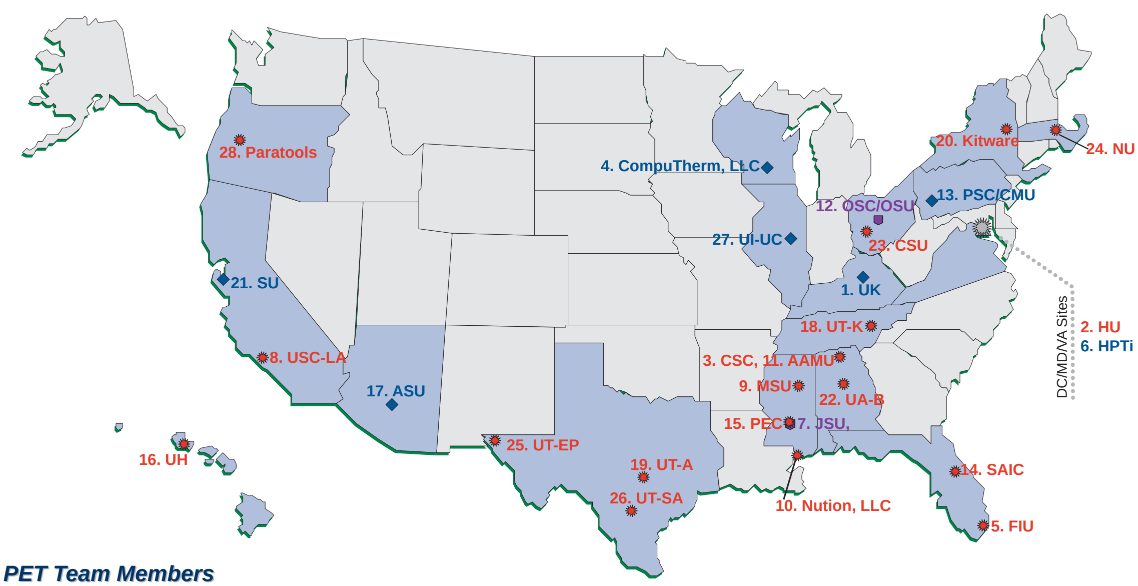


Historical context, the evolution of applications software

User Productivity Enhancement and Technology Transfer (PET)

The User Productivity Enhancement and Technology Transfer (PET) initiative enables the DoD HPC user community to make the best use of the computing capacity the HPCMP provides and to extend the range of DoD technical problems solved on HPC systems. PET is enhancing the total capability and productivity of the program's user community through training, collaboration, tool development, support for software development, technology tracking, technology transfer, and outreach to users.

PET is responsible for gathering and deploying the best ideas, algorithms, and software tools emerging from the national high performance-computing infrastructure into the DoD user community. The PET activities are conducted through two separate contracts; one to MOS University Consortium, led by Mississippi State University, and the second to High Performance Technologies, Incorporated (HPTi). The teams from both contracts involve academic leaders to serve as points of contact for each of the areas covered by PET and experienced personnel located at DoD sites to provide HPC and one-to-one scientific assistance to HPCMP users. The teams are comprised of experts from a broad range of universities and companies highly regarded in the HPC field. (See Figure 12) In addition, PET personnel lead short-term projects that focus on delivering capabilities for specific needs.



PET Team Members

1. University of Kentucky, Lexington, KY
2. Howard University*, Washington, DC
3. Computer Sciences Corporation, Huntsville, AL
4. CompuTherm, LLC, Madison, WI
5. Florida International University*, Miami, FL
6. High Performance Technologies, Inc., Reston, VA
7. Jackson State University*, Jackson, MS
8. University of Southern California, Los Angeles, CA
9. Mississippi State University, Starkville, MS
10. Nution, LLC, Bay St. Louis, MS
11. Alabama A&M University Research Institute*, Normal, AL
12. Ohio Supercomputer Center/The Ohio State University, Columbus, OH
13. Pittsburgh Supercomputing Center/Carnegie-Mellon University, Pittsburgh, PA
14. Science Applications International Corporation, Orlando, FL
15. PEC Solutions, Inc., Jackson, MS
16. University of Hawaii*, Honolulu, HI
17. Arizona State University, Tempe, AZ
18. University of Tennessee, Knoxville, TN
19. University of Texas, Austin, TX
20. Kitware, Clifton Park, NY
21. Stanford University, Palo Alto, CA
22. University of Alabama, Birmingham, AL
23. Central State University*, Wilberforce OH
24. Northeastern University, Boston, MA
25. University of Texas*, El Paso, TX
26. University of Texas*, San Antonio, TX
27. University of Illinois, Urbana-Champaign, IL
28. Paratools, Eugene, OR

** denotes Minority Serving Institution (MSI)*

Legend

- HPTi Team
- MOS University Consortium
- HPTi and MOS

Figure 12. HPCMP PET contractor teams

PET supports all ten HPCMP computational technology areas and the following four cross-cutting areas, with a broad HPCMP-wide management approach.

Enabling Technologies (ET)

The Enabling Technologies Functional Area addresses tools, algorithms, and standards for pre- and post-processing large datasets. Such processing includes the following technologies: mesh generation, visualization (both local and remote), data mining and knowledge discovery, image analysis, and problem solving environments.

