AHPCRC
Army High Performance Computing Research Center

AHPCRC QUARTERLY

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Welcome to AHPCRC *by Dr. Charbel Farhat*

It's my pleasure to welcome you to the inaugural edition of the AHPCRC Quarterly. Through the Quarterly, we intend to share periodic updates on our research projects, education and outreach activities, and other key science and engineering initiatives we are working to support Army applications.

Dr. Charbel Farhat
AHPCRC Director

The Army High Performance Computing Research Center (AHPCRC) is a multidisciplinary computational science and engineering research center based at Stanford University and is a partnership with the Army, industry and academia.

Our team includes engineers and scientists at Stanford University, Morgan State University in Maryland, New Mexico State University at Las Cruces, the University of Texas at El Paso and the NASA Ames Research Center, at Moffett Field, California. High Performance Technologies, Inc. (HPTi), based in Reston, Virginia, is a private-sector firm that provides program management and computational science and high performance computing (HPC) operations expertise.

These are exciting times to be working in high performance computing. Traditionally, HPC-based modeling and simulation has played a leading role in theory and physical experimentation. Today, HPC-based modeling and simulation plays an equally leading role in discovery-driven engineering research as well. By utilizing the most advanced HPC systems and leveraging the creativity of our team, AHPCRC has great potential for innovating technologies and reducing overall design-cycle time for key Army science and engineering initiatives.

One of the research areas we're focused on is to assist the Army in developing lighter materials that can enhance the agility of vehicles and soldiers alike. Using HPC to simulate the strength and other properties of structures made from promising new materials, the Army can develop lighter body-armor with enhanced protective properties, lighter and faster vehicles with greater protective and maneuverability capabilities, and micro-reconnaissance drones that a soldier could literally carry and launch in the field.

While our primary focus is on technology challenges of intensive interest to the Army, our research will likely produce tangible benefits for society more broadly as well. For example, light weight materials developed for armored vehicles will undoubtedly find their way into cars and trucks, making them much more fuel efficient, for example.

A second research priority area, led by Stanford's Eric Shaqfeh, addresses challenges in nanotechnology and biology where our teams are looking at how to engineer novel materials starting from structures on the scale of atoms. Additional research work is being done in biology where we're looking at computationally intensive problems such as designing sensors and systems that can rapidly detect biological weapons agents such as anthrax on the scale of individual rooms, or a battlefield, or entire cities.

Stanford's George C. Papanicolaou, a mathematics professor, leads our third research area in networks and wireless communications. His team is working to improve how

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The AHPCRC Consortium

The Army High Performance Computing Research Center Consortium is a collaborative research program between the U.S. Army and a university and industry consortium to advance computational science and engineering and its application to critical Army technologies. The AHPCRC Consortium is led by Stanford University, partnering with Morgan State University, New Mexico State University at Las Cruces, the University of Texas at El Paso, High Performance Technologies, Inc., and the NASA-Ames Research Center.

Simulation-based engineering sciences and high performance computing (HPC) have become indispensable to our nation's continued leadership in science and engineering: They are central to advances in new national defense technologies, force protection, battlefield communication, networking, and sensors. However, while the expansion of HPC continues to foster better and faster scientific discovery, its potential for innovating technology, reducing design-cycle times, and improving system performance has not yet been fully realized. This is because formidable challenges stand in the way of progress in developing scalable modeling and simulation tools on HPC platforms.

These challenges involve resolving open problems associated with multi-scale and multi-physics modeling, model validation and verification, scalable numerical algorithms, computer architecture, parallel programming tools, and the education of the next generation of scientists and engineers in the fundamental theories and best practices of simulation-based engineering sciences and high performance computing. The AHPCRC will address these challenges with an ambitious collaborative research program that demonstrates both depth and creativity in providing maximum support and impact on the Army's Transformation for the 21st century.

Stanford University is the AHPCRC Consortium lead organization and academic partner, with overall responsibility for the AHPCRC program. Well known for its research in engineering, interdisciplinary computational sciences, algorithms, and software development, Stanford has 1,771 tenure-line faculty, senior fellows, and center fellows, including 18 Nobel Laureates, 23 MacArthur Fellows, and 21 recipients of the National Medal of Science. All Stanford principal investigators for the AHPCRC Consortium are affiliated with Stanford's Institute for Computational and Mathematical Engineering (ICME), a program that reflects the importance of computational mathematics in virtually every science and engineering discipline. ICME capitalizes on Stanford's outstanding strengths in engineering applications and physical, biological, and earth sciences to guide the development of modern research and educational enterprise in computational mathematics. Its central research mission is to develop sophisticated algorithmic and mathematical tools that can advance many different applied disciplines.

High Performance Technologies, Inc. (HPTi) is the AHPCRC Infrastructure and Administration member of the Consortium and manages the Core Site Infrastructure. With over 15 years of experience managing HPC solutions, HPTi has provided management support of scientific computing and computational-science environments for numerous federal clients, helping them increase the productivity of their HPC systems. These clients have included the Department of Defense, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the Environmental Protection Agency, Intelligence Agencies, and National Labs at the Department of Energy. HPTi also has a long-standing partnership with the DoD High Performance Computing Modernization Program, where it provides computational science support in advanced materials, bio-warfare, networking/C4ISR, electromagnetics and acoustics, and nanotechnologies.

Morgan State University (Morgan State) has specialized research facilities in its Departments of Biology, Chemistry, Physics, and Mathematics, as well as its School of Engineering. In addition, it has recently completed modernizations to its science and engineering facilities, and it has acquired two supercomputers to support instruction and research. Morgan State is a Historically Black Colleges and Universities member of the Consortium.

New Mexico State University (NMSU) is a comprehensive institution dedicated to teaching, research, and service at the graduate and undergraduate levels. Ranked by the Carnegie Foundation as a top research institution, NMSU is home to the state's NASA Space Grant Program. A comprehensive, doctoral-level university, NMSU offers a wide variety of programs through the Graduate School and the Colleges of Agriculture and Home Economics, Arts and Sciences, Business Administration, Economics, Education, Engineering, and Health and Social Services. NMSU is a Hispanic-Serving Institution member of the Consortium.

University of Texas at El Paso (UTEP) has been named the top graduate engineering school for Hispanics in the nation and was designated by the National Science Foundation as a Model Institution for Excellence—one of only six in the country. Recently, UTEP became one of only 11 universities in the nation to receive a "Teachers for a New Era" research grant from the Carnegie Corporation of New York. The Corporation

The AHPCRC Consortium

also ranks UTEP in the Doctoral/Research University-Intensive category, placing it among the top 7 percent of all colleges and universities in the United States. UTEP offers 81 bachelors, 74 masters, and 14 doctoral degrees in many areas, including biological sciences, computer engineering, computer science, environmental science and engineering, geological sciences, and materials science and engineering. UTEP is a Hispanic-Serving Institution member of the Consortium.

