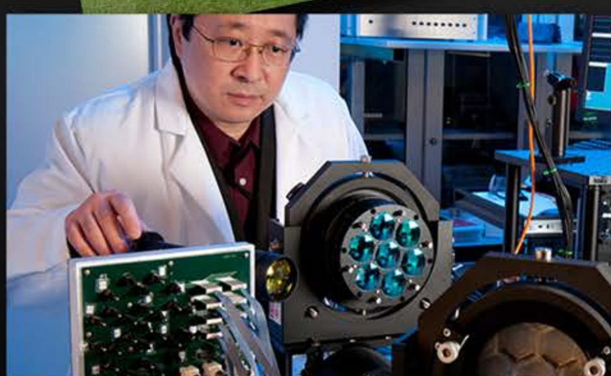
Open Campus Opportunities



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December 2014

INTRODUCTION

The mission of the U.S. Army Research Laboratory (ARL) is to provide innovative science, technology, and analyses to enable full spectrum Army operations, now and into the future. To execute this mission, ARL leverages the substantial intellectual resource represented by the global academic scientific research community. Formation of a collaborative and transparent relationship with this community, with industry, and with small business through the Open Campus initiative offers the prospect for enhanced discovery and innovation, and effective execution of basic and applied research programs in a variety of technical focus areas of high Army interest.

ARL's Open Campus initiative is a collaborative endeavor, with the goal of building a science and technology ecosystem that will encourage groundbreaking advances in basic and applied research areas of relevance to the Army. Through the Open Campus framework, ARL scientists and engineers (S&Es) will work collaboratively and side-by-side with visiting scientists in ARL's facilities, and as visiting researchers at collaborators' institutions. The global academic community, industry, small businesses, and other government laboratories benefit from this engagement through collaboration with ARL's specialized research staff and unique technical facilities. These collaborations will build research networks, explore complex and singular problems, enable self-forming expertise-driven team building that will be well-positioned for competitive research opportunities, and expose scientists, engineers, including professors and students to realistic research applications and perspectives, helping to ensure our nation's future strength and competitiveness in these critical fields.

ARL's technical portfolio encompasses a broad array of technical areas as well as technology maturity levels, from discovery of first-recognized phenomena to innovative systems. ARL's research in focused topic areas such as Energy & Energetics, Network Sciences, Autonomous Systems, and Imaging & Image Processing is highlighted in the Research@ARL collection, which may be found at www.arl.army.mil/ResearchARL. The Open Campus initiative opened select segments of our extended campus network in the summer of 2014. The Open Campus will accommodate both U.S. citizens and foreign national researchers who come to ARL to collaborate in research areas of mutual interest. Additional Open Campus laboratories and office spaces, as well as a virtual collaboration infrastructure, will be added in the future.

This document describes ARL's strategic research interests, facilities, and collaborative research opportunities within the Open Campus framework. Research opportunities include visiting scientist and researcher exchanges between ARL and academic, government, industrial, and small business collaborators internationally, as well as postdoctoral fellowships and internships. Additional opportunities may be identified within the research areas even if a specific opportunity is not listed. The final section includes Frequently Asked Questions (FAQs).

For additional information, please contact ARL Open Campus Program Manager Ms. Wendy Leonard at wendy.a.leonard.civ@mail.mil.

THE OPEN CAMPUS CONCEPT

The concept of a defense laboratory was inspired by Thomas Edison's vision of "a great research laboratory" maintained by the Government. This vision led to the creation of the Naval Research Laboratory in 1923.[1] In 1945, Vannevar Bush's concepts documented in *Science: The Endless Frontier* became a model for how the United States would pursue its scientific endeavors.[2] Bush stressed the necessity of establishing a robust and synergistic university, industry, and government laboratory research system.[3] Over the past 60 years, organizational changes and consolidations have created the National Laboratories structure and a DoD research laboratory structure now known as the Defense Laboratory Enterprise (DLE).[4] However, the DoD research laboratory internal structure and operation have not changed since their establishment, while the global university and industry research capabilities have evolved with the changing research and economic environments. This shift and the rigid and insular nature of the DLE have caused an erosion of the university/industry/government laboratory synergy that is vital to the discovery, innovation, and transition of science and technology critical to national security. In addition, the pace of technological change from 1990 to the present far exceeds the technology pace observed from 1950 to 1990 and will more than likely continue to increase in the future. The globalization of technology requires novel and new collaboration mechanisms that will reenergize the university/industry/government laboratory synergy.

ARL is adaptive and responsive to the challenges of 21st century national security. While the nature of our mission requires that segments of our research be restricted, it is widely acknowledged that innovation depends on bringing multiple disciplines together to engage in collaborative projects that often yield unpredictable, but highly productive, results. Formal and informal interactions among scientists lead to knowledge-building and research breakthroughs. By bringing together academia, industry, small business, and government to address fundamental research problems, the Army can enhance its performance through on-site R&D collaboration, at both ARL and collaborator locations. ARL will implement an Open Campus initiative as part of our business model to foster better collaboration across industry, academia, and government, attracting and leveraging the best and brightest across the collective research community to more effectively produce transformative science and technology. Participation in ARL's Open Campus will provide ready access to unique facilities, specialized researchers, and collaborative resources for all partners, including foreign nationals.

This represents a transition within our current business model, so during the early phases of the Open Campus initiative, escorting of foreign national collaborators may be required. Restricted unescorted access of foreign national collaborators in designated Open Campus areas will be introduced in a phased approach starting in the fall of 2014, and expanded as the initiative grows. In addition to collaborative engagement in existing ARL facilities, future phases of ARL's Open Campus will include opportunities for partners to establish new on-site facilities on our campuses.

Currently, ARL seeks to attract academic, government, small business, and industry partners for collaborative engagement. This document outlines research areas of interest to ARL and provides descriptions of collaboration

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[1] History of the Naval Research Laboratory. http://www.nrl.navy.mil/about-nrl/history/. 2013.
[2] Unlocking Our Future: Toward a New National Science Policy. U.S. House of Representative Committee on Science. 1998.
[3] Bush, Vannevar. *Science: The Endless Frontier, A Report to the President*. July 1945.
[4] Defense Laboratory Enterprise. http://www.acq.osd.mil/rd/laboratories/. 2013.

opportunities and the name, telephone number, and e-mail address for the ARL Principal Investigator. These research areas are represented in ARL's Technical Strategy and include Computational Sciences, Materials Sciences, Sciences for Maneuver, Information Sciences, Sciences for Lethality and Protection, Human Sciences, and Assessment and Analysis. Each of these research areas focus on critical challenges that arise in the extreme operational and threat environment in which the Army operates.

ARL LOCATIONS

ARL has five primary sites across the United States, as shown below, with collaborative opportunities at each. ARL's Open Campus pilot program will be centered in the Adelphi Laboratory Center (ALC) in 2014, and include ARL's Specialty Electronic Materials and Sensors Cleanroom (SEMASC), a 15,000 square foot Class 10/100 cleanroom equipped to process novel materials and device structures down to nanoscale dimensions, and ARL's Microsystem Indoor Testing Ground, an enclosed cityscape enabling experiments with unattended ground and air intelligent systems. Other collaborative opportunities will be coordinated on a case-by-case basis during the Open Campus pilot.

ADELPHI LABORATORY CENTER (ALC), MD

Microsystem Indoor Testing Ground

Specialty Electronic Materials and Sensors Cleanroom (SEMASC)

ABERDEEN PROVING GROUND, MD

ORLANDO, FL

WHITE SANDS MISSILE RANGE (WSMR), NM

RALEIGH-DURHAM, NC

RESEARCH AREAS

Computational Sciences

ARL's basic and applied research in Computational Sciences is focused on advancing the fundamentals of predictive simulation sciences, data intensive sciences, computing sciences, and emerging computing architectures to transform the future of complex Army applications. Gains made through these underpinning multidisciplinary research efforts and exploiting emerging advanced computing systems will lead to scientific breakthroughs that are expected to have significant impact on Army materiel systems. Technologies resulting from this multidisciplinary research, collaboratively with other ARL S&T campaign innovations, will have a significant impact on Power Projection Superiority, Information Supremacy, Lethality & Protection Superiority, and Soldier Performance Augmentation for the Army of 2030.

Computational Sciences uses advanced computing to understand and overcome complex fundamental challenges simultaneous to improving approaches of importance to the Army, including weapon systems design; materials-by-design; information dominated and networked battle command applications; system-of-systems analyses; human performance modeling; platform maneuverability; and tactical supercomputers. There are natural synergies among the challenges facing Computational Sciences and ARL's other S&T campaigns. Synergistic advances across all campaigns are expected to enable next-generation scientific breakthroughs. The Computational Sciences area heavily relies on ARL's research expertise and facilities devoted to emerging advanced computing architectures, mobile High Performance Computing (HPC), multiscale and interdisciplinary predictive simulation sciences, multidimensional distributed data analytics, and computing sciences. Discoveries and innovations made in this area will exert a significant impact on the Army of the future. Computational Sciences technical emphasis areas include Predictive Simulation Sciences, Data Intensive Sciences, Computing Architectures, and Computing Sciences.

Predictive Simulation Sciences concentrates on understanding and exploiting the fundamental aspects of verified and validated computational simulations that predict the response of complex Army systems and guide Army materiel design, particularly in cases where routine experimental tests are not feasible.

Data Intensive Sciences focuses on understanding and exploiting the fundamental aspects of large-scale multidimensional data analytics. Experiments, observations, and numerical simulations are on the verge of generating petabyte quantities of data. These massive amounts of data are distributed across desperate locations and pose a challenge in providing real-time analytics that support U.S. military operations.

Computing Architectures concentrates on understanding and exploiting the fundamental aspects of hardware and associated system software for emergent and future computing architectures for mobile, scientific, and data intensive applications. Computing systems include both mobile and fixed/virtual architectures optimized for faster communications, lower power consumption, larger hierarchical memory, novel and robust algorithms, resilience, and HPC networking.

Computing Sciences concentrates on understanding and exploiting the fundamental aspects of computer science research related to ease of programming, computing environments, languages, and reusable programming models for Army-specific applications.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

Predictive Simulation Sciences

Computational Fluid Dynamics (CFD)

Research is focused on the development and validation of highest-fidelity computational fluid dynamics (CFD)-based capabilities for prediction of non-linear and unsteady aerodynamic/flight dynamic behaviors of complex guided munitions. Conduct both fundamental and applied aerodynamic research for better understanding of flow interaction effects such as vortex flows and shock-boundary layer interactions. Collaborative efforts are sought in these areas: rapid and accurate prediction of maneuvering flight physics and experimental validation, higher order turbulence modeling/numerical schemes, multidisciplinary design and optimization , control mechanisms for high maneuverability of flight bodies across omni-sonic speeds to include, but not limited to plasma flow control, morphing bodies and exploitation of flow interaction effects.

Principal Investigator: Jubaraj Sahu jubaraj.sahu.civ@mail.mil (410) 306-0798

Scalable Algorithms for Simulating Dislocations in Micro-structured Crystals

Develop algorithms to explore the interactions of dislocations with microstructure in materials. The focus of this work is on addressing the large computational expense through novel parallelization, load balancing, and code coupling algorithms. Limited knowledge of dislocation behavior near microstructure must be addressed through collaboration with atomistic modeling and experimental efforts to characterize and validate dislocation behavior near free surfaces, interfaces, and grains.

Principal Investigator: Joshua Crone joshua.crone.civ@mail.mil (410)-306-2156

High Throughput Computational Drug Screening (APG)

In our lab, we use high performance computing to screen millions of small organic molecules against host and viral proteins involved in the lifecycle of viruses and bacteria. For example, current efforts include developing inhibitors against Ebola and Marburg viruses. On-site, we would like to work with computational chemists and computational biologists to improve the accuracy and efficiency of our prediction methods. Off-site, we would like to build new collaborations with experimentalists in the areas of virology, bacteriology, molecular biology, cell biology, crystallography/NMR, biophysics, and biochemistry.

Principal Investigator: Michael S. Lee michael.s.lee131.civ@mail.mil (301) 619-8066

Model Order Reduction (AHPCRC)

Nonlinear Model Order Reduction (MOR) methods are being developed that are applicable to a range of models, particularly those associated with the under-body blast problem. These MOR methods will enable parametric studies in a reasonable amount of time and will accelerate the meaningful interpretation of large amounts of data generated by high fidelity models minimizing the burdens associated with big-data. The availability of such models and MOR methods will significantly reduce the number and cost of real tests that must be performed in order to properly assess threats and improve safety.

Principal Investigators: Charbel Farhat cfarhat@stanford.edu (650) 723-3840
Pat Collins james.p.collins106.civ@mail.mil (410) 278-5061

Supporting Facility: ARL DSRC

The ARL Distributed Shared Resource Center (DSRC) is one of five centers delivering world-class, high-performance computational capabilities to DoD scientist and engineers. The ARL DSRC has an equivalent of 420 TFLOPS of computing capability in the unclassified domain and 522 TFLOPS in the classified domain. In 2015 ARL will take delivery of a Cray XC40 with 101,184 compute cores, 400 TB of memory and 4 PB of disk storage, delivering 3.7 PFLOPS of computing capability.

Methodologies for Scale-bridging in Multi-scale Simulation

We aim to develop numerical methods and algorithms to enable linking of at-scale models into complex multi-scale model hierarchies. Major areas of interest include: scalable data transfer, heterogeneous interpolation and multi-fidelity surrogate models.

Principal Investigator: Jaroslaw Knap jaroslaw.knap.civ@mail.mil (410) 278-0420

Multiscale Modeling of Transport in Optical Semiconductors

We are developing the capability to do high-fidelity, parallel, multiscale computations of photo-excitation in semiconductors. This will assist in designing materials and heterostructures to be used in sensors and communication devices. Our approach employs a two-scale, sequential multiscale method based on a spatio-temporal form Semiconductor Maxwell-Bloch Equations that use of different macro- and micro-scale methods.

Principal investigator: Brent Kraczek brent.e.kraczek.ctr@mail.mil 410-278-8881

Real-Time RF Propogation

Dr. Henz has been the Emulation team lead for the HPCMO HSAI Mobile Network Modeling Institute. During that time they have developed a number of real-time RF propagation applications for terrain dependent and urban environments. Some of these applications have been successfully transitioned to other DoD partners in the EW (electronic warfare) community. Dr. Henz also currently leads a development effort on large scale parallel discrete event simulations. ARL maintains a hybrid HPC system for mobile ad-hoc network simulation and emulation including modeling of electromagnetic propagation. We are looking to collaborate on the development of full wave EM propagation algorithms for hybrid architectures. ARL has extensive expertise in hi-fidelity mobile ad-hoc network simulation of traditional waveforms We would like to begin developing advanced models for EW (Electronic Warfare) such as intelligent jammers, Software Defined Radios/GNU radio, etc. ARL has expertise in computing MOPs (Measures of Performance) for understanding network performance such as latency, jitter, throughput We would like to develop new MOEs (Measures of Effectiveness), e.g. PESQ or POLQA for VoIP

Principal Investigator: Brian Henz brian.j.henz@us.army.mil 410-278-6531

Computational Fluid Dynamics of Reacting Flows for Propulsion

CFD is used in detailed numerical models of high-pressure reacting flows, including interior ballistics of guns, gun muzzle flow for blast/flash mitigation, and for rocket motor research. For success of the numerical models run on high-performance computers (HPCs), necessary inputs include detailed chemical kinetics and physical
simulators for validation.