Computational Environment (CE)

Improving the usability of the computational environments at the HPCMP centers is critical for easily and effectively using the program's resources. The computational environment includes all aspects of the user's interface to high performance computing resources, including programming environments (debuggers, libraries, solvers, higher order languages; performance analysis, prediction, and optimization tools), computing platforms (common queuing, clusters, distributed data, and metacomputing), reusable parallel algorithms, user access tools (portals and web-based access to high performance computing resources), and consistency across the centers for locating these capabilities.

Collaborative and Distance Learning Technologies (CDLT)

This functional area focuses on supporting HPCMP users who are unable to attend HPC-based events, such as training classes and meetings. CDLT is responsible for webcasting and video-capturing events and post-processing the material to create high quality instructional content. After approval, such content is available for downloading from the PET Online Knowledge Center. CDLT also provides support, on request, for video teleconferencing services. Strong interactions with the HPCMP Defense Research and Engineering Network component and with Centers' staffs ensure that CDLT activities are coordinated and incorporated into the Program's networking and security infrastructure.

Education, Outreach, and Training Coordination (EOTC)

This functional area coordinates formal and informal knowledge delivery to the DoD HPCMP user community and outreach to other communities. EOTC encompasses PET-sponsored HPC-based training, summer intern program, summer institutes at minority serving institutions (MSI), visiting faculty program, and general HPC outreach. EOTC provides opportunities for MSI staff, faculty and students; undergraduate and graduate students; postdoctoral and visiting faculty appointments; and the training of future DoD HPCMP users. Activities in this functional area include: coordinating on-site training at the program's shared resource centers and remote sites; selecting optimal training delivery methods and media; coordinating outreach forums, such as conferences, workshops, seminars, and symposia; establishing and maintaining a coherent framework to integrate undergraduate, graduate students, postdoctoral and visiting faculty into the PET activity; and developing programs and activities that promote careers in computational science and high performance computing.

PET Highlights

HPCMP technical and program management has emphasized and encouraged our entire team of functional experts, on-site personnel, Principal Investigators, and business administrators to focus on the key goals of the PET program; technology transfer, user productivity, and DoD mission impact. The following two examples show such achievements.

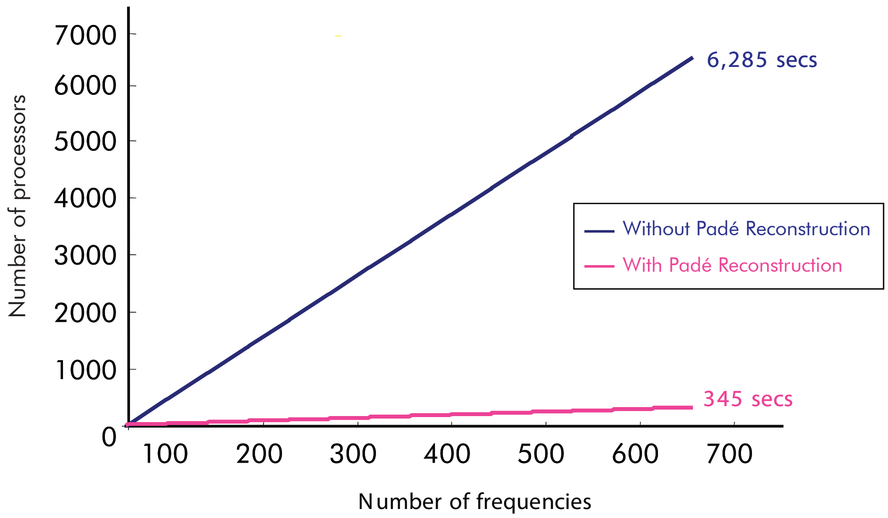


Figure 13. Performance with and without Padé Approximant Reconstruction

PET personnel demonstrated to the Army Model Exchange that the additional work required in setting up their production Xpatch® runs in the environment at the ASC MSRC was more than compensated for by the resulting benefits. Xpatch® benchmark tests were run and codes were customized for the Army Model Exchange to convince them that the MSRC system was convenient to use and, more importantly, based on benchmark results, realized significant time savings.

The first example (Figure 13) shows the time-speedup benefit of transferring to DoD HPCMP users a technology called Padé Approximant Reconstruction. This technology provides an approach for determining complex frequency-dependent results at may hundreds of frequencies from results obtained from a remarkably small number of frequencies.

The second example (Figure 14) demonstrates the benefit of PET's extensive outreach activity. The Army Model Exchange at the System Simulation & Development Directorate (SSDD) in Huntsville, AL is tasked to develop geometric models and run computational electromagnetic codes such as Xpatch® to compute radar cross section (RCS) signatures. The models at the Army Model Exchange are usually of very high fidelity, and their production "full-angle" Xpatch® runs on each model typically require thousands of incident angles that easily take weeks of CPU time. The objective was to bring the HPC resources at the MSRCs to the attention of the Army Model Exchange and to facilitate setting up and executing their production runs at the MSRCs.

The Army Model Exchange is now using MSRC resources for its production Xpatch® runs. In one typical run, it was reported that predictions that required about 37 days on machines at the Space & Missile Defense Command (SMDC) were completed in only 18 days on the SGI Origin 3900 at ASC MSRC.

