The High Performance Computing Modernization Program

By Cray Henry, Susan Pfeiffer-Vega and Bill Gabor

Introduction

Since the introduction of the ENIAC in 1945, high performance computing has played a major role in the development of new technologies. Today the Department of Defense (DoD) uses supercomputers and advanced computational methods to conduct basic research, develop and test precision weapons, and investigate new warfighting capabilities. Central to this activity is a partnership among the defense laboratories, test centers and the High Performance Computing Modernization Program (HPCMP). The HPCMP formally started in 1993 (see Figure 1) in response to Congressional and senior DoD leadership direction. The program grew from a collection of small high performance computing departments, each with a rich history of supercomputing experience, which independently evolved within the Army, Air Force and Navy laboratories and test centers.

The HPCMP provides the supercomputer services, high-speed network communications and computational science expertise that enables defense scientists and engineers to conduct a wide-range of focused research, development and test activities. This partnership puts advanced technology in the hands of U.S. forces more quickly, less expensively, and with greater certainty of success. HPC resources play a critical role in Homeland Security, such as, countermeasures to anthrax and DoD counterterrorism technology. HPC techniques were used to analyze and evaluate the Pentagon's structure in the Pentagon Retrofit Project, which will improve structural design to minimize damage and save lives in the event of attack.

Today, the HPCMP fields a unified set of supercomputing services to the DoD science, engineering, test and evaluation communities that includes some of the world's most powerful high performance computing systems, and a premier wide-area network, supporting a significant portion of the nation's top scientists and engineers with high performance computing software development and application assistance.

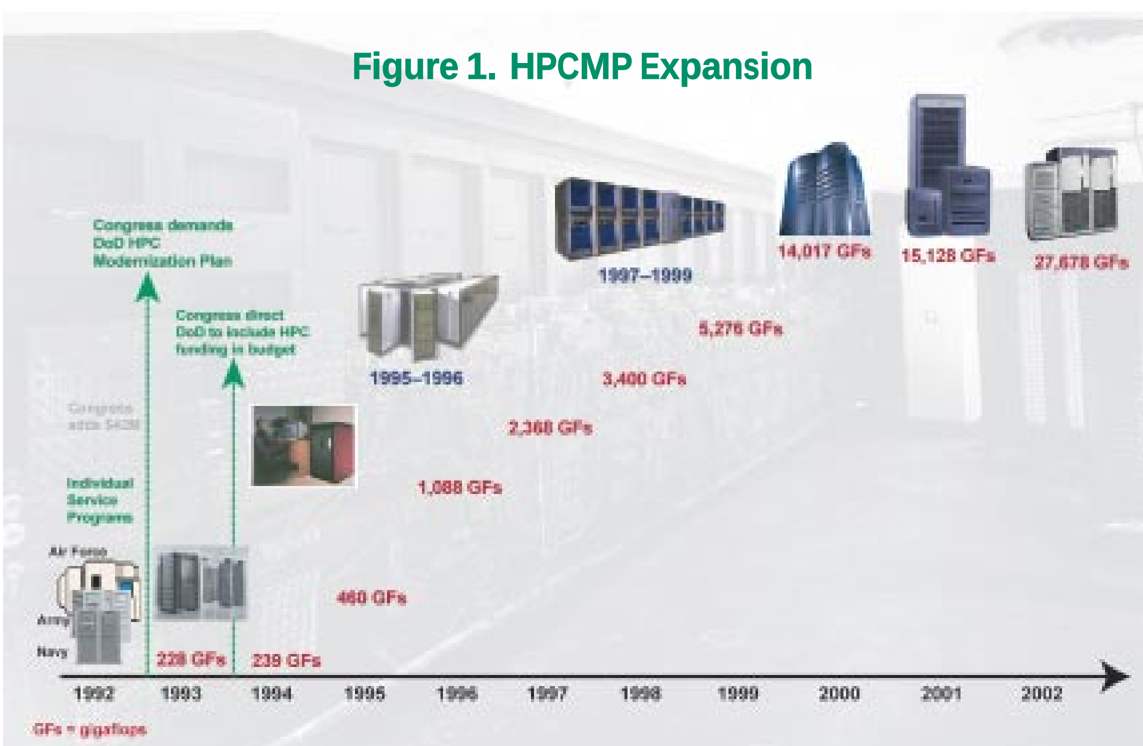

Figure 1. HPCMP Expansion

The HPCMP scope is bounded both in terms of the user community it serves and the technological capability that it delivers. By concentrating the majority of resources at a small number of HPC centers, the program provides computing capabilities that otherwise could not have efficiently been obtained and sustained by the individual Services or federal agencies. This sharing of resources reduces overall acquisition and sustainment costs, and fosters collaboration and cooperation across the DoD science and technology (S&T), and test and evaluation (T&E) communities.