NASA Ames Supercomputing (NASA Ames) is the Core-site Infrastructure Member of the Consortium and hosts AHPCRC West. Associated with leadership and innovation throughout the HPC community, NASA Ames plays a significant role in shaping HPC standards and developing large-scale, single-system image computers. NASA Ames is home to the 10,240-processor Columbia system, one of the fastest operational supercomputers in the world, according to the *Top500* list. ✭

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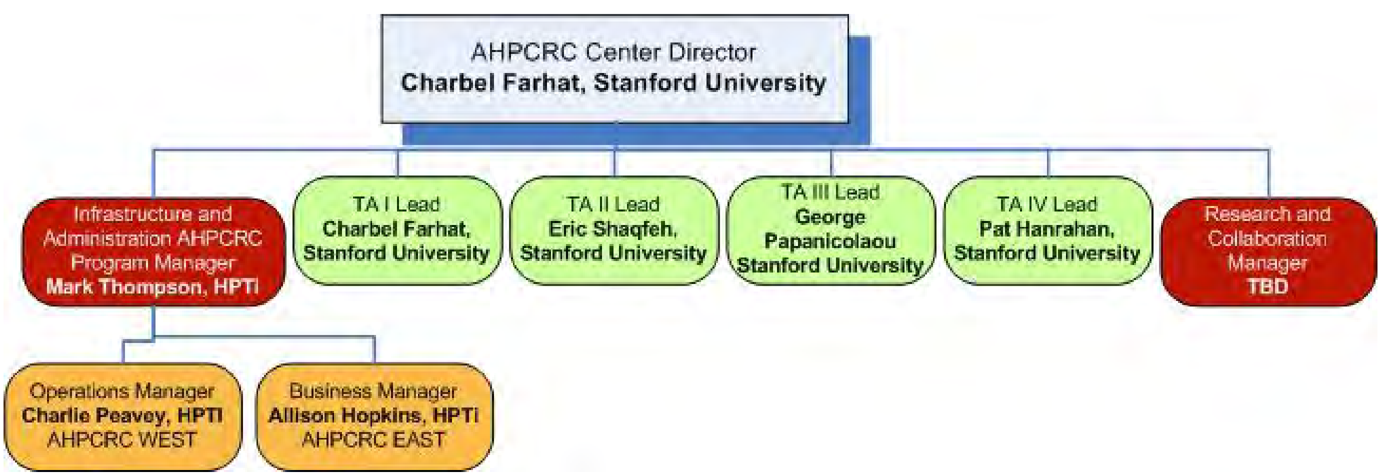
Welcome to AHPCRC

commanders and soldiers alike can make use of the myriad streams of information coming in from sources in the field including reconnaissance airplanes, UAVs, mobile patrols, arrays of sensors, and soldiers.

The fourth research area concentrates on advancing high-performance computing itself through better hardware and algorithm designs. Stanford's Pat Hanrahan, a professor of computer science and electrical engineering, is leading this research team and is working to improve hardware and software for supercomputing applications. This research area broadly applies to many areas of interest within the Army and should benefit many diverse research efforts that utilize HPC, such as climate modeling and aircraft design.

And finally, while AHPCRC is focusing on the future of computational science and engineering, one of our most important initiatives is working to inspire the future generation of scientists and engineers. Through our educational outreach programs, AHPCRC partner institutions have already begun to work with nearby school teachers to augment their efforts to teach math, science, engineering and computing to middle and high school students. This past summer, AHPCRC partners have leveraged Stanford's *Education Program for Gifted Youth*, New Mexico *State's Pre-Freshman Engineering Program* (PREP), University of Texas El Paso's *Excellence in Technology, Engineering & Science* Summer Institute (ExciTES), and Morgan State's *Saturday Science Academy*. This issue of the AHPCRC Quarterly reports on the summer educational activities at Stanford, New Mexico State, and University of Texas El Paso.

It's a privilege to be working with the Army on some of the most significant research and engineering challenges of the day. Speaking for all our partner institutions and research scientists and engineers, we're proud to be working with the Army on these challenges. ✭



AHPCRC Organization

AHPCRC Research

AHPCRC Supports RDECOM's Vision and Mission

By Mark W. Thompson, AHPCRC Program Manager

This past May, in its Strategic Plan for 2007, the Army Research, Development and Engineering Command (RDECOM) stated that RDECOM's vision is to be the world leader in rapid and innovative research, development, and engineering for the Warfighter. The plan also notes that through the RDECOM Strategic Management System, RDECOM has both the means and the ways to achieve those ends (see Figure 2). At AHPCRC, we are proud to be able to directly support RDECOM and its efforts to produce Innovative Human Capital, Value Added to the Warfighter, Continuous Improvement, and Alignment.

Innovative Human Capital. AHPCRC member-partners Stanford University, New Mexico State University, University Texas at El Paso, and Morgan State University are leading science and engineering universities. Through their education and outreach efforts, they are identifying talented students (from middle school through graduate school) in order to inspire these students to continue their studies in engineering and science and to attract them to careers that will allow them to work on some of the Army's toughest scientific challenges. At the research level, AHPCRC provides staff rotation and exchange opportunities, allowing Army scientists, for example, to teach at Stanford or join a research project with a team at the University of Texas at El Paso.

Through innovative programs such as these, AHPCRC is helping RDECOM *attract, develop, and retain an innovative, diverse workforce at all levels*.

Value Added to the Warfighter. To provide value to the Warfighter, AHPCRC's team of research scientists are tackling some of the Warfighter's toughest challenges. Teams at Stanford are exploring ways to make body armor more resilient, and they are discovering how low-cost, light-weight sensors and networks can be developed to detect bioweapon agents in buildings or in the field. To diminish the impact of shrapnel from blasts or rocket-propelled grenade attacks, AHPCRC researchers are learning how new materials and fabrics can be developed that are both lightweight and capable of absorbing some of the energy from an explosive blast.

Most of the projects in the AHPCRCs' research portfolio leverage existing leading-edge research. The difference is that through AHPCRC, the research team can *generate and exploit scientific discoveries to provide innovative technology solutions for the Warfighter*.

