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"High-Performance Computing in Test and Experimentation"

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The Army Research Laboratory
Major Shared Resource Center,
Aberdeen Proving Ground, Maryland

TECHNICAL PAPER ABSTRACTS:

Collaborative Simulation and Testing Using High-Performance Computing

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The nature of today's defense system acquisition process demands the procurement of increasingly complex systems in shorter time periods with decreased funding. In particular, the test and evaluation community is increasingly challenged to reduce overall test time and cost, yet not diminish its mission of comprehensive, independent assessment of the warfighters' weaponry. One of the most promising methodologies currently available to the tester to affect this challenge is virtual testing through the use of modeling and simulation (M&S). The potential benefits of M&S are well-known, but issues related to model validation, the lack of timely access to large-scale computing assets, and the lack of efficient user interfaces with multidisciplinary M&S capability have created a gap between the M&S and test communities who desire to use advanced M&S to effectively support test programs.

Applications of High-Performance Computing at Arnold Engineering Development Center (AEDC)

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High-performance computing (HPC) is an integral part of the research and development, test and evaluation mission of the Arnold Engineering Development Center. From facility design, to test planning, test execution, data analysis, and extrapolation to flight conditions, high-fidelity, physics-based modeling is used to increase the effectiveness of test programs, ensure the quality of the results and decrease cost and cycle time. The routine application of HPC resources and expertise to major developmental programs such as the F/A-22, Joint Strike Fighter (JSF) and Joint Unmanned Combat Air System (J-UCAS), as well as mature systems like the F-15E and B-1B, has resulted in millions of dollars in cost reduction.

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Joint Experimentation on Scalable Parallel Processors

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A major quandary facing researchers is what to do when the available computer resources are not sufficient. This usually forces the reduction in the amount of data, constraints on the physical area under study, limitations on the resolution of the details and restrictions on the sophistication of the analysis. This paper sets out a brief review of one group of researchers' needs that required more power, as well as the early development and current status of the use of high-performance computing to enable large-scale simulations of interest. It then covers architectural constraints and the designs that were implemented, followed by performance testing and analysis. This paper concludes with a look at future work and suggests some conclusions that may be drawn at this time. Implications for, and applications to, the test and evaluation community are implied, and others may be inferred.

Development of Synthetic Environments Using High-Performance Computing for Planning and Implementing Distributed Test Events

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One of the goals of the Army Test and Evaluation/Developmental Test Command (DTC) Virtual Proving Ground is to develop high-resolution representations of the natural and constructed environments from physics-based modeling and simulation. DTC initiated the Synthetic Environments Integrated Testbed (SEIT) to provide a standard and common application of environments to support life cycle simulation requirements in Department of Defense acquisition. The SEIT test capability is targeted for the Future Combat System, as well as for broad applications to Army research, development, test and evaluation and training applications and systems (Liebert et al., 2003). The weather and atmospheric effects in SEIT require a high-performance computer (HPC) to ingest data, conduct model computations, generate visualization products and output fields for synthetic environment components. This paper discusses the Four-Dimensional Weather (4DWX) system HPC resources and modeling components that are used to develop synthetic environments (atmospheres) in distributed testing. The 4DWX system is employed operationally on a "24/7" schedule at six DTC test centers, and the 4DWX Global Meteorology on Demand (GMOD) component allows for the system to be relocated to other geographic regions for specific applications. This paper describes how the GMOD meteorological modeling methodology was used for the SEIT in the recent Distributed Test Event (DTE) 4 at White Sands Missile Range, New Mexico.

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Toward Interactive Simulations of High-Power Microwave Devices

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The Department of Defense is investigating the production of focused high-power electromagnetic radiation in the microwave regime for non-lethal attack on electronics. In the past, numerical simulation of the physics of directed energy (DE) devices was done at relatively coarse resolution, and thus offered qualitative insight, but it generally did not allow for quantitative prediction of device performance in advance of construction and testing. With the advent of parallel computers with large distributed memory, numerical simulations now can be performed with sufficient fidelity and at sufficient resolution to allow for virtual design of DE systems. This paper addresses recent simulations for virtual prototyping of high-power microwave devices using high-performance computing techniques, and evaluates the simulations against tests that are performed with devices built according to specifications based on simulations. In the process, this paper develops a model to gauge the computational requirements as a function of resolution and desired simulation wall-clock time, as well as discusses the serial and parallel performance of the physics simulation code of choice. With an eye toward the future, this paper also discusses the class of computers that are required to allow even more realistic simulations in ever-shorter wall-clock times.

Obtaining Higher Confidence from Limited System Test Data

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During the "The 'E' in Test and Evaluation" Workshop hosted by the ITEA Francis Scott Key Chapter from October 5-7, 2004, in Baltimore, Maryland, various topics were covered on how to improve evaluation efforts. This paper reviews the ideas and discussions presented during the session titled, "Predicting Operational Reliability with Quantified Confidence from Limited System Test Data." Originally, the topic dealt with predicting operational reliability; however, the methods discussed may be applied to many fields. For this reason, the paper has a different title than the session. Nine different organizations (government and contractor) from across the United States were represented during this session. The majority of the attendees were from the Johns Hopkins University Applied Physics Laboratory, which also helped host the event.

