Computational Sciences Campaign

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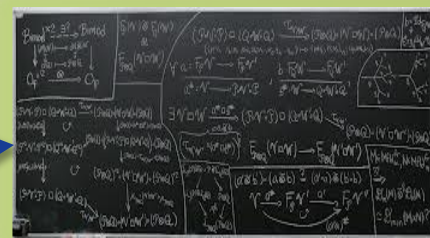
Computational Sciences Campaign
U.S. Army Research Laboratory

U.S. ARMY RDECOM

21st Century Research Continuum

ARL

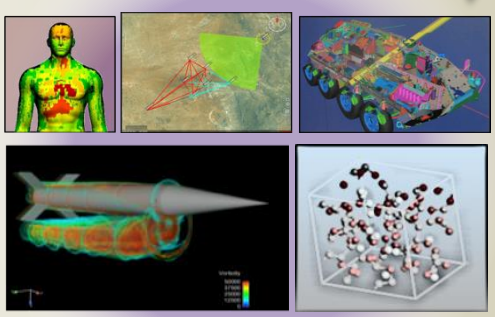
Theory



Theory embodied in computation

Hypotheses tested through experiment

SCIENTIFIC METHODS



Computation complements experiment

Computation ⟷ Experiment

Vision

Basic and applied research in computational sciences exploiting advanced computing to maintain the superiority of Army materiel systems and enable land power dominance.

- **Advanced Computing Architectures**
  - Emergent Architectures
  - Tactical Computing
  - Next Generation Computing Systems
  - High Performance Networking and Memory
- **Computing Sciences**
  - Programming Environments
  - Programming Languages
  - Software Integration
- **Predictive Simulation Sciences**
  - Computational Math & Algorithms
  - Scientific Computing
  - Verification, Validation & Uncertainty Quantification
  - Applied Computer Modeling and Analysis
- **Data Intensive Sciences**
  - Science of Large Data
  - Computational Math for Data Analytics
  - Real-time Data Access & Analytics

TAXONOMY

Advanced Computing Architectures	Computing Sciences	Predictive Simulation Sciences	Data Intensive Sciences

Key Campaign Initiative (KCI)

KCI 1: Tactical High Performance Computing (HPC)

KCI 2: Real Time, Very Large-scale Data Analytics for the Army

KCI 3: Computational Predictive Design for Interdisciplinary Sciences

Core Campaign Enablers (CCE)

CCE 1: Programmable Network Algorithms and HPC Models for Quantum and Classical Networks

CCE 2: Multi-scale Modeling for Predictive Computational Design

CCE 3: Advanced and Unconventional Computing Architectures and Algorithms

CCE 4: Distributed Computing Based algorithms for Quantum Networks and Controls

CCE 5: Distributed Simulation, Integration and Interoperability

Tactical High Performance Computing

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 Very Large Scale Data Analytics