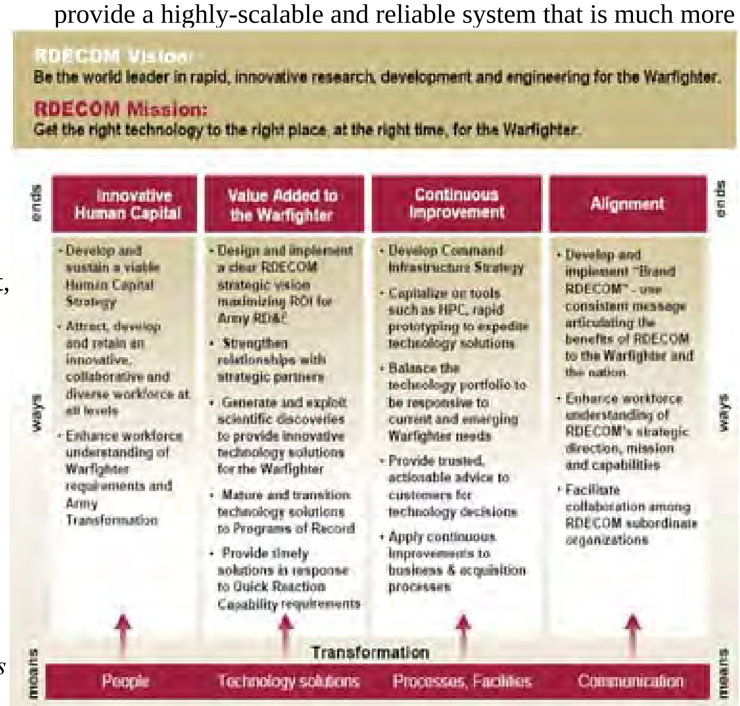
Continuous Improvement. Through AHPCRC, RDECOM can acquire early-access HPC systems and then use these systems for computational sciences and engineering research. AHPCRC is also researching new programming models that capitalize on the large, multiple-processor HPC systems being manufactured today. These HPC resources play an integral part in the research performed under the AHPCRC program, as well as other research carried out by the Army and the Department of Defense.

Through these efforts, AHPCRC is leading the way for RDECOM to *capitalize on tools such as HPC, rapid prototyping to expedite technology solutions.*

AHPCRC also features "innovation" projects to deal with new science and engineering challenges. As new mission needs arise, RDECOM partners and collaborators can bring these new challenges to the Consortium's scientists and engineers. Through AHPCRC, RDECOM is able to facilitate collaboration among RDECOM subordinate organizations and leverage the capability of the Consortium to address new science and engineering challenges.

The AHPCRC Consortium is excited about the challenges that await us, and we are honored to be an important component of the RDECOM's strategy. Through our collective work, we can help the Army solve some of its most significant science and engineering challenges—while helping the RDECOM realize its vision and achieve its mission.

The Cray XT3 is a massively parallel processor (MPP) supercomputing system that leverages the best of commodity technology and proprietary technologies where necessary to provide a highly-scalable and reliable system that is much more



RDECOM Strategic Management System (Reproduced from the 2007 RDECOM Strategic Plan, May 2007) cost effective than other completely proprietary solutions. The XT3 uses commodity procesors (AMD), the most common operating system in high-performance computing (Linux), and the high-performance filesystem Lustre, a widely used open-source product. To ensure reliability, Cray engineered the supporting infrastructure to maximize uptime and detect failures before they happened as well as removing components that are likely to fail frequently due to moving parts (such as local hard drives). This results in one of the most reliable supercomputer systems on the market that can also scale to tens-of-thousands of processors to support the solving of the large grand-challenge problems today. ✯

The AHPCRC Consortium's Research Portfolio

The AHPCRC Consortium's paramount objective is to provide real-world benefits to the American soldier through HPC-enabled basic research and modeling and simulation. To do this, the AHPCRC Consortium has devised a research portfolio composed of four Technical Areas. The ultimate goals of these Technical Areas are to advance both HPC and the Army's research goals.

Technical Area 1: Lightweight Combat Systems Survivability. The Army needs lightweight materials that are versatile, durable, and adaptable. Technical Area 1, led by Dr. Charbel Farhat of Stanford University, focuses on developing the HPC tools that will help researchers understand and optimize these kinds of materials. Research in this technical area addresses the challenges associated with developing lightweight, blast-resistant fabrics to protect vehicles and their occupants; developing high-strength, lightweight materials that will reduce the weight of military vehicles and the equipment the soldier must carry; and developing micro aerial vehicles (MAVs), which can help the soldier by providing reconnaissance, security, and target-acquisition capabilities in a variety of battlefield environments.

Adequately protecting soldiers without unnecessarily weighing them down is one of the Army's greatest technological and operational challenges. To meet this challenge, researchers are developing multifunctional ballistic fabrics that combine the energy-absorbent properties of fabric with metallic and ceramic layers that protect against blunt and sharp fragmentation. Along these lines, researchers are also developing high-strength, plastic materials that can be used to replace brass cartridge casings, for instance. In Technical Area 1, HPC modeling is helping researchers understand the microstructures of these materials, how the materials age and respond to stress, and how they can be optimized for a particular purpose.

Technical Area 1 will also contribute to research on MAVs: tiny, possibly stealthy, affordable aircraft capable of quickly deploying emerging sensor technologies in the battlefield. HPC is helping researchers understand the aerodynamic properties of these new vehicles, including how they could be designed to operate together in "swarms." All of these projects share a goal of creating systems and tools that will greatly increase a soldier's survivability.

Technical Area 2: Computational Nano- & Bio-Sciences. Computer simulations of materials and biological systems at nano- and micro- scales are expected to play an increasing role in science and engineering and in accomplishing the mission of the Army. Research involving nano- and bio-sciences falls across multiple disciplines, but the work in this technical area will address two broad classes of problems that are related to each other. The first class focuses on biological warfare agents (dispersion through the atmosphere and detection using novel microfluidic technology). This program is aimed at helping soldiers and first responders anticipate the effects of an aerosol weapon at all time and length scales after release. Moreover, the research involves developing computational models to identify hazardous biological weapons and viruses, thus enabling scientists to develop fast-response counteragents. The second class of problems includes developing computer simulations to understand and predict the fundamental mechanisms that control the rate-dependent response of materials to external loading. Understanding the deformation mechanisms of materials not only is necessary for the

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DR. CHARBEL FARHAT
AHPCRC DIRECTOR,
LEAD, TECHNICAL AREA 1

With a professional career spanning 21 years, Prof. Charbel Farhat is a highly regarded authority on parallel processing and high performance computing applied to simulation-based engineering. With numerous degrees—including a Ph.D. from the University of California, Berkeley, in Civil Engineering— Prof. Farhat has made seminal contributions to the areas of computational fluid dynamics on moving grids, fluid/ structure interaction, nonlinear computational aeroelasticity, computational structural mechanics, computational acoustics, numerical analysis, domain decomposition, supercomputing, and parallel processing. These contributions have been recognized by numerous major international and national awards. As the overall Principal Investigator and Center Director for AHPCRC, Dr. Farhat provides the leadership to fulfill AHPCRC's vision of accelerating the infusion of new HPC technologies in support of the Army Transformation. As manager of AHPCRC's research projects and exchange of researchers between the Army Laboratory sites and the Consortium sites, he oversees the Center's education and outreach initiatives.