Principal Investigators:

Richard Beyer	richard.a.beyer10.civ@mail.mil	(410) 278-6184
Michael Nusca	michael.j.nusca.civ@mail.mil	(410) 278-6108
Michael McQuaid	michael.j.mcquaid.civ@mail.mil	(410) 278-6185

Supporting Facility: Propulsion Science Branch Experimental Facilities (APG)
The Propulsion Science Branch has developed the capability to obtain data to validate our reacting CFD codes related to gun propulsion. High-pressure environments, including research gun firings, are safely accommodated. Novel experimental designs are developed as required.
Equipment Available: Ballistic simulators for acquisition of validation data for IB models. Optical diagnostics of chemistry, temperature, and pressure in muzzle flow field.

Meso- and Micro-scale Forecast Model Validation

Data from the Meteorological Sensor Array (MSA) and other sources are being used to validate meso- and micro-scale numerical weather prediction (NWP) models at sub-kilometer grid resolutions. Model assessment tools developed by other organizations are being adapted, and various statistical analysis methodologies and Geographic Information Systems techniques are being employed to conduct the validations. Data collected from the MSA is statistically analyzed against results from numerical weather prediction models to assess their
accuracy.

Principal Investigators:

Sean O'Brien	sean.g.obrien.civ@mail.mil	575-678-1570
David Knapp	david.i.knapp.civ@mail.mil	575-678-4574

Supporting Facility: Meteorological Sensor Array (MSA) (WSMR)
The MSA is a first-of-its-kind array of meteorological (Met) sensors designed to be emplaced to exactly overlay meso- and microscale forecast model grid points, enabling in-situ and remotely sensed Met observations that will more precisely assess and validate the accuracy of the models.

Atmospheric Boundary Layer Environment (ABLE) Model

The goal of this research effort is to develop an advanced, full-physics numerical weather prediction model that will generate meteorological forecasts at the Army-scale (spatial grid spacing: 1-100 m; temporal refresh rate: 1-15 min). Computing architectures are being designed to enable the model to execute on tactically-available compute platforms. We are seeking expertise with atmospheric modeling applications on HPC caliber computing platforms to include emerging heterogeneous (CPU/GPU) platforms, and distributed computing systems. In addition, we are seeking theoretical expertise on atmospheric turbulence modeling, complex microscale flows over mountains and in urban environments and access to laboratory capabilities (wind tunnel, water channel) for idealized fluid flow tests to evaluate the numerical model.

Principal Investigators:	Yansen Wang	yansen.wang.civ@mail.mil	(301)394-1310
	Benjamin MacCall	benjamin.t.maccall.civ@mail.mil	(301) 394-1463

Data Intensive Sciences

Data-Centric, Extreme Scale Computing using Legion

This effort involves ongoing research with Exascale computing using the task-oriented parallelism defined by the Legion programming system developed at Stanford University. Critical to this mission is balancing the computational demands of High Performance Computing (HPC) with the varied architectural resources available via distributed and shared memory heterogeneous hardware. Areas of interest include optimal parallel algorithm development and fault tolerance for large distributed systems.

Principal Investigator:	Richard Haney	richard.h.haney2.ctr@mail.mil	(410) 278-7866
	Song Park	song.j.park.civ@mail.mil	(410) 278-5444
	Dale Shires	dale.r.shires.civ@mail.mil	(410) 278-5006

Autonomous Mobile High-Performance Computing (APG)

To provide high-performance computing resources to Soldiers in the field, vehicle-mounted computer assets are envisioned. These assets could maintain communications via tactical cloudlets, and navigate autonomously to maintain maximum availability. New algorithms are being devised to address these requirements, and advanced computing architectures are being investigated. Research will also target hardware that is suitable for being deployed on a military vehicle.

Principal Investigator: Brian Rapp brian.m.rapp2.civ@mail.mil (410) 278-4542

Real-Time Data Analytics

Investigate the use of novel algorithms and HPC computing architectures to achieve improved analytical insights for real-time communications data. Develop new approaches in the application of streams processing to enhance the value and utility of real-time data.

Principal Investigator: Thomas Kile Thomas.g.kile.civ@mail.mil (410)278-6808

Large-Scale Data Reduction

This effort is focused on investigating and developing methods of reduction for terabytes of complexly related and potentially fragmented data for tests such as the Network Integration Evaluation (NIE). Algorithm and software engineering designs are applied to High Performance Computing technologies with the goal of reducing the timeline from database driven reductions. Correlating network data using Message Passing Interfaces such as OpenMPI allows us to significantly improve our operations and quickly produce data to be used in analytics.

Principal Investigator: Brian Panneton brian.c.panneton.ctr@mail.mil (410) 278-5345

Advanced Computing Architectures

Emerging Computing Architectures

Advanced computing architectures continue to grow in complexity making it difficult to achieve maximum performance of the available cores. Further complicating this is the gap between hardware capability and software utility. This effort attempts to address these problems by developing new approaches to dynamic code re-factoring, auto-tuning for complex cores, and development of new algorithms that can leverage the pervasive parallelism in these binary processors and emerging systems such as quantum annealing and neuro-synaptic. Compiler research is also considered as part of an effort to improve instruction scheduling at low-levels to consider power consumption vs. performance for mobile devices.

Principal Investigator: Dale Shires dale.r.shires.civ@mail.mil (410) 278-5006

Heterogeneous Computing

This effort is focused on achieving high performance while using disparate processing core technologies. Algorithm design and software engineering approaches will be investigated to effectively partition and use binary processing cores to reduce time to solution for Army-relevant problems. Factors such as performance, portability, and power will be considered in conjunction with developing new models to quantify computing capabilities in hybrid systems to facilitate algorithm signature mapping to available resources.

Principal Investigator: Song Park song.j.park.civ@mail.mil (410) 278-5444

Neurosynaptic Computing

Investigate the emerging topic of neuro-synaptic computing that roughly mimics natural processing phenomena in the brain. Elaborate on and develop additional biologically based computing models and determine how binary processors based on this design could be used for neurocognitive applications within the Army sphere of interest.

Principal Investigator: Manny Vindiola manuel.m.vindiola.civ@mail.mil (410) 278-9151

Algorithm Development and Assessment for Neurosynaptic Architectures (APG)
Develop computational science algorithms using neurosynaptic computing models for Army-relevant problem spaces such as reasoning and cognition. Investigate alternative and/or additional biologically based models for binary execution in order to more accurately mimic human brain processing and provide accurate and efficient processing solutions.

Principal Investigator: Manuel Vindiola manuel.m.vindiola.civ@mail.mil (410) 278-9151

ARL DOD Supercomputing Resource Center (DSRC)

The ARL DSRC provides large-scale computing architectures, advanced and novel computing technologies, high-speed networking tools, and data storage and archival to address the scientific computing needs of the DOD Research, Development, Test, and Evaluation Communities. The High Performance Computing (HPC) capabilities at the ARL DSRC provide the number crunching and scientific computing solutions to address problems of interest in fluid dynamics, materials science, computational chemistry, structural mechanics, and many other fields that can only be solved with large-scale parallel supercomputing. An expert staff is available to assist with user accounts, training, and scalable software development and optimization.

Principal Investigator: Lee Ann Brainard Lee.A.Brainard.civ@mail.mil 410.278.6664

Dynamic Optical Networking (DON) and IDVRN for HPC

Investigate and innovate to integrate the optical-transport layer Software Defined Networking (Transport-SDN) with DARPA CORONET protocols. Transform IDVRN/RDEnet into a fast high speed optical network based research tool using SDN approach.

Principal Investigators: Vinod Mishra Vinod.K.Mishra.civ@mail.mil (410) 278-0114
Colleen Adams Colleen.e.adams2.civ@mail.mil (301) 394-4640

Quantum Communications Networking using HPC

Investigate the modeling and simulation of Software Defined Quantum Communication Networks (SD-QCN) using HPC assets in both free-space and optical fiber channel environments. Develop Quantum Metadata (QMd) interfaces between Quantum Node and higher OSI stacks and more efficient quantum communication protocols.

Principal Investigator: Vinod Mishra Vinod.K.Mishra.civ@mail.mil (410) 278-0114

Investigation of Entanglement Dynamics

Model entanglement dynamics of open and closed systems under physically motivated random processes. Local random quantum circuits (L-RQC) and quantum walks based formalisms. Background in quantum probability is required.

Principal Investigator: Radhakrishnan Balu Radhakrishnan.Balu.civ@mail.mil (301) 394-4302

Computing Sciences

Computational Science for Application Domains

Facilitating the use of High Performance Computing requires novel approaches to reduce algorithm and software design while guaranteeing maximum performance on complex, often heterogeneous computing resources. The primary challenge usually involves finding a way to balance the competing requirements of performance, generality, and productivity. This research is devoted to the development and optimization of Domain Specific Languages (DSLs) that can assist domain experts in simplifying the representation of complex physical models while still targeting large-scale computational resources. Innovative approaches will be required to properly address DSL components including the Application Programming Interfaces (APIs), syntax, models, and computational engine.

Principal Investigator: Dale Shires dale.r.shires.civ@mail.mil (410) 278-5006

Parallel Programmability on Heterogeneous Architectures

Rise of heterogeneous architectures lead to an open challenge of parallel programmability in heterogeneous systems. The current state of software frameworks targeting heterogeneous computing systems can be viewed as scattered with many competing APIs. This project conducts research on developing a programming methodology for supporting emerging and future computing systems.

Principal Investigator: Song Park song.j.park.civ@mail.mil (410) 278-5444

Multi-Objective Geometric Optimization for Heterogeneous Architectures

Possibility of new capabilities investigated for an access to tactical supercomputing resources. Leveraging co-processing accelerators, geometric optimization of ballistic threat in 3D urban environment is implemented for enhanced tactical intelligence. To date, this ray-tracing-based application has been tested on ARM, CPU, and GPU architectures.

Principal Investigator: Song Park song.j.park.civ@mail.mil (410) 278-5444

Benchmark Suite Development (APG)

ARL is developing a suite of parallel number-crunching algorithms to create a benchmark suite to evaluate and analyze emerging architectures with concentration on heterogeneous systems. The algorithms represent some of the most common basic algorithms faced by scientists and engineers. Just-In Time (JIT) compiled kernels are utilized to minimize runtime along with mechanisms to find the best kernel parameters to use for each algorithm on each architecture. The code has been run on a variety of CPUs, GPUs and MIC hardware.

Principal Investigator: Jamie Infantolino jamie.k.infantolino.ctr@us.army.mil (410) 278-712

Novel Applications for Advanced and Tactical High-Performance Computing

Research and develop new capabilities for Soldiers based on mobile and tactical High-

Performance Computing (HPC). Focus on novel real-time processing capabilities to reduce network load and increase Soldier effectiveness. Areas of interest include line-of-sight-related processing, electronics warfare, vehicle navigation, etc.

Principal Investigator: Song Park song.j.park.civ@mail.mil (410) 278-5444

Real-Time Operating Systems for GPU-Based Tactical HPC (APG)

Graphics Processing Units (GPUs) are accelerator technologies that can allow for large-scale number crunching in deployed footprints. While these processors have a large capacity, they were not engineered with general-purpose inclusion into deployed systems with real-time processing restrictions. This project will investigate the state-of-the-art in incorporating this technology into deployed systems and suggest improvements in an Army-centric application.

Principal Investigator: Song Park song.j.park.civ@mail.mil (410) 278-5444

Energy Efficient Software Improvements for Constrained Devices (APG)

This effort is focused on investigating and developing more efficient approaches to software design and implementation on disparate core technologies to reduce energy consumption. Areas of interest include code refactoring, variations in low-level instruction scheduling, and dynamic gating utility, as well as developing parameterized models for software execution using various binary processing configurations to discover relationships between power utilization and software efficiency.

Principal Investigator: Song Park song.j.park.civ@mail.mil (410) 278-5444

Cloudlet-Based Processing

Develop optimization approaches to allow for self-forming "cloudlet"-based processing configurations with HPC assets providing key processing and offloading support for constrained hand-held devices. Develop models to account for network connectivity and offered computing load as mapped to a dynamic computing infrastructure (computing capacity). Develop new methodologies or apply existing concepts related to scheduling to achieve balance in transient and unstable networks common in Army operational realms.

Principal Investigator: David Bruno david.l.bruno4.civ@mail.mil (410) 278-8929

Verification and Validation of Cloudlet Provisioning Using EMANE (APG)

The Extendable Mobile Ad-hoc Network Emulator (EMANE) is a useful system to verify and validate network- based protocols. This project will investigate how to extend the system for models under development at ARL and also test current models being proposed for non-ad-hoc networks for scalability and performance.

Principal Investigator: David Doria david.l.doria.civ@mail.mil (410) 278-2310

Scheduling and Provisioning within Army Cloudlets (APG)

This research involves investigating new model developments to couple mobile ad hoc networking with computing assets deployed in the field. Approximation methods will be investigated to facilitate provisioning and scheduling in real time.

Principal Investigator: David Bruno david.l.bruno4.civ@mail.mil (410) 278-8929

Scientific Visualization for Large Scale Data

This effort leverages the capabilities of the DoD High Performance Computing resources to allow researchers to perform interactive analysis on HPC-sized datasets. Implementation of production-quality scientific visualization software applications such as EnSight, ParaView and Visit provide researchers with a robust suite of tools which utilize the inherent parallel processing capabilities of the HPC systems to post-process and analyze computational results.

Principle Investigator: Rick Angelini Richard.C.Angelini.CIV@mail.mil (410)278-6266

Developing Quantum Algorithms in HPC Environment

Develop HPC based scalable models based on QHDL for quantum optics feedback networks. To develop numerical algorithms for control systems based on quantum optics infrastructure. Background in quantum probability and experience with high performance computing environment are required.

Principal Investigator: Radhakrishnan Balu Radhakrishnan.Balu.civ@mail.mil (301) 394-4302

Extreme-Scale Parallel Discrete Event Simulation (APG)

ARL is involved in on-going research to improve the performance of Parallel Discrete Event Simulation (PDES) for upcoming exa-scale computing architectures. This effort looks to take advantage of such computing resources and apply them in support of extreme-scale modeling and simulation tools. High-fidelity network simulations at "Internet scale" are possible with architectures and algorithms to utilize resources efficiently.

Principal Investigator: Ken Renard Kenneth.d.renard.civ@mail.mil (410) 278-4678

Quantum Monte Carlo Studies

Quantum Monte Carlo studies and their use in and connections to quantum algorithms, quantum simulations (e.g., in optical lattices), and quantum walks. Related studies include approaches to overcoming the Fermion sign problem, particularly through an understanding of wave function nodal structure.

Principal Investigator: Peter J. Reynolds peter.j.reynolds16.civ@mail.mil (919) 549-4345

Quantum Monte Carlo Studies (*North Carolina State University*)

Conduct Quantum Monte Carlo studies primarily in diffusion and their use in and connections to quantum algorithms, quantum simulations (e.g., in optical lattices), and quantum walks. Related studies include approaches to overcoming the Fermion sign problem, particularly through an understanding of wave function nodal structure.