Figure 14. Radar signatures modeling at the Army Model Exchange

Goal 3: Acquire, deploy, operate and maintain a communications network that enables effective access to supercomputers and to distributed S&T/T&E computing environments

Defense Research & Engineering Network

The Defense Research & Engineering Network (DREN) was created to link high performance computational users and supercomputers, no matter where the person or resource is or with what Military Service they are associated (see Figure 15 on page 38). Since then, DREN has acted as an enabler in many ways for the research, development, test and evaluation (RDT&E) community, the Missile Defense Agency (MDA), DoD Modeling & Simulation Office, Joint Forces Command, Defense Threat Reduction Agency (DTRA), and others.

DREN is an enabler for major shared resource center efforts to perform secure, large-scale, remote, mass-storage for HPC disaster recovery. Although it's always been highly desirable to do in-band (live on-line) mass storage transfers, it was in the "too-hard-to-do" category. The challenge of transferring terabits of data daily between multiple centers was out-of-reach. Recently, a number of advances have made these types of data exchanges a reality. Access to the DREN backbone was expanded at each of the DoD major shared resource centers to OC-48 (approximately 2.4 gigabits per second). These centers are the first within the Department of Defense to have massive wide-area network (WAN) access capabilities. Anticipating rapidly rising bandwidth demands, DREN revamped its backbone nationwide using jumbo frame IP technology using new protocol architectures (multi protocol label switching and IPSec tunnels) which in turn, has enabled high-end tuning of computational resources over thousands of miles for massive data transfers.

DREN is centrally funded for science and engineering users of DoD high performance computational resources. Other congressionally authorized groups (MDA, modeling & simulation, operational test and evaluation groups) not part of HPC line-item funding must offset service delivery point and security costs to access the DREN.

It is in the best interest of the DoD to continuously expand the pool of quality scientists and engineers working on high priority DoD problems. Potential new users often discover the availability of HPC resources through initial exposure to DREN. Joint Forces Command in Suffolk, Virginia followed this pattern and eventually expanded into a joint, distributed, system-of-systems virtual communications concept for future real-time communications and network simulations.

An advantage of DREN is that it makes high capacity bandwidth available to all computational resources wherever they may be. This approach makes it much easier to ensure optimal use of high performance computing assets and reduces the effective cost of these scarce resources.

Historically, we associated access to scarce and expensive resources with close proximity to major centers of civilization. Today, we have much more flexibility in the placement of new computational resources. That flexibility allows growth of new skill and job opportunities to rural (Midwest, Southwest) or remote (Alaska, Hawaii) labor markets that otherwise would be overlooked. High bandwidth WAN access allows the HPCMP to get resources very close to specialized real-time systems while expanding the pool of potential users working on DoD problems and keeps those resources extremely busy.

Defense Research & Engineering Network (DREN)

Figure 15. DREN connections, HPC centers, and other network access points

Goal 4: Promote collaborative relationships among the DoD computational science community, the national computational science community and minority serving institutions (MSIs)

Defense Research & Engineering Network

As one of the three major areas of DoD's high performance computing modernization program, DREN draws from the nations' high performance computing community most familiar with Defense supercomputing for technical advisory and security group members. DREN personnel also participate in the more generalized DoD networking and security communities within the Global Information Grid, through direct participation on DoD control boards and technical advisory councils, and by participating as a Tier 2 DoD CERT (Computer Emergency Response Team for hostile acts of intrusion and compromise).

DREN contributes to overall federal agency networking and security through the Large Scale Network (LSN) and Joint Engineering Team (JET). These groups maintain and extend US technological leadership in leading-edge network technologies and coordinate Federal agency networking activities, operations, and plans represented by DoD DREN, DOE, NASA, NSF, Next Generation Internet (NGI), and Internet 2 (I2). The JET and LSN are part of the White House's Office of Science and Technology Policy Interagency Working Group.

DREN peers (exchanges network traffic) at well-known international exchange points such as Starlight in Chicago, and the Pacific Northwest Gigapop in Seattle, advanced exchanges such as Next Generation Internet Exchanges East and West in Maryland and California, and actively participates in international science exchanges such as the Australian Meteorological and Oceanographic Society and Asian Pacific Advanced Networks projects.

User Productivity Enhancement and Technology Transfer (PET)

The Education, Outreach, and Training Coordination (EOTC) functional area within PET is responsible for creating education opportunities targeted to undergraduate and graduate education, with emphases on minority serving institutions, by sponsoring summer intern programs and summer institutes. A goal is to create a workforce pipeline for the Department of Defense and the nation.

The Summer Intern program takes place in June, July, and August. The Summer 2005 Intern program was successful, and the student presentations are in the EOTC section on the PET Online Knowledge Center (https://okc.erdc.hpc.mil). From these presentations we get the clear message that not only do the students gain valuable experience in a DoD Laboratory environment, but the projects that these students work on directly impact DoD research. A total of 26 summer interns were placed at four locations: ARL-Aberdeen, MD, ERDC-Vicksburg, MS, ASC-WPAFB, OH, and NAVO-Stennis Space Center, MS.