Program Components

The program is organized into three components: HPCMP HPC Centers, Networking, and Software Applications Support. Each component focuses on the most efficient means of supporting the S&T and T&E communities' requirements.

HPCMP HPC Centers

The HPCMP operates four large Major Shared Resource Centers (MSRCs) that enable DoD S&T and T&E communities to effectively use the full range of HPC resources. Each MSRC includes a robust complement of high-end, high performance computing and communications systems that support a wide range of projects. The

Figure 2. Defense Research and Engineering Network (DREN)

Distributed Centers (DCs) provide HPC capacity and capability to a specified local and remote portion of the program's community. Modest-sized systems are deployed to DCs where there is a significant advantage to having a local HPC system, and where there is potential for advancing DoD applications using investments in HPC capabilities and resources.

Networking

The Defense Research and Engineering Network (DREN, shown in Figure 2) is DoD's recognized research and engineering network. The DREN is a robust, high-speed network that provides connectivity between the HPCMP's geographically dispersed user sites and HPC centers. Since users and resources are scattered throughout the United States, strong interconnectivity with other major networks and high performance test beds at key exchange points are critical for optimal use of high performance computers.

Software Application Support

"Software Applications Support" is a new terminology that captures the evolutionary nature of the program's efforts to *"Acquire and develop joint HPC application software tools, and programming environments,"* and *"Educate and train DoD's scientists and engineers to effectively use advanced computational environments."* There are two major components to software application support: Common High Performance Computing Software Support Initiative (CHSSI) and Programming Environment and Training (PET).

CHSSI provides DoD scientists and engineers efficient, scalable, portable software codes, algorithms, tools, models and simulations that run on a variety of HPC platforms. CHSSI, which is organized around 10 computational technology areas, involves several hundred scientists and engineers working in close collaboration across government, industry and academia. The PET component enables the Defense HPC user community to make the best use of the computing capacity the HPCMP provides and extends the range of DoD technical problems that can be solved on HPC systems. PET enhances the total capability and productivity of users through training, collaboration, tool development, software development support, technology tracking, technology transfer and outreach.

DoD Challenge Projects

Approximately 25 percent of the program's total resources are dedicated each year to a set of DoD HPC Challenge Projects. These computational intensive, high-priority projects are selected annually through a rigorous technical and mission relevance evaluation. The Services and other federal agencies allocate the remaining resources through their unique evaluation processes.

Challenge Project efforts produce and support key enabling technologies, capabilities, and demonstrations expressed by the Defense Technology Objectives (DTOs). These enabling DTOs, support Joint Vision 2020 and the 13 Joint Warfighting Capability Objectives (JWCOs) promulgated by the Joint Requirements Oversight Council of the Joint Chiefs of Staff. While not all inclusive, JWCOs provide focus, priority, and a common reference point for much of the DoD's research, test and evaluation efforts. Below are just a few examples of the 39 Challenge Projects currently in the program.

Coupled Environmental Model Prediction (CEMP)

Wieslaw Maslowski, Julie McClean, Albert Semtner, Robin Tokmakian, Yuxia Zhang, Ruth Preller and Steve Piacsek, Naval Postgraduate

