AHPCRC

Army High Performance Computing Research Center

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AHPCRC Consortium Members

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University of Texas at El Paso
NASA Ames Research Center

AHPCRC, The Army High Performance Computing Research Center, is a collaboration between the U.S. Army and a consortium of university and industry partners. It addresses the Army's most difficult scientific and engineering challenges using high performance computing, in alignment with the Army Research, Development and Engineering Command's (RDECOM's) vision to be the world leader in rapid and innovative research, development, and engineering for the warfighter.

High performance computing (HPC) provides significant advantages in designing and characterizing complex systems involving many interacting factors. Computer modeling and simulation reduce the time and expense of designing, optimizing, and characterizing complex systems. This, in turn, enables decision-makers to prioritize design tradeoffs and to make informed acquisition decisions. Computer models can stand in for real-world trial and error where such testing would be costly or dangerous.

Realistic computer simulations and models enable a sophisticated and intentional approach to the design, characterization, and optimization of complex systems. Many combinations of parameters and variables can be tested, leading to solutions that might not have been foreseen by the researcher. As applied science and engineering problems become more complex, computing capabilities must keep up with the demand. Existing codes must be adapted to run on parallel computing systems, toolkits and libraries must be operable on multiple platforms, and programs must be written so that they can be easily transferred to newer systems as they arise. Software must be comprehensible and applicable to the intended users.

Although HPC modeling, simulation, and mathematical calculations are well established as tools for fostering scientific discovery, significant unrealized potential exists for innovating technology and reducing design-cycle times. HPC architectures vary greatly, and the development of parallelized software that functions efficiently on a variety of platforms (including those that don't yet exist) is still in the early stages. AHPCRC seeks to develop this potential as a means of addressing the real-world needs of today's warfighter: strong, lightweight protective gear; agile unmanned aerial surveillance vehicles; early-warning systems for biowarfare agents; better medical treatments; lightweight vehicle and ammunition components; efficient wireless network designs; and rapid, secure data aggregation and dissemination.

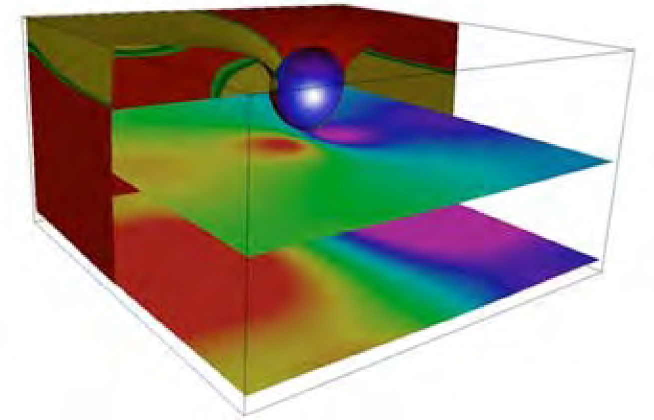
In addition, AHPCRC fosters the education of the next generation of scientists and engineers—including those from racially and economically disadvantaged backgrounds—in the fundamental theories and best practices of simulation-based engineering sciences and high performance computing.

Contents

AHPCRC Technical Areas

Lightweight Combat Systems Survivability

Strong, impact-resistant materials lighten the soldier's load, give the soldier increased protection, and minimize unnecessary risk to soldiers. Where possible, mechanical devices such as drone vehicles can stand in for humans to do hazardous or tedious work. Computer simulation allows designers to try out numerous mechanical and material configurations to see which ones work best. The resulting computational models can be applied to human tissue structures as well, enabling the development of better medical treatments and reconstructive capabilities.



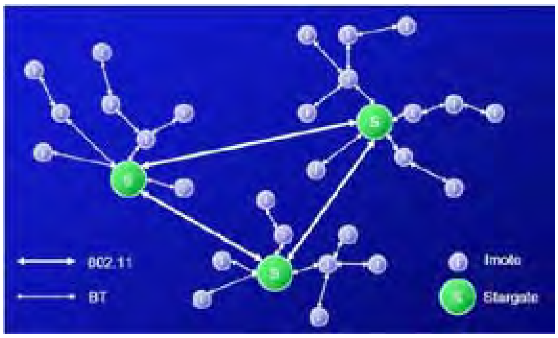
Computational Nanotechnologies and Biosciences

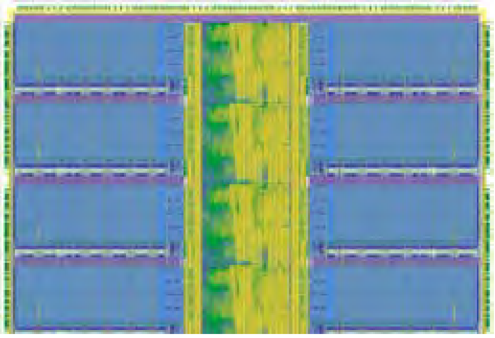
Many important changes happen on a tiny scale—the scale of molecules, viruses, and sub-microscopic particles. Computer simulation is ideally suited for setting up realistic scenarios and studying the interplay of many factors. High performance computing can be used to design strong, lightweight materials "from the atoms up" or to model biological systems at the molecular level. The speed and capacity of massively parallel computers are key to simulating real-world phenomena such as particle flows on scales ranging from nanometers to city neighborhoods and nanoseconds to hours.

Above: Spherical projectile penetrates a flexible sheet.
Left: Roof and ground temperatures affect contaminant dispersion.
(Stanford University)

Computational Battlefield Network and Information Sciences

Civilian wireless communications networks must provide reliability and mobility, while accommodating many applications (voice, data, images, navigation) within available bandwidth. Military networks require all of this, plus security, stealth, resistance to hostile interference, and the ability to set up ad hoc networks in a variety of environments. Computer modeling aids in designing complex wireless communications networks for optimum security and effectiveness. HPCs incorporated into operating networks provide fine-tuning and real-time adaptability to changing circumstances.





HPC Enabling Technologies and Advanced Algorithms

As computing applications become more demanding, computers and the programs that run on them must evolve as well. This is especially true for high performance computing, where power consumption levels, computing resource usage, and program portability between platforms are essential to the effective use of these resources. Capabilities developed for AHPCRC point the way toward wider application as multicore processors and parallel programming become common in the commercial marketplace.

Top: Communications network nodes.
Bottom: Computer chip design.
(Stanford University)

Testing a wing model in a water channel.
(NMSU photo)

Technical Area 1

Lightweight Combat Systems Survivability

Strong, impact-resistant materials lighten the soldier's load, give the soldier increased protection, and minimize the soldier's risk. Mechanical devices such as drone vehicles can often stand in for humans, doing hazardous or tedious work.

High performance computer simulation allows designers to try out numerous mechanical and material configurations to see which ones work best. Computer models enable designers to try many configurations of strong, lightweight materials and to design configurations without the time and expense of building physical models.

Complex, realistic computer simulations enable sophisticated and intentional approaches to material design, better understanding of modes of failure, and mechanical designs that imitate successful designs already used by biological organisms.

Computer simulations can also aid medical researchers to develop better wound treatments, based on the similarities between human soft tissue and plastic polymers. In such cases, computer simulations allow systematic evaluations that are not practical with live subjects.

Streamlined, massively parallel high performance computing structural codes allow researchers to examine many relevant physical factors simultaneously, or to examine parameters in isolation (often not possible in the physical world), thus creating models that more closely simulate—or improve on—their real-world counterparts.

Projects

1–1: Multiscale Ballistic Fabric Nets
1–2: Simulation of Fracture and Penetration
1–3: Multidisciplinary Parametric Modeling and
Lift/Drag Quantification and Optimization
1–4: Flapping and Twisting Aeroelastic Wings
for Propulsion

Ballistic Fabrics

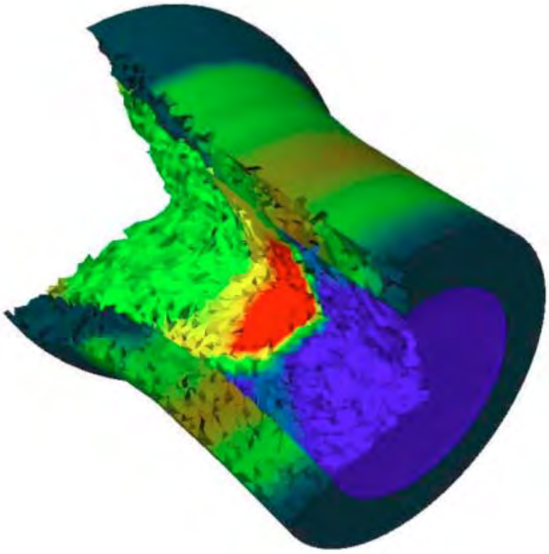
Adequately protecting soldiers and their vehicles without unnecessarily weighing them down is one of the Army's greatest technological and operational challenges. To meet this challenge, AHPCRC researchers simulate the behavior of ballistic fabrics to determine manufacturing processes and attachment configurations that provide the best resistance to penetration and damage.

Polymers and Tissues

AHPCRC researchers simulate the behavior of high-strength, light-weight plastic materials and how they respond to rapid, high-stress deformation, typical of shock or ballistic impact. This work is also being applied to the study of ballistic impact on human soft tissue, to provide a basis for better diagnostics and wound treatments.

Right: Kevlar fabric stops a bullet. (Army photo)

Below: Simulated detonation wave inside a canister. (Adrian Lew, Stanford)



MAV Aerodynamics

Micro aerial vehicles are tiny, stealthy, affordable aircraft that serve as the soldier's eyes, ears, and nose in hazardous or inaccessible areas, or in situations that require round-the-clock surveillance. High performance computing helps MAV designers understand the aerodynamic properties of these vehicles, leading to designs that provide the greatest lift and thrust for the least amount of energy input.

MAV Wing Design

High performance computing aids in designing birdlike flapping and twisting wings. These allow micro aerial vehicles to maneuver in tight spaces and stay on course despite unpredictable gusts and air currents. Simulations show how real birds generate lift and propulsion, and quantify the energy needed for flight.

Technical Area 1 Leader and Center Director

Charbel Farhat
Vivian Church Hoff Professor of Aircraft Structures
Chairman, Department of Aeronautics and Astronautics
Professor, Mechanical Engineering
and Institute for Computational and Mathematical Engineering
Stanford University

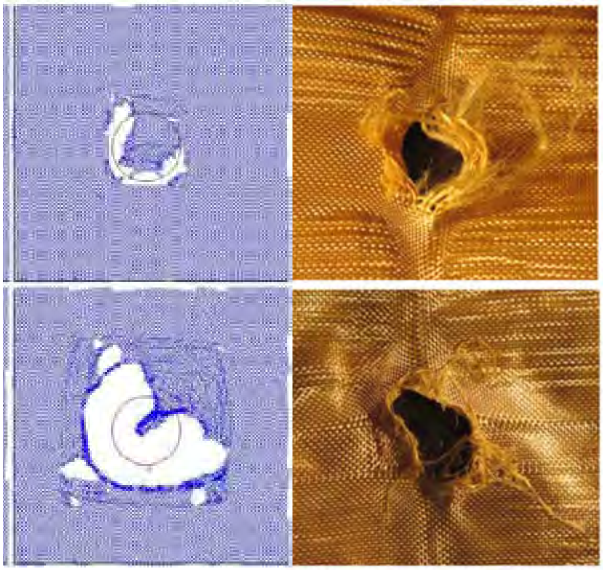
Project 1–1: Multiscale Ballistic Fabric Nets

Principal Investigators: Tarek Zohdi (University of CA – Berkeley)
and Charbel Farhat (Stanford University)
Collaborator: David Powell (University of CA – Berkeley)

Adequately protecting soldiers without unnecessarily weighing them down is one of the Army's greatest technological and operational challenges. To meet this challenge, AHPCRC researchers are developing advanced computer simulations of multifunctional ballistic fabrics, alone and attached to rigid supports. Lightweight protective fabrics reduce human casualties and damage to equipment, while standing up to the effects of weathering and prolonged storage. Computer models assist in trying out new configurations and understanding fabric properties.