Vision

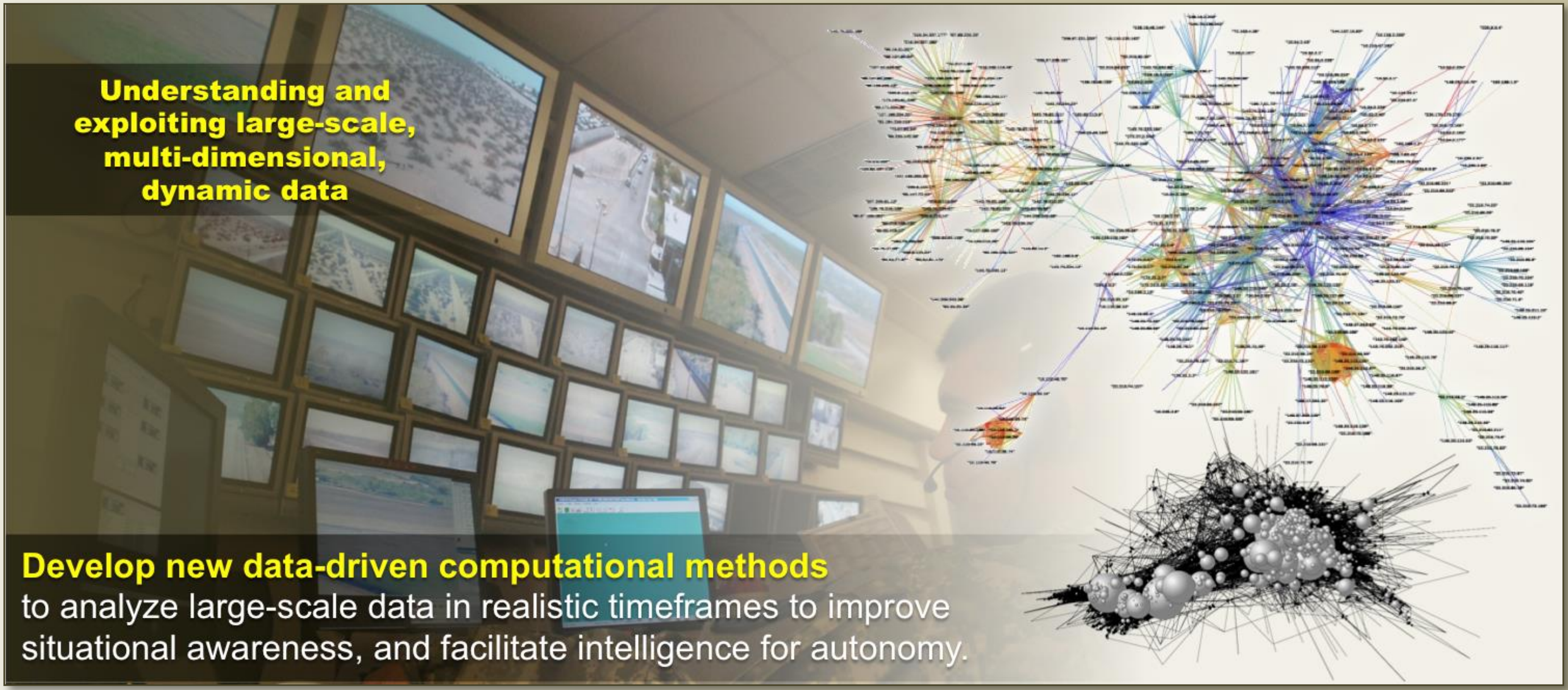
Provide data analytics for large scale data in real-time and time critical situations.

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



Vision

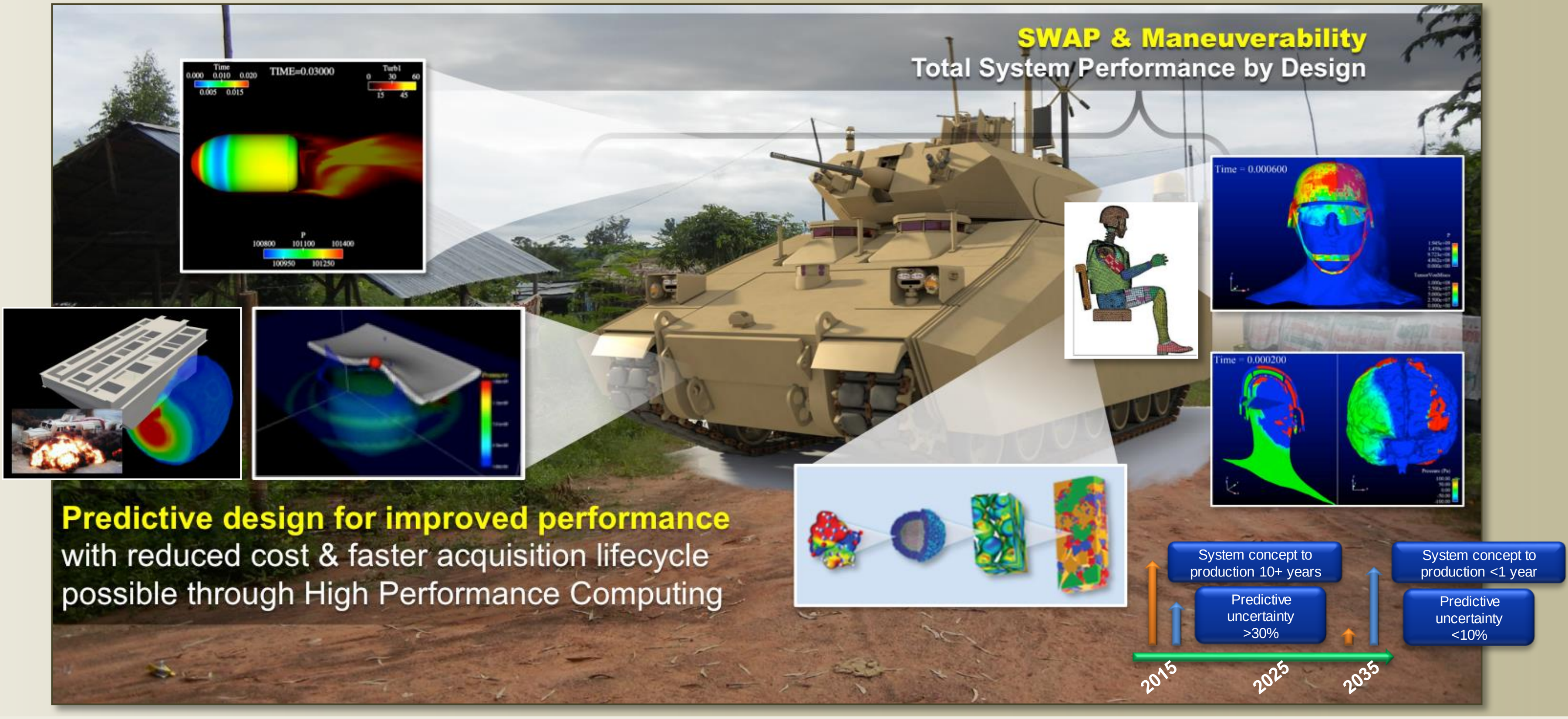
Accelerate Army system development through multidisciplinary predictive simulation methodologies for complex systems.