AHPCRC Research

Research Portfolio *Continued from page 5*

DR. ERIC STEFAN SHAQFEH
LEAD, TECHNICAL AREA 2
Dr. Shaqfeh is an award-winning Professor of Mechanical Engineering at Stanford University and is the Associate Editor for Physics of Fluids. He is a member of Stanford's Steering Committee for the Institute for Computational and Mathematical Engineering, and he serves as the Interdisciplinary Research Group Coordinator for the Center for Polymer Interfaces and Molecular Assemblies. His work is synergistic with the AHPCRC program's design, control, creation, and optimization of components via computational nano- & bio-sciences and systems whose effects are manifested in both Army personnel and material. Dr. Shaqfeh was the Hougen Professor at the University of Wisconsin (2004), held the Stanley Corrsin Lectureship at The Johns Hopkins University (2003), and was a Fellow of the American Physical Society (2000).

development of reliable micro-sensors, but also provides valuable physical inputs for the design of high performance macro-scale materials that can sustain high strain rate impacts (see Technical Area 1). This problem area includes simulations of metal foams as one class of interesting, novel, light-weight materials with the purpose of identifying (via simulation) possible flaws and breakdowns during application in battlefield environments before the material is actually produced—saving time, money, and lives. Dr. Eric Shaqfeh of Stanford University will lead this Technical Area in using high performance computing to design and optimize components and systems to benefit Army personnel and material. Projects in this technical area concentrate on soldier survivability as well as on systems reliability, versatility, functionality, and cost.

DR. PAT HANRAHAN
LEAD, TECHNICAL AREA 4
Pat Hanrahan is the CANON Professor of Computer Science and Electrical Engineering at Stanford University where he teaches computer graphics. His current research involves visualization, image synthesis, virtual worlds, and graphics systems and architectures. Before joining Stanford, he was a faculty member at Princeton. He has also worked at Pixar where he developed volume rendering software and was the chief architect of the RenderMan™ Interface--a protocol that allows modeling programs to describe scenes to high quality rendering programs. Before that, he directed the 3D computer graphics group in the Computer Graphics Laboratory at New York Institute of Technology. Professor Hanrahan has received three university teaching awards. He has received two Academy Awards for Science and Technology, the Spirit of America Creativity Award, the SIGGRAPH Computer Graphics Achievement Award, the SIGGRAPH Stephen A. Coons Award, and the IEEE Visualization Career Award. He was recently elected to the National Academy of Engineering and the American Academy of Arts and Sciences.

DR. GEORGE PAPANICOLAOU
LEAD, TECHNICAL AREA 3
Dr. Papanicolaou, winner of the SIAM von Neumann Prize in 2006, has extensive experience in applying high performance computing to computational networks and information sciences pertaining to battlefield situational awareness through virtual modeling and simulation technologies. He is the author of two books and over 200 published papers, and a recognized authority in electromagnetic wave propagation in the atmosphere, underwater sound, waves in the lithosphere, and diffusion in porous media. He has studied linear and nonlinear waves and diffusion, in both direct and inverse problems. Dr. Papanicolaou was the invited plenary speaker to both the German Mathematical Union (2004) and the International Congress of Industrial and Applied Mathematics (2003), and he is a member of the U.S. National Academy of Sciences (2000).

Technical Area 3: Computational Battlefield Network & Information Sciences. The modern Warfighter can no longer expect to engage an easily recognizable enemy on a clearly defined battlefield. More and more, insurgent forces are difficult to distinguish from peaceful civilians, targets are hard to identify, and intelligence information is rarely clear and unambiguous. To meet these challenges, the research conducted as part of Technical Area 3 has two main goals. First, it explores how wireless communication networks can provide better information-gathering capabilities and decision support for soldiers in the field. Second, it addresses the wireless links themselves: How can we build and maintain wireless communication links that have good reach, reliable coverage, and high throughput in a complex environment such as that found in a hostile urban landscape? Led by Stanford University's Dr. George Papanicolaou, Technical Area 3 will tackle these challenges with advanced developments in numerical algorithms, communications methods, and HPC software.

Technical Area 4: HPC-Enabling Technologies & Advanced Algorithmic Development. Technical Areas 1–3 all rely on the availability of a high-performing, cost-effective computing infrastructure and fast numerical algorithms that can execute on that infrastructure. Technical Area 4, led by Dr. Pat Hanrahan of Stanford University, helps the other AHPCRC technical areas benefit from state-of-the-art HPC technologies by pursuing three challenges. First, it investigates new methods for developing applications on emerging architectures. Second, it assists the other Technical Areas by developing enabling computational technologies. Finally, it develops efficient, reliable HPC libraries of computational tools that can be used by engineering and scientific communities at the Army and elsewhere.

The six projects included in this Technical Area are all targeted at creating highly parallel programming computing environments and advanced computational algorithms. These enabling technologies support cross-cutting areas of interest in almost all aspects of high performance computing, and the advances they provide will benefit the U.S. Army and other scientific communities. ✯

Stanford Hosts Workshop on Sensors, Communications, and Imaging

Last August 2–3, the research group of Technical Area 3 of the Army High Performance Computing Research Center hosted a workshop on Sensors, Communications, and Imaging. Speakers reviewed current research problems and methods for the analysis and simulation of sensor networks, sensor detection, and communication systems with applications of relevance to Army needs. -The workshop was advertised widely at Stanford and attracted some 50–60 attendees. The program included presentations by Stanford faculty, researchers from Army labs, and Stanford graduate students and postdoctoral researchers, and invited presentations on wireless communications by senior researchers from Beceem and Intel.

Each day concluded with a roundtable discussion of the presentations. Two general issues were discussed at length: how to organize the research programs at Stanford so as to benefit from the new high performance computing resources available through the AHPCRC program, and how to organize the wireless communications research to be relevant to Army needs. The latter topic recognizes the importance of the ad-hoc and mobile nature of the Army network, while taking advantage of the insights and advances that are being made at rapid pace in the commercial wireless industry, much of it in Silicon Valley and with strong Stanford contacts.

Stating the problem: the Army perspective
ARL Fellow Dr. Ananthram Swami and ARL scientist Brian Rivera addressed the requirement for HPC from an Army perspective. Swami expressed the need for developing a science that would enable computer scientists to, "model, design, analyze, predict, and control the behavior of secure (tactical) communications, sensing, and command-and-control (or decision-making) networks.'' More work is needed to understand the interactions between these complex networked system-of-systems. Fundamental understanding is also needed for structure and dynamics, functions and behaviors, controllable and uncontrollable aspects of networks, metrics and performance bounds, and interactions between networks. The desired outcome is network designs with predictable performance, Swami noted.

Swami expressed a need for techniques to better interpret large quantities of data, including novel ways of representing such data. A better understanding of network behavior is also needed, he said. Such issues could be addressed by incorporating realistic scenarios into the models, but significant computational resources are required for modeling such properties as the fidelity of wireless propagation, path loss, and interference under various conditions of terrain, location, and channel traffic, over multiple time scales.

Swami proposes leveraging an HPC cluster as a mobile ad-hoc network emulator. The cluster could be connected to several emulators and labs to enable remote testing; however, architectural issues must be addressed.