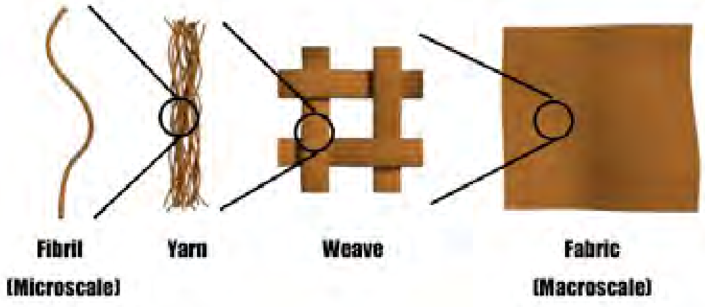
Ballistic impact produces multiple physical effects at high speeds. HPC simulations, using parallel code to model nonlinear solid dynamics, allow researchers to examine material failures frame-by-frame, and to test various components singly or in groups. Simulations may suggest effective material configurations that are not intuitively obvious from experimental data alone.

AHPCRC researchers are adapting existing simulation codes for use in parallel processing applications and finite element analysis.



Computer simulations (left) and ballistic fabric samples (right), showing damage from projectile penetration. (David Powell, UC Berkeley)

They are also building new capabilities, such as modeling damage from various types of projectiles, accounting for imperfections introduced during the weaving of fabrics, evaluating methods for attaching the protective fabric to an underlying structure, and simulating the propagation and growth of flaws in fabrics. Preliminary work has started on modeling fiber-based composite materials.



Individual fibril properties form the basis of simulations on progressively larger scales. (Tarek Zohdi and David Powell, UC Berkeley)

Project 1–2: Simulation of Fracture and Penetration

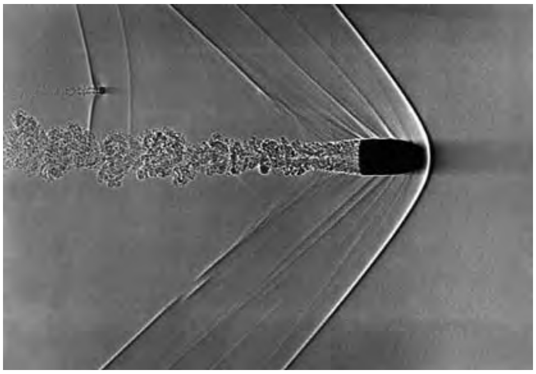
Principal Investigator: Adrian Lew (Stanford University)
Collaborators: Raymond Ryckman, Ramsharan Rangarajan, and Matthew Dixon (Stanford University)

AHPCRC researchers are developing computer models for lightweight, high-strength plastic materials that could replace metal components such as cartridge casings and vehicle panels. The reduction in weight and manufacturing costs could produce significant savings, but the new materials must perform at least as well under field conditions, including impact and penetration, as the materials they replace.

Ballistic impact produces multiple physical effects at high speeds. Materials deform, crack, and rupture at the site of the impact, and the effects are propagated to the surrounding areas and attached structures. HPC modeling helps designers understand how the materials respond to stress, impact, and shock, and how they can be optimized for a particular purpose.

The methods developed here are being extended to the study of ballistic impact damage and applied stress in human bones and soft tissue, to improve diagnostics and treatment of injuries. Computer models based on ballistic gels, which simulate human soft tissues, show how the energy from a ballistic impact is dissipated and illustrate the damage patterns characteristic of specific types of impact.

New methods facilitate the construction of geometric models that enable the simulation of high-speed penetration problems. Above, the simulated mechanical response of a femur bone to applied stress. (Adrian Lew, Stanford)



Ballistic impact deforms polymer materials and human tissues in much the same way that a bullet traveling through the air produces a shock wave, as shown in this shadowgraph.
(NASA image by Andrew Davidhazy, Rochester Institute of Technology)

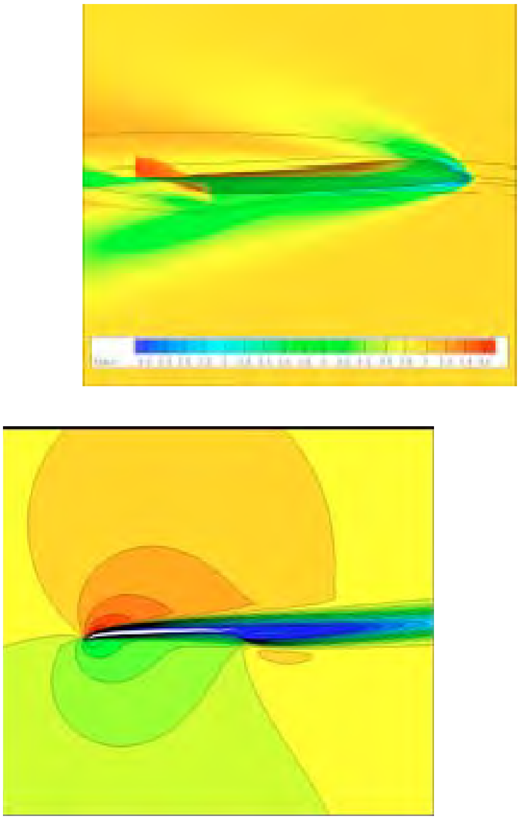
Project 1–3: Multidisciplinary Parametric Modeling and Lift/Drag Quantification and Optimization

Principal Investigators: Antony Jameson (Stanford University)
Collaborator: Matt Culbreth (Stanford University)

Small, inexpensive flying drones can serve as the soldier's eyes, ears, and nose in situations that are hazardous or that require 24 x 7 attention, but small flying vehicles face challenges, such as air turbulence and viscosity properties, that larger flyers do not.

Nature has provided several effective design examples in the form of birds and insects, but imitating these flyers is a complicated task. Unlike their natural counterparts, drone vehicles cannot spend most of their time in a search for food. Drone vehicle wings must achieve the most lift and propulsion with the least expenditure of energy, so that the drones can carry their load of sensors, communications devices, and fuel.

AHPCRC researchers are using massively parallel HPC simulations to create pressure distribution models that optimize airfoil shapes for maximizing lift and minimizing drag. Computer simulations have already generated promising airfoil shapes with non-intuitive characteristics such as supercritical wing forms (flattened upper surfaces and highly curved aft surfaces), expanding the realm of possibility beyond the imagination of the engineer. Large-scale three-dimensional turbulent flow simulations are being used to verify the fast two-dimensional shape optimization process for micro aerial vehicle airfoils.



Simulations show pressure distribution patterns around airfoils in a fluid stream. (Antony Jameson, Matt Culbreth, Stanford)

This commercial jet plane incorporates a supercritical wing design, which improves lift, resulting in better takeoff and landing performance.

(NASA photo)

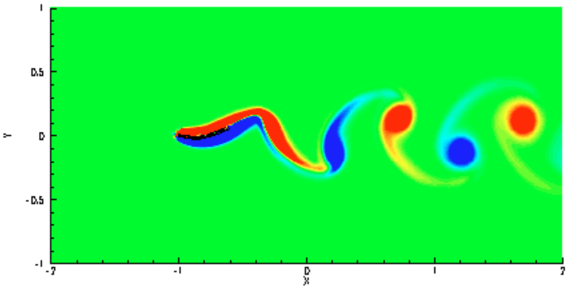
Project 1–4: Flapping and Twisting Aeroelastic Wings for Propulsion

Principal Investigators: Mingjun Wei, Banavara Shashikanth (New Mexico State University), Charbel Farhat (Stanford University)

Birds and insects use complex flapping and twisting wing motions to maneuver, hover, avoid obstacles, and maintain or regain their equilibrium in shifting and unpredictable wind currents. Flocks of birds travel in formation and insects form unstructured swarms using rudimentary communications. Parameterizing and simulating bird and insect behaviors will be instrumental in developing small, lightweight, sturdy unmanned aerial vehicles for use in sensing, surveillance, and wireless communications.

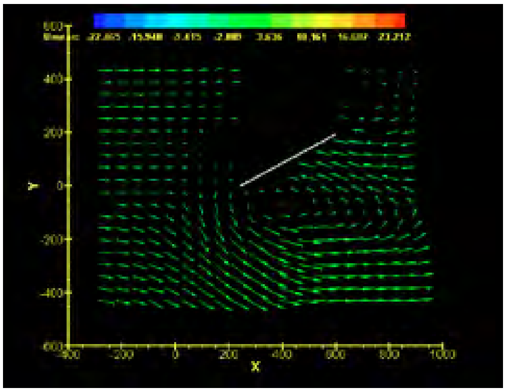
HPC simulations examine plunging, pitching, and twisting motions of aeroelastic wings, to optimize the amplitudes and frequencies of flapping and twisting motions for the maximum amount of thrust. Several methods of calculation are being adapted, extended, and validated for this purpose. Mechanical hummingbird wing models are used for particle image velocimetry measurements and flow visualization to provide real-world foundations for the HPC simulations.

Testing a wing model in a water tank. (NMSU photo)

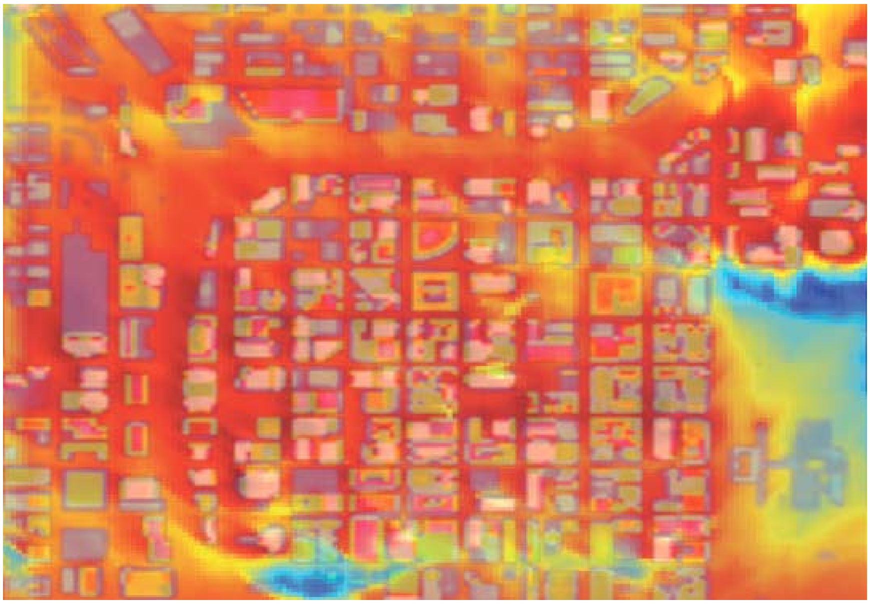


Simulation of uniform flow passing a flapping flexible plate. (Mingjun Wei, NMSU)

Particle image velocimetry plot, showing vortex structures. (NMSU graphic)



3:1 scale model of rufous hummingbird wing. (NMSU photo)



Left: Ozone levels over downtown Chicago. (Mark Jacobson, Stanford)

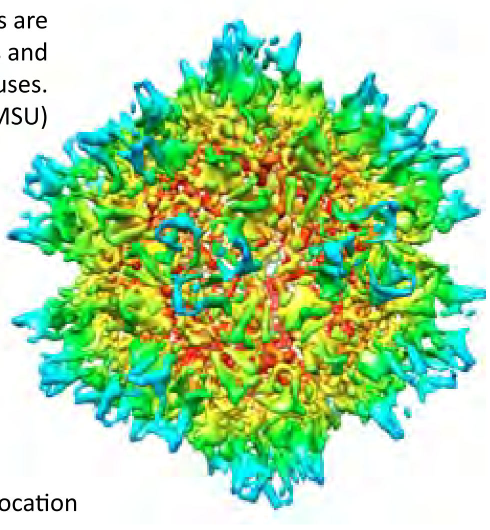
Above: Sedimentation model for rod-like particles. (Eric Shaqfeh, Eric Darve, Stanford)

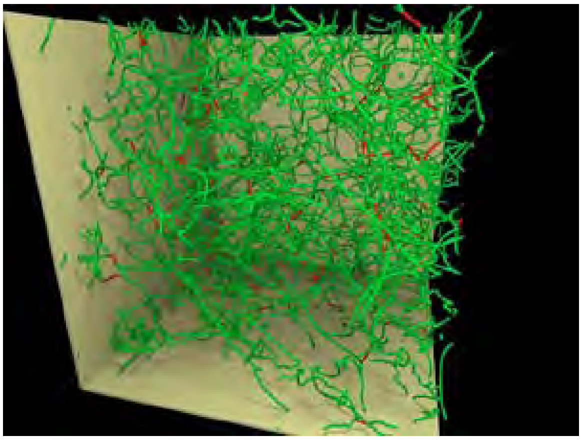
Technical Area 2

Computational Nanotechnologies and Biosciences

Computer simulations of material and biological systems at nano- and microscales are expected to play an increasing role in science and engineering and in accomplishing the mission of the Army. Research involving nano- and biosciences spans a wide range of disciplines and problems. AHPCRC research in this area addresses two broad classes of problems: responding to a release of biological warfare agents and the rate-dependent response of materials to external loading.