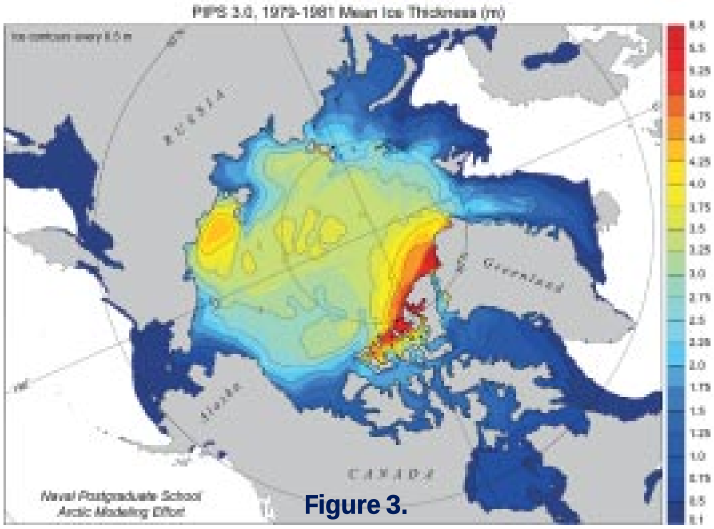

Figure 3.

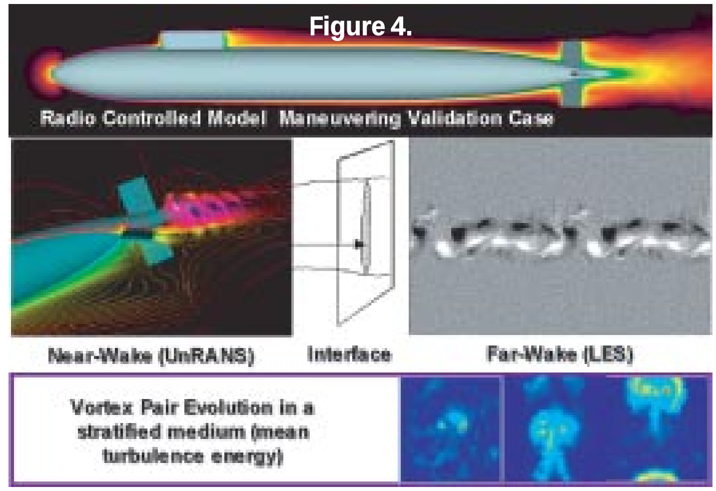

Figure 4.

School, Monterey, Calif., and Naval Research Laboratory, Stennis Space Center, Miss.

The purpose of the CEMP project is to develop coupled air/ocean/ice prediction models to provide short- to long-term forecasts in the battlespace environment and to deliver a state-of-the-art coupled pan-Arctic ice-ocean model to improve the Navy's operational forecasts for sea ice and ocean conditions. The realistic simulation of the present day sea ice thickness distribution is critical to predicting the possibility of partial/seasonal or full removal of permanent sea ice cover in the Arctic Ocean during the next century. An illustration of ice thickness is shown in Figure 3.

3-D Bomb Effects Simulations for Obstacle Clearance

A. Landsberg, Naval Surface Warfare Center (NSWC), Indian Head, Md.

This project will provide a system capable of simultaneously breaching obstacles and clearing mines during an amphibious assault. The goal is to study, identify, and verify the damage mechanisms of obstacles, both on land and in water, subjected to multiple bomb detonations. The rapid creation of transit lanes through shoreline defenses is necessary to enable landing craft to deposit troops and equipment directly onto and beyond the beaches.

Submerged Wakes in Littoral Regions

P. Purtell, Office of Naval Research (ONR), Arlington, Va.; W.R. Briley, Mississippi State University, Starkville, Miss.; J. Gorski, NSWC, Carderock, Md.; and D. Dommermuth, SAIC, San Diego, Calif.

This project provides the first-ever simulations of submerged propelled vehicles undergoing complex maneuvers induced by moving control surfaces. Simulations (Figure 4) of the flowfield itself, including the effects of stratification and trailing vortices are also being conducted. Together, these simulations will supply valuable knowledge of maneuvering characteristics and their effect on the flowfield including the complex characteristics of the littorals: stratification, shear, shallow water and wave motion. This will provide the means to improve platform design and operations and enhance the advantage in undersea warfare.

Chemical Warfare Agents with Acetylcholinesterase (AChE)

M. Hurley, J. Wright, A. Balboa, W. White, and J. Morrill, Army Research Laboratory (ARL), Aberdeen Proving Ground, Md.; G. Lushington, University of Kansas, Lawrence, Kan.; and W. Yang, Duke University.