Principal Investigator: Peter J. Reynolds peter.j.reynolds16.civ@mail.mil (919) 549-4345

Equipment Available: Ten-meter Met towers with standard thermodynamic instrumentation; three-axis sonic anemometers; scintillometers; SODAR; triple LIDAR configuration.

Materials Research

Materials Research is basic and applied research focused on gaining a fundamental understanding of structural, electronic, photonic, and energy materials & devices. Exemplary of Army and DoD-relevant high-interest research areas supported through these efforts include multifunctional materials; high field responsive materials; hierarchically designed & fabricated materials; semiconductor materials & devices; generation-after-next electronics; and synthetic biology. ARL's basic and applied research in materials focuses on scientific discovery and innovative problem-solving to provide superior materials and devices needed to achieve lasting strategic land power dominance. Materials research cross-cuts ARL's four focused S&T campaigns in Human Sciences, Information Sciences, Sciences for Lethality and Protection, and Sciences for Maneuver by providing materials with superior properties to address emerging requirements and capabilities for all Army platforms.

The Army of 2030 will require materials with unprecedented capabilities that can be rapidly grown or synthesized, and processed cost-effectively to enable Army platforms that are highly mobile, information reliant, lethal, and protected. ARL's Materials Research Campaign addresses the future Army's need to rapidly respond to emerging threats and to eliminate tactical surprise by creating a materials-by-design and on-demand enterprise, and a manufacturing science engine to ensure rapid progression from materials discovery to delivery, with the goal of producing materials in greatly reduced time frames and at a fraction of the cost compared to today.

ARL's Materials Research Campaign builds on fundamental pillars of materials science, physics, mathematics, computational chemistry, synthetic chemistry, biology, and engineering to conduct research in areas including Advanced Experimental Techniques; Modeling and Simulation; Bridging the Scales—a materials-by-design paradigm; Material Property Characterization to measure materials properties and performance to inform the research community across the scales; and Growth or Synthesis and Processing—a materials-on-demand paradigm.

Key enablers, which are expected to lead to disruptive discoveries yielding new Army capabilities, are emphasized. Discovery enablers include biological and bio-inspired materials, metamaterials, two-dimensional and nanoscale materials, and multifunctional and hierarchical materials. Recent scientific emphasis areas that promise disruptive capabilities include quantum science to alter time, space, and information processing; the coupling of energy fields to matter to create new materials and selectable system responses with vast performance improvements; and interfacial science research from which many key Army capabilities are enabled. Recent discoveries in these scientific areas are setting the course of future ARL research.

Materials research areas of specific emphasis include Photonics; Electronics; Energy & Power; Biotechnology & Bio-Inspired; Structural Materials; High Strain Rate & Ballistic Materials; and Manufacturing Science, Processing, & Sustainment.

Photonics is focused on materials and devices for photonic sensors and sources, scalable high energy lasers, secure communications via quantum networking, and protection of sensors and human eyes against high power and short pulse laser threats.

Electronics is focused on specialized electronic materials and devices and circuits to achieve Army dominance over the entire electromagnetic spectrum, particularly in contested environments. The two primary thrusts of this area are

Energy-Efficient Electronics and Hybrid Electronics. Energy-Efficient Electronics is focused on low-power-demand electronic components having increased performance capabilities, and Hybrid Electronics focuses on high-performance semiconductor-based conformable, flexible electronics for advanced sensors and processors.

Energy & Power is focused on materials and devices for more efficient power generation, energy storage, energy harvesting, fuel processing, micropower, and novel alternative energy solutions at lower cost.

Biotechnology & Bio-Inspired is focused on new biological materials derived through synthetic biology as well as classical approaches. Novel biological materials are combined with inorganic devices to sense chemical and biological agents, generate power from organic sources, and produce materials to create new protection designs inspired by nature.

Structural Materials is focused on novel and specialized materials to enhance the structural efficiency and systems performance of advanced platform structures while maintaining the same or greater levels of protection compared to today's platforms.

High Strain Rate & Ballistic Materials is focused on novel and specialized materials to enhance the performance and efficiency of Army weapons and protection systems, including lightweight extreme performance materials, novel energetic materials, and energy absorbing materials.

Manufacturing Science, Processing, & Sustainment is focused on discovery, innovation, and maturation of manufacturing innovations to facilitate agile, adaptive, mobile processing & manufacturing capabilities to enable superior performance and implementation of cost reduction methodologies. Sustainability is focused on understanding material properties and degradation mechanisms to improve durability of Army systems in extreme environments.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

Growth of III-V-Nitride Materials and Devices

Growth of materials and device structures targeting sources and detectors operating in the spectral region from ultraviolet to terahertz, using 2 Molecular Beam Epitaxy facilities uniquely configured for high-temperature growth (> 1100 C) and with novel sources (Boron, Be, Nd) and a custom metal-organic chemical vapor deposition (MOCVD) system.

Principal Investigators:	Anand Sampath	anand.v.sampath.civ@mail.mil	(301) 394-0104
	Michael Wraback	michael.wraback.civ@mail.mil	(301) 394-1459
	Meredith Reed	meredith.l.reed.civ@mail.mil	(301) 394-0603

Novel Transparent Hole Injection Schemes for UV Emitters (ALC)

Investigate the incorporation of novel impurity and polarization-enhanced doping schemes to simultaneously improve hole injection and UV extraction efficiency.

Principal Investigator:	Anand Sampath	anand.v.sampath.civ@mail.mil	(301) 394-0104

High-Temperature MBE Growth Dynamics (ALC)

Investigate the dynamics of group III adlayer formation, surface mobility, and adsorption, as well as impurity incorporation in III-N material growth at high growth temperatures comparable to those employed for commercial MOCVD processes.

Principal Investigator:	Anand Sampath	anand.v.sampath.civ@mail.mil	(301) 394-0104

Rare Earth Doped III-Nitride Heterostructure Materials and Devices (ALC)
Investigate the incorporation of rare earth ions into III-Nitride heterostructures and diodes and the impact of large tunable electric fields on the optical properties of the rare earth ions.

Principal Investigator:	Anand Sampath	anand.v.sampath.civ@mail.mil	(301) 394-0104

Phonon Dynamics and Transport in Condensed Matter

This program focuses on femtosecond ultrasonics and thermoreflectance studies of phonon transport across interfaces, elastic properties, and phonon attenuation, as well as pump-probe studies of interaction between electronic and phonon excitations.

Principal Investigator:	Michael Wraback	michael.wraback.civ@mail.mil	(301) 394-1459

Supporting Facility: Femtosecond Pump-Probe Laboratory (ALC)

This program focuses on femtosecond ultrasonics and thermoreflectance studies of phonon transport across interfaces, elastic properties, and phonon attenuation, as well as pump-probe studies of interaction between electronic and phonon excitations.
Equipment Available: Light source includes femtosecond Coherent RegA pumped-optical parametric amplifier (OPA) tunable from UV through IR wavelengths; femtosecond Spectra-Physics Tsunami pumped-inspire high-repetition rate oscillator system tunable from visible through infrared wavelengths.

Physics of Quantum Phenomena

Investigate quantum phenomenon in semiconductor-light interactions for applications in quantum information using coherence spectroscopy. Strong collaborations with ARL theorists.

Principal Investigators:	Michael Wraback	michael.wraback.civ@mail.mil	(301) 394-1459
	Gregory Garrett	gregory.a.garrett.civ@mail.mil	(301) 394-1966
	Grace Metcalfe	grace.d.metcalfe.civ@mail.mil	(301) 394-2864

Supporting Facility: Coherent Spectroscopy Laboratory (ALC)

Four-wave mixing techniques including pump-probe spectroscopy, differential reflection/transmission, and photon echo.
Equipment Available: Light source includes femtosecond Spectra-Physics Tsunami pumped-inspire high-repetition rate oscillator system tunable from visible through infrared wavelengths.

Semiconductor Physics (Vis-NIR through Terahertz)

Investigate carrier dynamics and transport in semiconductor materials used in optoelectronic devices, such as infrared (IR) detectors, solar cells, and liquid/semiconductor junctions using unique Vis/near-IR through terahertz (THz) ultrafast spectroscopy in combination with modeling and data analysis.

Principal Investigators: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459
Grace Metcalfe grace.d.metcalfe.civ@mail.mil (301) 394-2864

Supporting Facility: Visible, Near-Infrared (IR), and Terahertz (THz) Spectroscopy Laboratories (ALC)

Time-resolved photoluminescence in ranges including near IR, Medium-Wave Infared (MWIR) (3-5 microns) and Long-Wave Infared (LWIR) (8-10 microns), time-resolved THz spectroscopy, pump-probe spectroscopy with tunable pulses between 400 nm and 10000 nm, combined pump-probe and THz spectroscopy, continuous-wave THz spectroscopy with tunabilty from 0.09 THz to 1.2 THz.

Equipment Available: Light source includes femtosecond Coherent RegA pumped-OPA tunable from visible through long-wave infrared wavelengths; custom-built continuous-wave THz spectroscopy facility containing sample cells with path lengths from 0.5 m to 9.5 m, and multiple photomixer/Schottky diode sources and detectors to control spectral resolution and tunable range, including coherent heterodyne detection.

Ultrafast Spectroscopy of Electronic, Optoelectronic, & Structural Materials

Femtosecond spectroscopy with ultrashort pulses tunable from 200 nm to 10000 nm, probing dynamics, and transport of electronic and phonon excitations in condensed matter.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Supporting Facility: Ultrafast Spectroscopy Laboratories (ALC)

Multiple laboratories providing femtosecond spectroscopy with lasers continuously tunable from 200 nm to 10000 nm.

Carrier Localization and Recombination Dynamics in Semiconductor Alloys (ALC)

Investigate the impact of alloy and interface fluctuations in semiconductor alloys on carrier transport and recombination using femtosecond pump-probe, electroabsorption, and luminescence.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Radiation and Doping Effects on Minority Carrier Lifetimes in Wide Bandgap Semiconductors (ALC)

Investigate the impact of radiation dosage and doping on minority carrier lifetime using a time-resolved pump probe and luminescence.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Measurement of Thermal and Elastic Properties and Phonon Transport in Textured Ceramics and Wide Bandgap Materials (ALC)

Investigate acoustic phonon propagation in transparent ceramics and other wide bandgap materials as a function of texturing, as well as phonon transport at interfaces of these materials with metals and wide bandgap semiconductors.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Strong Coupling in Nitride Semiconductor Quantum Dots (ALC)
Investigate the coherent transient properties of nitride semiconductor quantum dots in the strong coupling regime.

Principal Investigator: Gregory Garrett gregory.a.garrett.civ@mail.mil (301) 394-1966

High Field Carrier Dynamics and Transport in Deep UV Photodetectors (ALC)
Investigate carrier dynamics and transport above the direct bandgap in SiC and Si deep UV photodetectors.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Hot Carrier Assisted Transport Across Liquid/Semiconductor Junctions (ALC)
Investigate the creation of semiconductor heterostructures that enable electron velocity and energy overshoot at a liquid/semiconductor junction and their impact on transport across the junction.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Nonlinear Optical Properties of III-Nitride Polar and Nonpolar Heterostructures (ALC)
Employ ultrafast spectroscopy to investigate the optical switching dynamics in III-Nitride polar and nonpolar heterostructures for optical modulators.

Principal Investigator: Michael Wraback michael.wraback.civ@mail.mil (301) 394-1459

Wide Band Gap Semiconductor Physics

Investigate carrier dynamics and transport in semiconductor materials used in light-emitting devices, such as light-emitting diodes (LEDs) and lasers, and photodetectors and energy conversion devices operating in the ultraviolet (UV) through visible spectral range using unique UV-visible ultrafast spectroscopy facility, in conjunction with modeling and data analysis.

Principal Investigators:	Michael Wraback	michael.wraback.civ@mail.mil	(301) 394-1459
	Gregory Garrett	gregory.a.garrett.civ@mail.mil	(301) 394-1966

Supporting Facility: Ultraviolet (UV)-Visible Spectroscopy Laboratory (ALC)

UV (200-400 nm)-visible time-resolved photoluminescence including unique sub-picosecond optical gating, time-correlated single photon counting, and synchronous-scan streak camera. Continuous-wave photoluminescence. Femtosecond pump-probe spectroscopy with tunable UV pump and probe pulses.
Equipment Available: Light source includes femtosecond Coherent RegA pumped-optical parametric amplifier (OPA) tunable from UV through visible wavelengths, and high brightness, broadband, continuous-wave energetic laser-driven UV light source.

Photon Traps for Infrared Detectors

The mission of ARL includes the research and development future infrared detectors to improve Army operation. ARL is striving to build an advanced scientific and engineering infrastructure to further existing technologies as well as realize new detection capabilities unimagined today. Currently, we are exploring a new type of detector architecture we call the photon trap infrared detector. This detector captures and traps incident photons until they are absorbed in the material. Under this approach, the detector no longer needs a thick or highly absorbing material, with which many types of materials become useful. ARL offers a wide range of material growth and processing facilities that can bring a pure concept from the idea stage to a prototype camera for field test in Army relevant environment. Working with ARL, one can assure that every worthy concept will be examined carefully and has a significant chance in impacting national security. In addition to device concepts, ARL also seeks R&D collaborations in fundamental sciences, material growth, detector and array fabrication and testing, readout integrated circuits, camera integration, and field demonstration.

Principal Investigator: Dr. KK Choi kwong.k.choi.civ@mail.mil (301) 394-0495

Supporting Facilities:

IR detector and focal plane array characterization lab, and the SEMASC

Quantum Memories and Components for Quantum Communication and Networking

Investigate quantum systems capable of generating, storing and processing entangled quantum information. Integrate quantum memories, including neutral atom and atomic ions, in an entangled quantum network connected through fiber and free-space. Explore and develop components needed for remote entanglement between quantum devices, include quantum frequency conversion, high efficiency photon retrieval and transmission and integrated interference and detection of photon pairs. Develop modular and compact quantum devices, including detectors, quantum interfaces and quantum memories for integration into a quantum network. Develop theoretical models for the behavior of quantum devices and theoretical protocols and applications for a distributed entangled quantum network.

Principle Investigator: Qudsia Quraishi Qudsia.quraishi.civ@mail.ml (301) 394 - 2239

Supporting Facilities: Cold Atom Optics and Quantum Network Laboratory (ALC)

The Cold Atom Optics and Quantum Network Laboratory laser-cools atoms to millionths of a degree above absolute zero and then traps the atoms using wires on a microfabricated chip. The lab exploits the atoms' quantum nature for applications in timekeeping, inertial sensing, and quantum information processing. A quantum fiber network between ARL and the Joint Quantum Institute at the University of Maryland, College Park enables the transfer of photons carrying quantum information between research laboratories at the two institutions. Current experiments use cold atoms as quantum memory and quantum processors for sending and receiving photons across the fiber.

Advanced Solid-State Lasers

Development of state-of-the-art solid-state laser technologies to enable medium to high-power lasers. Research areas include both bulk solid and fiber gain media in various near- and mid-infrared wavelength ranges, for both CW and pulsed operation.

Principal Investigators: Larry Merkle larry.d.merkle.civ@mail.mil (301) 394-0941
Mark Dubinskiy mark.dubinskiy.civ@mail.mil (301) 394-1821

Bulk Solid-state Laser Materials with Superior Thermal Properties (ALC)

Research on high thermal conductivity hosts for laser ions, composites of laser materials and high thermal conductivity materials, and techniques for their use.

