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High-Performance Computing and Test and Experimentation

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In the beginning, there was experimentation and test. No one really knows when the wheel was invented, but I postulate that the wheel was the result of an experiment. Someone found a rock that rolled. After some experiments, some tests, some modifications and some more tests, they had a wheel. Thus, the first pillar of research, development, test and evaluation (RDT&E) was born. Some years later, mathematics and logic were invented, allowing theoretical analysis, and the second pillar of RDT&E was born. For centuries, scientists and engineers have used the combination of theoretical analysis and experimentation to advance our understanding and to create. Much more recently, computer technology has allowed the expansion of theoretical analysis into complete science-based simulations and thus, the third pillar of RDT&E was born. Today, scientists and engineers are just beginning to use science-based simulation to virtually design, test and evaluate new ideas and systems.

Cray J. Henry

Organizations all across the Department of Defense (DoD) are changing their business processes to take advantage of simulation-based processes enabled by supercomputers and parallel software. Many members of the T&E community saw the potential benefits nearly a decade ago, and today these T&E leaders are working with improved capabilities. For example:

- The use of supercomputers and science-based software has transformed the stores certification process. Air Force and Navy test engineers are using supercomputers to augment current ground testing techniques and to reduce open-air flight-testing, resulting in faster stores certifications and reduced certification costs.
- Computational science, specifically computational fluid dynamics (CFD) running on supercomputers, is used to predict aerodynamic loads for aircraft stores before, during and after release *(see Figure 1).* Using CFD allows for the determination of the structural loads on the airplane prior to the release of the store and to determine the six-degree-of-freedom motion of the store after release. The results are then used to determine (1) if the loads are within the structural limits of the airplane; and (2) if there are problems of mutual interference between the released store and the airplane, or between the store and other stores. Performing initial computer simulation helps to focus and minimize the number of flight tests on the most critical parts of the performance envelope, while improving the safety and reducing the cost of the overall test program. This capability has recently been used extensively in certifying new aircraft-weapons combinations prior to deployment in Afghanistan and Iraq.

The Arnold Engineering Development Center used its high-performance computing (HPC) resources to assist in the design and to predict performance of the Joint Strike Fighter (JSF) engine inlet. Using CFD, Lockheed-Martin was able to model and analyze the complex flows at the inlet, thus supporting a quick design and test cycle.

The use of supercomputer-based simulations is allowing the development of new operational concepts. Simulations often start with legacy weapon systems in relevant operational settings. Then, additional simulations are run, replacing the legacy system models with new or theoretical weapon system designs in an effort to identify the most

Figure 1

important operational capabilities. In the case of the JSF, this process allows for the comparison of new aircraft effectiveness against legacy aircraft, in addition to supporting the evaluation and trade-off of performance and affordability requirements. The process has been used to assist in the development of the JSF Key Performance Parameters for the Operational Requirements Document. High-fidelity T&E simulation facilities, stimulated by supercomputers, have allowed pilots to be heavily involved up front and early in the concept phase of the JSF program.

To improve the protection of U.S. soldiers in Iraq, the materials group at the Army Research Laboratory (ARL) supported the development of a fast-response field modification to the Stryker. Using supercomputers at the ARL Major Shared Resource Center (MSRC), simulations were run to evaluate add-on blast protection for the Stryker wheeled vehicle *(Figure 2)* to lessen the danger from improvised explosive device blasts and fragmentation. This analysis was used to guide prototype design *(Figure 3)* and formal testing, resulting in the quick development of modification kits for the Stryker.

The Javelin Integrated Test and Simulation Network (JITSN) is a hardware-in-the-loop test facility, made possible through the use of supercomputers. This facility tests

Figure 2

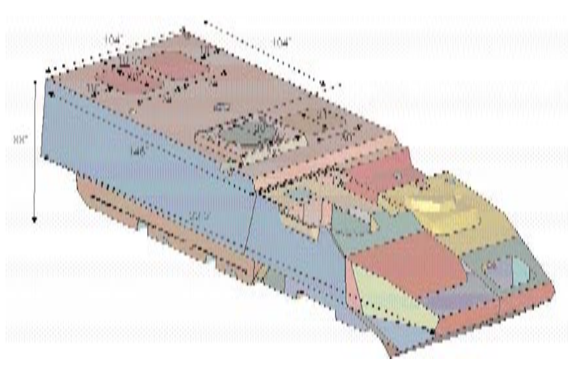

Figure 3

real tactical hardware and software in a virtual environment. It allows testers to create many virtual environments with different terrain, vegetation, weather, targets and engagement practices. JITSN is used by the developer (Raytheon Missile Systems), researchers (Aviation and Missile Research, Development and Engineering Center) and testers (Redstone Technical Test Center), all interconnected through the Defense Research and Engineering Network (DREN).

The supercomputers and parallel software are used to render scenes, control projection of the scenes to weapon system sensors, control the flight motion simulator, and synchronize the scenes and flight motion simulator with missile avionic system flight commands. Classified voice, data and video are shared in real time over the Secret DREN, giving all participants access to test events and simulations. The collaboration and wide area network (WAN) connectivity permit timely evaluation of software modifications prior to fielding. The virtual environment is capable of producing 50 firings per day, versus 2-3 on the open-air range (*Figure 4*). This provides for an accelerated development and test schedule at a significantly reduced cost. This virtual environment also has been used to support training.