Right: Simulated virus structures are built from their constituent parts and compared to known viruses. (Jing He, NMSU)

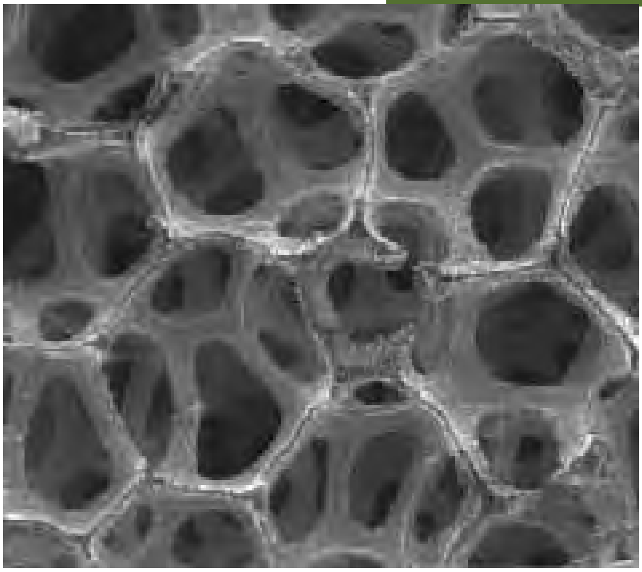




Left: Simulation of dislocation defect lines in molybdenum metal. (William Cash, Stanford)

Projects

- 2–1: Dispersion of BWAs in Attack Zones
- 2–2: DNA and Proteins in Microfluidic Channels
- 2–3: Protein Structure Prediction for Virus Particles
- 2–4: Nanomechanics of Metal Foams and MEMS Devices



Micrograph of a metal foam. (Wei Cai, Stanford)

BWA Dispersion

HPC modeling and simulation helps soldiers and first responders anticipate the effects of an aerosol biological warfare agent (BWA) over many time and length scales after release. Understanding the mechanisms and rate of dispersion of these agents through the atmosphere is essential to developing effective response strategies.

Microfluidic Channels

HPC-aided design will assist device developers in constructing small, economical sensors for detecting and identifying BWAs in the field.

The novel microfluidic technology arising from this research can be used to design artificial blood platelets and drug delivery agents that assist in emergency medical response and long-term treatments.

Virus Structure Models

Viruses can mutate rapidly into new strains, naturally or as a result of genetic engineering. Computational models enable scientists to identify known and newly developed viral BWAs and to develop fast response counteragents.

Nanomechanics

Understanding the fundamental mechanisms that control the behavior of materials under stress will assist the development of reliable micro-sensors and provide physical inputs for the design of materials, such as lightweight metal foams, that can sustain high strain rate impacts. HPC simulations can identify possible sources of flaws and breakdowns in battlefield environments before the material is actually produced—saving time, money, and lives.

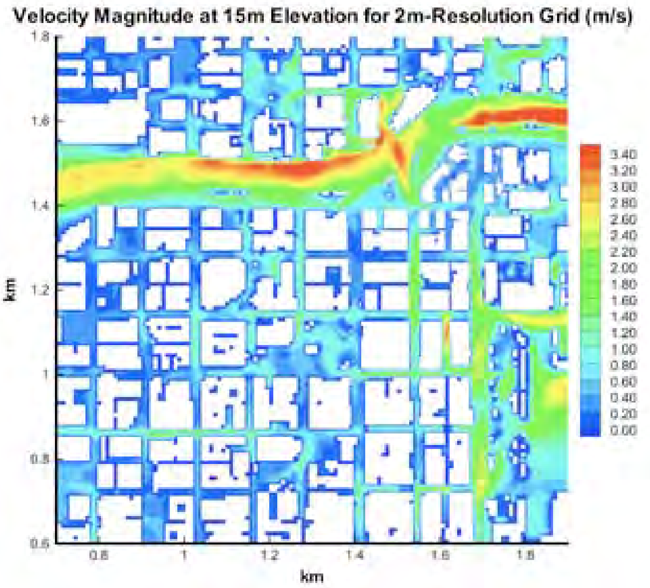
Technical Area 2 Leader

Eric Shaqfeh
Professor of Chemical Engineering and Mechanical Engineering,
Institute of Computational and Mathematical Engineering,
Flow Physics and Computation
Stanford University

Project 2–1: Dispersion of Biowarfare Agents in Attack Zones

Principal Investigators: Gianluca Iaccarino, Eric Shaqfeh, and Mark Jacobson (Stanford University)
Collaborators: David Woodbury, David Richter, Riccardo Rossi (Stanford University)

Planning an emergency response to a toxic substance release requires knowing the air circulation patterns around rivers, buildings, and ventilation systems and knowing whether the substance is more likely to stay near the ground or remain high in the air. This knowledge enables responders to know how large an area to evacuate, how long the substance is likely to linger, and the speed and direction of toxin dispersal. Real-world trial-and-error methods for emergency response planning are largely impractical, making computer simulation a key tool in disaster response planning.



Air flow over and around the Chicago River. (David Woodbury, Gianluca Iaccarino, Stanford)

Computer simulations take many variables into account, integrating real-world information from many sources to construct predictions and “what-if” scenarios. Simulations must not only factor in numerous parameters and variables, but they must also model agent behavior over a sufficiently long time span to produce useful results. Massively parallel codes and HPC facilities provide the computing resources necessary to run realistic simulations of this nature. AHPCRC simulations using downtown Chicago as a test case have shown significant differences in the dispersion of biological warfare agents as a function of local topographical features, such as rivers and buildings. AHPCRC researchers are developing a non-Newtonian fluid model to represent the dispersion of rod-like and particulate biological warfare agents through a variety of fluid media. Various calculation methods are being compared for consistency and accuracy.

Simulation of contaminant dispersion in the wake of a building.
(Ricardo Rossi, Gianluca Iaccarino, Stanford)

Project 2–2: DNA and Proteins in Microfluidic Channels

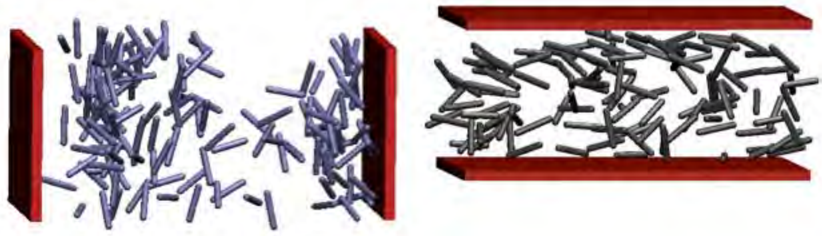
Principal Investigators: Eric Shaqfeh and Eric Darve (Stanford University)
Collaborators: Juan Santiago, Anders Berliner, Brendan Hoffman, Fabio Baldessari (Stanford University)

Cantilevered microdevice for sensing and identifying particles in a liquid stream. (National Cancer Institute)

Computer modeling is a valuable tool for designing inexpensive, rugged field sensors capable of detecting and identifying biological warfare agents rapidly and accurately. In the micro- or nano-sized channels typical of miniaturized sensors, charged particles, such as DNA molecules, have strong hydrodynamic and electrostatic interactions with nearby particles or the channel walls, which affects the way they flow.

AHPCRC researchers have developed a technical approach for simulating the flow of rod-shaped particles (such as DNA or protein molecules) through a microchannel sensing device. They have modeled rods with various characteristics under several flow conditions. Results of the simulation runs compare well with laboratory results for microfluidic flow, including electro-osmotic effects. Simulating channel configurations including bends and splits requires coupling channel geometry with the particle interaction code using new fast algorithms.

Because human blood vessels are a type of microchannel, these simulations can be extended to the study of particles in the bloodstream. Medical researchers can use HPC simulations to study the effects of synthetic clotting agents and drug delivery molecules that can then be applied to treating soldiers in the field and in clinical settings.

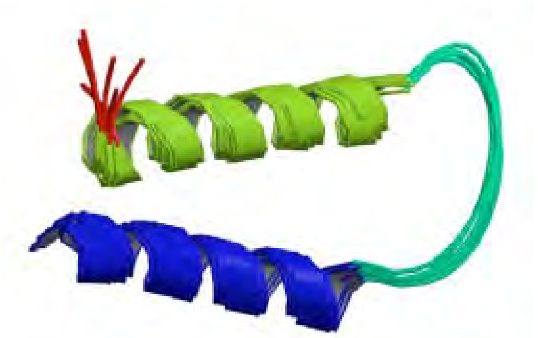


Microchannel geometry influences the flow of rod-shaped particles. (Eric Shaqfeh, Eric Darve, Stanford)

Project 2–3: Protein Structure Prediction for Virus Particles

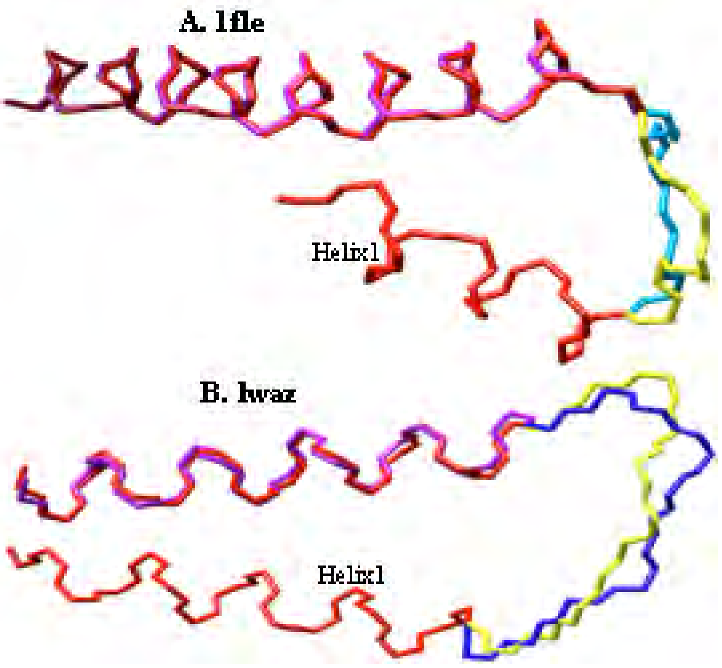
Principal Investigator: Jing He (New Mexico State University)

Viruses, one major category of biological warfare agents, mutate rapidly and can be genetically engineered to resist existing vaccines. Protein structure prediction, a well-known tool for pharmaceutical development, can point to likely adaptations of known viruses and guide efforts to combat the new forms. This method is computationally intensive and requires advanced visualization tools to be effective—making this field an ideal candidate for high performance computing.



Structure of 1waz, a transport protein.
(Protein Data Bank)

AHPCRC researchers have developed a computational method to assemble fragments of a protein structure, an important step in predicting the structure of viruses. The protein fragments are identified using an existing protein databank, considering both the protein sequence information and the geometrical constraints provided by laboratory analysis of virus particles. The results have proven this method to be faster and more accurate than a popular conventional loop modeling method. A computational mutation energy analysis method has been developed to study the topological mutations of secondary structure elements of a protein. This method, which has been adapted to run on parallel computing clusters, requires only partial structure information to evaluate the stability of a permutation.



Assembled structure segments for 1f1e (an anti-inflammatory protein) and 1waz (a bacterial mercury transport protein) are superimposed on their original structures.
(Jing He, NMSU)

Project 2–4: Nano-Mechanics of Metal Foams and MEMS Devices

Principal Investigator: Wei Cai (Stanford University)
Collaborator: Sylvie Aubry (Stanford University)

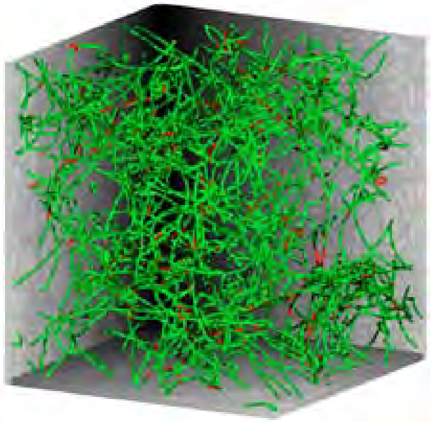
In their efforts to produce strong, lightweight structural materials (including vehicle components and artillery casings), materials scientists are developing new forms of familiar materials—metal foams, for example. These new materials offer potential advantages over their predecessors, including better impact energy absorption, heat transfer properties, and flame resistance, but they are not yet well characterized.