Principal investigators: Alex Newburgh george.a.newburgh.civ@mail.mil (301) 394-2007

Highly power-scalable fiber lasers (ALC)

Research on diode-pumped rare-earth doped and Raman fiber lasers with properties that enable high efficiency and scalability to very high powers, while preserving excellent beam quality. Wavelengths of interest include (but are not limited to) ~1 µm and ~1.6 µm.

Principal investigator: Jun Zhang jun.zhang4.civ@mail.mil (301) 394-1827

Efficient Solid-state Lasers at Mid-infrared Wavelengths (ALC)

Research on laser materials that enable unusually high efficiency at mid-infrared wavelengths such as three microns, and on their use to pump devices with still longer-wavelength emission.

Principal investigator: Tigran Sanamyan tigran.sanamyan.civ@mail.mil (301) 394-2044

Pulsed Laser Materials and Techniques (ALC)

Research on efficient diode-pumped pulsed lasers (mode-locked and Q-switched) primarily at wavelengths near ~1 µm and ~1.6 µm.

Principal investigator: Nikolay Ter-Gabrielyan nikolay.e.ter-gabrielyan.civ@mail.mil (301) 394-1579

Supporting Facilities

High Power Fiber Laser Lab: Unique, high-power Fiber Laser Testbed, primarily for CW lasers at eye-safe wavelengths.
Materials Characterization Lab: Absorption and fluorescence spectroscopy facilities, thermal conductivity.
Eye-safe (~1.6 µm) Solid-state Laser Lab: Pump diodes, characterization and laser testing facilities for bulk and Raman fiber lasers.
Two-micron Laser Lab: Pump diodes, characterization and laser testing facilities for Tm- and/or Ho-doped lasers.
Designated Open Campus Lab: Facilities for development of pulsed eye-safe lasers, both bulk and fiber, principally at ~1.6 µm and ~2 µm.

RF Photonics

Research on the generation, transportation, reception, and signal processing of RF domain signals in the optical domain for applications in Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR), Electronic Warfare (EW), and Position, Navigation and Timing (PN&T).

Principal investigators: Weimin Zhou weimin.zhou.civ@mail.mil (301) 394-1435
Olukayode Okusaga olukayode.k.okusaga.civ@mail.mil (301) 394-1983

Supporting Facilities:

RF-Photonics Lab: State-of-the-Art phase noise measurement system; Unique RF-Photonic analog correlation receiver system; Ultra-low-phase noise optoelectronic oscillator system
Optical Waveguide Device Characterization Lab: Meta-structure slow-light hollow-core waveguide test; Low-loss waveguide test.

Piezoelectric MicroElectroMechanical Systems (PiezoMEMS) Technology

Research based on improving the current state of the art in piezoelectric thin film materials and fabrication processing, device modeling and simulation, and material and prototype testing and evaluation used as sensors, actuators, and microelectromechanical structures for RF communication and radar systems (e.g. switches, phase shifters, resonator and filters, transformers, tunable microwave components), mm-scale robotics (e.g. mobility actuators and proprioceptive sensors), position, navigation, and timing, or PNT (e.g. gyroscopes, accelerometers, and integrated package and assembly strategies).

Principal Investigator: Ronald Polcawich ronald.g.polcawich.civ@mail.mil (301) 394-1275

Supporting Facilities: Specialty Electronic Materials and Sensors Cleanroom (SEMASC) (ALC)

This 15,000 gross square feet Class 10 and 100 cleanroom facility houses a comprehensive set of semiconductor fabrication tools—including specialty material deposition, etch, lithography, and thermal—and research characterization systems for the next generation of sensors and electronic devices for the Soldier. These systems enable the fabrication of advanced micro and nanoscale devices using an extremely broad set of device materials including silicon; III-V and IIVI semiconductors; silicon carbide; quartz; lead zirconate titanate (PZT) and aluminum nitride piezoelectrics; many metals and oxides; and graphene and carbon nanotubes. Support applications fabricated with these devices range from bio- and trace gas detection; secure communication (radiofrequency [RF] switches, filters, varactors, and tunable inductors); improvised explosive device (IED) detection (RF switches and filters); mobile sensor platforms for Soldier Intelligence, Surveillance, and Reconnaissance (bio-inspired microflight and terrestrial actuation, ultrasonic motors, bio-inspired sensors); traumatic brain injury (shock sensor, G-switch); RF (resonators, switches); power generation (microturbine, energy harvesting); infrared, ultraviolet, and optical detectors and emitters (imagers, lasers, LEDs); on-chip energetic devices (microthrusters, fuzing); and next-generation flexible, transparent, and high performance electronics and devices based on graphene and other 1D and 2D materials.

Advanced Concepts for RF Antennas

Develop specialized and low-profile, high performance antennas and phased arrays for Army sensor, communications and electronic warfare systems using novel design techniques and specialized materials. Research includes investigation of metamaterial and metaferrite design techniques for extremely low-profile, broadband antennas and the application of emerging nanomaterials (e.g. carbon nanotubes, graphene) for durable, textile integrated and flexible antennas.

Principal Investigators: Eric Adler eric.d.adler.civ@mail.mil 301-394-0933
Steven Weiss steven.j.weiss14.civ@mail.mil 301-394-1987

Nanomaterials for Flexible and Textile-Integrated Antennas (ALC)

Investigate the application of emerging nanomaterials such as carbon nanotubes and graphene to flexible, textile-integrated, and multifunctional (e.g. gas sensor, strain gauge) RF antenna designs.

Principal Investigator: Steven Keller steven.d.keller8.civ@mail.mil 919-280-6670

Electrically Small Antennas (ALC)

Develop small antennas to replace conventional dipole antennas with additional operational features and shapes. This includes structures that are produced using 3-D printers and make use of surface-filling curve concepts and metamaterial-enhanced designs. Optimizing the designs for broadband matching and simple feeding mechanisms are goals.

Principal Investigator: Amir Zaghloul amir.i.zaghloul.civ@mail.mil 301-394-0886

Metasurfaces and/or Periodic and Random Metamaterials for Broadband, Low-profile Antennas (ALC)

Develop supporting surfaces for antennas to produce desired reflection phase properties that result in low profiles for the antenna/surface combination. The metasurfaces may fall under light-weight metaferrite surfaces for high permeability, electromagnetic band-gap structures for high-impedance surfaces, and tunable surfaces for adaptive reflection properties of surfaces, all operating over a broadband. Additionally, investigate the theoretical underpinnings and design of periodic and randomly oriented metamaterials for broadband low-profile antenna design through analysis, electromagnetic simulation and prototype measurement.

Principal Investigator: Amir Zaghloul amir.i.zaghloul.civ@mail.mil 301-394-0886

Magnetic Metamaterials for Broadband, Low-profile Antennas (ALC)

Design of low-profile magnetic metamaterials for broadband antenna design through analysis, electromagnetic simulation and prototype measurement.

Principal Investigator: Steven Weiss steven.j.weiss14.civ@mail.mil 301-394-1987

Supporting Facility: Antennas Laboratory (ALC)

Equipment Available: Multi-room laboratory that enables antenna design/simulation, fabrication, and measurement. Equipment includes: Computer with Ansoft HFSS, EMSS FEKO, Agilent ADS/Momentum, REMCOM XFdtd, network analyzers, spectrum analyzers, oscilloscopes, miscellaneous electronics, circuit board router, 3-D printer.

Supporting Facility: Far-field Anechoic Chamber (ALC)

Equipment Available: Indoor facility that enables accurate antenna radiation pattern and gain measurements (lower frequency limit of ~200 MHz). Equipment includes: Anechoic chamber, standard gain horn antennas, signal generator, RF receivers, network analyzer, and power meter.

Supporting Facility: Near-field Anechoic Chamber (ALC)

Equipment Available: Indoor facility that enables accurate antenna radiation pattern and gain measurements in a compact, convenient chamber (lower frequency limit of ~1 GHz). Equipment includes: Anechoic chamber, standard gain horn antennas, signal generator, RF receivers, network analyzer, and power meter.

Supporting Facility: Electromagnetic Simulation Tools (ALC)

Software Available: Simulation tools support the analysis and design of developed antennas and concepts. This includes full-wave simulation tools such as FEKO, HFSS, and CST, in addition to special purpose software such as Rotman Lens Analysis and other in-house developed tools.

Wide Band Gap Power Device Reliability

Wide band gap power devices are key components for next generation military sub-systems. However, the reliability of these devices has not been well established and the harsh operating conditions that will be typical in military applications are expected to introduce failure modes that are not critical to the commercial market. Therefore, investigation and modeling of key failure mechanisms in emerging GaN and SiC power devices is needed. Research to investigate key degradation mechanisms and failure modes of emerging GaN power semiconductor devices and develop improved test methods that ensure reliable device operation.

Principal Investigator: Aivars Lelis aivars.j.lelis.civ@mail.mil (301) 394-5426

Supporting Facility: Wide Band Gap Electronics Characterization Laboratory (ALC)

Laboratory supports static and dynamic power device evaluation and semiconductor/dielectric interface characterization to study reliability physics.

Equipment Available: Semiconductor parameter analyzers, curve tracers, high voltage/high power SMUs, pulse measurement units for fast I-V, electromagnet for hall effect, ovens and heaters for high temperature testing, semi-automatic and manual probe stations

GaN High Power Electronic Devices

Design, fabricate and test GaN/AlGaN based high power electronic devices. Work on improving the crystalline quality and reducing the background carrier concentration of the semiconductor material, as well as improve the quality of the dielectric used in field plates and for passivating the surface. Develop ion implantation activation processes for junction termination.

Principal Investigator: Kenneth Jones kenneth.a.jones162.civ@mail.mil (301) 394-2005

Supporting Facilities

Complete clean room for fabricating the devices and automated device testing facility to characterize them. Measure the electrical properties of the semiconductor material with Hall effect, C-V profiling, contactless mobility measurements, and DLTS system. Examine the structure of the material with double crystal x-ray diffraction, CL and TEM, and the surface morphology with AFM.

High Power Semiconductor Devices

Design, fabricate and test GaN/AlGaN based high power electronic devices. Work on improving the crystalline quality and reducing the background carrier concentration of the semiconductor material, as well as improve the quality of the dielectric used in field plates and for passivating the surface. Develop ion implantation activation processes for junction termination.

Principal Investigator: Ken Jones kenneth.a.jones162.civ@mail.mil (301) 394-2005

Supporting Facility

ARL Clean room, Power Electronics Measurement Lab, Material Characterization Labs. The ARL Clean room has the facilities for fabricating all types of semiconductor devices. Devices are automatically probed in the measurements lab; those selected for detailed meas are measured at different temp and power settings. Carrier concentrations & mobilities are measured & defect states are probed via DLTS. Clean room lithography, etching, metallization, & dielectric depostion capabilities. Automatic semiconductor probe stations with variable temperature capabilities. Hall effect, contactless conductivity, and DLTS.

Micro-scale / MEMS Power Components

High frequency power conversion will enable fully integrated power supplies on a chip. Such power supplies are attractive for lightweight and wearable power management and distribution networks, power management for portable electronics, miniature robotic platforms, and high efficiency antenna arrays requiring varying voltages at each element. This research area focuses on developing new, high-frequency components, enabled by MEMS and microfabrication, with low-profile and high efficiencies. The modeling fabrication, and characterization of miniature power converter circuits and topologies for power supplies on chip leverages MEMS and micromachined power passive devices.

Principal Investigator: Sarah Bedair sarah.s.bedair.civ@mail.mil 301-394-0021

Supporting Facility

Power passives fabrication laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

Heterogeneous Device Integration

Investigation of a new 3D High Density Integration Process (3D-HIP) to create 3D stacked electronic systems compatible with diverse device technologies, substrates, and materials. 3D-HIP focuses on wafer-level packaging of heterogeneous devices with released MEMS components. Investigation of the modeling and microfabrication of MEMS power passive devices, development of fabrication processes for new power materials and devices, and development of high-efficiency materials (e.g. magnetics and dielectrics) and MEMS / micro-machined devices.

Principal Investigator: Sarah Bedair sarah.s.bedair.civ@mail.mil 301-394-0021

Supporting Facility

Power Passives Fabrication Laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

High Voltage Power Electronics

Develop components and materials that will enable the next-generation of high-power military electronics. Investigate system, component, and materials implications of high voltage (>50kV) power electronics.

Principal Investigator: Wes Tipton wes.tipton@us.army.mil (301) 394-5209

Supporting Facility

The ARL Power Conditioning Laboratory is equipped to design, fabricate, and evaluate power conversion systems operating at 200 kW and 50 kV. Available resources include voltage power sources up to 150kV, electronics diagnostic instruments.

Power Control & Distribution

Investigate circuit breaker architectures and semiconductor device performance to improve the performance of 1200V class solid state circuit breakers. Also design sensing and supporting control electronics.

Principal Investigator: Damian Urciuoli damian.p.urciuoli.civ@mail.mil (301) 394-3240

Supporting Facility

Pulse power testbeds, simulation software, circuit design software, data acquisition equipment.

Extreme Semiconductor Switching - Design, Evaluation, Simulation, Analysis (ALC)

Research supporting the Army's extreme switching needs for high-power systems. Includes surveying and analyzing Army application needs, designing appropriate evaluation circuitry and techniques, understanding mechanics and safety of working with high power, evaluating and analyzing components, collaborating with external research partners, developing models of devices and applications, and creating a better understanding of semiconductor physics under extreme electrical conditions.

Principal Investigator: Skip Scozzie charles.j.scozzie.civ@mail.mil (301) 394-5211

Supporting Facility

The Power Conditioning Lab is designated for high-voltage, high-current, and high-energy circuits and component evaluations at the several kilo-volt, kilo-amp, and kilo-joule levels. List of equipment: high-voltage power supplies, passive components capable of high-energy storage and dissipation, curve tracers, oscilloscopes, probes, a large oven, and safe procedures and barriers in place for high-power work.

Semiconductor Components and Simulations (ALC)

Investigation of Army extreme switching needs and evaluation of semiconductor components to their maximum capabilities at high voltage, high current, varying pulse widths, varying duty cycle, across wide temperature ranges. Includes circuit design, measurement technique, data analysis, and study of semiconductor physics. Implement models and active simulations of existing or future semiconductor components, and develop an understanding of semiconductor physics and how to incorporate laboratory measurements with simulations.

Principal Investigators:	Heather O'Brien	heather.k.obrien.civ@mail.mil	(301) 394-5545
	Aderinto Ogunniyi	aderinto.a.ogunniyi.civ@mail.mil	(301)394-0058

Wide Band Gap Semiconductor Packaging Materials and Technologies (ALC)

Investigate novel packaging materials and technologies for high temperature and high voltage power electronics applications to enable the next-generation of high-power military electronics.

Principal Investigator:	Dimeji Ibitayo	oladimeji.o.ibitayo.civ@mail.mil	(301) 394-5514

Supporting Facility

The ARL Power Semiconductor Packaging Laboratory is designated to develop and evaluate advanced packaging technologies and processes that enable higher performance and reliability of electrical power conversion in Army systems.