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



Distributed Simulation, Integration and Interoperability

Vision

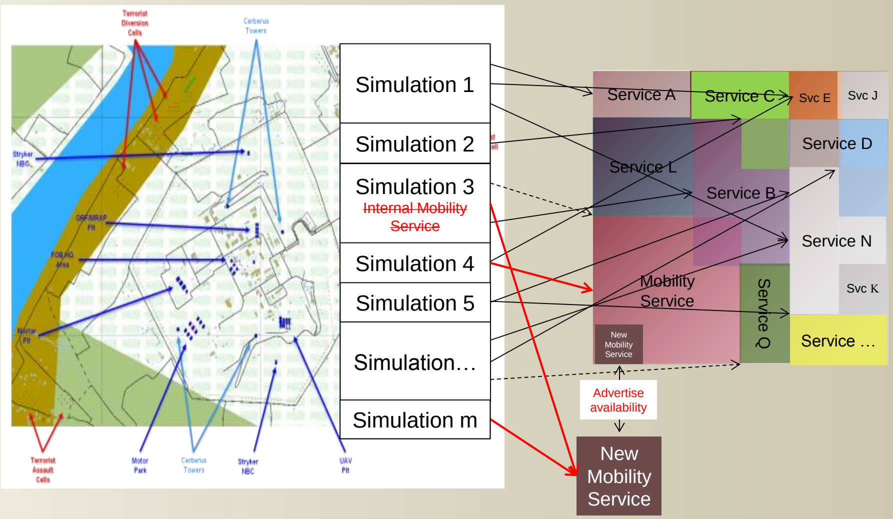
Robust Army simulation capabilities with composable synthetic representations delivered where they're needed in the form in which they're needed.

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.

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Programmable Network Algorithms and HPC Models for Quantum and Classical Networks