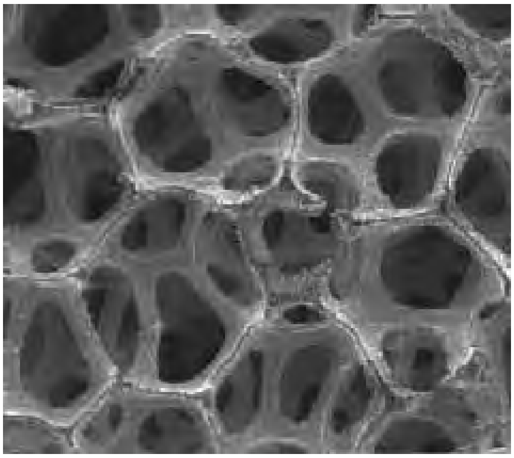
Modeling and simulation tools guide materials scientists toward the best methods of producing metal foams that can withstand impact and other stresses. Simulating such systems requires detailed models of materials with a high degree of structural randomness, the capability to simulate effects on a variety of size scales, and the inclusion of methods for simulating strain characteristics produced under varying stress rates.

For particles smaller than one micron, many mechanical properties are size-dependent. These properties, including yield strength and resistance to fatigue, are not well predicted by macroscopic characterization. Material behavior at small scales is an important predictor of the durability and useful lifetime of micro-electronic and micro-electromechanical devices.

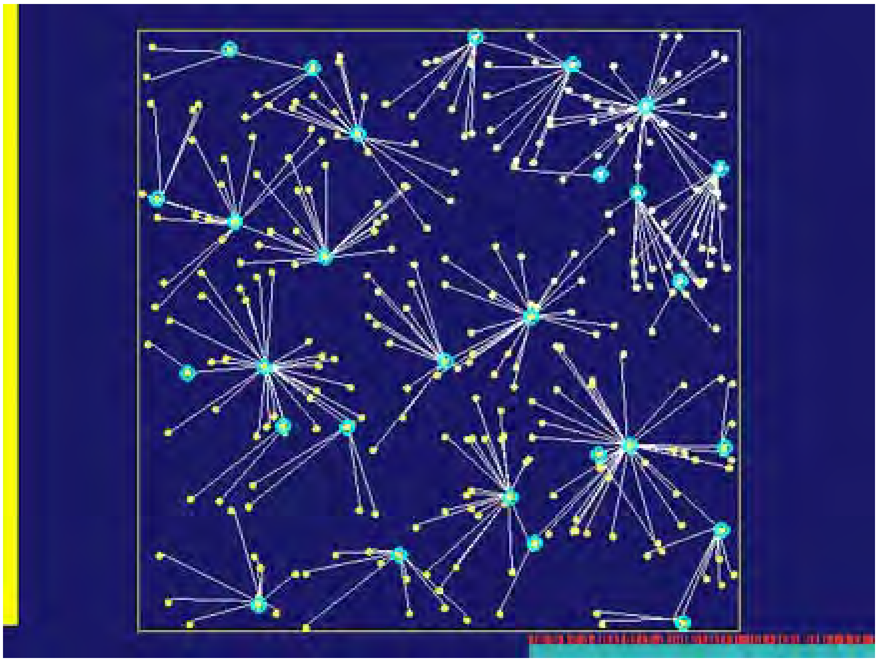
A dislocation dynamics HPC code is being developed to simulate the plastic deformation of single and multiple struts and cells in metal foams under high rates of strain. Efficient algorithms have been designed to simulate strain hardening effects and stresses from free surfaces in films.

The simulation methods developed here are being extended to other materials, including metal thin films in microelectromechanical system (MEMS) devices.





Above: Simulation map of dislocation defects in molybdenum metal. (William Cash, Stanford)
Left: Micrograph of a nanostructured metal foam. (Wei Cai, Stanford)



Communications network containing discrete mobile centers. (J. Gao, L. J. Guibas, Stanford)

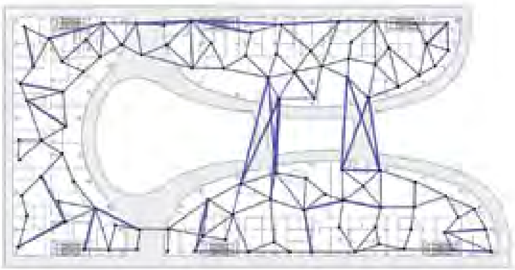
Technical Area 3

Computational Battlefield Network and 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?

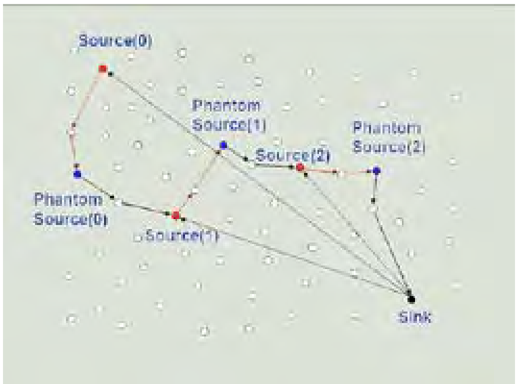
Technical Area 3 will tackle these challenges with advanced developments in numerical algorithms, communications methods, and HPC software.



Mobility graph superimposed on building layout. (L. J. Guibas, Stanford)

Projects

- 3–1: Information Aggregation and Diffusion Under Mobility
- 3–2: Robust Wireless Communications in Complex Environments
- 3–3: Secure Sensor Data Dissemination and Aggregation
- 3–4: Fast and Scalable Parallel Solvers for Complex Electromagnetic Antenna Simulations



Phantom routing in a recursive adaptive context obfuscation framework.
(H. Huang, A. Bhattacharya, NMSU)

Information in Networks

Situational awareness demands that incoming data be timely, relevant, and interpreted in order to make effective decisions.

HPC is used to design and optimize large-scale simulations of communications networks. HPC resources can also be incorporated into real-world communications networks to optimize deployment and performance.

Wireless Communications

Effective military wireless communications require robust networks and links that are capable of operating in complex environments, especially in dense urban neighborhoods. Such networks must resist hostile jamming while keeping low power at terminals. HPC modeling and simulation methods address the unique problems of wireless network performance in complex military scenarios.

Secure Sensor Data

Battlefield operations rely heavily on information and communications for situational awareness and rapid response to changing conditions. Data security and privacy considerations must be balanced with the need for fast, efficient in-network processing. HPC provides a means of developing a general model of sensing tasks, as well as a means to capture the uncertainties related to throughput, deadline, privacy, and security.

Antenna Simulations

Designing and building complex antenna systems requires an equally complex system of algorithms for performing the necessary computations. In the high-frequency regime of microwave and millimeter wave integrated circuits, the sheer numbers of components makes HPC an essential tool for solving design problems and identifying and addressing factors that can limit the performance of these networks.

U.S. Army

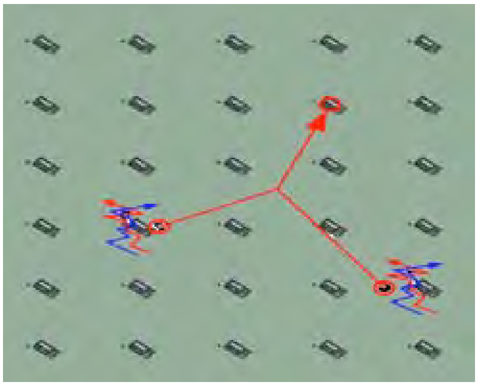
Technical Area 3 Leader

George Papanicolaou
Professor of Mathematics
Stanford University

Project 3–1: Information Aggregation and Diffusion Under Mobility

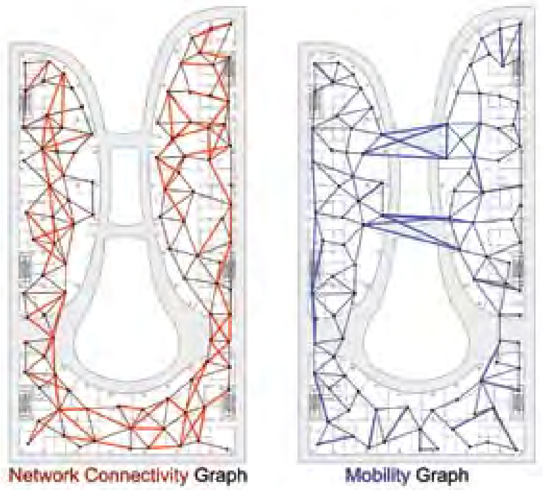
Principal Investigator: Leonidas Guibas (Stanford University)
Collaborators: Phil Levis, HyungJune Lee, Nikola Milosavljevic, Brano Kusy, J.W. Lee (Stanford University)

High performance computing (HPC) is used to design and optimize large-scale simulations of communications networks, allowing developers to try out many configurations and choose the most efficient one for a given purpose. HPC resources can also be incorporated into real-world communications networks to optimize deployment and performance. Data collected during actual network operations are streamed to HPC servers at the periphery of the network for use in fine-tuning the network and adapting to changes in the environment and traffic load distributions as they occur.



Above: One network node receives a data summary from two nodes that have interesting data to report. The nodes do not know each other's locations.
Below: Network node connectivity (red) at Stanford's Clark Center. Users can walk outside the coverage area and receive signals through walls (blue).
(Leonidas Guibas, Stanford)

AHPCRC researchers have finalized the architecture of a sensor node testbed to provide connectivity data for studies on how to improve low-latency data delivery to mobile users. The intention is to reroute a data stream to a mobile user by predicting best communication neighbors a few seconds ahead. The AHPCRC group has also studied last-hop data delivery and network reconfiguration methods to restore broken connections with a mobile user, using randomized spirals centered on the user's last known location. The algorithm they implemented achieved an order of magnitude performance improvement over current state-of-the-art data collection algorithms for sensornets.



The group has developed an algorithm for ensuring that neighboring network nodes do not interfere with each other by sending signals too close together. They are working to establish coordinated sleep schedules, collision-free communication windows, and evenly shared sensing burden across nearby nodes.

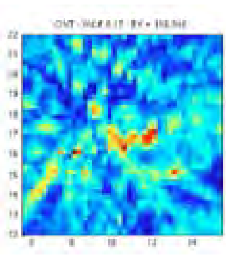
Project 3–2: Robust Wireless Communications in Complex Environments / Sensor Imaging and Communications

Principal Investigators: Arogyaswami Paulraj, George Papanicolaou (Stanford University)
Collaborators: S.J. Thiruvengadam, Aydin Sezgin, Gökmen Altay, Nicolai Czink, Mohamad Charafeddine, Stephanie Pereira (Stanford University)

Effective military wireless communications require robust networks that can operate in complex environments. Links must be reliable, rapid, and multimedia-capable, connecting large, dynamic, mobile networks of users. Such networks must resist hostile jamming and signal "spoofing" while minimizing consumption of electrical power. Designing such communications systems requires the rapid, high-throughput resources provided by high performance computing.

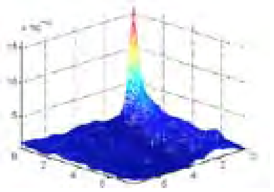
AHPCRC researchers are developing high performance computer simulations for studying time reversal techniques, which can minimize co-channel interference to friendly users. Computer simulations also reduce the time and expense of designing smart antennas that reduce battery drain by transmitting radio energy only in the required direction, while making it more difficult for hostile forces to intercept or transmit unauthorized radio signals.

Technological innovations and knowledge of wireless communications networks gained through this project could be used to advance geolocation, imaging, radar, sonar, and lidar.



Distributed sensor networks monitor complex environments. (G. Papanicolaou, Stanford)

In a related effort, AHPCRC sensor technology researchers are developing in-network data aggregation and processing capabilities, with the intention of giving end users rapid access to relevant, applicable data. They have developed an algorithm to locate changes in the sensor environment by adjusting the probing strength of the signals sent by sensors, coupled with a selection of the sensors that have the most relevant information. They are studying small sensor arrays to increase the efficiency of through-wall detection in the microwave regime. High performance computing resources are being developed to provide the demanding numerical simulations needed to validate this application.