3kW to 300kW AC/DC Microgrids Hardware/Software/Hardware-Software Control

Advance technologies for efficient utilization of all available energy and to provide intelligent distribution of power. Technologies to encompass simple to use power distribution hardware; power line sensing that can learn and apply load and source signatures; prognostics and diagnostics for loads and sources; lightweight and compact multi function power conversion and distribution systems and compact energy dense energy storage systems. Technologies to encompass distributed control of power distribution systems and the estimation and prediction of solar flux on PV arrays. Technologies to encompass cognitive systems for improved and automated Data-to-Decision; utilization of learned behaviors from previous operations; Software that can rapidly adapt to grid operation while learning system behavior; use of tangible and intangible energy costs in the prioritization of demands; trainable systems and the utilization of learned behaviors from previous operations.

Principal Investigators:	Bruce Geil	bruce.r.geil@mail.mil	(301) 394-3190
	Donald Porschet	donald.h.porschet.civ@mail.mil	(301) 394-5528

Tactical Energy Network Research Facility (TENRF) Command, Control, Communications, Computer and Intelligence (C4I) (ALC)

Implement novel AC/DC Micro-grid related command, control, communications, and computer and intelligence structures in a controlled environment.

Principal Investigators:	Donald Porschet	donald.h.porschet.civ@mail.mil	(301) 394-5528
	Damian Urciuoli	damian.p.urciuoli.civ@mail.mil	(301) 394-3240
	Wes Tipton	wes.tipton@us.army.mil	(301) 394-5209

Supporting Facility

Tactical Energy Network Research Facility (TENRF) is intended to serve as a Stat- of-the-Art facility for testing 6.1 - 6.5 micro-grid focused components in a controlled setting with highly variable and configurable AC/DC sources and loads. Available resources include both 18 kVA & 36 kVA variable frequency/voltage power sources, 20 kW 208 VAC/3 ph generator, PhotoVoltaic Simulator, 10 kW Dynomometer, Dynamic AC/DC loads and a Real Time Digital Simulator.

3kW to 300kW AC/DC Microgrids Modeling and Simulation

Develop modeling and simulation software and architecture analysis for tactical energy networks.

Principal Investigator: Ed Shaffer edward.c.shaffer.civ@mail.mil (301) 394-2002

Modeling and Simulation for Novel Microgrid Architectures and Technologies (ALC)
Develop novel simulation platform for modeling and analysis of microgrid power system architectures. Develop library of tools for optimized design and simulation of microgrid and power electronics components integration, and various energy management systems.

Principal Investigator: Ed Shaffer edward.c.shaffer.civ@mail.mil (301) 394-2002

Supporting Facility

Modeling and simulation effort and architectuaral analysis for microgrids and microgrid components integration. Access to numerous software packages Matlab, LabView, Simulink.

Nanoelectronics and Nanosensors for Army Applications

Explore and exploit layer interactions in stacks of emerging 2D materials to engineer new materials to enable transparent, high performance tunable/mutlifunctional/conformal electronics.

Principal Investigator: Madan Dubey madan.dubey.civ@mail.mil (301) 394-1186

Supporting Facilities: Specialty Electronic Materials and Sensors Cleanroom (SEMASC) **(**ALC**)**

This 15,000 gross square feet Class 10 and 100 cleanroom facility houses a comprehensive set of semiconductor fabrication tools—including specialty material deposition, etch, lithography, and thermal—and research characterization systems for the next generation of sensors and electronic devices for the Soldier. These systems enable the fabrication of advanced micro and nanoscale devices using an extremely broad set of device materials including silicon; III-V and IIVI semiconductors; silicon carbide; quartz; lead zirconate titanate (PZT) and aluminum nitride piezoelectrics; many metals and oxides; and graphene and carbon nanotubes. Support applications fabricated with these devices range from bio- and trace gas detection; secure communication (radiofrequency [RF] switches, filters, varactors, and tunable inductors); improvised explosive device (IED) detection (RF switches and filters); mobile sensor platforms for Soldier Intelligence, Surveillance, and Reconnaissance (bio-inspired microflight and terrestrial actuation, ultrasonic motors, bio-inspired sensors); traumatic brain injury (shock sensor, G-switch); RF (resonators, switches); power generation (microturbine, energy harvesting); infrared, ultraviolet, and optical detectors and emitters (imagers, lasers, LEDs); on-chip energetic devices (microthrusters, fuzing); and next-generation flexible, transparent, and high performance electronics and devices based on graphene and other 1D and 2D materials.

Electronic Materials, Devices, and Circuits

This program focuses on areas of modeling, processing, fabrication, and metrology of advanced electronic materials & devices to enable more efficient high frequency circuits.

Principal Investigator: Romeo D Del Rosario romeo@arl.army.mil (301) 394-3562

Emerging Technologies for Semiconductors (ALC)

Characterization and control of trace impurities, defects and interfaces in semiconductors and masks are of interest, particularly for sub90-nm devices and circuits.

Principal Investigator: Glen Birdwell anthony.g.birdwell.civ@mail.mil (301) 394-0601

Emerging Technologies for Semiconductors (ALC)

Principal emphasis is on surface or interface control during processing of these materials, characterization of their near-surface transport behavior and surface properties, and modeling or theoretical predictions of their properties.

Principal Investigator: Tony Ivanov tony.g.ivanov.civ@mail.mil (301) 394-3568

III-V Devices

This program focuses on improved microwave and mm-wave (up to 200 GHz) devices that are reliable and cost effective to handle large volumes of data on a real-time basis.

Principal Investigator: Romeo D Del Rosario romeo@arl.army.mil (301) 394-3562

III-V Devices (ALC)

Physics-based modeling of microwave devices, components, packages, and radiating structures using semiconductor analysis and computational electromagnetic.

Principal Investigator: John Penn john.e.penn16.civ@mail.mil (301) 394-3568

III-V Devices (ALC)

Model extraction techniques to obtain lumped element models for circuit designs up to the GHz to THz frequency range, Devices support RF/power applications for operating in extreme environments such that high temperature performance and thermal management and packaging issues become critical.

Principal Investigator: Edward Viveiros edward.a.viveiros2.civ@mail.mil (301) 394-0930

Silicon Analog and Mixed Signal Integrated Circuits

This program focuses on areas of broadband integrated circuit design with leading edge nodes/technologies and analysis to enable efficient (low power) broadband complex-modulated vector-waveforms for applications in communication, radar and electronics warfare.

Principal Investigator: Romeo D Del Rosario romeo@arl.army.mil (301) 394-3562

Silicon Analog and Mixed Signal Integrated Circuits (ALC)

Novel broadband high-frequency circuits and techniques for modulation and demodulation of complex waveforms including circuits and techniques to generate and distribute highly stable and low jitter clock signals.

Principal Investigator: James Wilson james.e.wilson889.civ@mail.mil (301) 394-0328

Advanced Battery Chemistries

Fundamental and applied research on advanced battery materials.

Principal Investigator: Cynthia Lundgren cynthia.a.lundgren2.civ@mail.mil (301) 394-2541

Electrolyte Additives for Advanced Battery Chemistries (ALC)

Breaking out the limit on energy densities of Li ion batteries, advanced (or "beyond Li ion") battery chemistries pursues the ability of accommodating Li^+ or other guest cations (Na^+, Mg^{2+}) by adopting non-intercalation type electrode materials, whose drastic morphologic change presents unprecedented challenge to electrolyte and interphases. This research opportunity aims to develop and understand interphasial chemistry of electrolytes or additives for "Beyond Li Ion Chemistries" using Si anodes, Na and Mg electrolytes, S and O^2 cathodes.

Principal Investigator: Kang Xu conrad.k.xu.civ@mail.mil (301) 394-0321

Dual Intercalation Battieries (ALC)

There are project areas including the investigation of new electrolytes and electrolyte additives that improve the performance of dual-graphite cells for grid storage applications, fundamental studies to characterize the material property changes in anion intercalated graphite, and applied research on full dual-graphite cell performance.

Principal Investigator: Jeffrey Read jeffrey.a.read4.civ@mail.mil (301) 394-0313

Solid Li-Ion Conducting Membranes (ALC)

Investigation of new solid Li-ion conducting materials and their processing into dense membranes and structural, physical and electrochemical characterization at room and elevated temperature. Evaluation of the chemical and electrochemical stability of solid Li-ion conductors based on the garnet structure with various potential anode (e.g., lithium) and cathode (e.g., sulfur) materials at room and elevated temperature.

Principal Investigator: Jeff Wolfenstine jeffrey.b.wolfenstine.civ@mail.mil (301) 394-0317

Li Ion Batteries (ALC)

Fundamental and applied research on developing higher energy density safe Li-ion batteries, which are to be achieved through the use of high voltage and/or high capacity intercalation type compounds as cathode and carbonaceous materials with or without Li alloys such as LiSix alloys as anode, than the state-of-the-art Li-ion batteries. Developments of structurally stable cathodes are urgently needed. Meanwhile, electrolytes that are compatible with both the new cathodes and anodes are also in urgent need.

Principal Investigator: Richard Jow t.r.jow.civ@mail.mil (301) 394-0340

Solid-Electrolyte Interphase (SEI) Characterization (ALC)

Principal Investigator: Arthur Von Cresce Arthur.v.cresce.civ@mail.mil (301) 394-1967

Computational Modeling of Battery Materials (ALC)

Computational modeling of battery materials from quantum to mesoscale levels with a focus on understanding structural and transport properties of battery electrolytes and SEI components in bulk and at the interfaces. Modeling of electrolyte oxidation and reduction stability, prediction of electrolyte decomposition reactions at electrodes.

Principal Investigator: Oleg Borodin oleg.a.borodin.civ@mail.mil (301) 394-0066

Supporting Facility

Dedicated lab space (dry room, fume hoods, glove boxes) and equipment for processing (e.g., high energy mixers/mills, high temperature inert atmosphere furnaces) and characterization (e.g., thermal analysis set-up, x-ray diffraction unit, electron microscopy facility, in-situ atomic force microscope, high frequency impedance analyzers, potentiostats/galvanostats).

Polymeric Dielectrics for Next Generation Capacitors

Fundamental and applied research on advanced high energy density polymeric dielectrics and capacitors.

Principal Investigators:	Janet Ho	janet.s.ho.civ@mail.mil	(301) 394-0051
	Richard Jow	t.r.jow.civ@mail.mil	(301) 394-0340

Dielectric Performance (ALC)

Army needs to go beyond the present state-of-the-art poly(propylene) and poly(ethylene terephthalate) for pulse power and power conditioning applications. The immediate research opportunity aims to modify existing commercially-available capacitor-grade polymers either by surface treatments or polymer structure alteration in solid state to improve dielectric performance, through an interconnected feedback between experimental research and first-principle computational modeling such as density-functional theory. The future research will leverage results from the present MURI “Rational Design of Advanced Polymer Capacitor Dielectrics” sponsored by Office of Naval Research to tailor-make new materials.

Principal Investigators:	Janet Ho	janet.s.ho.civ@mail.mil	(301) 394-0051
	Richard Jow	t.r.jow.civ@mail.mil	(301) 394-0340

Higher Energy Density Polymeric Dielectrics (ALC)

The Army is in need of higher energy density film capacitors than the state-of-the-art capacitors made of biaxially oriented polypropylene (BOPP) for high pulse power and continuous power condition applications. To achieve this goal, higher energy density polymeric dielectrics that can withstand high field under fast charge/discharge conditions and high temperatures at around or above 150 oC with low loss are urgently needed. Research areas of interest include the following. Investigate breakdown mechanism in relation to morphology (amorphous vs. crystalline polymers), processing condition (melt extrusion vs. solution cast) and polymer structures (high molecular weight, backbone and functional groups) of advanced polymers such as high temperature polycarbonate and fluoropolymers. Develop and investigate techniques for improved polymer metal interfacial bonding, polymer/blocking layer/metal interfacial bonding for high current capability and self-clearing under breakdown conditions.

Principal Investigators:	Janet Ho	janet.s.ho.civ@mail.mil	(301) 394-0051
	Richard Jow	t.r.jow.civ@mail.mil	(301) 394-0340

Microfluidics for Energy Conversion

Microfluidics play an important role in shrinking energy conversion devices. Current thrusts are focused on electrospray fuel injection, direct fuel vaporization in micro-channels, and micro-channel heat recuperation for monolithic integration with combustion heat sources. Design, modeling, and microfabrication of electrospray and microchannel devices, and experimental characterization of the devices for multiplexed electrospray and microchannel liquid vaporization, respectively, of JP-8 fuel. Investigating methods to electrospray JP-8 without additional electrostatic additives, and implement the methods into the compact, multiplexed electrospray devices.

Principal Investigator: C. Mike Waits christopher.m.waits.civ@mail.mil (301) 394-0057

Supporting Facility

Dedicated lab space contains extensive capability for liquid spray characterization and micro-channel visualization and measurements. Extensive use of the ARL clean room and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software.

Equipment Available: Phase Doppler Particle Analyzer, high voltage power supplies, low flow rate VICI liquid gear pump, optical inspection equipment, high speed camera, DAQ.

Microcombustion

Pursuit of micro-combustion technology focuses on developing highly efficient and scalable heat sources using JP-8 and other fuel alternatives. These heat sources can be combined with energy conversion technology to develop compact, high density power sources or serve as an efficient heat source for applications like cooking stoves. Developing new approaches to integrate combustion, heat recuperation and liquid vaporization that enable scaling combustion based power sources for extremely compact platforms. Investigation of improved experimental techniques for micro-combustion and improved fast numberical techniques to combine thermal, mass transport, and reaction (surface and gas-phase) modeling.

Principal Investigator: C. Mike Waits christopher.m.waits.civ@mail.mil (301) 394-0057

Supporting Facility

Dedicated lab space provides fume hoods for micro-reactor characterization and equipment for catalyst preparation. Catalytic Conversion Laboratory also utilized for chemical analysis. Extensive use of the ARL clean room and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software.

Equipment Available: LabVIEW controlled micro-reactors with flow, visiual, and thermal characterization equipment. High temperature oven.

Thermal-to-electric Energy Conversion

Electrothermal characterization of thin-films, measurements of radiative heat from gray-body or selective emitters, setting up and running experiments that characterize thermal-to-electric conversion components and breadboard systems, and analyzing collected data. Investigate the design, materials, and preferred approach to integrate high spectral efficiency selective emitters with micro-combustors and/or meso-scale combustors.

Principal Investigator: C. Mike Waits christopher.m.waits.civ@mail.mil (301) 394-0057

Supporting Facility

Dedicated lab space provides fume hoods for micro-reactor characterization and equipment for catalyst preparation. Catalytic Conversion Laboratory also utilized for chemical analysis. Extensive use of the ARL clea nroom and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software.

Equipment Available Phase Doppler Particle Analyzer, high voltage power supplies, low flow rate VICI liquid gear pump, optical inspection equipment, high speed camera, DAQ

Wireless Power

Wireless power transfer is attractive for electronics at power levels ranging from milliwatts for body health monitoring up to kilowatts for vehicle charging, and at all levels in between. However, implementations of wireless power solutions are commonly disrupted by poor efficiency and poor adapatability in dynamic environments. New materials, circuits, and topologies are required to provide solutions that are better than the legacy power cord. For example, soldiers are being outfitted with an ever increasing number of electronic gadgets, each of which has unique battery requirements. An inductively coupled wireless power solution is required to distribute power from a single, centrally-worn battery source to numerous electronic devices at length scales up to 1 m.