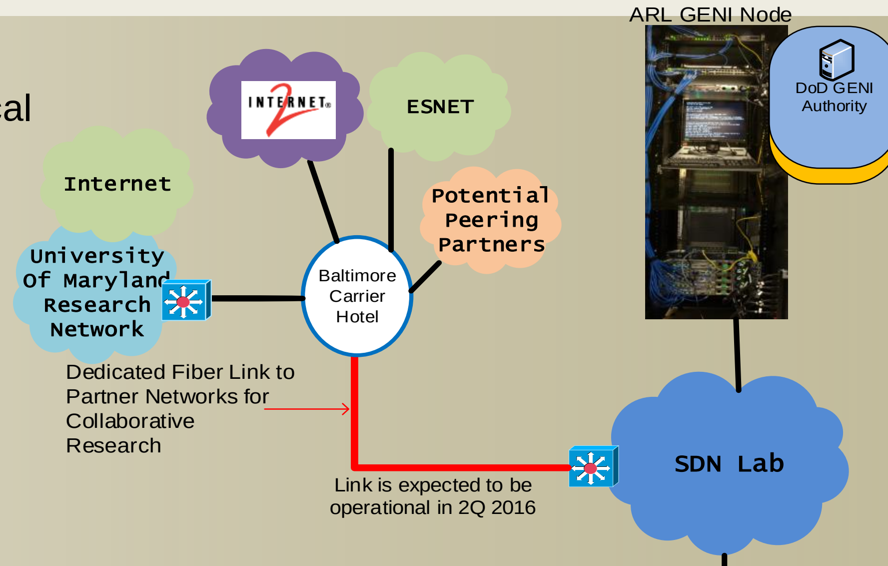
ARL

Vision

Develop programmable Quantum & Classical Network Interfaces to create intelligent, adaptive and intent-aware networks to support distributed computing and data analytics at the edge.

Problem Statement

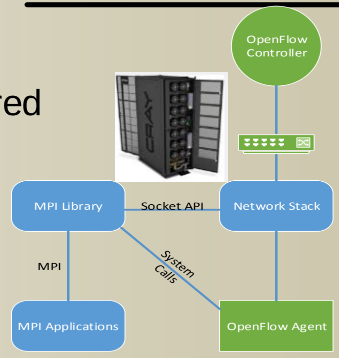
Lack of programmability, embedded control plane and emergence of new network node types drives the development of flexible, programmable and intent-aware networks.



Challenges and Impact

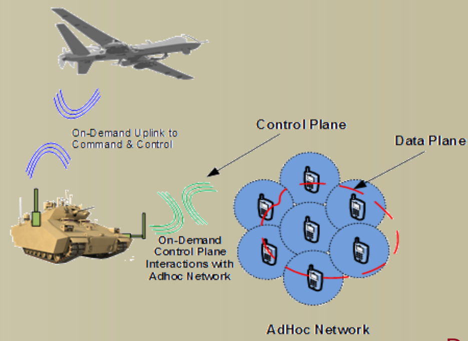
Active Research Projects

- Programmable networks are disruptive & adaptation is required
- New transport algorithms & network graph analytics needed
- Development of unified control plane is non-trivial
- Integration of quantum network protocols require development of new data structure for OpenFlow



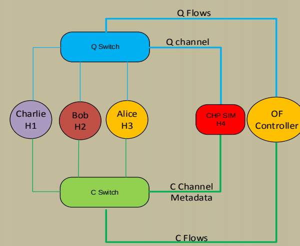
Extending SDN functions into HPC network fabric through custom APIs & HPC network algorithms for integration

Collaborators: Boise State University



Programmable on-demand control plane functions to enable distributed intelligence for ad-hoc networks

Collaborators: Yale University



Development of metadata-based 3-node programmable quantum network models & extending them to ion/photon systems

Collaborators: ORNL, AFRL & Budapest University

The Nation's Premier Laboratory for Land Forces

Research Computing Facilities

Research Facilities Include:

- ARL DoD Supercomputing Resource Center
- Scientific visualization laboratory

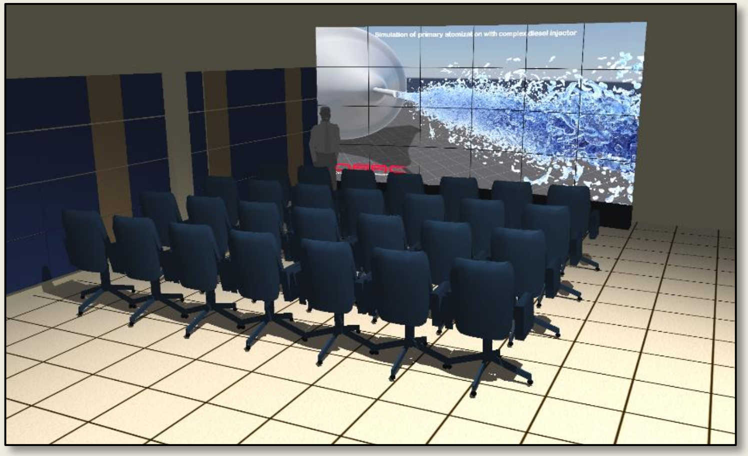
Collaboration Opportunities:

- Scalable computational algorithms for complex interdisciplinary systems
- UQ-based predictive design methods
- Robust approaches to validate model accuracy
- Hierarchical scale-bridging methods
- Computational additive manufacturing processes