Rivera noted that some tactical network applications require global knowledge at each node. Each node has a local part of that knowledge, and it must learn third-party information that is not local to itself. At present, information is broadcast over a common control channel—only one node transmits at a time and all other nodes listen.

Rivera envisions a fully-mobile, agile, situation-aware, and survivable lightweight force with internetted C4I systems. Research challenges to achieving this vision include:
• Inadequate models of network behavior
• Lack of analytic methods and heuristics to understand impact of network design options and tradeoffs

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Left to right: George Papanicolaou, Philip Levis, Larry Horton (all Stanford), Raju Namburu (ARL).

AHPCRC Consortium Attends SC07

Supercomputing Conference 2007 was held in Reno, NV, and AHPCRC was there to showcase its new team and new research. The AHPCRC booth was seen by thousands of attendees as they wandered into the academic wing of the show. Stanford, UTEP, and NMSU all created posters for the booth and HPTi arranged for brand new graphics.

Four Standford students presented their research during impromptu poster sessions. Severin Obertuefer spoke on Computational Fluid Dynamics using GPUs, William Fong spoke on Fast Multipole Method, Mike Houston presented on Machine Portability, and David Richter talked about BioAgent Dispersion.

Members of the AHPCRC Consortium at Supercomputing Conference 2007.

AHCPRC Visits the Army's TARDEC Lab

On October 18-19, members of AHPCRC and the Army Research Lab Computational and Information Sciences Directorate (ARL-CISD) visited the Army's Tank –Automotive Research Development Engineering Command (TARDEC) in Warren, Michigan.

The technical discussions included highlights of TARDEC current research challenges and projects, a discussion of AHPCRC research projects and potential research collaborations with TARDEC, and computing resources and capabilities of the Army's Major Shared Resource Center (Aberdeen Proving Ground, MD).

Afterward, TARDEC Senior Research Scientist Dr. David Gorsich and his colleague Ted Currier offered their observations on

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Members of AHPCRC and the ARL's CISD, left to right: Mark Thompson, High Performance Technologies, Inc.; Dr. Charbel Farhat, Stanford University; Dr. Raju Namburu, ARL-CISD; Dr. Paul Decker, TARDEC; Dr. David Gorsich, TARDEC; Charles Nietubicz, ARL-CISD / MSRC Director; Dr. Windell Ingram, ARL-CISD; Dr. David Lamb, TARDEC; Ted Currier, TARDEC; Dr. John Schmuhl, TARDEC.

Educational Outreach: Inspiring Interest in the Future of HPC

The focus of this year's AHPCRC Educational Outreach is on tailoring programs for middle-school and high-school curricula so that they highlight the application of HPC technologies to science and engineering challenges. The program also provided opportunities to a small number of graduate students, who participated as summer interns at ARL Adelphi and Aberdeen.

In addition to the programs outlined below, the Consortium is also planning workshops focused on Technical Areas 1 & 2 and a seminar series at various locations. These activities are designed to jumpstart the AHPCRC research portfolio and integrate it with related Army programs.

Stanford's Education Program for Gifted Youth

The Education Program for Gifted Youth (EPGY) Summer Institutes is a residential program for academically talented and motivated middle-school and high-school students, providing them with the opportunity to study advanced topics in subject areas not normally taught in their schools. In addition to enriching and accelerating their academic pursuits through engaging and challenging courses, these students are immersed in a social environment with others from across the country and around the world who share their academic interests and abilities. Students leave the program with a sense of academic accomplishment, new friends, and fond memories of a wonderful time spent at Stanford University.

As part of its outreach component, AHPCRC provided scholarships to 30 EPGY Summer Institutes participants in physics, computer science, biotechnology, engineering, and mathematics. These students came from 10 states and were close to evenly split between male and female. Just over one third of the students were in the Middle School Program, the rest were in the Summer Institutes for high school students. The scholarships were awarded based on academic ability and promise, targeting those with economic need and from historically under-represented groups.

Summer Institutes students participate in intensive study in a single course and they live in small residences with students who are all taking courses in the same subject area. Students are taught by Stanford instructors who design courses specifically for the EPGY Summer Institutes population. Subject areas include mathematics, science, writing, humanities, computer science, engineering and business. The instructors are assisted by undergraduate and graduate student mentors who have expertise in the course subject areas. These mentors serve a dual role of Residential Counselor and Teaching Assistant so that the academic and social aspects of the program are tightly integrated. In addition the academic program students participate in a wide range of recreational activities.

In their courses, the AHPCRC-supported students studied such topics as particle physics, cosmology, quantum mechanics, robotics, Java™ programming, aeronautics, microbiology, biomechanical engineering, material science, non-Euclidean geometry, and number theory. Many of these courses included lab projects and visits to laboratory facilities at Stanford or in the local area. In one section of the Biotechnology course, students worked in small teams to develop an electro-mechanical catheter that is capable of navigating through, and sensing various signals in, a simulated heart environment. In the Quantum Mechanics course, students learned how to solve the Schrödinger equation for simple one- and two-dimensional cases. Later in the course, they received an advanced introduction to quantum computing. In the Aeronautics section of the Engineering course, students visited the Hiller Aviation Museum and the NASA Ames Research Center. As one of their projects, students built radio-controlled gliders. In the course in non-Euclidean geometry, students learned the Poincaré disk model of hyperbolic geometry.

Palm Drive, Stanford University

Participants in the program find the experience fun, challenging and rewarding. Their responses in the evaluations they fill out at the end of the program are very positive about the experience, and they indicate that for many students the program has a substantial impact on their academic and social development. Many students return for a second summer in the program, and many have ended up at Stanford and other top universities as undergraduates. There is high hope for the academic success of the students who participated this past summer at Stanford with AHPCRC support.

New Mexico State University's Pre-Freshman Engineering Program

The Pre-Freshman Engineering Program (PREP) located on the campus of New Mexico State University (NMSU) in Las Cruces, New Mexico recruits pre-college students with a history of academic achievement for a six-week, academically intense, summer program with the goal of preparing them for careers in science, technology, engineering, and mathematics (STEM). Courses including logic, algebraic structures and physics stimulate students' interest in higher mathematics and science. Problem solving sessions equip them with the necessary tools and develop the enthusiasm to complete pre-calculus and calculus during high school. Through Friday field trips and Career Awareness Seminars, the students meet and interact with professionals who instill the vision and passion to become the scientific leaders of tomorrow. Participants may begin the program as early as sixth grade, and attend for three years prior to college entrance. Although PREP is open to everyone, the program focus is on female and minority populations traditionally underrepresented in the STEM fields.

Although increasing the participation of disadvantaged Americans in STEM is important nationally, this challenge is especially critical in New Mexico as the state has the highest proportion of Hispanics and the third highest proportion of Native Americans of any state in the United States. Furthermore, New Mexico ranks 46th among the 50 states in per capita income. Doña Ana County, the primary focus of PREP, ranks 24th out of 33 counties for per capita income in New Mexico. This county is largely agrarian and resides on the southern Rio Grande Corridor where 54.4 percent of the population (age five and older) speaks a language other than English at home. The three participating school districts are Las Cruces Public Schools, Gadsden Independent School District, and Hatch Valley Public Schools.

