Computational Sciences Campaign Overview

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Computational sciences is the third methodology in scientific research along with traditional approaches of theory and experiment.
Computational Science combines

- Theory
- Applied Mathematics
- Computer Science
- Data
- High Performance Computing

To create knowledge in applied disciplines

Computational Science Campaign

- Predictive Sciences
- Data Intensive Sciences
- Advanced Computing Architectures
- Computing Sciences

### Vision

Basic and applied research in computational sciences to exploit and extend the superiority of Army materiel systems to project power despite adversary A2/AD capabilities.
KCI: Tactical High Performance Computing

Mobile HPC at the tactical edge optimized for mission command applications using emerging low power heterogeneous distributed computing.

KCI: Real-time Very Large Scale Data Analytics

Provide data analytics for large scale data in real-time and time critical situations.

KCI: Computational Predictive Methods for Interdisciplinary Sciences

Accelerate Army system development through multidisciplinary predictive simulation methodologies for complex systems.

KCI Related Posters

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<td>Tactical High Performance Computing</td>
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<td>Real Time RF Propagation</td>
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CS Technical Implementation Plan – Core Campaign Enablers (CCEs)

**CCE: Multiscale Modeling of Complex Systems**
Accelerate Army system development through high-fidelity predictive multiscale simulation methodologies for complex systems.

**CCE: Programmable Network Algorithms and HPC Models for Quantum and Classical Networks**
Develop programmable Quantum & Classical Network Interfaces to create intelligent, adaptive and intent-aware networks to support distributed computing and data analytics at the edge.

**CCE: Advanced and Unconventional Computing**
Discover new non Von Neumann techniques and computing paradigms that will be able the development of future low-power adaptable computing systems.

**CCE: Distributed Simulation, Integration and Interoperability**
Robust Army simulation capabilities with composable synthetic representations delivered where they’re needed in the form in which they’re needed.

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Research Facilities include:

- ARL DoD Supercomputing Resource Center
- Scientific visualization laboratory
- Software Defined Networking Testbed
- Neuromorphic Research Laboratory

Collaboration Opportunities:

- Scalable computational algorithms for complex interdisciplinary systems
- UQ based predictive design methods
- Robust approaches to validate model accuracy
- Hierarchical scale-bridging methods
- Scalable learning and deep learning algorithms
- Visual data analytics for large data
- Streams processing of varying time-scale, varying size datasets
Visualization Framework for High Fidelity Display Wall

- Collaboration with University of Hawaii Prof. Leigh and student Dylan Kobayashi at ARL for the summer
- Integrated SAGE2 (NSF funded) visualization framework to ARL Visualization Wall to support collaborative research
- Extension of SAGE2 to include Paraview
- Provides capability to visualize results of massively large data sets resulting from high fidelity physics based simulations

Collaborators: Su (ARL), Leigh and Kobayashi (Hawaii)

A Parallel Monte Carlo Tree Search for Safe Target Surveillance

- Developed a tree-parallel Monte Carlos Tree Search algorithm for maximizing decision quality and minimizing decision time.
- Allows scaling the problem to much larger sizes while still computing high quality solutions.
- David Eberius an award winner at ARL’s Summer Symposium graduate category

Collaborators: Song (ARL) and Eberius (UTK)
Programmable Network Research

- Collaboration with University of Maryland
- Development of new networks abstractions and algorithms to extend control plan functions
- Unified programmable on-demand control plane for tactical networks
- Resulting in a federated community to support development and testing of collaborative software applications

Collaborators: Dasari, Kile, Busse (ARL), Lehman, Hildebrand and Yang (Maryland)

Quantum Dot at End of Transmission Line

- Develop Scalable HPC based computational framework to model quantum network processes
- Investigate a variety of architectures, including photons (employed in continuous variable quantum computation, simulation of quantum (stochastic) walks, etc.), neutral atoms, trapped ions, cavity arrays, electronic spins (quantum dots), nuclear spins (NMR), and superconducting circuits
- Qfields suite of tools: QNET, QuTip, QSD

Collaborators: Balu (ARL) and Siopsis (UTK)
Benefits of Open Campus

Benefits to Academic and Industrial Partners

- Insights into real-world domain
- New and exciting problems
- Contributions from experienced, capable collaborators
- Access to ARL technology
- Use of facilities and data
- Evidence of relevance to real-world challenges
- Opportunity for transitions
- More publications
- Better-grounded publications
- Credibility for future proposals
- Insights for future proposals
- Broadening of the professional network
- Collaborations in proposals
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<td>Tactical High Performance Computing</td>
<td>Dr. Barry Secrest</td>
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<td>Mr. Christopher McGroarty</td>
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Questions?
Vision

Basic and applied research in computational sciences exploiting advanced computing to maintain the superiority of Army materiel systems and enable land power dominance.
University of Maryland, Baltimore County
  • Exponential capacity of Associative memories under Quantum Annealing recall
  • Visiting professor and students

University of Delaware
  • Development of new Programmable Network Abstractions and Data Structures.
  • Visiting student

University of Hawaii
  • Installation of sage2 software framework on visualization cluster. Ported visualization applications onto sage2
  • Summer intern