Excalibur: Debuted at 19th fastest computer in the world
101,312 processors, 32 NVIDIA Tesla K40 GPCPUs
411 TB memory, 122 TB SSD, 3.7 Petaflops

IBM iDataPlex
20,160 cores/ 80 TB

IBM iDataPlex
17,472 cores/ 70 TB



Scientific Visualization Lab:
Video Wall

Research Computing Facilities

Research Facilities Include:

- Large-scale heterogeneous cluster with Xeon Phi & accelerators
- Low-power, RISC-based system
- Software Defined Networking Testbed
- 3-D architecture integration concepts
- Integrated HPC and Neuromorphic System

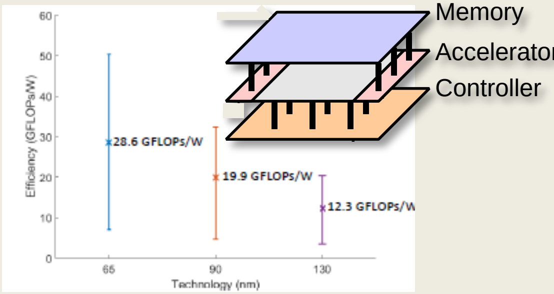
Collaboration Opportunities:

- Novel methodologies for scalable software
- Algorithms for emerging hardware designs (qbits, neuro-synaptic, etc)
- Power optimization across a diverse spectrum of processors/cores
- Task provisioning based on architecture type and compute load

Epiphany many-core processor technology

Emulation Testbed

GENI Testbed



3-D Integrated Chip

TrueNorth Cluster

Computational Research Infrastructure

Research Facilities Include:

- Neuromorphic research laboratory
- Large-scale heterogeneous cluster with Xeon Phi & GPU
- Hadoop Cluster
- Domain-specific computing architecture test bed
- ARL Supercomputing facilities

Collaboration Opportunities:

- Dynamic graph analysis for enormous datasets
- Predictive data driven algorithms
- Scalable learning & deep-learning algorithms
- Visual data analytics for large data
- Streams processing of varying time-scale, varying size datasets

Big Data MPI

IBM TrueNorth

hadoop

64 nodes
48 nodes Intel Phi
16 nodes NVidia GPUS

SDN Testbed

BACKUP

U.S. ARMY RDECOM ARL

Predictive Science: Multiscale Modeling of Complex Systems

Vision

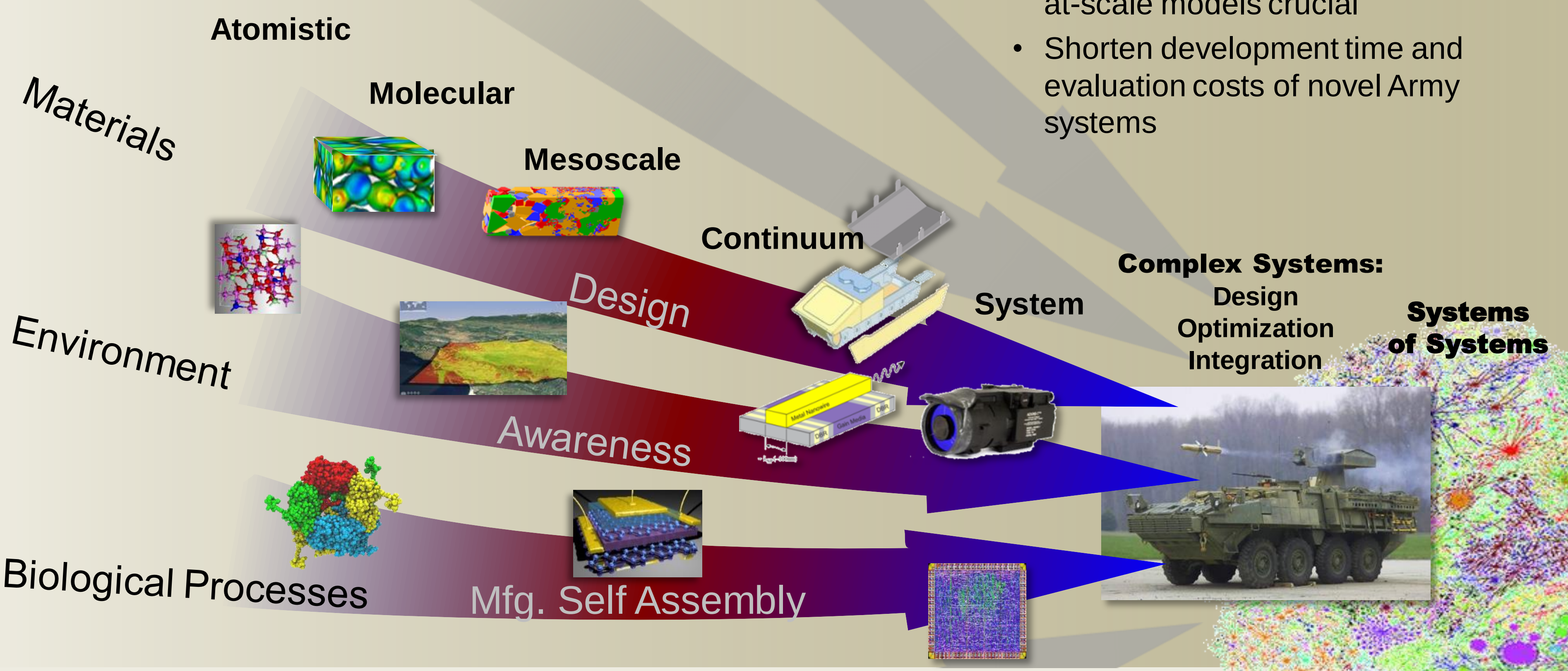
Accelerate Army system development through high-fidelity predictive multiscale simulation methodologies for complex systems.