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Simplifying and Evaluating Threat and Target Models for Constructive and Virtual Simulations

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A growing emphasis on joint operations and network-centric warfare is placing requirements on acquisition and test and evaluation organizations that make modeling and simulation (M&S) capabilities a requirement. Increasingly, M&S capabilities will be required to supplement existing physical resources such as land area, air space or weapons systems in the quantity needed.

PRESIDENT'S CORNER

Base Realignment and Closure (BRAC):

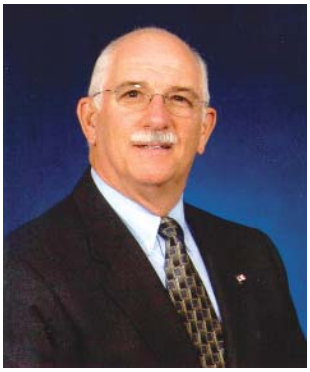
Curse or Blessing—Depending on Where You're Located

On May 15, 2005, like most of you, I reviewed the 2005 Department of Defense (DoD) Base Realignment and Closure (BRAC) List for the first time. Days later, I received a copy of the full written report, in two volumes. Volume One provides an overview of the process and a summary of the results. Volume Two contains the statutory recommendations, justifications and process summaries that the Secretary of Defense transmitted to the Commission and to Congress.

Upon reflection, I can honestly say that I was happy to see that the DoD report is true to the goals and objectives of the department's transformation. If you truly believe in "jointness" across the board, as I do, then you can take satisfaction in the fact that, with the implementation of this report, DoD research, development, test and evaluation (RDT&E) bases, facilities and organizations will be able to play a major role in our efforts to acquire joint network-centric systems needed to achieve transformation. If you have not yet seen a copy, I recommend that you obtain one and look it over. Studying the released documents allows one to best visualize the impact on the T&E community. Here are some highlights:

Secretary of the Army, Francis Harvey, in a recent appearance before the BRAC commission, stated "The recommendations of BRAC 2005 will holistically transform the current infrastructure into a streamlined portfolio of installations with an 11-percent increase in military value which, thereby, enables the operational Army to better meet the challenges of the 21st-century security environment." Secretary Harvey's remarks reflect the current thinking of the Secretary of Defense to enact a sweeping plan to close, reduce or realign forces at 62 major bases and nearly 800 minor facilities. Certain facilities will gain activities. Additionally, the BRAC List represents another stage in the transformation of the U.S. military from a force positioned to address Cold War threats to one with a more versatile, responsive force structure.

The Pentagon plan will pull out at least 23,000 employees from dozens of Northern Virginia buildings that do not meet the stringent security requirements put in place after the September 11, 2001, attacks. Given current emphasis on force protection, relocating defense activities to secure military installations will involve a massive movement of military, civilian and a sizeable contractor workforce to new facilities. The Army, for example, will move a considerable number of people and organizations to Fort Belvoir, Virginia, and Aberdeen Proving Ground, Maryland. Over time, as a result of these moves, the majority of DoD leased spaces within Crystal City, Alexandria, and other Virginia locations will be vacated by their current occupants.


Robert T. Fuller

The Navy absorbs some big cutbacks, with 20 base closures and realignments. These changes include several naval air stations, such as Brunswick, Maine, with a loss of 2,420 jobs; and the Naval Shipyard Portsmouth in Kittery, Maine, with a loss of 4,510 jobs. While a total listing of adjustments is available through normal public affairs channels, I want to highlight several noteworthy acquisition or T&E changes for you:

- ■ Army Materiel Command moves from Fort Belvoir, Virginia, to Redstone Arsenal, Alabama;
- ■ Missile Defense Agency moves from Arlington, Virginia, to Redstone Arsenal;
- ■ Creation of a Naval Integrated Weapons and Armaments Research Development and Acquisition, Test and Evaluation Center at China Lake, California; and
- ■ Relocation of the Secretary of the Air Force for Acquisition from Arlington, Virginia, to Andrews Air Force Base, Maryland.

Areas that find themselves bettered by BRAC movements will include China Lake and Edwards Air Force Base in California, along with Redstone Arsenal, Alabama. The impact of these shifts on the infrastructure of a given region will be impressive. Roads, airports, housing and schools will all feel the effect of these changes.

To adequately prepare for the inevitable alterations, we must examine the available material, formulate a strategy to best serve the needs of the T&E community, and discuss the various options available. ITEA will be in the forefront of these changes by informing and preparing its members for the anticipated DoD moves. Dialog and reflection will allow our membership to be better prepared to continue its activities and to support ongoing operations during the impending transition. As your president, I shall lead the effort to understand and explain the effect of these modifications on our community. I will need your support, and I hope that you will join me in this endeavor. ❑

High-Performance Computing and Test and Experimentation

Cray J. Henry

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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 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).