Prior to 1994, there was only sporadic use of supercomputing within the T&E community. Although minicomputers and workstations were being used for test data reduction

Figure 4

and for simple simulations, many of the computing needs of the T&E community were not being addressed. In 1994, Congress amended the scope of the DoD High Performance Computing Modernization Program (HPCMP) to include support for the T&E community. HPCMP support for this community has grown from a few projects in 1995 to a base of approximately 1,250 users working on about 70 different projects.

Today, the DoD HPCMP *(see Figure 5)* provides supercomputing services in support of the science and technology (S&T) and T&E communities across DoD. The program provides:

- Access to some of the world's largest and most capable supercomputers at eight locations across the country;
- Awards of small supercomputers to support local S&T and T&E missions (for example, hardware-in-the-loop test facilities);
- WAN connectivity through the DREN to more than 100 location across the country;
- Formal training and access to senior computational scientists from dozens of leading universities; and
- Support for a limited number of supercomputer software development and maintenance activities.

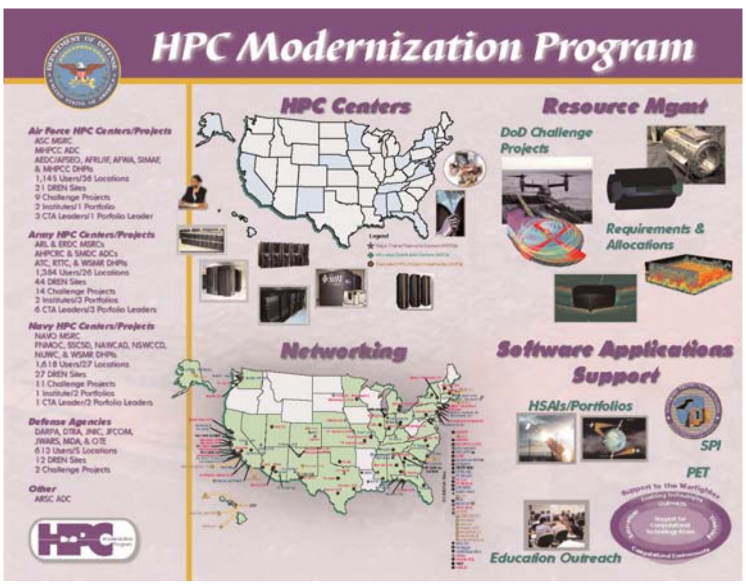

Figure 5

In addition to enabling the third pillar of RDT&E in DoD, the HPCMP creates an opportunity for the S&T and T&E communities to work together across military Service lines. Most of the projects supported by the program have a strong cross-Service and cross-community component. Science-based models typically developed in the S&T community have been extremely beneficial in supporting testing. Simulations developed for the Air Force, for example, are often just as useful for the Navy.

Science-based simulation combines science-based mathematical models with physical experimentation and testing to take advantage of the best aspects of both. In addition, science-based simulations can be used to further the understanding of the behavior of complex systems or to develop plans for a physical experiment to yield maximum information. In many cases, physical experimentation or test is needed to calibrate or validate the simulation. In others, it may be impossible to conduct the physical experiment, and the investigator or test engineer will be entirely dependent on simulation results. The HPCMP's ultimate goal is to assure that DoD scientists and engineers routinely have access to enough computing power (hardware and software) to fully develop and test new ideas and complex systems.

The HPCMP is corporately funded with resources available to all the scientists and engineers supporting the DoD S&T and T&E communities. Based on the high demand for these resources, the Office of the Secretary of Defense and each of the military departments have an established process to prioritize and allocate their share of the program resources. For information on how to request access to the supercomputers and how to engage in the resource allocation process, visit the HPCMP web site at *www.hpcmo.mpc.mil*. ❑

CRAY J. HENRY is director, Department of Defense (DoD) High Performance Computing Modernization Program (HPCMP), Arlington, Virginia. He oversees the operations of the department's supercomputing centers and wide area network services, supporting the DoD science and technology (S&T) and test and evaluation (T&E) communities, in addition to leading acquisition efforts for new capital investments in HPC hardware and targeted HPC software development. He previously served as the deputy director, HPCMP, where he was responsible for acquisition planning and financial management. He began his involvement with the HPCMP in 1997 as program manager, Defense Research and Engineering Network (DREN), responsible for development, deployment, day-to-day operations and future planning. In most of his 23-year career with DoD, he has been in program management with a focus on leading-edge technology weapon systems. He has served as program manager, Range Operations Control Center, Eastern Launch Range, Cape Canaveral, Florida; staff action officer supporting acquisition reform efforts; support systems manager for Air Force weather systems; and senior systems engineer for the Peace Shield program. He holds management degrees from the Graduate School of Business, Stanford University, and the Florida Institute of Technology; engineering degrees in electrical engineering and computer science from Tulane University; and has completed the program management curriculum at the Defense Acquisition University. He is a member of the DoD Acquisition Corps and an active participant in the Defense Leadership and Management Program.