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



Advanced and Unconventional Computing

Vision

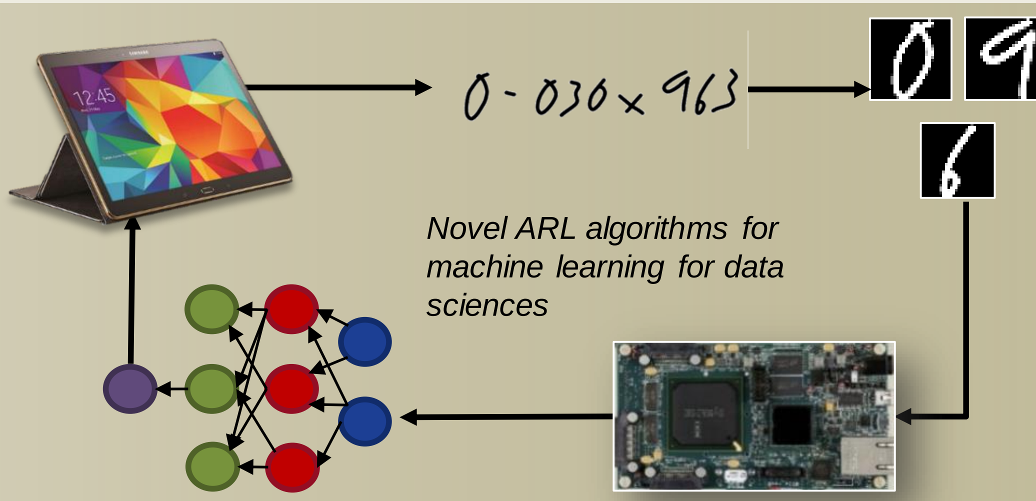
Discover new non Von Neumann techniques and computing paradigms that will be able the development of future low-power adaptable computing systems.

Problem Statement

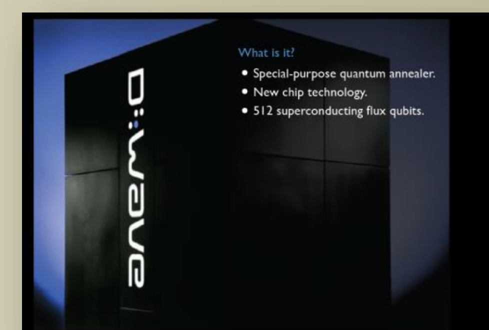
Von Neumann architectures are limited in scalability by the bottleneck between processing and memory.