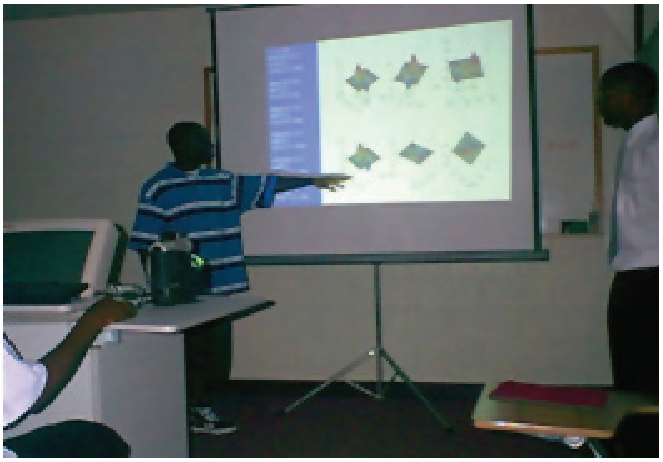


Figure 16. A student presenting at a summer institute

One of our primary efforts in attracting and preparing students at MSIs for the intern program is the summer institute program. The summer institute program is comprised of a two-week event (i.e., institute) at each of four MSIs. each institute introduces students to HPC and provides introductory instruction. In the Summer of 2005, PET sponsored institutes at Jackson State University, Florida International University, University of Hawaii, and Central State University. Forty-six students attended the summer institutes where they collaborated with PET personnel from several function areas, thus giving them a well-rounded experience, including the opportunity to present their work (see Figure 16). The Computational Science Workshop for Underrepresented Groups was held again in January 2005 (see Figure 17). This annual event, jointly supported by PET and other sources, brings together students and faculty from MSIs for a week-long course on building a parallel computer and on methods for solving problems in computational science. The 2005 workshop, attended by approximately 45 students and faculty from MSIs, was held on the campus of the University of Southern California.

In 2005, the following MSIs participated in PET education and technology transfer activities: Alabama A&M University, Central State University, Florida International University, Howard University, Jackson State University, University of Hawaii, University of Southern California, University of Texas at El Paso, and University of Texas at San Antonio.

Figure 17. Participants at the 2005 Computational Science Workshop for Underrepresented Groups

Goal 5: Continuously educate the RDT&E workforce with the knowledge needed to employ computational modeling effectively and efficiently

User Productivity Enhancement and Technology Transfer (PET)

The PET contracts offered 66 training events this past year, attended by 767 students, covering subjects ranging from Code Profiling and Error Estimators to user training on codes such as Accelerys and Xpatch®. See Table 4 for a sampling of courses given in FY 2005.

PET courses captured on video and transferred on compact disc are available for ordering on the PET Online Knowledge Center by DoD personnel and contractors. Some of those courses are available to be downloaded onto the users' desktops and viewed at their leisure (see https://okc.erdc.hpc.mil).

The value of these CDs is evidenced by the following user comment:

> *I was very impressed with the quality of the PET courses that are offered on CD for those that were not able to attend a particular course. A couple of weeks ago, I went to the PET website and was able to select a couple of PET courses that I was not able to attend and request them on CD. Now I am able to go through the class at my own pace, and I was astonished by the quality of the course material; being able to watch a video of the class and look at the slides that were presented (on the same Real player window) was awesome. I think this is a great resource and hope that the course offerings on this format get expanded in the future.*

Juan C Cruz
Missile, Launcher and Payload Integration Department, Analysis and Technology Branch

Table 4. A Sampling of Training Courses Given in FY 2005

Course Name	Number of Attendees
ABAQUS (2)	23
Accelerys (2)	13
Advanced ACAD	9
Advanced Concepts for Finite Element Methods Workshop	11
Advanced LS-DYNA	7
Advanced MATLAB® Programming (2)	31
Advanced MPI (2)	25
ANSYS Workbench Environment	9
CFD Pre-Processing, Practice, Current Research and Future Directions	21
CFD++	6
Chemical Reacting Flow Simulations and Turbulence Modeling	7
COBALT	6
Columbus Chemistry Codes	8
Coupled 3D Simulation of Microwave and Optoelectronic Devices	7
DARWIN	16
FISC	8
High Performance Computing using an Interpretive Language (2)	23
HyperMesh®	10
IBM POWER4 Workshop (2)	18
Image Processing using MATLAB®	13
Introduction to GEMACS	24
Introduction to Distributed Oceanographic Data Systems (DODS)	11
Introduction to the Earth Systems Modeling Framework (ESMF)	11
Introductory and Intermediate MATLAB (3)	47
MatlabMPI	6
Mesh-free Methods in LS-DYNA	9
Modeling Spin Transport in Magnetic Semiconductors	4
Modern Perspective on Verification and Validation of Computer Simulations	4
Multidisciplinary Design Optimization Workshop	27
Numerical Methods in Computational Structural Methods: An Introduction	7
NWChem	5
Overset 2004 Symposium	110
Parallel Programming using MatlabMPI	16
Performance Optimization and Tools for HPC Architectures	5
Python for Signal Processing	9
Signal Mining	7
Turbulence Modeling Workshop	8
VSIPL™	12
Xpatch®	23

SECTION 3

FINANCIAL STATEMENTS

Section 3—Financial Statements

FY 2005 Budget Resources

Financial Analysis

The HPCMP funds are used for (1) capitalization, sustainment, and operations at the MSRCs; (2) annual capitalization for selected DCs and Dedicated HPC Project Investments; (3) wide area network services for the DoD HPC community; (4) investments in human capital and key HPC software applications; and (5) expert HPC services from leading academic institutions. Figure 18 displays FY 2005 spending by componet and Figure 19 shows FY 2006 planned spending by component.