Smart antennas focus a signal. (A. Paulraj, Stanford)

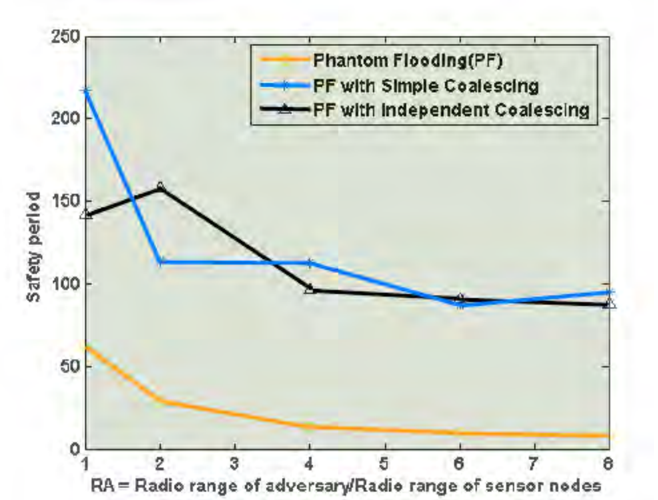
Passive microwave sensor networks that extract background information from random noisy sources can be deployed in urban environments. These sensors, which use only the wireless communication traffic as sources, estimate the properties of the background medium and use this information to detect and track changes in the environment.

Compressed sensing relies on the concept that only a small fraction of the available data is needed to recover information such as a localized disturbance in an environment. This concept has the potential to reduce significantly the volume of data needed for effective monitoring using very large sensor networks.

Project 3–3: Secure Sensor Data Dissemination and Aggregation

Principal Investigators: Amiya Bhattacharya and Hong Huang
(New Mexico State University)

A wireless sensor network offers the opportunity to observe the physical world with unprecedented spatial and temporal detail. Sensor nets used for military purposes must be designed such that the network cannot be co-opted or used effectively by an adversary, but the constraints that security places on a communications network must be balanced with the need for fast, efficient in-network processing. Optimizing the complex tradeoffs between processing, security, communication bandwidth, and power consumption in complex urban settings will push the frontier of high performance computing.



Safe communications period as a function of radio range. (Hong Huang, NMSU)

Distinguishing transmissions and reception by hostile forces from those of civilians and friendly forces is key to maintaining communications security. Data and communications come from ground and air sensors, voice and text communications, and video and audio streams. In remote or hostile locations, the communications infrastructure must often be assembled on an ad hoc basis. Network users and data transmission nodes may be highly mobile, and their movements may be unpredictable. Accurate, secure data transmission must be coupled with data throughput, analysis, reasoning, and simulation. Relevant data must be identified and stored securely, but must be easily accessible to authorized persons.

AHPCRC researchers are developing new protocols and methods specifically for operation in a complex battlefield-like environment, where nodes are mobile and wireless channels are subject to fading, interference, and obstacles. They are developing secure data aggregation methods that limit the risks from data falsification by an adversary, and they are developing dissemination protocols for protecting the content and contextual privacy of sensor data against traffic analysis by an intruding adversary.

Probabilistic sensor data aggregation reduces security risk by selecting sensor data aggregation nodes dynamically, making it more difficult for an adversary to compromise the process. AHPCRC computer simulations have demonstrated that this method can reduce security risks with only a moderate increase in communications costs. AHPCRC researchers are working to design a sensor data routing protocol that optimizes tradeoffs between power and privacy.

Project 3–4: Fast and Scalable Parallel Solvers for Complex Electromagnetic Antenna Simulations

Principal Investigators: Gregory Wilkins (Morgan State University), Charbel Farhat (Stanford University)
Collaborator: Lawrence Walker (Morgan State University)

The computations necessary to design and build complex systems of antennas, which can contain millions of components, require an equally complex system of algorithms. The behavior of the electromagnetic field within each component must be analyzed while taking into account the effects from materials that support and connect the components to one another, among other factors.

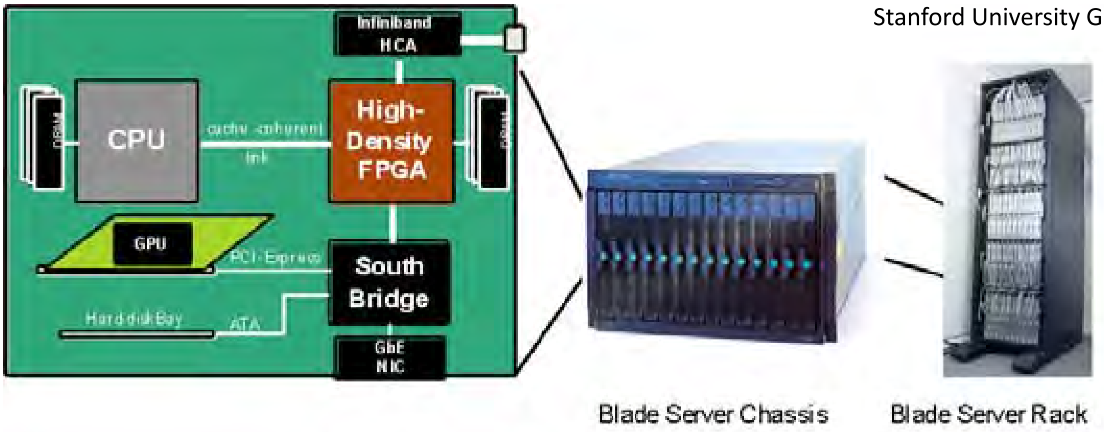
Antenna arrays transmit information to mobile users from sensor networks incorporated into homes, cars, stores, roads, or cities. High performance computing is ideally suited to address such needs as rapid, frequent information updates; reducing cross-interference caused by the concurrent operation of multiple networks (cellular, WiFi, WiMax); and providing adequate security and privacy. By developing the tools and methods to assess such situations, AHPCRC researchers are identifying and optimizing the factors necessary to construct and maintain these complex networks in a variety of environments.

High performance computing also assists in integrated circuit design. Especially in the high-frequency regime of microwave and millimeter wave integrated circuits, the sheer number of components and the mesh resolution required for analysis makes HPC an essential tool for solving design problems and identifying and addressing factors that can limit the performance of these networks.


Antenna Farm in Gakona, Alaska (U.S. Air Force photo)

AHPCRC researchers are analyzing and simulating the behavior of electromagnetic fields in the vicinity of an antenna, and this work will be extended to arrays of antennas and receive-only broadband antenna systems. Individual electromagnetic properties are being examined separately and in combination. This research addresses a variety of factors that can limit the performance of very large-scale integrated antenna networks.

Stanford University Graphic



Technical Area 4

HPC Enabling Technologies and Advanced Algorithmic Development Activities

Technical Areas 1, 2, and 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 helps the other AHPCRC technical areas benefit from state-of-the-art HPC technologies.

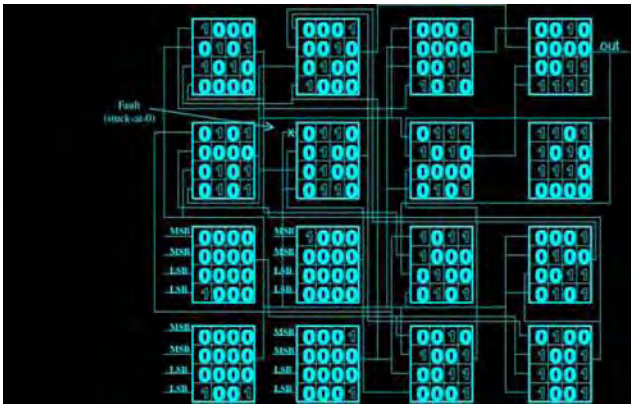
Researchers in this area investigate new methods for developing applications on emerging architectures. They assist the other technical areas by developing enabling computational technologies. And they develop efficient, reliable HPC libraries of computational tools.

These projects aim to create highly parallel programming environments and advanced computational algorithms to 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.

Stream Programming

Writing an efficient high performance application requires the programmer to have detailed knowledge of the underlying machine's architecture. Optimizing performance requires ensuring that processors do not frequently idle waiting on memory. Machine architectures are evolving quickly, so programs must be written to run efficiently on the next generation of hardware as well as on existing machines.

NASA



Flexible Architecture

Improving performance and programmability in high performance scientific computing requires experiments that combine computer systems and scientific applications running on large data sets at full speed and at large scale.

The Flexible Architecture Research Machine (FARM) is a prototyping platform for exploring new software and hardware approaches to parallel system design.

Stanford University

Projects

- 4–1: Stream Programming for High Performance Computing
- 4–2: Flexible Architecture Research Machine (FARM)
- 4–3: Simulation & Modeling to Enhance the Performance of Systems of Multicore Processors
- 4–4: Advanced Optimization Algorithms and Software
- 4–5: PFMMPACK
- 4–6: Hybrid Optimization Schemes for Parameter Estimation Problems
- 4–7: Supporting Army Applications using Heterogeneous Many-Core Platforms

Multicore Processors

As the processing power on microprocessing chips increases, so does the challenge of getting data in and out of the chip.

Componentized modeling and simulation systems can be used to study large-scale multicore parallel computing systems and their application to problems of interest to the Army.

Heterogeneous Platforms

Many Army applications can run more efficiently and cost-effectively on heterogeneous multicore processor systems, which are becoming more common in commercial computers. For example, an autonomous vehicle simultaneously senses its environment, communicates, and executes maneuvers. Some of these tasks are highly data-parallel and others are task-parallel.

Optimization Library

A toolkit of high-performance optimization capabilities will greatly facilitate researchers' ability to capitalize on existing problem-solving algorithms in an HPC environment. Ideally, this user-friendly library will be portable to a wide variety of HPC platforms.

PFMMPACK

Many scientific and engineering problems of importance to the Army can be solved by methods based on integral equations.

PFMMPACK will provide an efficient, portable library to solve these equations, and it will be integrated easily into existing and new HPC applications. The package will include error estimation and is designed specifically to take advantage of existing and new architectures, including GPGPUs.

Parameter Optimization

A simple, shared memory programming model can scale to systems comprising thousands of processors and a hardware/software framework that allows detailed monitoring and performance analysis of the parallel code. A practical migration path is being developed from the current programming approaches to the transaction-based model.

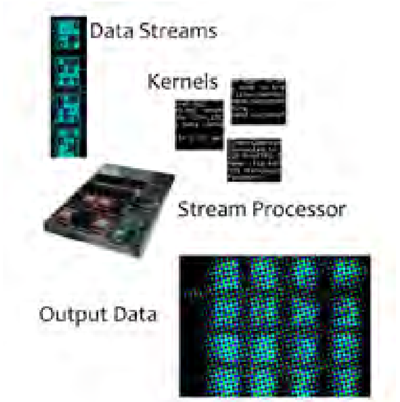
Technical Area 4 Leader

Pat Hanrahan
Professor of Computer Science and Electrical Engineering
Computer Systems Laboratory
Stanford University

Project 4–1: Stream Programming for High Performance Computing

Principal Investigators: William Dally, Pat Hanrahan, and Alex Aiken
(Stanford University)

Writing parallel computer applications that are functionally correct, portable, and high-performing has proven to be a challenging task. AHPCRC researchers are addressing this task by developing an open-source version of the streaming programming language Sequoia that supports irregular data structures and access patterns. They hope to decrease dramatically the difficulty of writing high performance kernels by allowing programmers to write functionally correct, but simple and inefficient, versions of kernels that are then automatically compiled into optimal or near-optimal code sequences.

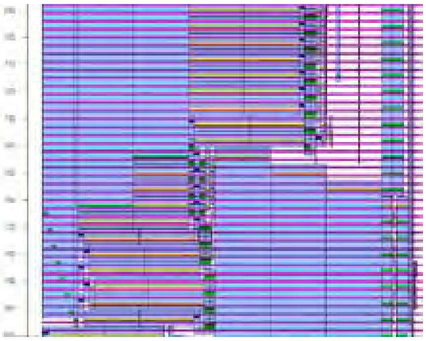


In stream processing, memory modules feed data streams to small programs called kernels, which process the data in cooperation with each other. (HPTi graphic)

Sequoia decomposes a given problem into smaller subproblems, which are passed to other tasks that carry out the actual problem-solving work. A programmer can use this system to express the decomposition of a program in a manner that makes data movement explicit while remaining independent of the target machine.

An automatic tuning framework for Sequoia programs has been implemented and evaluated on several platforms. This framework allows a given program to be optimized for a specific target machine. The framework searches all possible tunable variables to find the set that minimizes the program's execution time. Several search algorithms have been implemented and evaluated.