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



16 System TrueNorth Cluster

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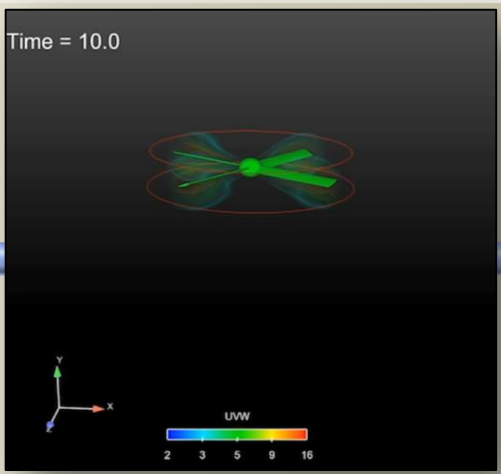
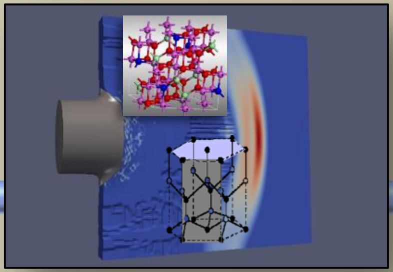
Cross Cutting Campaign

ARL

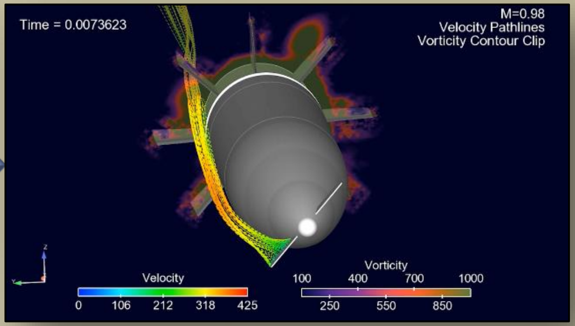
Computational Sciences



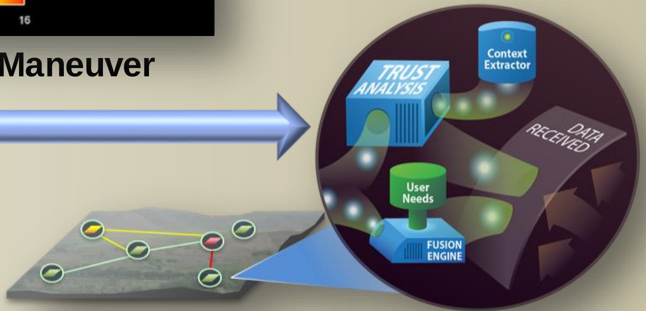
Sciences for Maneuver



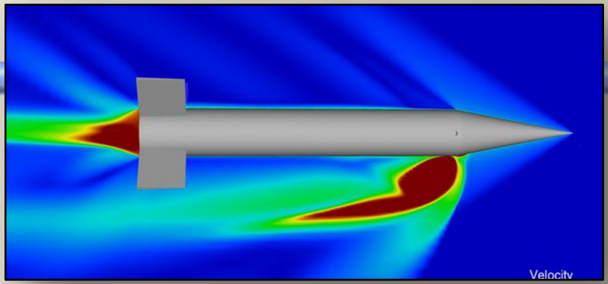
Materials Sciences



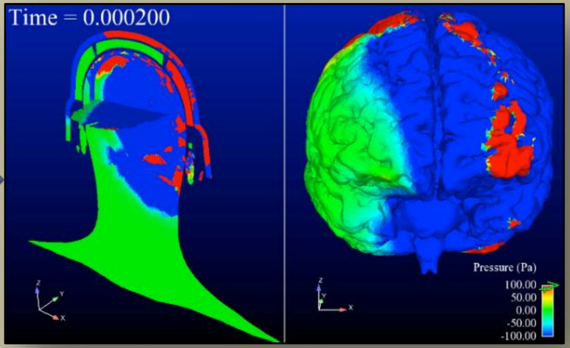
Assessment & Analysis



Information Sciences



Sciences for Lethality & Protection



Human Sciences

Open Campus Supercomputing Resource

SGI ICE 8200 Ex

Cores 7,168 – 2.8 GHz Intel
Memory 21 TB
Storage 350 TB

Leverage ARL & OC expertise

- ARL Computational Sciences Research
- ARL Supercomputing Research
- DoD HPCMP Outreach
- ARL in-house Scientific Software

Network Connectivity:

atanasoff.edu (University of Maryland)

To access the ARL Open Campus System, contact outreach@arl.hpc.mil