Figure 10: Goddard Tower, New Mexico State University

Dr. Vallen Emery, Outreach Program Manager for the Army Research Laboratory (front, right), and representatives from the offices of New Mexico Representative Steve Pearce and Senator Pete Domenici pose with the students of the PREP program in July.

Since the program's inception in 1997, PREP has had 644 students complete PREP 1, 405 students complete PREP 2, and 282 students complete PREP 3. Approximately two-thirds of the former participants completing PREP 1 return to complete PREP 2. The PREP 2 to PREP 3 retention rate is approximately 75 percent. This year, a total of 152 students completed one of the PREP components with a summer retention rate of 94 percent. Eighty-seven percent of this population was underrepresented minorities and of that group 56 percent were female.

Of the 644 students who have successfully completed PREP 1 since 1997, 268 are now college age. The results of the returned surveys showed:

- 159 PREP students are currently in college, 35 PREP students are college graduates, and 4 PREP students are in the military, entrepreneurs, or private sector
- 100 percent of those who returned the survey are high school graduates
- 52 percent of the college attendees are majoring in STEM fields
- 83 percent are members of underrepresented minority groups
- 54 percent are female
- 93 percent of those currently in college are enrolled at New Mexico State University
- 94 percent are attending universities in New Mexico

As a part of the curriculum the students visited the White Sands Missile Range, a unique tri-service facility for test, evaluation, research, and assessment of military systems and commercial products worldwide; Energetic Materials Research and Testing

A remote-controlled blimp, one of the PREP student projects.

Center (EMRTC), an internationally recognized explosives laboratory; Holloman Air Force Base, home to the F-117A Nighthawk—the world's first operational aircraft to exploit low observable (stealth) technology—and the world's longest and fastest test track; among other science and technology centers that reinforce the PREP curricula. As a part of this activity, career awareness speakers shared their personal, educational, and professional experiences with the PREP students. Dr. Vallen Emery, Outreach Program Manager of the Army Research Laboratory in Adelphi, Maryland, enlightened the students as to potential career opportunities with the U.S. Army and the educational skills needed to become a part of their program. Major Agustin Natamoko, U.S. Army ROTC Instructor on the campus of NMSU, also shared his experiences.

PREP is funded through grants and contributions from the U.S. Army's AHPCRC, Intel, Wolslager Foundation, and Lockheed Martin. Through the generous support of the U.S. Army and others, this program is free to eligible students.

ExciTES Program at University of Texas at El Paso

The Excellence in Technology Engineering and Science Summer Institute (ExciTES) program at the University of Texas at El Paso (UTEP) is now approaching its 35th year of service to the El Paso/Ciudad Juarez community. Since its inception, at least 3,500 middle school and high school students have attended ExciTES. In recent years, the program has shifted its focus to high performance computing (HPC), thanks to a grant from the United States Army Research Laboratory (ARL).

High school juniors stayed on the UTEP campus for three weeks, while middle school students commuted to the campus for a one week session. Both the residential 3-week and the 1-week commuter sessions have received rave reviews from the participants. Students of the 3-week sessions were accommodated at the UTEP Hilton on the edge of campus, serving as the first opportunity for many to visit a university or stay at a hotel. From the first minutes after waking up every morning to the last hours of finishing up project milestones each evening, participants were truly given a unique experience. Daily program activities were structured for participants to work in a team environment with many hands-on and thematic modules prepared by UTEP's Engineering Student Ambassadors. All participants were encouraged to apply their knowledge, imagination, and creativity to traditional math and science problems. In addition to the daily activities, field trips were conducted to local area companies in order for the students to witness real world implementations of problem solving techniques.

Recruitment efforts for ExciTES, complemented by HPC modular activities demonstrated by the Engineering Student Ambassadors, occur throughout the year at area schools. In the coming school year, the ARL HPC ExciTES grant will be focused on recruiting participants for the 2008 sessions, engaging faculty and Education majors to create activities, and beginning to identify companies that will support field trips. ✯

Sound Off!

AHPCRC researchers: Did your research group recently publish a paper, make a presentation at a conference, or reach a project milestone?

Army HPC users: Do you have a research problem that you would like AHPCRC to address? Did the consortium resolve a problem for you?

Let us know!

Send your comments, questions, ideas, and articles to Nancy McGuire, nmcguire@hpti.com

AHPCRC User Support Services

AHPCRC Spans the Continent with East and West Facilities

To provide optimal support to the Army research community, the AHPCRC is deployed at two separate centers on the east and west coasts. Supporting AHPCRC centers on both coasts expands coverage hours and provides better proximity for user support, direct interaction with Army scientists and engineers, and training initiatives.

AHPCRC West. AHPCRC West is located at Moffett Field, Mountain View, California. NASA Ames Research Center is the host site of AHPCRC West and is in its own right, a recognized leader in high performance computing. AHPCRC West hosts AHPCRC supercomputing and storage systems within the NASA Advanced Supercomputing division (NAS) at NASA Ames. By bringing NASA and AHPCRC together at AHPCRC West, both the Army and NASA can benefit from an exchange of ideas, technologies, and operational practices to share and collaborate while providing Army and Consortium scientists and engineers with the computational infrastructure to support the Consortium's research activities.

Another major benefit of AHPCRC West's location is the close proxity to Stanford University and Silicon Valley, the center of technology innovation.

AHPCRC East. Based at the headquarters of the Army Research Lab, at its Adelphi Laboratory Complex in Adelphi, Maryland, AHPCRC East allows the Consortium to be more closely integrated with the leadership of the Army Research Lab and the large concentration of Army scientists and engineers at RDECOM and ARL sites in the mid-Atlantic area (Adelphi, Edgewood, Aberdeen, Ft. Belvoir, Ft. Detrick, Research Triangle Park, and Ft. Monmouth).

The staff located at AHPCRC East form a small, dedicated team that provides advanced customer services in applications support, scientific visualization, and special project initiatives in support of Army and consortium scientists across the country. Locating these staff on the east coast expands the overall window of high-level support available to AHPCRC and Army sites within a close proximity to a large base of Army scientists and engineers.

Army Research Lab—Adelphi Laboratory Complex. Home of AHPCRC East

Stanford Institute for Computational and Mathematical Engineering

With the advent of ever increasing computer power the role of mathematical modeling of engineering systems is becoming ubiquitous. Numerical simulation technology has advanced all areas of engineering including, aerospace, chemical, communication, networking, manufacturing, bio-medical, materials, semi-conductor processing, environmental engineering and transportation. It now plays an equal role to theory and physical experiments in discovery driven engineering research.