We use multiple contracting officers assigned in support of different efforts. We use contracting officers at the General Services Administration in support of HPC equipment and services purchases and use contracting officers at various DoD installations in support of service contracts. This structure is necessary because the program requires multiple contracts and contract types with an ongoing need to ensure that state-of-the-art technical capabilities are made available to DoD scientists and engineers in a timely manner. Contracts are a combination of firm fixed price, cost and/or indefinite delivery/ indefinite quantity. All procurement awards are made for commercially available systems. Acquisitions are accomplished competitively to the fullest extent possible and encourage the inclusion of small, disadvantaged businesses and MSIs.

We evaluate the effectiveness of each program component by measuring actual cost and schedule performance versus planned cost

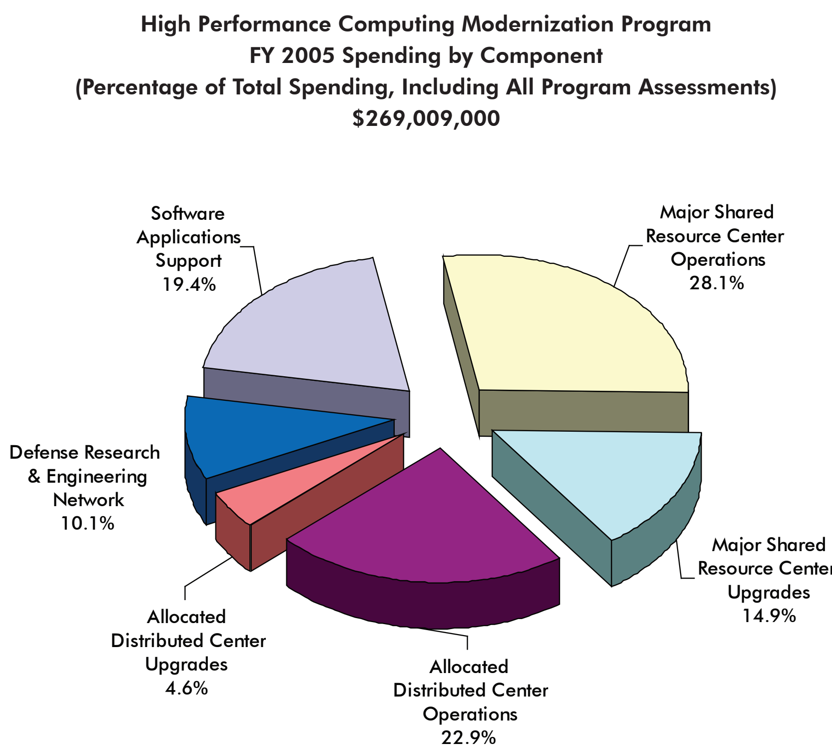


Figure 18. HPCMP FY 2005 spending by component

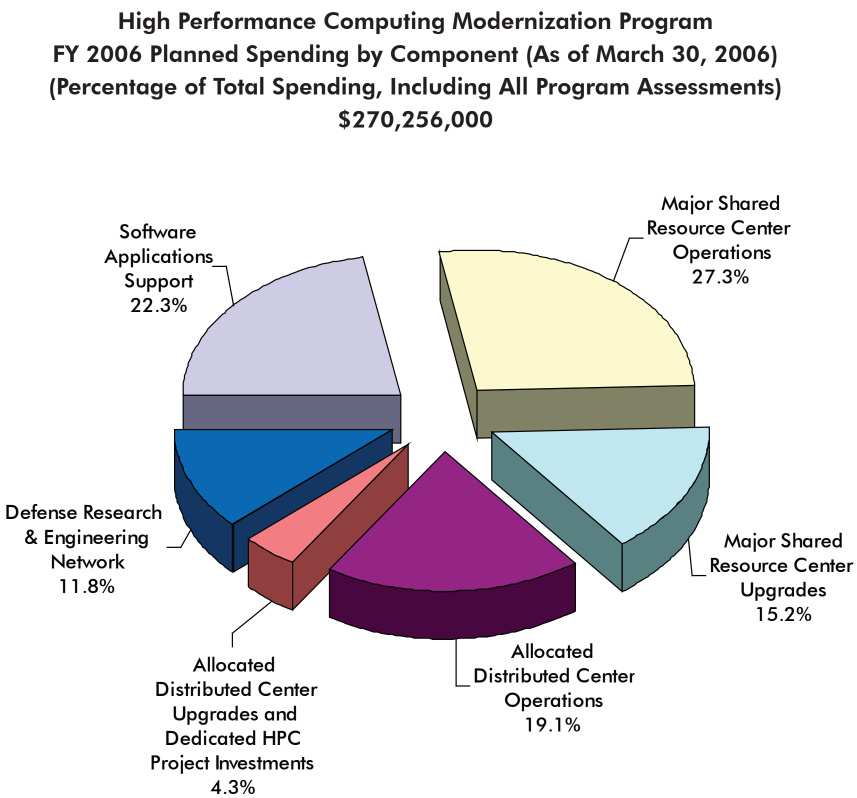


Figure 19. HPCMP FY 2006 planned spending by component

and schedule performance and through the measurement of actual outcomes versus planned outcomes. The MSRC contractors submit several reports regularly including a monthly and quarterly cost performance report and quarterly contract funds status report. Each contract specifies, as a deliverable, a work breakdown structure to facilitate the on-going review of smaller task components. Cost/schedule status reports are one of the primary tools used for oversight management of the MSRCs.

The balance sheet on page 48 shows the cumulative value of the program.