Principal Investigator: Chris Meyer christopher.d.meyer1.civ@mail.mil 301-394-4286

Supporting Facility

Power passives fabrication laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

Energy Harvesting

Energy harvesting could enable indefinite-length missions in hostile environments, but any solutions must carefully balance stringent requirements in power levels, metabolic cost, comfort, durability, and ease of use. A systems-level model is required to guide the development of new energy harvesting technologies that can simultaneously handle the breadth of possible use cases while capturing the intricacies of power management and human behavior.

Principal Investigator: Chris Meyer christopher.d.meyer1.civ@mail.mil 301-394-4286

Supporting Facility

Power passives fabrication laboratory - Integrated power passives require low loss materials with nano- and micro-scale feature resolutions. Electrochemical plating chemistries and power supplies for depositing copper, nickel, gold, and tin on wafer and chip scale devices. Piezoelectrically driven ink jet deposition of custom nanoparticle solutions. Vacuum degasification.

Solar Fuels

Fundamental research on alternative routes to fuels to include plasmonic catalysis, photosynthesis and direct photoelectrolysis. The development of on-site fuel generation requires disruptive technologies for photocatalytic applications. Plasmonics and metamaterials offer a great potential to increase reaction rates and solar absorption cross-sections for photoelectrochemical reactions. Nanostructured arrays are intricately designed to enhance and manipulate electric fields which impart energy to the desired reactions, such as water splitting and synthesis of carbon based fuels.

Principal Investigator: Cynthia Lundgren cynthia.a.lundgren2.civ@mail.mil (301) 394-2541

Alternative Routes to Fuel - Effect of EM Radiation and Metamaterials on Catalysis (ALC)
Fundamental research on the use of different types of EM radiation and metamaterials and their effects on catalysis for the purpose of making fuels out of readily available resources. Photosynthesis, artificial photosynthesis, direct photoelectrolysis with wide bandgap semiconductors, plasmonically enhanced electrocatalysis, effects of electromagnetic fields on catalysis.

Principal Investigator: Cynthia Lundgren cynthia.a.lundgren2.civ@mail.mil (301) 394-2541

Supporting Facilities

Several facilities at ALC support this research area. The Electrochemistry lab uses potentiostats and light sources for solar simulation purposes along with optical elements for electrochemical characterization. ARL clean room tools are used for sample fabrication. Modeling techniques used for directed sample design.

Ultra-energetic Materials

Radioisotopes store ~ 100,000× times the energy density of chemical batteries, and many release that energy on a time scale of decades or longer. Practical packaging of radioisotopes like tritium or ^{63}Ni, and improved energy conversion techniques may enable drop-and-forget sensor networks for persistent battlespace awareness. An ability to control the rate and mechanism of energy release may enhance this or other applications, based on manipulation of nuclear isomers. These are excited quantum states of atomic nuclei with very long half-lives, due to their large angular momenta, that can also exceed decades: in the most extreme case the isomer of ^{180}Ta lives longer than 10^{16} years, while its ground state half-life is 8.2 hours. Nuclei can, therefore, be "switched" between long-lived (energy storage) and short-lived (energy release) states upon demand, using reactions to access pathways via higher-lying levels. This process has been demonstrated experimentally for five isomers, with the most recent being the switching of ^{108m}Ag at ARL. Practical use of isomers will require better understanding of the physics of switching, production of isomers, matching of switching devices and efficient energy conversion. The ARL research program in this field represents a unique effort.

Principal Investigators: James J. Carroll james.j.carroll99.civ@mail.mil (301) 394-0243
Marc Litz marc.s.litz.civ@mail.mil (301) 394-5556

Radiation Detection and Effects on Materials; Nuclear Physics (ALC)

Existing theory is not sufficient to predict the paths for depletion of energy from excited nuclear states (isomers) to ground states or decaying isotopes. Basic and applied research investigating nuclear structure is required in order to better understand both stimulating and depleting excited states within the nucleus. Both energy storage(stimulated) and energy-on-demand(depleted) conversion paths are studied. Detailed characterization of radiation detectors, radiation effects in materials and measurement of fundamental properties of nuclear reactions and nuclear structure are pursued.

Principal Investigator: James J. Carroll james.j.carroll99.civ@mail.mil (301) 394-0243

Radioisotope Battery Development (ALC)

Applied research focuses on energy conversion from decaying isotopes for utilization as a power source. Energy conversion efficiencies of phosphors under stimulation of keV energy electrons from beta-decay are studied. Bulk material properties and fabrication dependent surface properties of photovoltaic energy conversion is evaluated with specific interest in minimizing dark currents under low-light conditions. Nuclear scattering and transport processes in semiconductors are modeled with the goal of designing higher efficiency direct energy conversion wide band-gap materials.

Principal Investigator: Marc Litz marc.s.litz.civ@mail.mil (301) 394-5556

Supporting Facility

X-ray Effects Laboratory (XEL) for studies on radiation detection and radiation effects on materials; nuclear physics studies. Extensive instrumentation for dosimetry and spectroscopy of radiation, and ability to produce electron and photon beams with energies in the 1 - 6 MeV range. 1 MeV/2 MeV electron linear accelerator. 6 MeV electron linear accelerator. Radiochromic film dosimeter system. Extensive suite of alpha, beta and gamma-ray detectors, including single-crystal and Clover HPGe detectors, with associated analog and digital-processing instrumentation. Tritium laboratory for development and testing of isotope battery configurations.

AlGaN Beta(photo)voltaic Batteries

Design, fabricate and test GaN/AlGaN based betavoltaic and betaphotovoltaic devices. In betavoltaics work on improving the ability to capture excited electrons and holes before they recombine by creating a wider depletion layer and associated electric field using polarization effects. In betaphotovoltaics work on improving the efficiency of phosphors excited by beta particles and matching the AlGaN energy gap to their output spectra. Develop devices for both ^{3}H and ^{63}Ni.

Principal Investigators: Ken Jones kenneth.a.jones162.civ@mail.mil (301) 394-2005
Jeff Carroll james.j.carroll99.civ@mail.mil (301) 394-0243

Supporting Facilities

Complete clean room for fabricating the devices and automated device testing facility to characterize them. Test the device response with *i*-V, photo *i*-V, and EBIC. Measure the electrical properties of the semiconductor material with Hall effect, C-V profiling, contactless mobility measurements, and DLTS system. Examine the structure of the material with double crystal x-ray diffraction, CL and TEM, and the surface morphology with AFM. Nuclear facilities

Nuclear Batteries

Design, fabricate and test GaN/AlGaN based betavoltaic and betaphotovoltaic devices. In betavoltaics work on improving the ability to capture excited electrons and holes before they recombine by creating a wider depletion layer and associated electric field using polarization effects. In betaphotovoltaics work on improving the efficiency of phosphors excited by beta particles and matching the AlGaN energy gap to their output spectra. Develop devices for both 3H and 63Ni.

Principal Investigators: Ken Jones kenneth.a.jones162.civ@mail.mil (301) 394-2005
James J. Carroll james.j.carroll99.civ@mail.mil (301) 394-0243

Supporting Facilities (ALC)

ARL Cleanroom, Power Electronics Measurement Lab, Material Characterization Labs. The ARL cleanroom has the facilities for fabricating all types of semiconductor devices. Electronics measurements lab has the ability to measure the IV and photo-IV properties as well as make EBIC measurements. Cleanroom lithography, etching, metallization & dielectric depossition capabilites. Semiconductor probe stations can measure IV and photo-IV. Modified SEM can make EBIC and CL measurements.

Superconducting Materials Investigation

High Temperature YBCO-based Superconductors (HTS) have high potential for a wide range of applications. The objective is to increase the critical current density of YBCO superconductors by pinning enhancement and precise control of energy transfer and mass transfer by MOCVD deposition. Basic and applied research on materials growth of YBCO with process parameter optimization, superconductivity measurements and characterization, and performance evaluation in certain aspects. Additional phenomena such as persistent current relaxation and normal zone propagation will be studied, as well as potential application of YBCO in sensor development.

Principal Investigator: Charles Rong charles.c.rong.civ@mail.mil (301) 394-0286

Supporting Facility

Superconductor laboratory at ALC for MOCVD YBCO deposition and persistent current measurement at 77 K.

Catalysis and Fuel Chemistry

Our objective is to rationally design new durable catalyst materials for fuel conversion of JP-8 fuel and its surrogates. This program features materials-by-design approach using multiscale modeling with advanced experimental techniques in synthesis and reaction kinetic studies. Investigation of sulfur tolerant JP-8 combustion catalysts include catalyst synthesis, materials characterization and catalyst evaluation in bench top prototype reactors. Investigation of deactivation of JP-8 combustion catalyst using experiments and kinetic modeling to elucidate the mechanism of catalyst deactivation by coke and sulfur impurities in the catalytic oxidation processes.

Principal Investigator: Ivan Lee ivan.c.lee2.civ@mail.mil (301) 394-0292

Supporting Facility

The Catalytic Fuel Conversion Facility allows catalyst materials preparation, characterization and evaluation. **Equipment Available:** The facility is equipped with LabVIEW controlled reactors, analytical tools such as micro-GC and mass spectrometer, a glove box, a Bruker Vertex 70 FTIR spectrometer with in-situ time-resolved capability, as well as a Quantachrome physiorption-chemisorption analyzer. Other on-site capabilities include X-ray diffraction and electron microscopy.

Fuel Processing

Fundamental and applied research on reforming military jet fuels, alcohols and alternative fuels to syngas for power generation including engines and fuel cells. Efforts include desulfurization of jet fuels, fuel reformation catalysis, desulfurization of syngas, and palladium (Pd) alloy purification membrane and Pd-based membrane reactor design.

Principal Investigators:	Ivan Lee	ivan.c.lee2.civ@mail.mil	(301) 394-0292
	Dat Tran	dat.t.tran4.civ@mail.mil	(301) 394-0293
	Zachary Dunbar	zachary.dunbar.ctr@mail.mil	(301) 394-0306

Supporting Facility

Fuel reforming laboratory with 24/7 unattended operation.
Equipment Available: The facility is equipped with multiple reactors for materials evaluation, and analytical tools such as micro-GC, mass spectrometer, GC/MS with sulfur chemiluminescence detector, total sulfur analyzer, and sulfur gas detector for reformate analysis.

Alkaline Fuel Cells (ALC)

Fundamental research and development projects on alkaline membrane fuel cells, involving fuel cell component development, characterizations, and fuel cell tests.

Principal Investigator: Xiaoming Ren xiaoming.ren.civ@mail.mil (301) 394-0379

Supporting Facility

Fuel cell test stations, Impedance analyzer and other electrochemical test equipments, fume hood for electrochemical catalyst synthesis and membrane electrode assembly preparation. Polymer electrolyte membrane and catalysts characterization setups.

Computational Modeling of Alkaline Fuel Cells (ALC)
This area involves the modeling and simulation of anion exchange membrane materials and interfaces relevant to the alkaline membrane fuel cell. Research includes the development and application of models related to transport and interfacial phenomena in the corresponding materials, components, and systems. Of particular interest are efforts related to the transport and stability of the alkaline membrane materials and interfacial processes associated with the elctrochemical (ionomer/catalyst/reactant) interface.

Principal Investigator: Kyle Grew kyle.n.grew.civ@mail.mil (301)394-3561

Microscale Thermal Measurement -Time Domain Thermal Reflectance Measurement of Materials and Interfaces

Time domain thermal reflectance is a technique capable of measuring heat transfer from picosecond to microsecond timescales. The project will focus on improving the fidelity of ARLs TDTR capability, followed by thermal characterization of electronic materials and solid-solid and solid-liquid thermal interfaces. This will include extension of the technique to measure long-time constant transient phenomena. Solid state materials, low melting temperature metals, and other materials are promising phase change materials with limited knowledge of critical material data. Measuring and cataloguing this data is a critical step to enabling future system design.

Principal Investigator: Nick Jankowski nicholas.r.jankowski.civ@mail.mil (301) 394-2337

Boiling Heat Transfer -Behavior of Pool Boiling on Micro-scale Heat Sources (ALC)
The behavior of a static boiling system in the presence of heat sources smaller than critical bubble and wetting length scales is poorly understood. Enhanced modeling and measurement of such systems should result in higher fidelity boiling models which can improve predictablity of two-phase heat trasfer systems.

Principal Investigator: Nick Jankowski nicholas.r.jankowski.civ@mail.mil (301) 394-2337

Boiling Heat transfer - Binary Fluid Behavior in Two-phase Flows (ALC)
Many engineering fluids are multi-constituent liquids. These liquids will have unique behavior under boiling conditions, and their impact when used in heat transfer applications is largely unknown. There is interest in better understanding the behavior of binary liquids under boiling conditions, the system level impacts of their use, and whether components/systems can be designed to take advantages of their unique behavior.

Principal Investigator: Nick Jankowski nicholas.r.jankowski.civ@mail.mil (301) 394-2337

Phase Change Materials - Supercooling Reduction in High Performance Phase Change Materials (ALC)
Promising high performance phase change materials suffer a temperature-phase hysteresis that could potentially lead to critical failure in a thermal protection system. The literature contains some reference to mechanical, chemical, and electrical (or electrochemical) mitigation, but little fundamental understanding of the

mechanism. Focusing on methods of mechanical or electrical supercooling reduction would avoid material modification, and provide insight into nucleation behavior. Project would model nucleation potential under various stimuli, and experimentally characterize the effects.

Principal Investigator: Nick Jankowski nicholas.r.jankowski.civ@mail.mil (301) 394-2337

Supporting Facility

Thermal Sciences laboratory has dedicated lab space containing single and two-phase flow loops compatible with water and dielectric fluids at high power and temperatures. Extensive use of the ARL clean room and machine shop facilities are used to make devices. Numerical simulation and CAD software are available locally as well as on the ARL supercomputer and include access numerous FEA and CFD packages and mathematical software. Boiling flow loop test stand. Condensation enhancement test stand. IR cameras. High-speed video camera. Thermal control and data acquisition hardware/software. Custom thermal interface material test stand.

Microscale Heat Transport

Research into heat propagation in electronic devices, and coupled electronic-thermal-material interactions; non-standard measurement techniques for characterizing solid properties in semiconductor devices, and interfacial heat transfer across dissimilar solid, liquid, and gaseous material boundaries; electronics packaging thermal improvement techniques including low impact microchannel cooling, heat spreading, interface materials, and air-side convection enhancement.

Principal Investigator: Nicholas Jankowski nicholas.r.jankowski.civ@mail.mil (301) 394-2337

Phase Change Thermal Sciences

Research on enhanced steady and transient thermal transport using material phase change; enhancing and improving prediction of boiling mode heat transfer under steady and transient conditions; improving dropwise condensation heat transfer and enhancing condensate removal. Additional focus on using solid-liquid phase change to bridge source-to-sink time constant mismatches for thermal protection of high-rate electronics, and thermal buffering of vehicle, climate control, and power systems; includes investigations into high latent heat, high conductivity materials and supercooling reduction.

Principal Investigator: Nicholas Jankowski nicholas.r.jankowski.civ@mail.mil (301) 394-2337

Supporting Facility: Thermal Sciences Laboratory (ALC)

Laboratory to perform tests on high power electronics cooling, single and two-phase flow loops, and packaging materials.