Sequoia is being extended to manage irregular memory references using "gathers and scatters" and manage the bulk synchronization of mutable shared objects using a "claim and release" strategy to ensure that all tasks are working on the same modified version of an object. By developing hardware as well as software support for claim, release, and a related primitive called "localize," AHPCRC researchers hope to reduce the overhead burden imposed by such a strategy.

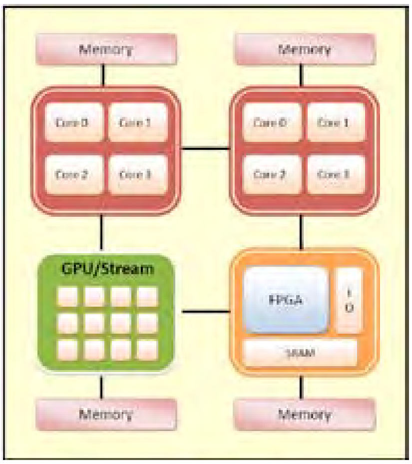


Stream programming facilitates the scheduling of scarce bandwidth resources. (Pat Hanrahan, William Dally, Stanford)

Project 4–2: Flexible Architecture Research Machine (FARM)

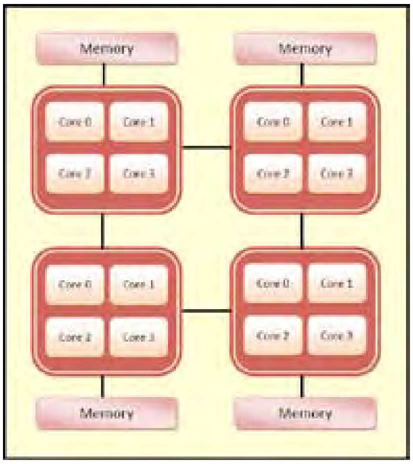
Principal Investigators: Kunle Olukotun and Christos Kozyrakis (Stanford University)

If heterogeneous systems and other non-traditional coprocessors are to gain widespread acceptance for visualization and other data-intensive tasks, collaborative work must be done in architecture, algorithms, and system software tools such as compilers and schedulers. Improving performance and programmability in high performance scientific computing requires insights generated by experiments that combine innovative computer systems and demanding scientific applications running on large data sets at full speed and at large scale.



Above and below: Two configurations of the Flexible Architecture Research Machine. (Stanford University graphics)

The Flexible Architecture Research Machine (FARM) is a flexible, high performance prototyping platform that allows researchers to demonstrate full-system prototypes running full-sized HPC applications, which is necessary for fast technology transfer to the Army or industry. The lessons learned from the FARM will be useful for the design of future large-scale computing systems for scientific applications. The FARM closely couples commodity processor and field-programmable gate array (FPGA) technologies, making it ideal for experimenting with application-specific accelerators and novel memory system designs.



AHPCRC researchers are developing a hybrid software–hardware transactional memory system for the FARM, with the intention of simplifying the task of parallel programming. A simulation environment developed for this system has demonstrated that excellent parallel performance can be achieved using a hybrid transactional memory system accelerated by an external coherently connected FPGA. A hardware model is being developed for the coherent hypertransport interface to be implemented in the FPGA—no implementations of this sort exist at present.

Project 4–3: Simulation & Modeling to Enhance the Performance of Systems of Multicore Processors

Principal Investigators: Patricia Teller (University of Texas at El Paso), Jeanine Cook (New Mexico State University)

Time-efficient performance modeling and analysis of Army applications can reduce expenditures of time and money related to computer system configuration and procurement decisions; assist identification of optimal application-to-architecture mappings; and optimize performance of code, operating system services, and hardware design.

HPC systems increasingly rely on emerging technologies, such as multicore processors, and hardware accelerators such as GPUs (graphics processing units) and FPGAs (field programmable gate arrays). The effective choice and efficient use of such systems depend on quickly analyzing performance in a large design space that includes the core microarchitecture, compute node configuration, memory hierarchy, interconnection network, and I/O subsystem. A microarchitecture's design comprises the number, type, and performance of functional units, the supported execution order, and the supported number of hardware threads—related design decisions may significantly affect performance. A processor's memory hierarchy design determines how quickly data required for the scheduled computations can be delivered to and from the chip. AHPCRC researchers are designing and developing a modeling framework that focuses on time efficiency and performance prediction and analysis of contemporary and future systems.

AHPCRC researchers are also examining methods to increase the performance of large-scale systems. Research areas include cache and I/O performance, and the performance of applications that use periodic checkpointing as a means of fault tolerance.

CHIMERA: The AHPCRC heterogeneous cluster at UTEP

Other research focuses on optimizing the performance of processor cores with hardware to support the concurrent execution of two or more execution threads. A set of shared microarchitecture resources has been identified that can be monitored during application execution, using hardware performance counters, to capture the application's usage of these resources. Scheduling decisions can use this information to enhance core performance. Experiments using a suite of library routines for solving scientific problems will assist in generalizing these results to kernels of important scientific applications.

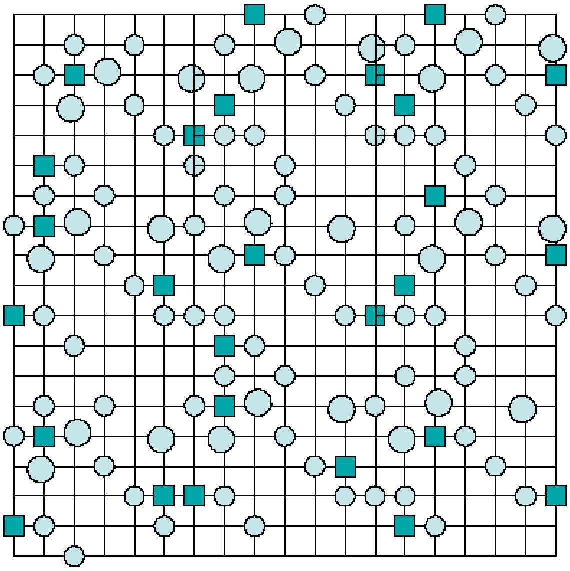
To develop and test these models in a real-world environment, the Chimera heterogeneous computing cluster links various commercial multicore processors, GPUs, FPGAs, and accelerators for performing vector operations. Applications are being developed and tested for their ability to perform well on a variety of processors, and to identify ways to reduce execution time using specialized resources.

Project 4–4: Advanced Optimization Algorithms and Software

Principal Investigators: Walter Murray and Michael Saunders
(Stanford University)

Optimization is a vital part of most branches of computational science and engineering. General-purpose optimization packages are constantly finding new applications in aerospace, economics, geophysics, manufacturing, and many more areas. In aerospace, shape optimization and trajectory optimization for aircraft and spacecraft are important to all branches of DoD.

AHPCRC researchers are in the forefront of designing and implementing effective optimization software. The goal of this project is to enhance existing packages by incorporating HPC techniques such as parallel linear-system solvers, and to assist other AHPCRC projects in need of optimization techniques.



High performance optimization tools enable problem solving on a variety of scales, as shown by this scalable approach to facility location. (W. Murray, Stanford)

An example is project 1–3, where micro aerial vehicles (MAVs) are designed to maximize lift and minimize drag. This requires interaction between fluid-flow partial differential equation solvers and optimization solvers requesting a sequence of solutions to partial differential equations. The model formulation should take advantage of the fact that the optimal solution values for neighboring variables tend to be similar (an assumption not made in general-purpose optimization solvers).

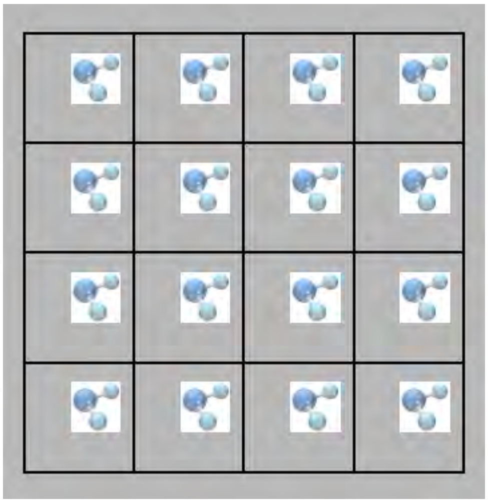
Another aim is to apply efficient continuous optimization methods to large problems involving integer or discrete-valued variables.

Project 4–5: PFMMPACK

Principal Investigator: Eric Darve (Stanford University)

Many scientific and engineering problems of importance to the Army can be solved using integral equations. Such problems include material fracture behavior, microfluidic flows in sensing devices, electrostatic calculations in protein toxin simulations, and detection and imaging using acoustic signals.

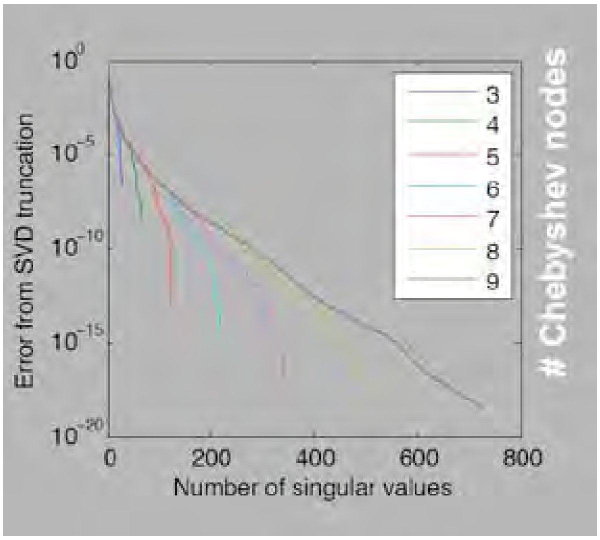
The fast multipole method (FMM) reduces dramatically the computational cost and memory for simulating the dynamics of systems of particles and solving integral equations; however, the mathematics behind this method are extremely complex and its implementation is a real challenge, particularly on parallel systems.



The FMM technique has been extended to deal with systems that have periodic boundary conditions.
(Above and below: E. Darve, Stanford)

The goal of this project is to develop FMMs for a variety of applications on sequential and parallel computers with an emphasis on computational efficiency, scalability, and error control.

PFMMPACK will provide an efficient, portable library to solve these equations, and it will be integrated easily into existing and new HPC applications. The package will include error estimation and is designed specifically to take advantage of existing and new architectures, including general purpose graphics processing units (GPGPUs).



In linear algebra, the singular value decomposition (SVD) technique has several applications in signal processing and statistics.

Project 4–6: Hybrid Optimization Schemes for Parameter Estimation Problems

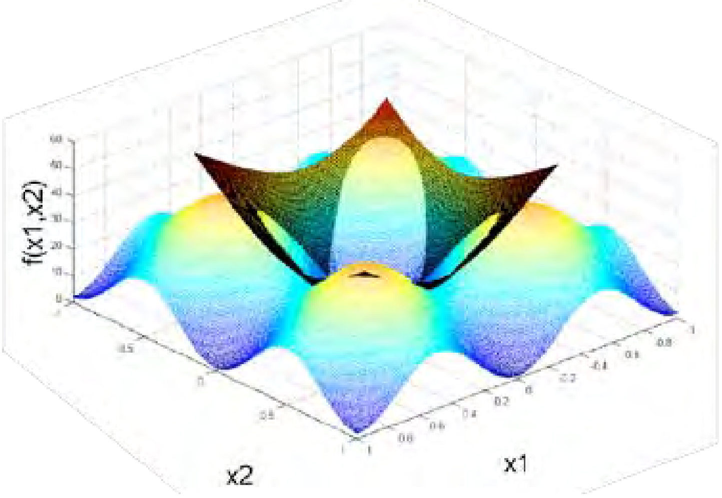
Principal Investigators: Miguel Argáez and Leticia Velázquez
(University of Texas at El Paso)
Collaborators: Michael Saunders (Stanford University), James Cogan (ARL/CISD),
Mary Wheeler (University of Texas at Austin)

Effective use of the recent innovations in computer architecture can be limited by difficulties in writing functionally correct parallel applications that also achieve high performance. Hybrid algorithms combine the advantages of more than one computing method to obtain the desired results.

AHPCRC researchers are working to make it easier to implement HPC applications on highly parallel systems. They are developing and demonstrating a practical migration path from current programming approaches to a transaction-based model. Introducing transactions (individual small operations) as the key abstraction for expressing parallelism facilitates maintaining a computer system in a known, consistent state by ensuring that interdependent operations are either all completed successfully or all canceled successfully.