Obligations and Costs

Our Financial Manager conducts semi-annual reviews with each major component manager and major field activity to review actual cost performance against budgeted cost goals in a tailored work breakdown structure format with special attention on variance analysis. Significant variances are reported to our Program Director and corrective actions taken. We receive approximately $250,000,000 each year in funding appropriated for the DoD. Cash flow during 2005 is illustrated by the Cash Flow Statement on page 49.

While the program has leveraged major cost performance improvements in computer technology since 1994, validated requirements have always exceeded the computing capability available to address those requirements. This occurs: 1) because the use of science-based models and simulations to answer research questions and solve engineering problems has grown dramatically; and 2) because fully funding the HPC requirement is unaffordable given the entire scope of activities the DoD budget must address. While fiscal resources do not fully meet the computational requirements of the science and technology and test and evaluation communities, the returns provided are substantial and are allocated to the highest priority projects. The FY 2005 Income Statement on page 50 show these shortfalls.

Financial Trends

Except for minimal inflation adjustments, HPC budgets are essentially flat. We are addressing urgent new requirements by adjusting priorities within the existing funding profile. We increased the overall capability of our HPC systems by about 80%, and add or upgraded systems at the ADCs. However, even with these increased capabilities, we are unable to meet validated DoD requirements. Development of the portfolios and institutes will continue. The

DoD HPC user community will continue to be supported by the PET efforts. Our Software Protection Initiative will continue to mature. The charts on the previous page break out program-wide and planned spending during 2006.

The Income Statement on page 50 shows that we currently have a continuing deficit in that the dollars we spend are not keeping up with the rapidly growing needs of the scientific community. Figure 20 displays spending by vendor in FY 2005 and Figure 21 shows planned spending by vendor in FY 2006.

We deploy, sustain, and upgrade commercially available high performance computing environments and networking services in support of DoD laboratories and test facilities. We have substantially improved the Department's computational capabilities with the objective of providing the DoD the technology to ensure dominance on the battlefield by the early fielding of the most advanced computing capability available.

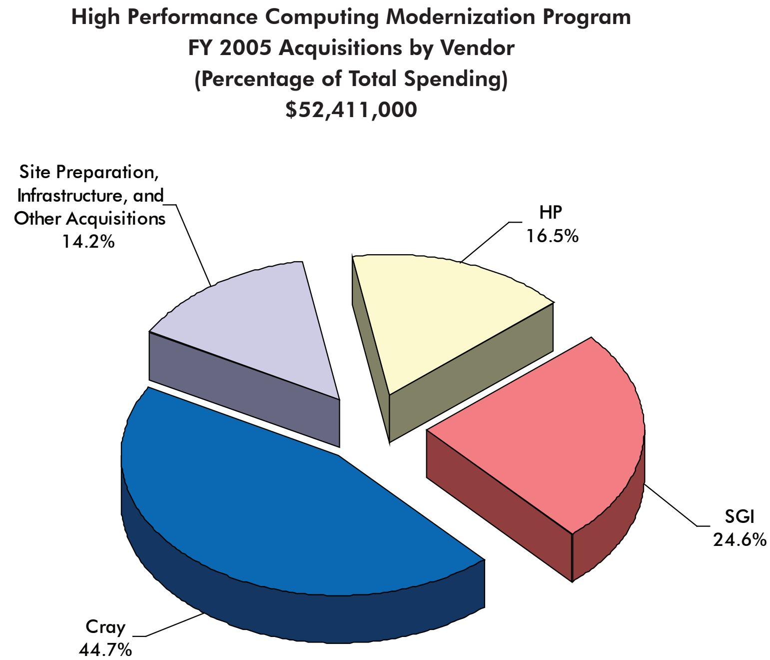


Figure 20. HPCMP FY 2005 acquisitions by vendor

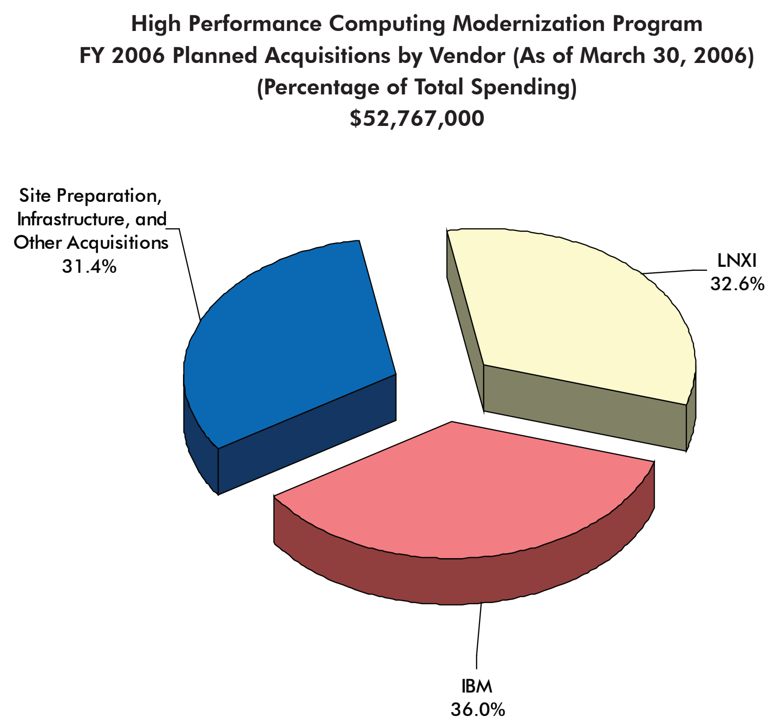


Figure 21. HPCMP FY 2006 planned acquisitions by vendor

High Performance Computing Modernization Program
Balance Sheet
As of March 30, 2006