Equipment Available: Water and dielectric liquid flow loop test stand (>5kW), humidity controlled condensation test stand, FLIR LWIR, custom 1DSS interface conductance tester, 20g rotary acceleration thermo-fluid test stand.

Bio-/Neuro-Inspired Sensors and Controls

Bio-inspired and/or biocompatible microscale sensors, and bio-/neuro-inspired approaches for optimizing the coordination of orthogonal fused-sensing approaches with computation in extremely size-, weight-, and power-constrained, arrayed heterogeneous sensor systems. Envisioned future applications range from autonomous control of micro autonomous systems, to helmet- or textile-integrated physical health monitoring or situational awareness flexible sensor network arrays.

Principal Investigator: William Nothwang william.d.nothwang.civ@mail.mil (301) 394-1163

Supporting Facilities: Sensors and Autonomous Systems Experimental Facility (ALC)

The Sensors and Autonomous Systems Experimental Facility evaluates emerging robotics and sensor systems. Researchers assess autonomous navigation in complex and confined 3D and urban environments using a three-story high urban terrain replica; single platform and collaborative platform simultaneous localization and mapping; collaboration of heterogeneous teams of air and ground platforms, robotic perception, and intelligence; the human-robot interface; platform state estimation; mobility from man-portable-sized systems to the micro-scale; and next-generation see-through-the-wall, ground penetrating radar, IED detection, and unattended ground sensor technologies. The facility includes a fully integrated camera and GPS system for ground truthing; a dark room to simulate cave-like environments; a control room and lab environments for system repair, development, and experimental control; various urban features to include sidewalks, stairs, ramps, variable pitch roofs, various ingress and egress features, balconies, telephone poles, and overhead wiring; a three-feet deep sand bed for characterization of buried devices; and a 120-feet long above-ground computer-controlled trolley.

High-Performing Bio-Based Polymers

Petroleum-based polymers are not sustainable. Lignin, cellulose, carbohydrates, triglycerides, other renewable feedstocks, and green chemistry represent a sustainable source to generate monomers and polymers; development can result in innovation, resulting in chemical and material advances that would not otherwise come to fruition. Thus, we are developing novel polymers from renewable resources to replace petroleum-derived high-performance polymers for Army applications from fabric for uniforms to high-strength fibers for armor. Research focuses on chemical synthesis of monomers, and synthesis of thermoplastic and thermosetting polymers from biological sources. Analytical tools and instrumentation, such as titration methods, NMR, FTIR, and GPC, are used to characterize the resulting chemicals and monomers. Polymerization of the monomers and characterization of the polymer properties, including molecular weight, functionality, and thermal and mechanical properties, are integral to the investigation.

Principal Investigator: John La Scala john.j.lascala.civ@mail.mil (410) 306-0687

Supporting Facility: Polymer Preparation and Characterization Laboratories and MMSD Laboratories (APG)

Laboratories to chemically prepare and characterize monomers and polymers, laboratories to formulate and compound polymers, laboratories to evaluate thermal and mechanical properties of polymers.
Equipment Available: Bruker 600 MHz NMR, picospin NMR, fume hoods, GC, Thinky Mixer, Nicolet FTIR, TA Q800 DMAs, DSCs, TGAs, TMAs, AR1000 Rheometer, Hitachi SEM, Instron mechanical testing laboratories.

Biological, Chemical, and Atmospheric Aerosol Detection and Characterization

Develop new technologies for real-time, in-situ detection and characterization of aerosol particles based on different optical methodologies and laser spectroscopic signatures; Study the properties of single individual atmospheric aerosol particles, which could be smoke, dust, pollen, fungi, particulate emissions from burning pits, especially aerosolized chemical, biological warfare agents.

Principal Investigators:	Yongle Pan	yongle.pan.civ@mail.civ@mail.mil	(301) 394-1381
	Steven Hill	steven.c.hill32.civ@mail.mil	(301) 394-1813
	Gorden Videen	gorden.w.videen.civ@mail.mil	(301) 394-1871

Supporting Facility: Aerosol Research Facility (ARF) (ALC)

The aerosol research facilities are used for detecting, discriminating, and identifying chemical and biological aerosol threats, mainly by obtaining fingerprint signatures from fluorescence spectra, elastic scattering patterns, and Raman spectra of individual single, micron-size aerosol particles on-the-fly.

Equipment Available: Various continuous-wave (CW) and pulsed laser sources from deep UV to visible and near IR; Spectrographs; Image and spectral detectors; Microscopes; Aerosol trapping devices; Aerosol generators; Polarimetric imagers, Nephelometers etc.

Adhesives and Interfaces/Bio-based Adhesives

The development of modern adhesives can trace a timeline originating in the aerospace industry in the 1930's, experienced rapid development during the Second World War, and reached maturity in the 1990's. Successful adhesives technology progression, regardless of the application, typically takes approximately fifty years to fully develop. From an Army perspective, fifty years is an impractical length time to wait for materials solutions needed to meet new threats that continually emerge in the field. However, scientists in the 21st century have access to computational power that was unavailable seventy, or even ten, years ago. Adhesive bonding for Army applications is extremely challenging due to high loading rate conditions, a need for high damage tolerance, and a much broader (and continuously shifting) configuration spectrum compared to traditional aerospace applications. The approach of the Adhesives and Interfaces Research Team is to couple traditional experimental formulation, characterization, and mechanical testing with modern database informatics capability from the inception with the goal of significantly reduced development time. Collaboration opportunities are available in both aspects; adhesives development and statistical data analysis/informatics.

While bulk adhesive technology has reached a high level of static performance, the weak link for adhesives is frequently the interface between the adhesive and material to be bonded. Material performance at this interface can differ dramatically from the bulk, and is often the point of failure due to the ingress of adventitious moisture or stresses accumulated due to thermal cycling. Biological adhesives have shown performance in challenging environments that can be superior to man-made adhesives (e.g. underwater, bonding to dirty substrates), and it is hypothesized that both chemical group diversity and sequence control contribute to the performance of these bioadhesives. We are undertaking a program to incorporate chemical groups mimicking the active residues of these adhesives, but combining them with high performance polymer backbones, in an effort to access improved interfacial performance while maintaining robust bulk material properties. Collaboration opportunities are also available in the realm of synthetic polymer chemistry and interface characterization.

Principal Investigators: Robert Jensen robert.e.jensen.civ@mail.mil (410) 306-1910

Joshua Orlicki joshua.a.orlicki.civ@mail.mil (410) 306-0931

Supporting Facility: Adhesives Laboratory (APG)

Full suite of mechanical testing capabilities, focused on tensile and shear failure modes. Computational modeling of adhesive interfacial interactions, polymer network interactions. Characterization capabilities including XPS, SEM, TEM, FTIR microscopy, RAMAN microscopy, AFM.MSAT database with pedigreed dataset, acquisition protocols

Biomaterials: Next Generation Sensing to Living Materials

Biomaterials research is focused on fulfilling the need for alternative and hybrid materials addressing critical gaps in adaptability, manufacturability, and stability through an integrated basic and applied research program. This includes comprehensive discovery tools understanding interactions and predicting enhanced performance at the interface of peptide, protein, and cell interactions for a variety of applications ranging from ubiquitous biosensing of threats, soldier performance, smart skins and uniforms to bottom up materials fabrication and assembly, to living paints and materials. A key emphasis is the ability to rapidly discover and develop functional biomaterials that are stable in austere military environments including temperature extremes. With improved understanding of the biointerface, future work may focus upon autonomous and directed patterning and reconfigurable binding, self-healing properties, responsive properties and more advanced function. Specifics of the ARL effort include:

- Facilities & expertise for discovery, custom engineering, and study of peptides via bacterial cell surface display
- Genetically engineered peptides for inorganics, hybrid biomaterials, and living material system interfaces
- Specialized modeling and simulation tools for bio-bio and bio-bio interactions, using secure DOD High Performance Computing Facilities
- Development of extremely stable (protease resistant, extreme thermostability), and highly manufacturable peptide reagents for biosensing

Principal Investigators: Jim Sumner james.j.sumner4.civ@mail.mil (301) 394-0252
Dimitra Stratis-Cullum dimitra.n.stratis-cullum.civ@mail.mil (301) 394-0794

Supporting Facilities: Biolab BSL I-II Biotechnology Multi-User Facility (ALC)

The BSL I-II Biotechnology Multi-User Facility provides an environment for comprehensive biotechnology research: from fundamental studies of complex biological systems and biomolecular interactions through prediction, design, and engineering of advanced biological/ bio-hybrid materials and systems for a wide range of Army applications. The facility's capabilities cover a broad spectrum, including micro and molecular biology equipment in conjunction with advanced characterization tools and biochemistry instrumentation. These capabilities enable multi-scale studies of cells, subcellular components, and metabolic networks of aerobic and anaerobic organisms as well as natural and engineered biologic materials. Instrumentation includes advanced optical and environmental electron microscopy; spectroscopic tools for dynamic structural determination; biomanufacturing capabilities including fermentation, separation, and purification in controlled environments; biological and bio-hybrid materials fabrication; classical and custom biological performance studies; and electrical property characterization. The facility is commissioned to handle biosafety level I and II materials.

Structural Materials for Improved Vehicle Mobility and Stealth

Research multifunctional structural materials capable of storing or harvesting energy in pursuit of increased vehicle range and concealed vehicle location.

Principal Investigator:	Mark Bundy	mark.l.bundy2.civ@mail.mil	(410) 278-4318

Lightweight Structural Energy Storage Materials for Vehicles or Energy Harvesting Materials for Combustion Engine Sound Abatement (APG)
Investigate the assembly of flexible/moldable Si-Li energy storage designs into the structure of small unmanned vehicles. Investigate phenomenological modeling of magnetostrictive shunt damper configuration to maximize the shunt damper performance for reducing the sound emission of combustion engines. Investigate technologies and materials for reducing the structural vibration and acoustic emission from combustion engine platforms.

Principal Investigators:	Mark Bundy	mark.l.bundy2.civ@mail.mil	(410) 278-4318
	Jin Yoo	jin.h.yoo6.civ@mail.mil	(410) 278-7758

Aperiodic to Nanostructured Materials

Research based on experimental, computational, and analytic solutions relates to the design and thermal stabilization of metastable materials; specific focus is on the effective utilization and exploitation of nanostructured materials via the discovery of new compositions and/or defect and interface engineering, such as novel multiphasic solvent-solute combinations, augmented with grain size reduction and grain boundary modification techniques. Approaches entail the use of thermodynamic and kinetic principles to develop materials with unprecedented or greatly improved mechanical, thermal, or chemical properties.

Principal Investigator:	Kristopher Darling	kristopher.darling.civ@mail.mil	(410) 306-0862

Supporting Facility: Atmospheric Plasma Modification Laboratory (APG)

Laboratories to perform atmospheric and low vacuum plasma modification of materials. Laboratories to characterize the modification of such materials.
Equipment Available: Plasma Jet, plasma roll to roll, Kratos XPS, Nicolet FTIR, contact angle goniometer, Hitachi SEMs, planar atmospheric plasma system, plasma-enhanced chemical vapor deposition.

Atmospheric Plasma Modification of Materials

Research and development of novel, scalable methods to modify the surface of materials using plasma to improve adhesion, reduce defects, kill microorganisms, etc., without affecting bulk properties. Surface modification of and deposition of thin coatings on materials surfaces using plasma-assisted wet chemistry and spray deposition techniques. Material analysis techniques including SEM, XPS, contact angle goniometry, FTIR, XRD, and tensile strength testing will be employed. Development and characterization of novel polymers/fibers, polymer blends/hybrids, nanomaterials, new process methods for applying or modifying polymers to increase service life, environmental durability, and providing chemical-biological protection/detection and/or ballistic protection. Development of experimental and theoretical methods to explore the potential of applying plasma technology to the growth of thin conformal multifunctional coatings for specific Army applications.

Principal Investigator: Andres Bujanda andres.a.bujanda.civ@mail.mil (410) 306-0680

Supporting Facility: Atmospheric Plasma Modification Laboratory (APG)

Laboratories to perform atmospheric and low vacuum plasma modification of materials. Laboratories to characterize the modification of such materials.
Equipment Available: Plasma Jet, plasma roll to roll, Kratos XPS, Nicolet FTIR, contact angle goniometer, Hitachi SEMs, planar atmospheric plasma system, plasma enhanced chemical vapor deposition.

Chemical Agent Resistant Coatings (CARC) Development

New agents and new analysis of CARC show that CARC has more vulnerabilities than previously known. As a result, work is needed to be able to understand why some coatings formulations are resistant to some chemical agents and why some fail vs. the same or other agents.

Principal Investigators:	John Escarsega	john.a.escarsega.civ@mail.mil	(410) 306-0693
	John La Scala	john.j.lascala.civ@mail.mil	(410) 306-0687

Supporting Facility: Coatings Suite and Materials and Manufacturing Sciences Division (MMSD) Laboratories (APG)

Laboratories to formulate and characterize coatings components and the properties and performance of coatings.
Equipment Available: spray hoods, elcometer, profilometer, contact angle goniometer, high-speed mixers, Varian FTIR, Atlas weatherometers, QUVs, Bruker AFMs, Hitachi SEMs, NEC 1.7 Megavolt Ion Accelerator.

Coatings Fundamental Research (APG)

Fundamental research and analysis to support the development of coatings, understanding of the chemical resistance of coatings, reducing the environmental footprint, and reducing materials degradation/corrosion. Formulate epoxy, polyurethane, and other thermosetting materials for use as coatings. Characterize thermosetting resins for chemical resistance via positron annihilation spectroscopy (PALS), solvent absorption, and other studies. Characterize thermal and mechanical analysis of organic-based films and coatings. Formulate and prepare model coatings and coatings for Army applications using thermosetting resin binders. Provide expert analysis of product performance and characteristics through various instrumental methods. Develop structure/property relationships for coatings materials via measurement of material properties and analysis of chemical, nano, and micro-structure using tools such as dynamic mechanical analysis (DMA/DMTA), differential scanning calorimetry (DSC), PALS, infrared spectroscopy (IR), microscopy, and scanning electron microscopy (SEM). Conduct performance testing of coatings according to military specifications and related ASTM protocols. Develop improvements for quality of applications, products, and/or procedures. Formulate and evaluate camouflage coatings and related epoxy coatings used to extend life cycles of coating performance. Formulate improved coatings for resistance to chemical infiltration/absorption, resistance to degradation, mitigation of corrosion, and reduction in environmental footprint. Evaluate materials for corrosion resistance using accelerated weathering techniques and coatings evaluation techniques, including electrical impedance spectroscopy (EIS).

Principal Investigators:	John Escarsega	john.a.escarsega.civ@mail.mil	(410) 306-0690
	John La Scala	john.j.lascala.civ@mail.mil	(410) 306-0687

Corrosion at the Nano/Micro Scale

Perform fundamental corrosion research at the micro/nano scale. Use and develop new techniques to analyze and understand corrosion at micro/nano scale that could be used to potentially mitigate corrosion
.

Principal Investigator: Joseph Labukas joseph.p.labukas.civ@mail.mil (410) 306-4939

Supporting Facility: Corrosion Micro/Nano Research (APG)

Laboratories to induce and examine corrosion at the macro through nano scale.
Equipment Available: EIS, CV, accelerated corrosion chambers, Electrochemical AFM, Scanning Kelvin Probe Microscopy, scanning electrochemical microscopy, Hitachi SEM, EDAX, NEC 1.7 Megavolt Ion Accelerator.