The purpose of this project is to calculate accurate energetic pathways of reversible and irreversible binding of agents in enzymes and to develop novel absorbents for filtering and deactivating toxic substances. This work will impact the design of therapeutic and prophylactic treatments for nerve agent exposure by devising nerve agent defensive mechanisms.

Multiscale Simulations of Nanotubes and Quantum Structures

J. Bernholc, North Carolina State University, Raleigh, N.C.

The focus of this work is to investigate and predict properties of advanced new materials and technologies critical to DoD's needs as well as to predict properties and technological applications of carbon nanotubes and wide gap semiconductors. Nanotubes are prime candidates for novel electron emitters, to be used in ultra-high resolution flat panel displays and cold-cathode-based microwave amplifiers. The hundredfold increase in the emission current density would obviously have a major effect on the utilization and efficiency of electron emitters in the battlefield and in support systems.

CFD for Aircraft-Store Compatibility and Weapons Integration

J. Martel, Air Force SEEK EAGLE Office (AFSEO), Eglin AFB, Fla.

The goal of this project is to perform engineering analysis, develop flight test profiles, and direct real-time flight tests in support of the aircraft and store certification process. By supplementing inexpensive lower order methods and costly, sub-scale testing, computational fluid dynamics (CFD), shown in Figure 5, has been used to reduce the certification costs, increase flight test safety margins, and develop more confidence in the numerical predictions that lead to the determination of flight test requirements.

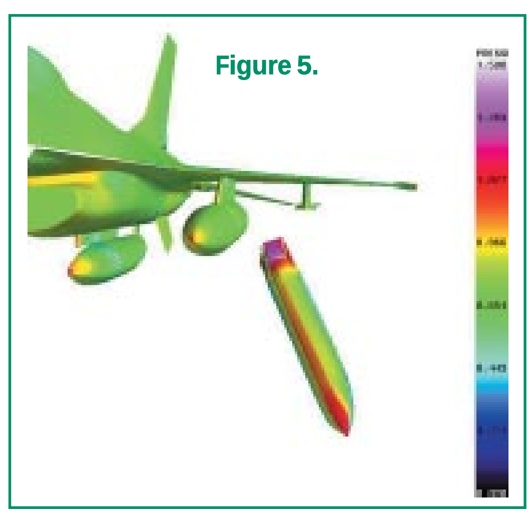
Figure 5.

Homeland Security

The tragic events of September 11, 2001, brought a new focus on the security of our nation. The attacks on the World Trade Center Towers and the Pentagon, and the ensuing anthrax threat have triggered research and development in areas not previously explored. The HPCMP has played a significant role in some areas of homeland security. The following projects used HPCMP HPC resources to solve some of the most demanding problems.

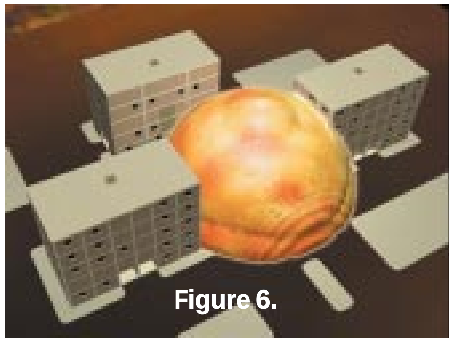

Figure 6.

Blast Response of the Pentagon

Tommy L. Bevins, Byron J. Armstrong, James T. Baylot, and James L. O'Daniel, U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, Miss.

The DoD placed a high priority on the rapid repair of the Pentagon. The U.S. Army Corps of Engineers quickly responded to their tasking to provide possible retrofit designs to improve the Pentagon's structural response to a range of terrorist threats. Because of the objective to speedily repair the damage, the Corps of Engineers' recommendations for improvements had to be finalized and presented to the Pentagon Renovation Office (PenRen) within eight weeks. This effort involved determining the loads on the components of the Pentagon and the response of these components to the loads. It also involved developing, analyzing and evaluating retrofit concepts to improve employee safety. This research is important to DoD not only to improve the survivability of the Pentagon and its occupants, but it also decreases costs by helping to determine the critical vulnerable areas of the Pentagon so that resources are expended in those locations where they are most needed.