Figure 2

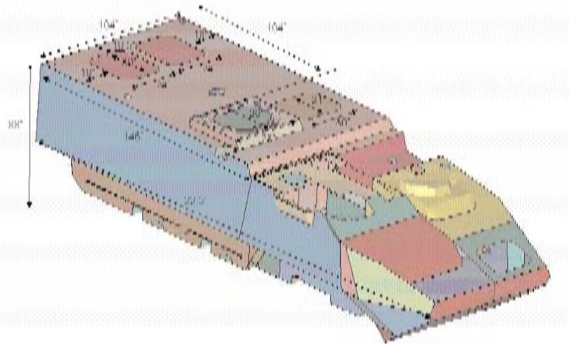


Figure 3

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 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.

Figure 4

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.

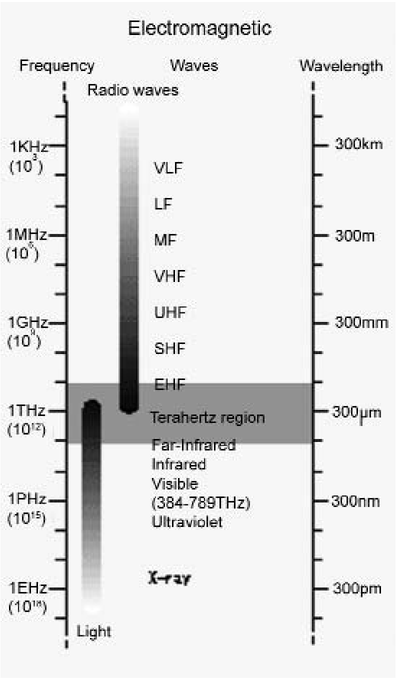
The HPCMP is corporately funded with resources available to all the scientists and engineers supporting the DoD S&T and T&E communities. Based on the high demand for these resources, the Office of the Secretary of Defense and each of the military departments have an established process to prioritize 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.

Is Terahertz Technology Ready for T&E Applications?

By G. Derrick Hinton

Future weapons and mission scenarios are driving the need for ever-increasing quantities of accurate and timely information. Today, a combination of radio frequency (RF) and wire/fiber networks is meeting these high-bandwidth requirements. RF spectrum is limited, and worldwide access to RF networks is problematic, with limited choice of available frequency. In this environment, where requirements are increasing and available spectrum is decreasing, there is a push to find methods of accessing greater bandwidths for communications and radio determination applications. This is especially true for the communications of telemetry data to meet Major Range and Test Facility Base test requirements.



This situation has prompted a desire to move to higher frequencies, where large bandwidths are more obtainable. Above 50 GHz, frequency allocations of 100 MHz or more are the rule, and allocations of multiple GHz are not uncommon. Furthermore, the demands for spectrum above 60 GHz, and up to the Terahertz range (100 GHz and above), have historically been much less than the demands for spectrum below several GHz. For these reasons, Terahertz frequencies appear to be attractive for test and evaluation (T&E) applications.

However, there are a number of significant obstacles in implementing Terahertz systems. First, the wavelength of a Terahertz signal is approximately 0.01 inches. This short wavelength has a number of implications, not the least of which is in the area of propagation. Signals of this wavelength will not bend significantly. Consequently, testers recognize that, at these frequencies, they need a clear line of sight for proper operation. The transmitter must literally be able to see the receiver. Furthermore, penetration losses through any obstacle will be substantial. Obstacles can include rain, clouds, mist, dust and atmospheric situations that might not disturb other, lower-frequency transmissions.

A second obstacle is in the area of antenna technology. For dish antennas, it is commonly thought that antenna size mitigates path loss as a function of frequency. However, this is only true up to a certain point. At very high frequencies, the physical characteristics of a dish antenna create large losses. Furthermore, antenna beam widths are extremely narrow, making the antenna pointing problem significant, thus requiring basic research in this area. Advanced antenna techniques are required for operations at Terahertz frequencies.

A previous "TechNotes" (*ITEA Journal*, December 2004/January 2005, page 15) discussed new technologies, such as nanotechnology, and their possible application as antennas. Sumio Iijima first discovered carbon nanotubes in Japan in 1991. These tiny molecules are made entirely of carbon and possess remarkable electrical and mechanical properties. Researchers foresee applications of the nanotube antennas in high-frequency Terahertz communications. However, a survey of current research and development (R&D) efforts in the Terahertz spectrum revealed a 10- to 15-year horizon before useful systems operating in this region of the spectrum could be available for T&E applications.

The T&E community must recognize that Terahertz technology is not as mature as technology for systems at more traditional frequencies. This has serious implications for those designing and developing signal generation, amplification, modulation and transmission line components. The challenges of implementing Terahertz systems for telemetry communications are formidable.

While technology is expected to advance in a way that makes the design of such systems more attainable, the issues related to propagation still remain. New and innovative system-level approaches to solve the propagation problem are required in order to capitalize on the large bandwidths available in the Terahertz range. Without a sizeable infusion of R&D investments, T&E systems operating at Terahertz frequencies will not be realized. ❑

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