The Stanford Institute for Computational and Mathematical Engineering (iCME) leverages the outstanding strengths of Stanford in engineering applications and physical, biological and earth sciences to focus and guide the development of modern research and educational enterprise in computational mathematics. iCME's central research mission is the development of sophisticated algorithmic and mathematical tools, which impact many different applied disciplines.

AHPCRC Supercomputers

AHPCRC West serves as host site for the AHPCRC systems. Today, there are two supercomputing systems housed at AHPCRC West, which provide the bulk of the computational resources for the consortiums scientists. These systems supply a combination of peak performance through commodity hardware as well as specialized vector processing technology to support specific demands of several science and engineering applications. Both systems were designed to support large-scale parallel applications.

Cray X1E

The Cray X1E is a scalar/vector supercomputer system that combines the processor performance of traditional vector systems with the scalability of microprocessor-based architectures. With its unique processor and network architecture, scientists and engineers have the resources necessary to compute solutions to certain classes of problems that are not suitable for commodity technology. Features and capabilities include an advanced processor architecture combining vectorization with hardware-enabled processor coupling for extreme performance, and a scalable system architecture with thousands of processors (16 to 8192) able to share each other's memory. The X1E also features

AHPCRC User Support Services

a true single-system image operating system that minimizes system administration and simplifies application development, and a mature programming environment that includes vectorizing compilers and support for a variety of highly optimized parallel programming models.

Alignment. One of AHPCRC's primary missions is to bring together leading capabilities in academia, industry, and government so that their talents can be combined to address some of RDECOM's greatest science and engineering challenges. At the program level, AHPCRC accomplishes this by working closely with Army scientists and engineers at the Army Research Lab and RDECOM research and engineering directorates. The AHPCRC Consortium takes this collaboration a step further, collaborating with the NASA Ames Research Center (a consortium member) to leverage NASA's leading role in many of these areas. ✯

1024 vector cores
Capable of 4.5 Teraflops
High-bandwidth memory
subsystem
512 Gigbytesof memory
50 Terabytes of disk storage
Capable of 4.5 Teraflops

CRAY X1E

1,152 AMD cores
Capable of 5.5 Terflops
2.3 Terabytes of memory
76 Terabytes of disk storage

Cray XT3

AHPCRC User Support provides a full range of support to insure that the HPC systems are utilized effectively and that Army, DoD and Consortium users have access to the resources that they need to solve their problems effectively.

A 24x7 Operations Center at the AHPCRC-West is staffed on a 24x7 basis where analysts are available by both phone and email 7 days a week. Helpline analysts assist users with questions such as obtaining a user account, system status, queue status, software availability, and general system usage issues. Advanced questions are forwarded to the applications software support scientists and are continuously tracked by the analysts at the Operations Center to ensure that all user issues are resolved quickly.

Applications software support scientists are located at both AHPCRC West and AHPCRC East. These scientists work with users on questions regarding COTS software, porting and optimization issues, effective utilization of the system resources, and more advanced software questions such as how to more efficiently utilize HPC resources for scientific problems and implementation of new algorithms and methods.

AHPCRC User Support maintains the HPCMP baseline configuration standards which includes standardizing scratch space retention time, Kerberos ticket life, environment variables, queue names, login shells, math libraries, SSH access to the systems, editors and scripting tools, debuggers, and open source utilities.

AHPCRC user accounts are created following the standard policies set in place by the DoD High Performance Computing Modernization Program and is managed through the Information Environment. Standard queues are provided through PBS Pro and special queues are available for challenge projects and for (free) background jobs.

The mission of the AHPCRC User Support team is to maintain a productive relationship with the scientists and engineers using AHPCRC systems and to develop the most effective and productive environment for addressing AHPCRC's computational needs.

24 x 7 Phone Support
1-888-274-2134

24 x 7 E-Mail Support
help@ahpcrc.hpc.mil

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Workshop on Sensors, Communications, and Imaging

- Limitations of large-scale discrete-time, event-driven simulations
- High fidelity modeling from the physical layer (PHY) to the applications layer (APL)
- Very large parameter space
- Lack of large-scale network emulation capability
- Techniques to analyze and visualize large quantities of network data

Dr. John Kosinski of the Army's RDECOM CERDEC 12WD directorate observed that the military entity should be viewed holistically as an autonomous system at multiple scales. Each subordinate individual and unit has an explicit expectation of autonomous and/or collaborative action supporting global goals. Critical decisions are made across echelons, and they have complex interrelationships. Sensor, communications, and information networks contribute to achieving goals across multiple scales. Such goals include making "good" decisions, avoiding mistakes, and enabling both autonomous and cooperative action.

Kosinski noted that if the sensor, communications, and information networks derive value from their contribution to achieving goals across multiple scales, then metrics are required that quantify the value of sensor and library data feed to the decision process or scheduled action. Metrics that quantify value must link sensor properties such as accuracy and precision, and reporting properties such as truthfulness and mistakenness, with decision process properties such as "clarity" and "confusion."

Communicate and Process
In a summary of the project goals (see sidebar), the Stanford group divided the problem into two areas: robust communications and information processing.

Robust communication refers to the ability to maintain clear communications channels in environments that may have multiple sources of interference (including intentional jamming) and that may change rapidly.

Stanford assistant professor Philip Levis presented his work on modeling and classifying robust, flexible, low-power wireless communication environments. Levis described the problem of achieving these networks as stemming from the lack of a "lexicon" to describe the complexities of real-world wireless networks and a lack of knowledge of what factors are most important. He posits that once such a lexicon exists, formalisms can be defined that better model the real world. Toward that end, Levis proposes measuring networks to discover their important properties using protocol-driven evaluations.

Stanford professor Leonidas Guibas (computer science) addressed the issue of problems and methods for managing information discovery, brokerage, and dissemination in sensor networks. Guibas is building a sensor lab as part of this project, and he is also applying theoretical methods, such as iterative

Computational Battlefield Network and Information

Current and future wars may be fought against untraditional enemies in settings where insurgent forces are hard to distinguish from peaceful civilians, in urban theaters where occlusion and clutter make targets only intermittently observable and therefore difficult to track, and in situations where intelligence information is rarely clear and unambiguous. To operate successfully in such scenarios, an agile army is needed, aided by ground and air sensors, communication infrastructure, and high performance computation for intensive information throughput, data analysis and mining, probabilistic reasoning, and detailed simulation. To this end, the Tech Area 3 program has two main parts:

Information Processing. At a high level, the research addresses information gathering and decision support for soldiers carrying wireless devices. By deploying large numbers of low-cost, untethered nodes with a variety of image, infrared, acoustic, motion, temperature, pressure, magnetic or vibration sensors, urban and non-urban landscapes can be sampled in a way that was previously impossible. The nodes can aggregate and cross-reference their data over a wireless network according to the demands of the task at hand. Much of this fusion can take place in-network, reducing expensive and disruptable long-range communication.