University of Tennessee, Knoxville
  • Developed a tree-parallel Monte Carlos Tree Search algorithm for maximizing decision quality and minimizing decision time. Allows scaling the problem to much larger sizes while still computing high quality solutions.
  • Continuous Time Limit of Topology Walks
  • Visiting professor and students

Virginia Tech
  • Unified Programmable Control Plane: Design and Optimization
  • Postdoc
Oak Ridge National Laboratory
- Software Defined quantum communications. Successfully developed OpenFlow arbitrated quantum communication model
- Visiting faculty and Postdocs

Lawrence Livermore National Labs
- Large-scale distributed neural network training over massive multi-modal audio, image, text, and video database
- Mutual short term visits

Louisiana State University
- Quantum Control. Locating subsystems that had minimal noise properties. Developed a numerical method to locate minimal noise subsystems.
- PhD thesis Committee

Bowie State
- Continuous-time open quantum walks
- Characterizing the Nash equilibrium of a three player Bayesian quantum game
- Visiting professor and student

Boise State University
- Programmable HPC network fabrics. Developed network labels to create programmable networks
- Visiting professor and students
Vision
Mobile HPC at the tactical edge optimized for mission command applications using emerging low power heterogeneous distributed computing

Impact & Relevance
- Rapid informed decision making
- Increase logistical efficiency & unit self-sufficiency

Key Research Challenges
- Power, Performance, Portability
- Distributed heterogeneous computing
- Cloudlet: aggregating and provisioning coupled resources (including embedded HPC)

Real-time data analytics and processing at the tactical edge
**Vision**
Provide data analytics for large scale data in real-time and time critical situations.

**Impact & Relevance**
- New insights to large data sets
- Earlier and better informed materiel acquisitions

**Key Research Challenges**
- Multi-dimensional analytics of disparate data types
- Applying learning to volume and velocity of tactical data analytics

**Understanding and exploiting large-scale, multi-dimensional, dynamic data**

**Develop new data-driven computational methods**
to analyze large-scale data in realistic timeframes to improve situational awareness, and facilitate intelligence for autonomy.

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The Nation’s Premier Laboratory for Land Forces
**Vision**

Accelerate Army system development through multidisciplinary predictive simulation methodologies for complex systems.

**Problem Statement**

Increasing complexity system M&S necessitates novel approaches, interdisciplinary methods enable cross-domain integration and scalability.

**Challenges & Impact**

- Significantly shorten development cycle and sustainability
- Coupled modeling methodologies for systems optimization
- Uncertainty quantification

**Predictive methods** for improved performance, reduced cost and faster concept to acquisition lifecycle through High Performance Computing
**Vision**
Accelerate Army system development through high-fidelity predictive multiscale simulation methodologies for complex systems.

**Problem Statement**
Computational cost of complex system M&S necessitates novel approaches, multiscale methods provide needed fidelity while addressing cost constraints.

**Challenges and Impact**
- Need new methodologies for scale bridging (spatial and temporal)
- Need new algorithms for automatic construction of surrogate models
- Uncertainty quantification between at-scale models crucial
- Shorten development time and evaluation costs of novel Army systems

**Materials**
- Atomistic
- Molecular
- Mesoscale
- Continuum

**Environment**
- Design
- Awareness
- Mfg. Self Assembly

**Complex Systems**
- System
- Optimization
- Integration
- Of Systems

**The Nation’s Premier Laboratory for Land Forces**
Vision
Discover new non Von Neumann techniques and computing paradigms that will be able the development of future low-power adaptable computing systems

Problem Statement
Von Neumann architectures are limited in scalability by the bottleneck between processing and memory

Key Research Challenges
• New algorithms and software development paradigms are needed for next generation.
• New applications have to mapped to QUBO paradigm supported by quantum annealing architectures.
• Decoherence have to be minimized during the annealing schedules.
• Portable and efficient software design across divergent cores

Novel ARL algorithms for machine learning for data sciences

Low Power HPC
10^2 greater computational efficiency

Neuromorphic Computing
Vision
Understand how to design and control quantum networks to harness and process information from distributed sources, and how to do so securely and efficiently.

Problem Statement
Exploiting quantum phenomena has the potential to harness distributed information in powerful new ways, and may also allow distributed processing of such information well beyond present capabilities.

Key Research Challenges
• Understand how to design and control quantum networks to harness and process information from distributed sources, and how to do so securely and efficiently.
• Explore how quantum networks may gain an advantage over traditional parallel processing by applying distributed operations to distributed information.

Diagrammatic depiction of the functioning of a quantum-enhanced accelerometer
Vision
Robust Army simulation capabilities with composable synthetic representations delivered where they’re needed in the form in which they’re needed.

Problem Statement
Existing simulation systems are black boxes that interface externally allowing internal computations to be non-standard between model representations, introducing fair fight issues and additional inconsistencies, necessitating an architectural approach that supports composability and the ability to be accessed at the point of need.

Challenges and Impact
- Single simulation architecture capable of supporting complex real-time and non-real-time uses
- Modeling & Simulation as a cloud-based service that supports experimentation and testing across geographically distributed areas
- Impact: More effective training, experimentation and acquisition.

Paradigm shift from simulations interoperating to a composable synthetic environment enabling training, experimentation and acquisition.