One area of particular interest is estimation theory—a branch of statistics that is often used to assist in interpreting the results of scientific experiments. Mathematical calculations use observable information as input to produce an approximation to the parameter of interest when an exact solution is not possible. Such techniques are especially useful for signal processing and telecommunications problems, as well as for scientific applications with irregular and adaptive behavior.

AHPCRC researchers are also developing a simple shared-memory programming model that can scale to systems composed of thousands of processors, as well as developing a hardware/software framework that allows detailed monitoring and performance analysis of parallel code. Hybrid optimization codes developed as a result of this project will be tested using applications in which the Army has expressed an interest.



Surrogate models can reduce considerably the high computing cost and time requirements associated with real-world problems. At right, a Gaussian radial basis function surrogate model (dark) is superimposed on the original Rastringin function model (multicolored). (UTEP graphic)

Project 4–7: Supporting Army Applications using Heterogeneous Many-Core Platforms

Principal Investigators: Pat Hanrahan, Kunle Olukotun, and Christos Kozyrakis (Stanford University)

Many commercially available personal computers and servers now routinely use dual-core and quad-core processors, and soon octo-core processors will be available. Aggressive and scalable architectures are becoming available for applications needing more processing power, such as prototyping and simulating hardware. These technological trends and the pace of innovation will lead to disruptive changes in the platforms being used by the Army, from high-performance computing centers to embedded computing systems used by the soldier.

Multicore processors, such as this quad-core processor, are becoming common in commercial personal computers and servers. (Lawrence Livermore National Laboratory photo)

AHPCRC researchers foresee a very heterogeneous platform in the future. A single chip may contain several cores optimized for sequential performance—designed to execute a single thread as fast as possible and optimized to tolerate high-latency memory access. In the near future, the same physical chip will also likely contain cores optimized for data-parallel, high-throughput computing. These cores will have many more arithmetic logic units and be optimized for highly parallel workloads having hundreds or thousands of active threads. Memory latency will be handled using multi-threading. Many chips will also contain specialized functional units designed for specific tasks. These units could handle low-level signal processing tasks such as compression and decompression, audio, video and signal processing, and networking.

There are two main rationales for such processors. First, many workloads are inherently heterogeneous; for example, an autonomous vehicle performs many simultaneous tasks, including environmental sensing, communications, and vehicle control. Some of these tasks are highly data-parallel and others are task-parallel. Second, architectures use power efficiently when they are optimized for different types of parallelism. A heterogeneous architecture has the potential to be much more cost-effective than a homogenous architecture.

AHPCRC researchers will acquire several representative systems using innovative hardware, investigate new approaches to programming heterogeneous multicore systems, and evaluate these technologies using computing applications.

Principal Investigators, Administration, and Support

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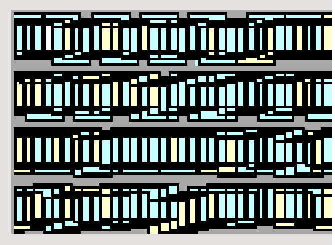
Project 4–1: Stream Programming for High Performance Computing
Design and compilation of parallel programming languages, static and dynamic analysis of programs, program verification.



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Project 4–6: Hybrid Optimization Schemes for Parameter Estimation Problems
Developing large-scale optimization algorithms with applications to science and engineering problems.

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Project 3–3: Secure Sensor Data Dissemination and Aggregation
Mobile computing and communication systems; wireless sensor networks; peer-to-peer and overlay networks; network performance modeling and simulation; network protocol algorithmics; adaptive, on-line and randomized algorithms in networks; application of information theory and coding; self-organization in networks.

WEI CAI
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Project 2–4: Nano-Mechanics of Metal Foams and MEMS Devices
Predicting mechanical strength of materials through theory and simulations of defect microstructures across atomic, mesoscopic and continuum scales. Developing new atomistic simulation methods for long time-scale processes, such as crystal growth and self-assembly. Introducing magnetic field in quantum simulations of electronic structure and transport.

JEANINE COOK
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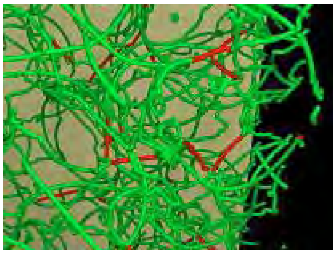
Project 4–3: Simulation & Modeling to Enhance the Performance of Systems of Multicore Processors
Director, NMSU Advanced Computer Architecture Performance and Simulation Laboratory. Research interests in microarchitecture simulation techniques, performance modeling and analysis, workload characterization, and microarchitectural power optimizations.



WILLIAM DALLY
Willard R. and Inez Kerr Bell Professor of Computer Science and Electrical Engineering and Chairman of the Computer Science Department,
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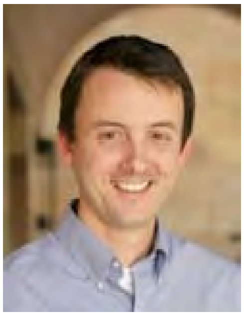
http://cva.stanford.edu/billd_webpage_new.html

Project 4–1: Stream Programming for High Performance Computing
Streaming supercomputer development; scalability from a single chip to thousands of chips; improving performance at least an order of magnitude per unit cost on a wide range of demanding numerical computations compared to conventional cluster-based supercomputers through combining stream processing with a high-performance network to access a globally shared memory.



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Projects 2–2: DNA and Proteins in Microfluidic Channels; 4–5: PFMMPACK
Numerical method development for large-scale scientific computing. Applications in biomolecular simulations, electrodynamics, and acoustics. Numerical techniques to reduce computational expense and enable the simulation of large-scale systems over realistic time scales. Fast multipole method, molecular dynamics of proteins, integral equations for fluid flow and acoustics, computational linear algebra, and multi-scale time integrators.

CHARBEL FARHAT Center Director and Tech Area 1 Lead
Vivian Church Hoff Professor of Aircraft Structures, Chairman, Department of Aeronautics and Astronautics, Professor, Mechanical Engineering and Institute for Computational and Mathematical Engineering, Stanford University
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Projects 1–1: Multiscale Ballistic Fabric Nets;
1–4: Flapping and Twisting Aeroelastic Wings for Propulsion
Mathematical models and computational methods for high-performance simulations of multidisciplinary scientific and engineering problems, especially distributed computing and massively parallel processing. Structural dynamics, contact problems, nonlinear aeroelasticity of fighter aircraft, fluid-structure interaction, underwater acoustics, inverse problems, and shape optimization. Multiscale methods, dynamic data-driven systems, model reduction, near-real-time computing, and large-scale applications in aerospace, mechanical, naval, and marine engineering.

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http://graphics.stanford.edu/~guibas

Project 3–1: Information Dissemination and Aggregation under Mobility
Computer representations and algorithms for sensing, modeling, manipulating, and rendering physical objects and processes. Data structures for mobile data, global illumination algorithms, image database browsing and navigation, visibility and motion planning algorithms, and probabilistic and robust techniques for handling geometric data.

PATRICK HANRAHAN Tech Area 4 Lead
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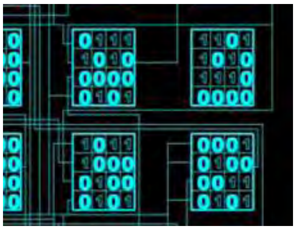
Projects 4–1: Stream Programming for High Performance Computing; 4–7: Supporting Army Applications Using Heterogeneous Many-Core Platforms
Rendering algorithms, high performance graphics architectures, and systems support for graphical interaction. Raster graphics systems, computer animation, and modeling and scientific visualization—volume rendering in particular.



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Project 2–3: Protein Structure Prediction for Virus Particles
Computational structural bioinformatics, protein structure prediction, image processing.

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Project 3–3: Secure Sensor Data Dissemination and Aggregation
Wireless networks, sensor networks, and optical networks.

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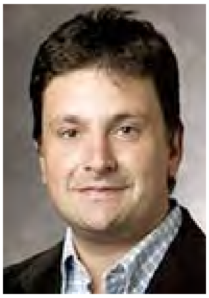

Project 2–1: Dispersion of BWAs in Attack Zones
Computational fluid dynamics of industrial problems, turbulence modeling (RANS/LES) and numerical methods for computational fluid dynamics.

MARK Z. JACOBSON
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Project 2–1: Dispersion of BWAs in Attack Zones
Understanding physical, chemical, and dynamical processes in the atmosphere better to address atmospheric problems such as climate change and urban air pollution, with improved scientific insight and more accurate predictive tools. Evaluating the atmospheric effects of different solutions to climate change and air pollution problems. Mapping and analysis of winds for wind energy and optimizing transmission among multiple renewable energy sources. Developing and applying numerical solvers to simulate gas, aerosol, cloud, radiative, and land/ocean-surface processes.

ANTONY JAMESON
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http://aero-comlab.stanford.edu/jameson/

Project 1–3: Multidisciplinary Parametric Modeling and L/D Quantification and Optimization
Numerical solution of partial differential equations with applications to subsonic, transonic, and supersonic flow past complex configurations, as well as aerodynamic shape optimization.

CHRISTOS (CHRISTOFOROS) KOZYRAKIS
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Projects 4–2: Flexible Architecture Research Machine (FARM);
4–7: Supporting Army Applications using Heterogeneous Many-Core Platforms
Architectures, runtime environments, and programming models for parallel computer systems. Transactional memory, architectural support for security, and power management techniques.

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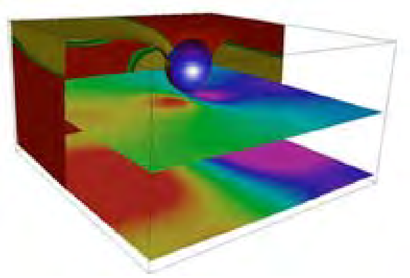
Project 1–2: Simulation of Fracture and Penetration
Computational solid mechanics, material modeling, numerical analysis. Homeland security applications: mechanics of materials under highly dynamic deformations, such as impact, blasts and shocks. Interplay between chemistry and mechanics in biology: mechanics of polymeric networks and biomaterials.



WALTER MURRAY
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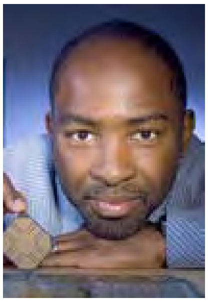
http://www.stanford.edu/~walter

Project 4–4: Advanced Optimization Algorithms and Software
Creating, analyzing, and implementing optimization algorithms. Developing general-purpose optimization software for the solution of practical problems.



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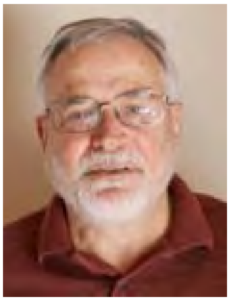
Projects 4–2: Flexible Architecture Research Machine (FARM);
4–7: Supporting Army Applications using Heterogeneous Many-Core Platforms
Design, performance analysis, and verification of computers. Hydra single chip multiprocessor project and the TCC Transactional Coherence and Consistency project. Developing novel simulation, estimation, and verification techniques for system-level design.



GEORGE PAPANICOLAOU Tech Area 3 Lead
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Project 3–2: Sensor Imaging and Communications
Waves and diffusion in inhomogeneous or random media and in the mathematical analysis of multi-scale phenomena that arise in their study. Application to electromagnetic wave propagation in the atmosphere, underwater sound, waves in the lithosphere, diffusion in porous media. Linear and nonlinear waves and diffusion in direct and inverse problems. Assessing multi-pathing effects in communication systems, especially when time reversal arrays are used.

AROGYASWAMI J. PAULRAJ
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Project 3–2: Robust Wireless Communications in Complex Environments
MIMO wireless: capacity, coding, pre-coding, modulation, and receivers. OFDM / OFDMA wireless, opportunistic scheduling, performance modeling of wireless networks, WIMAX standards evolution, exploiting rich multipath wideband channels (e.g., time reversal).

MICHAEL SAUNDERS
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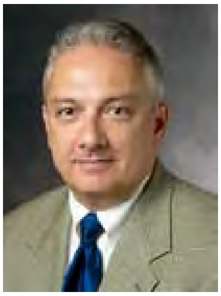
http://www.stanford.edu/~saunders/

Project 4–4: High Performance Optimization Library
Developing mathematical methods for solving large-scale constrained optimization problems and large systems of equations. Implementing such methods as general-purpose software to allow their use in many areas of engineering, science, and business. Co-developer of the large-scale optimizers MINOS, SNOPT, SQOPT and the linear equation solvers SYMMLQ, MINRES, LSQR, LUSOL.