The proper integration of all this evidence will require powerful probabilistic reasoning algorithms and high performance computing capabilities. Ultimately, however, a battle is not won because one can collect and analyze battlefield data outside the battlefield theater. The real challenge is to provide low-latency actionable information to warfighters operating in the same space where the sensor network is deployed, and for this goal, in-network processing of sensor data and information is essential. Users can either subscribe to data of interest to them regarding emergent situations and dangers, or perform real-time queries to the sensor network to request information proactively. In such a setting, the warfighters are not just consumers of information from the network, but are “soft” sensor nodes, introducing new information into the network based on their observations and helping with the interpretation of sensor data captured at other sensor locations.

Robust Communications. At a low level, our research addresses the links themselves: how to build and maintain wireless communication links that have range reliability and high throughput in a complex environment such as a hostile urban landscape. The challenges in establishing and maintaining high speed, reliable communications links in dense urban, high foliage, and lossy indoor propagation environments are many. We have to deal with low SNR, high-delay spread, severe interference and rapidly time-varying environments. The performance measures of interest are throughput, bit/frame error rate, and outage or reliability.

The large channel delay spread, leading to frequency selective channels, often motivates orthogonal frequency division multiplexing (OFDM) modulation. However, equalization still requires estimating the channel in OFDM, which, in the presence of all the impairments and with limited pilot density, often requires very sophisticated, often non-linear, computationally intensive algorithms.

We also need to deal with co-channel interference and, in hostile environments, intentional jamming. Both of these can be addressed by non-linear methods such as multi-user detection and by linear, including blind, canceling methods. Time and frequency selective channels further complicate such processing. Multi-user approaches to interference mitigation increases computational complexity exponentially in the number of interferers.

There are many ways in which the impairments of a complex environment can be mitigated, but they are all very computationally demanding, and the big challenge is to find algorithms that consume low power at the terminal. This requires very extensive simulations in the design phase to try out candidate algorithms in numerous likely scenarios spanning 30 to 40 dimensions and then the choice of good candidates. The challenge in this research is to find effective, scalable computational methods that reduce the adverse effects of the hostile communications environment.

methods based on discrete potential theory, for discovering network properties and delivering sensor information to mobile network users.

Guibas described sensor networks as a novel type of computing device—sensor computers. One of the first tasks of the network is to understand the morphology of its layout, analyze the signal landscape observed, and establish information highways and sensor collaboration groups. Ubiquitous networked sensors provide a dense spatial and temporal sampling of the physical world, he said. They allow low-latency access to information that is highly localized in time and space, and thus provide a way to sense and act on the physical world beyond what has been possible up to now.

Guibas hopes to build sensor networks that deliver distance-sensitive, low-latency, highly specific data and information to mobile users. Social-network style user collaborations—matching information providers and seekers directly in the network—would enable users to interpret sensor data through the same network. At servers on the edges of the sensor network, off-line HPC computing would be used to optimize and tune the protocols and algorithms for the particular deployment parameters of the network.

Stanford professor Arogyaswami Paulraj (electrical engineering) reviewed his work on the role of interference in multiuser wireless communications—mainly cellular networks, but with basic aspects that apply to ad-hoc and mobile networks. Interference—"the final frontier" according to Paulraj—can be treated as noise, and this simplification allows treatment of multiuser links with near optimal throughput.

High-performance computing is key to addressing the 20–30-dimensional problems typical in such designs. Paulraj noted that, "The huge constraint in designing new systems is the computational burden to properly evaluate the design space. It is faster to build a full system and field test a design rather than simulate the system properly before building it! Better simulation methodologies and larger computational facilities are badly needed."

Information processing. Receiving data transmissions is of limited usefulness without the ability to select the most useful information and apply it to the problem at hand. An ideal network would consist of many low-cost untethered nodes connected by a wireless network and with the ability to aggregate, interpret, and apply data in the field rather than transmitting it offsite for processing.

Stanford professor George Papanicolaou (mathematics) presented some recent work on imaging with distributed sensor networks. In some such networks, some sensor locations are known but others are not known and can be treated as targets whose location is to be imaged. He presented algorithms presented based on interferometry that are computationally intensive because they go through several optimization cycles.

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Workshop on Sensors, Communications, and Imaging

Papanicolaou cited an example of distributed sensor imaging for monitoring the structural health of airplanes or bridges containing embedded sensors. Migration imaging, which is widely practiced today, does not work well in complex environments, he noted. Newer methods make optimization possible, stabilizing the image by setting the threshold so as to screen out clutter. Combined optimal subspace and optimal illumination gives very stable images, but new algorithms that deal with environmental complexity introduce a corresponding degree of computational complexity—a clear case for high performance computing.

Kyle Heath, a graduate student in Prof. Guibas' group, illustrated an example of tracking humans using a camera sensor network. Facial recognition algorithms identified the person who took the tool from a lab bench, and activity monitoring traced his path to find where he was later on. Challenges to implementing such a system include limited resources for communication, computation, and power; the large volume of data involved; and filtering out hours of "uninteresting" surveillance video to home in on the relevant events.

Stanford assistant professor Amin Saberi uses spectral graph theory and Markov chain comparisons to characterize and quantify congestion and throughput in complex ad hoc wireless networks. He discussed the use of "gossip" algorithms to aggregate information: when messages are passed among neighboring nodes on the network, the information converges to an average or median at a rate that depends on the spectral gap. Saberi spoke of topology-aware networks that could measure, maintain, and improve connectivity while helping to guide local network protocols. Metrics are important for such systems because they measure network robustness and identify critical areas within the network. Metrics also characterize a network's performance and scalability, and they provide global guidance the help various local algorithms.

Over the course of the workshop, it became clear that wireless sensor networks will be a fertile field of research for the foreseeable future. As the newly reconstituted AHPCRC consortium begins to produce results, the impact will be felt in the military and civilian arenas. Stay tuned. ✯

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AHPCRC Visits the Army's TARDEC Lab

the meeting. The TARDEC group looks forward to establishing a partnership with AHPCRC, especially in areas involving lightweight combat systems and HPC enabling technologies (Technical Areas 1 and 4). They intend to leverage as many of AHPCRC's efforts as they can, and to integrate this research into Army programs. They see encouraging potential in the new organizational structure of the consortium, which offers more flexibility than in the past. Gorsich was pleased to discover the diversity of the projects under the AHPCRC umbrella, and he is especially interested in the parallelization efforts, particularly within the time domain, which addresses traditionally serial algorithms in analyses.

The TARDEC group foresees that AHPCRC will provide a great deal of assistance in TARDEC's efforts in Army platform level analysis and design optimization involving complex materials and structures. This effort requires code coupling of multi-physics, multi-scale, and multi-level software applications and new approaches. The TARDEC group greatly appreciated the willingness of the AHPCRC consortium to work with them, provide input to their projects, and to transition technologies and enabling HPC tools to TARDEC and the Army. ✯