Assets and Equity

Hardware	$959,121,999	
Less: Depreciation		
Fiscal Year 1994–2001:	$787,792,339	
Fiscal Year 2002:	$33,219,999	
Fiscal Year 2003:	$20,460,857	
Fiscal Year 2004:	$7,487,286	
Fiscal Year 2005:	$0	
		$110,161,518
Software (1)	$225,840,528	
Less: Depreciation		
Fiscal Year 1994–1999:	$106,815,239	
Fiscal Year 2000:	$15,667,212	
Fiscal Year 2001:	$14,247,283	
Fiscal Year 2002:	$9,357,355	
Fiscal Year 2003:	$4,620,365	
Fiscal Year 2004:	$2,162,300	
Fiscal Year 2005:	$0	$72,970,774
Manpower Contracts (2 & 3) Software Development		
Exercised Contract Value	$29,733,815	
Less: Value Consumed Remaining Exercised Value	$26,910,532	$2,823,283
Maintenance Contracts (2 & 3)		
Hardware Maintenance		
Fiscal Year 2006:	$23,475,019	
Software Maintenance		
Fiscal Year 2006:	$2,429,581	
Less: Value Consumed		
Hardware Maintenance		
Fiscal Year 2006:	$14,486,457	
Software Maintenance		
Fiscal Year 2006:	$1,534,685	$9,883,458
Intellectual/Operations		
Government Labor		
Fiscal Year 2006:	$22,649,457	
Contract Labor		
Fiscal Year 2006:	$102,859,646	
Less: Value Consumed		
Government Labor		
Fiscal Year 2006:	$15,701,310	
Contract Labor		
Fiscal Year 2006:	$70,223,727	$39,584,066
	Total Assets	**$235,423,099**

Liabilities

Uncompleted Software Development	$2,823,283	
Maintenance Contract Liabilities		
Hardware		
Fiscal Year 2006:	$8,988,562	
Software		
Fiscal Year 2006:	$894,896	
Intellectual/Facilities Expense		
Government Labor		
Fiscal Year 2006:	$6,948,147	
Contract Labor		
Fiscal Year 2006:	$32,635,919	
Total Liabilities	**$52,290,807**	
	Program Equity	**$183,132,292**
	Total Liability and Program Equity	**$235,423,099**

(1) Research, Development and Engineering Funding used to develop inventory software.

(2) Office of Management and Budget Circular A-11, Section 300 - Planning, Budgeting, Acquisition, and Management of Capital Assets (Paragraph 300.4), defines capital assets as land, structures, equipment, intellectual property (e.g., software), and information technology (including IT service contracts) that are used by the Federal government and have an estimated useful life of two years or more. Therefore, manpower is treated as a capitol asset

(3) Small consumable items such as computer tapes and supplies are considered as expense items and not carried as inventory items.

High Performance Computing Modernization Program
Cash Flow Statement
October 1, 2004 — September 30, 2005

	Fiscal Year 2005
Revenue	
Research, Development and Engineering Funding	
President's Budget	$186,666,000
Congressional Funding	$51,550,000
Department of Defense Reprogramming - In	$0
(Less Department of Defense Reprogramming - Out)	($21,618,000)
Net Research, Development and Engineering Funding	**$216,598,000**
Procurement Funding	
President's Budget	$50,147,000
Congressional Funding	$6,300,000
Department of Defense Reprogramming - In	$0
(Less Department of Defense Reprogramming - Out)	($4,036,000)
Net Procurement Funding	**$52,411,000**
Net Revenue	**$269,009,000**
Investments	
Major Shared Resource Center Upgrades	$40,052,123
Allocated Distributed Center Upgrades	$12,358,877
Software Development	$22,604,944
Expense	
Major Shared Resource Center Operations	$75,758,703
Allocated Distributed Center Operations	$61,520,536
Defense Research & Engineering Network	$27,056,421
Software Initiatives	$29,657,396
Net Expense	**$269,009,000**
Balance (As of September 30, 2005)	**$0**

High Performance Computing Modernization Program
Income Statement
October 1, 2004 — September 30, 2005

	Fiscal Year 2005
Income	
Research, Development and Engineering Funding	
Major Shared Resource Center Operations	$75,758,703
Allocated Distributed Center Operations	$61,520,536
Defense Research & Engineering Network	$27,056,421
Software Initiatives	$52,262,340
Procurement Funding	
Major Shared Resource Center Upgrades	$40,052,123
Allocated Distributed Center Upgrades	$12,358,878
Defense Research & Engineering Network	$0
Software Initiatives	$0
Total Income	**$269,009,000**
Expense[1]	
Research, Development and Engineering Funding	
Major Shared Resource Center Operations	$75,758,703
Allocated Distributed Center Operations	$61,520,536
Defense Research & Engineering Network	$27,056,421
Software Initiatives[2]	$29,657,396
Depreciation of Capital Assets	
Hardware (Depreciated based upon a 48-month life-cycle)[3]	$59,609,857
Software (Depreciated based upon a 60-month life-cycle)[4]	$18,179,128
Total Expense[5]	**$271,782,041**
Balance (As of September 30, 2005)	**-$2,773,041**

Note 1: Expenses include travel; supplies; government and contractor salaries and training; maintenance of hardware and software; studies and analysis; annual operations investments; communications, utilities, facilities lease and facilities maintenance.