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Projects 2–1: Dispersion of BWAs in Attack Zones,
2–2: DNA and proteins in microfluidic channels
Transport mechanics of complex fluids (polymers, DNA, fiber suspensions): large scale simulations of poorly understood phenomena coupled with detailed experiments to elucidate the important physics in a variety of processes. Elastic effects in coating instabilities, studies of DNA dynamics in mixed flows with application to scission and sequencing, investigations of the separation of complex macromolecules in Brownian ratchets and fabricated post arrays, and molecular simulation of turbulent drag reduction by polymers and fibers.

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Project 1–4: Flapping and Twisting Aeroelastic Wings for Propulsion
Theoretical and computational fluid dynamics, vortex dynamics, interactions of solid bodies with coherent vortices in fluid flows, geometric control theory with applications to spacecraft and satellite maneuvering.

PATRICIA J. TELLER
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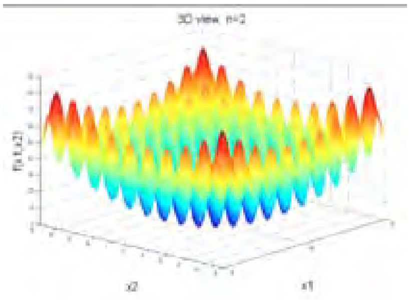
Project 4–3: Simulation & Modeling to Enhance the Performance of Systems of Multicore Processors
The dynamic adaptation of applications, operating systems, and computer architectures; performance evaluation, modeling, and enhancements; parallel and distributed computing; computer architecture, operating systems, and simulation methodologies; workload characterization; and education.



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Project 4–6: Hybrid Optimization Schemes for Parameter Estimation Problems
Developing high performance optimization algorithms for large-scale computational science problems.

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Project 1–4: Flapping and Twisting Aeroelastic Wings for Propulsion
Computational fluid dynamics, aeroacoustics, control and optimization, low-dimensional modeling.

GREGORY M. WILKINS
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Morgan State University
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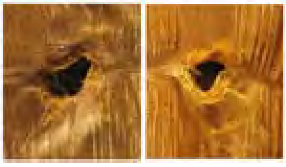
http://www.eng.morgan.edu/~gwilkins

Project 3–4: Fast and Scalable Parallel Solvers for Complex Electromagnetic Antenna Simulations
Computational and applied electromagnetics.



TAREK I. ZOHDI
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University of California Berkeley
(510)-642-9172
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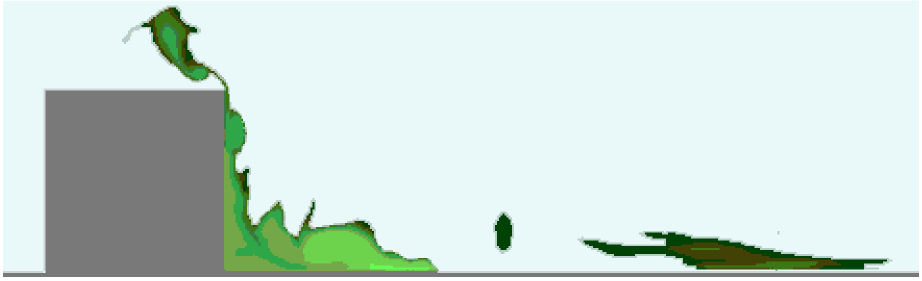
Project 1–1: Multiscale Ballistic Fabric Nets
Micromechanical material design, granular flow, and the mechanics of high-strength fabric. Emphasis on computational approaches for nonconvex multiscale–multiphysics inverse problems—in particular, addressing the crucial issue of how large numbers of micro-constituents interact to produce macroscale aggregate behavior.



BARBARA BRYAN
AHPCRC Research and Outreach Manager, HPTi
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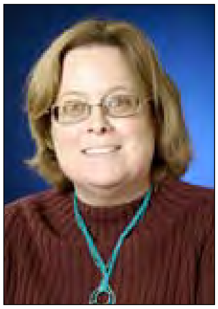
bbryan@hpti.com

Ms. Bryan, who is based at Stanford University, oversees the management of the research and outreach programs, working with the Center Director. She works with the Army and the Center Director to communicate research objectives and report on accomplishments, and to align and identify potential HPC resources on at-institution or DoD platforms. She works with each university's outreach manager and Consortium representative to establish an integrated outreach program emphasizing the Army research and HPC/computational science objectives.



NANCY MCGUIRE
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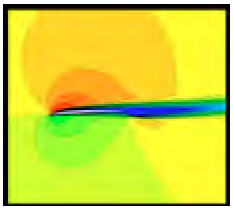
nmcguire@hpti.com

Dr. McGuire coordinates reports, project publications, and publicity materials for AHPCRC. She holds a Ph.D. in chemistry from Arizona State University, and she has career experience in laboratory research and scientific and technical communications. She has written and edited scientific journal manuscripts, print magazine and web content, and corporate communications materials. She has worked on website and print magazine redesign projects, and she has training and experience in website usability and content management. In addition, she has worked in media relations and represented her employers at trade shows and professional conferences.



MARK POTTS
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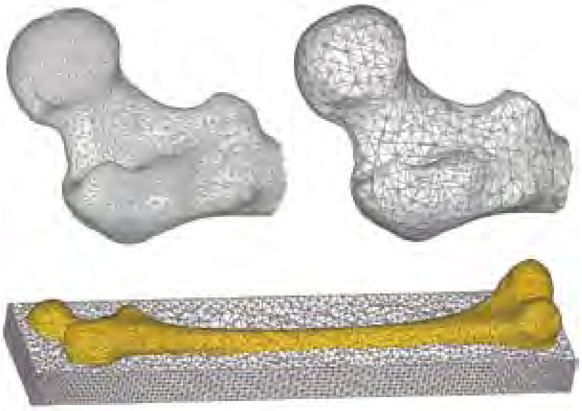
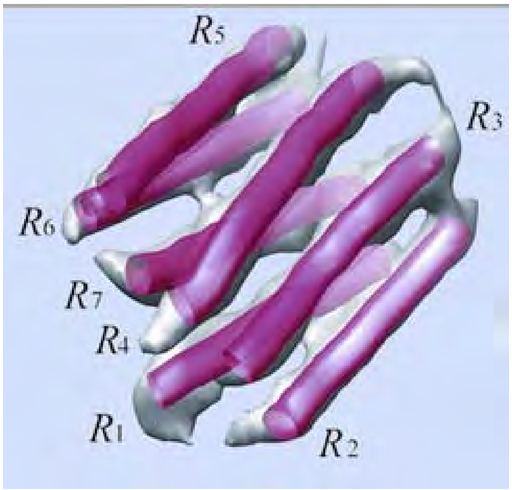
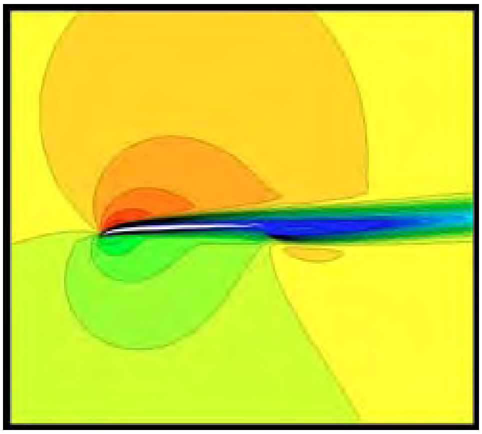
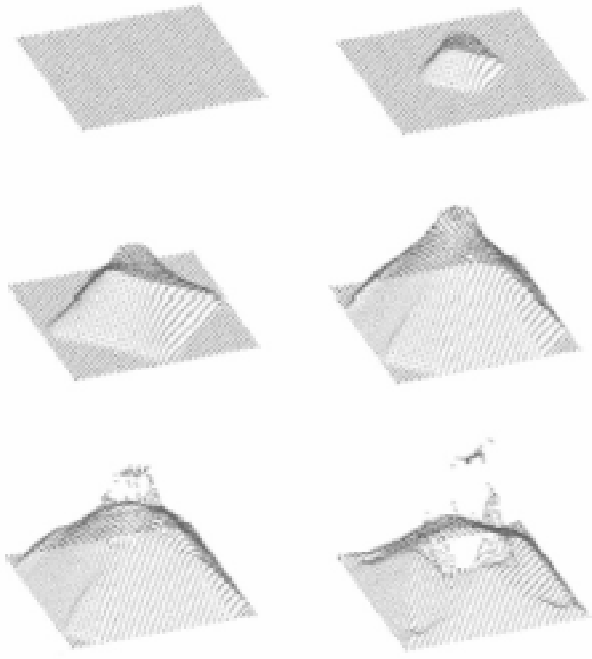
mpotts@hpti.com

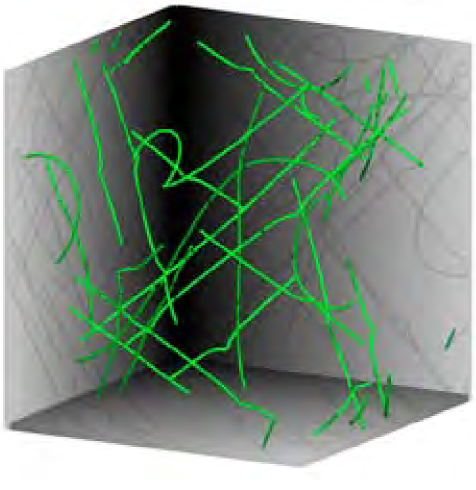
Dr. Potts has over 15 years of software development experience, including more than 12 years of work in research and application development using HPC systems. He joined HPTi in 2007 as a senior computational scientist supporting AHPCRC's academic research partners. Although the majority of Dr. Potts' research has been related to computational fluid dynamics, he also has experience in data mining, biometrics and computational finance.











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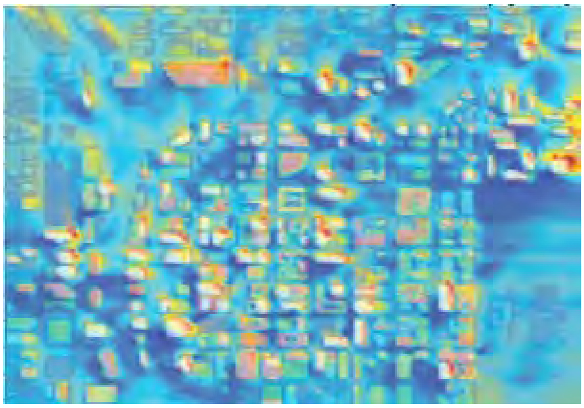

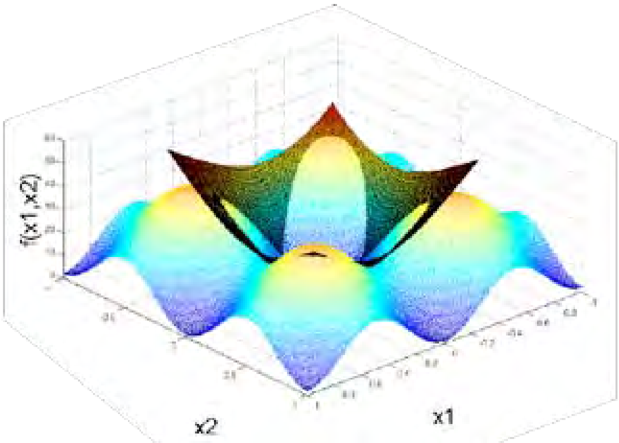

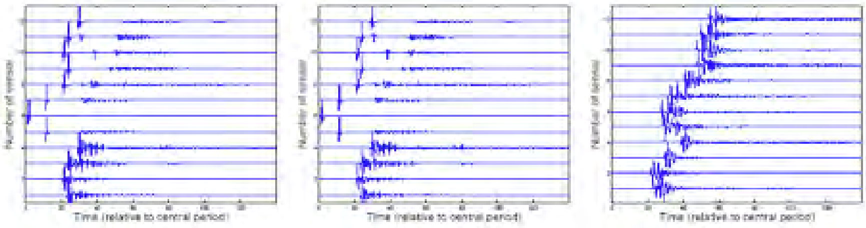

Healthy *Damaged* *Differences*


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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.