Blast Protection in Urban Terrain

J. Baylot, T. Bevins, and J. O'Daniel, ERDC, Vickburg, Miss.; Y. Sohn, Defense Threat Reduction Agency (DTRA), Alexandria, Va; D. Littlefield, University of Texas, Austin, Texas; and C. Eamon, Mississippi State University, Mississippi State, Miss.

An Anti-Terrorism (AT) Planner software tool was developed to rapidly evaluate the safety of structures. This tool is a fast and accurate method of predicting loads on a structure (Figure 6) when a terrorist weapon is detonated between groups of structures (urban terrain). Improved methods of predicting response of conventional structures and developing retrofits for these structures will result from these predictions. This research will provide the DoD community with an improved methodology for evaluating the safety of U.S. forces from terrorist attack and for designing retrofits to improve safety.

Countermeasures to Anthrax

Yuan-Ping Pang, Mayo Foundation and Mayo Medical School.

Inhalation anthrax is often fatal because early diagnosis is very difficult. Early symptoms of inhaled anthrax resemble the common cold or flu. One effective way to counteract anthrax is to use therapeutic agents that specifically block the catalytic activity of the anthrax lethal factor. This approach is supported by the fact that certain metalloprotease inhibitors block the effects of the toxin in vitro. Dr. Y.P. Pang of the Mayo Clinic working with Maj. Charles Millard and Dr. Rekha Panchal began a yearlong effort to develop an effective inhibitor. Using HPC resources, they screened 2.5 million chemical structures using a specially designed algorithm. They identified 20 high potential inhibitors of Botulinum toxin serotype A. They have since synthesized three of these materials (Figure 7) in wet laboratories and initial tests indicate that all three are effective inhibitors.

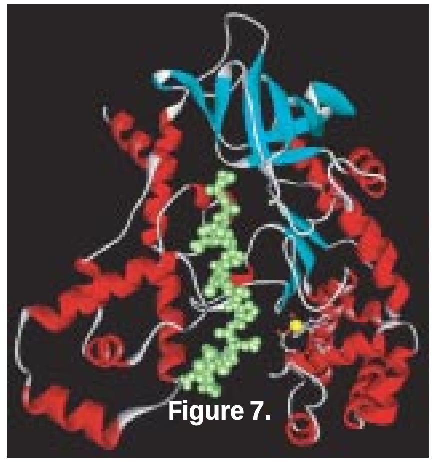

Figure 7.

DoD Counter Terrorism Technology

Charles Needham, John Perry, Terry Caipen and Joe Crepeua, Applied Research Associates, Inc. (ARA), Albuquerque N.M.

Developing explosives designed to produce better results against hardened and/or deeply buried targets has been an ongoing effort for many years. In December 2001, a 2000-pound weapon casing known as the BLU-109 was filled with a new non-ideal explosive called PBX-IH-135. The new weapon was designated the BLU-118 and delivered to Afghanistan for use in the war on terrorism. ARA conducted three-dimensional HPC calculations of the new weapon's performance both inside and outside of tunnel structures in support of live fire testing in Nevada. The decision to send the weapon to Afghanistan was based on the observed performance test data.

The Future of HPC

The DoD HPCMP exists to enable over 4,000 scientists and engineers to address engineering challenges of the S&T and T&E communities linking users at over 100 DoD laboratories, test centers, universities, and industrial sites.

In the future, HPC will continue to take advantage of the best commercially available hardware and software to enable users to standardize where it makes sense to do so, and to make access and use of our capabilities as easy as possible. The rapid evolution of high performance computing requires that the program focus on delivering improved capability early in a weapon systems life cycle. This allows the DoD to maintain the technological edge required to analyze, design, produce, and deploy advanced weapons systems and capabilities to the warfighter — before similar computational capabilities are available to our adversaries.

For more information on the High Performance Computing Modernization Program, please visit our Web site at www.hpcmo.hpc.mil.

Cray Henry is the Director of the DoD High Performance Computing Modernization Program (HPCMP). He oversees the operations of the HPC centers and wide-area network services, in addition to leading acquisition planning for HPCMP capital investments. Susan Pfeiffer-Vega is the HPCMP Outreach Coordinator. Bill Gabor is a Technical Writer/Editor in the HPCMP Office.