Note 2: Software initiatives are separated into 2 distinct categories – expenses associated with research and development, management, education/training and expert services; and capitol assets resulting from developed software.

Note 3: Depreciation for HPC hardware is calculated using a 42 to 48 month straight-line depreciation method. Current HPC technology development results in predictable obsolescence. Generally after 42 to 48 months of use, HPC systems are retired with little or no residual value. Fiscal year 2005 depreciation includes the 12 month value calculated for all systems in the inventory between October 1, 2004 through September 30, 2005.

Note 4: Depreciation for HPC software is calculated using a 60 month straight-line depreciation method. A period of 60 months is used because it is the typical life cycle of HPC software before significant modifications are required. Fiscal year 2005 depreciation includes the 12 month value calculated for all software in the inventory between October 1, 2004 through September 30, 2005.

Note 5: Annual program investments in system hardware have not been made at levels sufficient to maintain stable equipment inventories. For several years depreciated values have not been offset by new assets.

ACRONYMS

Acroynms

3-D	three-dimensional
ABL	Airborne Laser
ADA	atmospheric decision aid
ADCs	allocated distributed centers
AEDC	Arnold Engineering Development Center
AFB	Air Force Base
AFSEO	Air Force Seek Eagle Office
AFWA	Air Force Weather Agency
AHPCRC	Army High Performance Computing Research Center
AMR	automatic mesh refinement
ARL	Army Research Laboratory
ARSC	Arctic Region Supercomputing Center
ASC	Aeronautical Systems Center
ATC	Aberdeen Test Center
BEI	Battlespace Environments Institute
BHSAI	Biotechnology HPC Software Applications Institute for Force Health Protection
C4ISR	command, control, communications, computers, intelligence, surveillance and reconnaissance
CAP	capability applications projects
CBD	chemical/biological defense
CBoD	Centers Board of Directors
CCM	computational chemistry, biology, and materials science
CDLT	collaborative and distance learning technologies
CE	computational environment
CEA	computation electromagnetics and acoustics
CEO	chief executive officer
CERT	computer emergency response team
CFD	computational fluid dynamics
CSM	computational structural mechanics
CTAs	computational technology areas
CWO	climate/weather/ocean modeling and simulation
DHPIs	dedicated HPC project investments

DIOT	Distributed Implementation and Operations Team
DoD	Department of Defense
DOE	Department of Energy
DNS	direct-numerical simulations
DREN	Defense Research and Engineering Network
DTO	Defense Technology Objectives
DTRA	Defense Threat Reduction Agency
ED&PMB	Engineering Design and Process Management Board
ENS	electronics, networking, and systems/C4I
EOTC	education, outreach, and training coordination
ERDC	Engineer Research and Development Center (USACE)
EQM	environmental quality modeling and simulation
ET	enabling technologies
FLOPS	FLoating-point OPerations per Second
FMS	forces modeling and simulation
FNMOC	Fleet Numerical Meterology Oceanography Center
FY	fiscal year
GFLOPS	gigaFLOPS
GFs	gigaFLOPS
Gov	government
HI-ARMS	HPC Institute for Advanced Rotorcraft Modeling and Simulation
HMMVV	High-Mobility Multipurpose Wheeled Vehicle
HPC	high performance computing or high performance computer
HPCMP	High Performance Computing Modernization Program
HPCMPO	High Performance Computing Modernization Program Office
HPTi	High Performance Technologies, Incorporated
IHAAA	Institute for HPC Applications to Air Armament
IMT	integrated modeling and test environments
IMTPS	Institute for Maneuverability and Terrain Physics Simulation
ISSA	HPC Software Applications Institute for Space Situation Awareness
JFC/J9	Joint Forces Command/J9
JET	Joint Engineering Team
LES	large-eddy simulations
LSN	large scale network
MBD	materials by design
MDA	Missile Defense Agency
MHPCC	Maui High Performance Computing Center

MSIs	minority serving institutions
MSRCs	major shared resource centers
NASA	National Aeronautics and Space Administration
NAVO	Naval Oceanographic Office
NAWCAD	Naval Air Warfare Center Aircraft Division
NGI	Next Generation Internet
NRL-DC	Naval Research Laboratory, Washington, DC
NSF	National Science Foundation
NSWCCD	Naval Surface Warfare Center, Carderock Division
NUWC	Naval Undersea Warfare Center
OC	optical carrier
OKC	Online Knowledge Center
PET	User Productivity Enhancement and Technology Transfer
RCS	radar cross section
RDT&E	research, development, test, and evaluation
RF	radio frequecy
S&T	science and technology
SAS	software applications support
SGS	subgrid-scale
SIMAF	Simulations & Analysis Facility
SIP	signal/image processing
SMDC	Army Space and Missile Defense Command
SOS	system-of-systems
SPG	sensor/scene processing and generation
SPO	system program office
SSCSD	Space and Naval Warfare Systems Center, San Diego
SSDD	System Simulation & Development Directorate
T&E	test and evaluation
TB	terabytes
TFLOPs	teraFLOPS
TI	technology insertion
UAVs	unmanned air vehicles
US	United States
USACE	US Army Corps of Engineers
VED	virtual electromagentics design
VV&A	validation, verification, and accreditation
WAN	wide area network

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