Corrosion of Organic Molecules

Corrosion of organic molecules to initiate desired breakdown or synthesis. This especially includes the desired breakdown of coatings to monomers to be able to more effectively recycle components for sustainable use of coatings.

Principal Investigator: Joseph Labukas joseph.p.labukas.civ@mail.mil (410) 306-4939

Supporting Facility: Electrochemical Breakdown or Synthesis of Organic Molecules (APG)

Laboratories to induce and examine corrosion at the macro through nano scale and to characterize organic molecules, including polymers.
Equipment Available: Thinky Mixer, Nicolet FTIR, TA Q800 DMAs, DSCs, TGAs, TMAs, AR1000 Rheometer, Hitachi SEM.

Deformation Processing of Lightweight Materials

Severe plastic deformation processing of novel materials entails the top-down refinement of coarse-grained microstructures to the ultra-fine and nanoscale regime, resulting in a dramatic improvement in strength without a loss of ductility. Methodologies include equal channel angular extrusion, high-pressure torsion, accumulative roll bonding, friction stir welding, and surface mechanical attrition treatment processing to create material systems with controlled properties such as texture, morphology, and unique or metastable phase chemistries.

Principal Investigator: Kevin Doherty kevin.j.doherty18.civ@mail.mil (410) 306-0871

Supporting Facility: Severe Plastic Deformation Processing Laboratory (APG)

Equipment Available: Equal Channel Angular Extrusion Press; Plate and Bar Tooling Geometries; Friction Stir Processing Capability.

Detonation Science

Investigation of reactive rate for CHNO compounds.

Principal Investigator: Kevin McNesby Kevin.l.mcnesby.civ@mail.mil (410) 306 – 1383

High-Speed Diagnostics (APG)
Experimental techniques to characterize the reaction of energetic materials when subjected to shock.

Principal Investigator: Matt Biss matthew.m.biss.civ@mail.mil (410) 278-3708

Supporting Facility: Detonation Science Facility (APG)

Energetic Materials Characterization
Equipment Available: high-speed cameras, detonation chambers, Schlerin imaging.

Disruptive Energetics

Discovery and inventions of novel energetic materials. Methodologies for discovery include chemical synthesis, mechanochemical synthesis, and high-pressure chemistry and physics. The research area also focuses on investigating novel and efficient energy release concepts.

Principal Investigator: Nirupam Trivedi nirupam.j.trivedi.civ@mail.mil (410) 306-3108

High-Pressure Synthesis (APG)
Discovery and inventions of novel energetic materials. Methodologies for discovery include mechanochemical synthesis and high-pressure chemistry and physics.

Principal Investigator: Jennifer Ciezak-Jenkins jennifer.a.ciezak-jenkins.civ@mail.mil (410) 278-6169

Synthesis of Energetic Materials (APG)
Research into higher-energy CHNO molecules that offer increased output and are less sensitive than current material.

Principal Investigator: Joe Banning joseph.e.banning2.civ@mail.mil (410) 278-9656

Supporting Facility: High-Pressure Synthesis/Laser Diagnostic Lab (APG)

Equipment Available: Paris-Edinburg Press, Diamond Anvil Press, various laser equipment.

Materials Manufacturing & Processing Science

Cryogenic Processing of Nano-Materials. Investigate processing windows suitable for manufacturing to enable production of nano-particles via liquid nitrogen attrition.

Principal Investigator: Kyu Cho kyu.c.cho2.civ@mail.mil (410) 306-0820

Supporting Facility: Cryogenic Processing Research Facility (APG)

Conduct cryogenic manufacturing and processing of nano-materials.

Equipment Available: Cryogenic (liquid nitrogen) Attritor, Glove Box evaporator, power degassing unit.

Materials State Awareness for Aviation Sustainment

Develop embedding sensing capability for military aircraft composite structures to identify, characterize, and categorize specific materials damage precursors that can be used to predict failure of aircraft structures prior to the onset of actual damages. Explore and establish full understanding of science and technology to detect and identify material damage precursors prior to the onset of any material damages/flaws in composite materials systems.

Principal Investigator: Asha Hall asha.j.hall.civ@mail.mil (410) 278-8036

Multiscale Reactive Modeling for Energetics

Theoretical Modeling and Simulations of Energetic Materials in order to understand the structure-property and structure-phenomenological responses of Energetics. The program focuses on building models from Quantum Mechanical to Micro- to Meso- to Continuum scale with emphasis on building the models that bridge the length scales.

Principal Investigator: Betsy Rice betsy.rice.civ@mail.mil (410) 306-1904

Ground Vehicle Structural Mechanics and Dynamics Technology

Establish and evaluate non-linear control algorithms for active and semi-active dynamic systems. Establish non-linear modeling and simulation capabilities to address ground vehicle crashworthiness and Soldier protection.

Principal Investigator: Muthuvel Murugan muthuvel.murugan.civ@mail.mil (410) 278-7903

Establish a phenomenological model for magnetostrictive material behavior. For instance, obtain a numerical expression for the strain and magnetization response as functions of applied magnetic field and external stress. Use the model to predict the performance of magnetostrictive material in the role of an actuator or a sensor for responding to or monitoring vehicle dynamics.

Principal Investigator: Jin Yoo jin.h.yoo6.civ@mail.mil (410) 278-7758

Supporting Facility: Structural Integrity Laboratory (APG)

Equipment Available: LS-DYNA software, dSpace hardware, MTS for damper testing.

Additive Manufacturing, Direct Write and Hybrid Manufacturing (APG)

The materials research field is critical to new performance standards for soldiers and soldier systems. The assembly concepts achieved by additive processing methods results in new levels of performance being attained by material optimization strategies. Hybridized manufacturing of materials is achieved in a facility with great versatility and technical capability, expanding the performance envelope for materials for enhancing the comfort, protection and lethality for the war fighter.

Principal Investigators: LJ Holmes larry.r.holmes.civ@mail.mil (410) 306-0854
James Sands james.m.sands.civ@mail.mil (410) 306-0878

Supporting Facility: Micro-Compositronics and Rapid Operations (MiCRO) Lab within the Composites and Hybrid Materials Branch (CHMB) (APG)

An environment for the development of advanced manufacturing techniques and material supply for future manufacturing.

Equipment Available: Commercial technologies: Fuse Deposition Modeling (FDM), Digital Light Projection and Laser Stereolithography (SLA), Direct Metal Laser Sintering (DMLS), Polymer Jetting, InkJet, Micro-Pump, Aerosol Jet, and Screen Printing. Novel technologies: Field-Aided SLA, Fiber Reinforced FDM, Multi-vat SLA, Multi-material (polymer, ceramic and metal) Laser Sintering, 6-Axis Multi-tool platform (includes: thermoplastic, thermoset, and ink deposition, as well as micro-milling, laser scanning, laser sintering and pick-and-place), and other technologies under development.

Additive Manufacturing Research (APG)

Additive Manufacturing (AM) technologies are perceived as processing methods to engage new performance capability from materials. The processes offer substantial manufacturing flexibility while enabling new approaches to hybridization and structural design engineering. Readily available material supply tends to be focused less on high performance structural applications and is limited by commercial machine sources and well-defined process strategies. Recently, AM fabricated solutions have been explored for the automotive, aerospace and defense markets with promising results. However, the military performance standards need to be achieved before AM parts can be certified and qualified for high-tech arenas. The certification and qualification procedures for single manufacture single product processes remain a significant unknown. Process optimization through in-situ characterization and feedback, and simulated manufacturing will decrease the time of delivery for future product enabling rapid laboratory to field solutions. The ARL lab enables new generations of performance through innovative materials and open architecture equipment, allowing full control of design and processing parameters in the manufacturing process. Ongoing research includes: material synthesis, design optimization, and in-situ process monitoring. Results are supported with robust characterization tools to enable strategic design with AM.

Principal Investigators: LJ Holmes larry.r.holmes.civ@mail.mil (410) 306-0854
James Sands james.m.sands.civ@mail.mil (410) 306-0878

Energy Coupled to Matter (ECM)

Energy Coupled to Matter (ECM) is an emerging technology that goes beyond the traditional process optimization factors of scale, composition, temperature, and pressure. It holds great promise in facilitating the realization of transformal materials through the aid of externally applied fields. The application of fields may alter phase transformation pathways, create new microstructures, shift equilibrium favoring new metastable alloys, align phases, manipulate and shape nanoscale architectures, and produce materials with revolutionary structural and multifunctional properties otherwise unattainable by conventional processing and production methods. The application of external fields, or combinations thereof, which include electric, magnetic, acoustic, microwave, radiation, and others, offers the unique opportunity to direct the architecture of materials features across atomic, molecular, micro, meso, and continuum levels. These fields may either be used to induce a permanent material property improvement or to selectively activate enhanced time-dependent properties via dynamic stimulation.

As technical challenges are overcome through basic research, a fundamental understanding of the mechanisms influencing field-material interactions and the phenomena that control manipulation of applied fields will be realized. This will be aided by the discovery of in-situ characterization methods for analyzing materials under high energy fields, the development of predictive models for simulating the influence of applied fields on various materials, and a combination of additional experimental, modeling, and characterization efforts that have yet to be explored.

Technological advancements in the ECM discipline will have significant impact on Army capabilities in the near and distant future for a number of key areas that include, but are not limited to (1) novel materials with tailored microstructures to produce unprecedented physical and mechanical properties (2) enhanced processing and manufacturing capabilities for rapid rate production of net-shape components in extreme environments, and (3) adaptive/responsive protection and lethality applications that can be controlled/activated in real-time and utilized in-theater.

Principal Investigator: Raymond Brennan raymond.e.brennan.civ@mail.mil (410) 306-0913

Supporting Facility: ECM Laboratory (APG)

The ECM Laboratory is currently under development. It will include a number of facilities for applying high energy fields for enhanced materials processing and manufacturing. It will also incorporate the use of in-situ characterization tools for studying field-material interactions as well as modeling and simulation software for prediction of the influence of high energy fields on materials development.

Equipment Available:

ECM Laboratory under development to include:

- Physical Property Measurement System (PPMS)
- Ultrasonic Additive Manufacturing (UAM)
- Single Mode Microwave Sintering Systems
  - 2.45/5.8 GHz, 2000°C, 5,000 psi pressure
- Thermomagnetic Processing Systems
  - 9 Tesla, 8” bore, 2200°C, pressure

ECM modeling & simulation software to include:

- Thermo-Calc
- COMSOL Multi-Physics

Electric Field Assisted Sintering

The application of an electric field during sintering has been demonstrated to increase the sintering kinetics for a wide range of metallic and ceramic powders that are otherwise difficult to consolidate via traditional power processing operations. Very high heating rates can be obtained which limits the potential for grain growth enabling processing of bulk nanocrystalline materials. A major thrust of this research is the development of enhanced multi-physics process models to establish a computational virtual manufacturing based framework for electric field assisted sintering of ceramics and metals in order to fully exploit field enhancements for scalable net shape manufacturing of next generation ceramics and metals and promote rapid transition of technologies. Additional research entails identifying and quantifying the influence of fields on the thermal, electrical, and mass transport mechanisms active during powder processing and their resulting effect on the final microstructure(s) and properties of the material.

Principal Investigator: Brandon McWilliams brandon.a.mcwilliams.civ@mail.mil (410) 306-2237

Supporting Facility: Field Assisted Sintering Laboratory (APG)

Fully instrumented electric field assisted sintering chamber with hydraulic load frame and supplemental external heating for sintering under atmosphere or vacuum to temperatures > 2000^{o}C.
Equipment Available: 60 kW Plasma Pressure Compaction (P^2C) electric field assisted sintering machine, access to DoD Supercomputing Resource Center (DSRC) for high fidelity simulations

Advanced Materials and Processing for Soldier Protection

Basic and applied research and development for novel materials, materials processing/manufacturing science and materials design for the improvement of Soldier protection performance and integration. Focus areas of materials research for Soldier systems include: Characterization and processing science for novel fibers, membranes, tapes; enhancement of penetration resistance and back face deformation through materials processing and design; materials design for reduction of behind armor blunt trauma (BABT) in impact, ballistic and blast scenarios; improvements toward mass efficiency, flexibility, and thermal management; development of load-sharing/shunting/offsetting concepts; process cycle and ballistic/impact/shock modeling of fibers and composite materials.

Principal Investigator: Lionel Vargas lionel.r.vargas.civ@mail.mil (410) 306-0702

Supporting Facility: Materials Manufacturing Sciences Division (MMSD) Laboratories (APG)

Laboratories for processing science and small scale manufacturing of composites and hybridized materials with conventional and novel tooling equipment. Laboratories for mechanical and analytical characterization of materials. Ballistic ranges for high-rate characterization of protection system demonstrators and concepts.
Equipment Available: high tonnage uniaxial presses, autoclaves, automated material assembly systems, tensile load frames, drop towers, SEM, confocal microscopy, Digital Image Correlation, high frame rate cameras

Micro Autonomous Systems and Technology (MAST)

Developing enhanced tactical situational awareness in urban and complex terrain by enabling the autonomous operation of a collaborative ensemble of multifunctional and mobile microsystems. Research areas include: Mobility, Control, and Energetics; Communication, Navigation, and Coordination; and Sensing, Perception, and Processing for size and resource constrained autonomous robotic systems and heterogeneous teams of systems.

Principal Investigator: Brett Piekarski brett.h.piekarski.civ@mail.mil (301) 394-1263

Supporting Facilities: Sensors and Autonomous Systems Experimental Facility (ALC)

The Sensors and Autonomous Systems Experimental Facility evaluates emerging robotics and sensor systems. Researchers assess autonomous navigation in complex and confined 3D and urban environments using a three-story high urban terrain replica; single platform and collaborative platform simultaneous localization and mapping; collaboration of heterogeneous teams of air and ground platforms, robotic perception, and intelligence; the human-robot interface; platform state estimation; mobility from man-portable-sized systems to the micro-scale; and next-generation see-through-the-wall, ground penetrating radar, IED detection, and unattended ground sensor technologies. The facility includes a fully integrated camera and GPS system for ground truthing; a dark room to simulate cave-like environments; a control room and lab environments for system repair, development, and experimental control; various urban features to include sidewalks, stairs, ramps, variable pitch roofs, various ingress and egress features, balconies, telephone poles, and overhead wiring; a three-feet deep sand bed for characterization of buried devices; and a 120-feet long above-ground computer-controlled trolley.

On-Chip Integration of MicroElectroMechanical Systems

This program aims to develop, characterize, and implement energetic materials (propellants, explosives, pyrotechnics) integrated on-chip with electronics, MEMS, or other microfabricated devices and structures which either benefit from the presence of a chemically exothermic energy source, or which enable new modes of initiation, characterization, or control of on-chip energetic reactions. Technical areas of interest include, but are not limited to: materials and methods for integration of energetic materials on-chip (deposition and lithographic patterning, drop casting, 3D printing, etc.), methods and devices for energy conversion to other useful modes (heat, light, pressure, electrical current, etc.), and novel microactuators based on energetic chemical reactions.

Principal Investigator: Chris Morris christopher.j.morris58.civ@mail.mil (301) 394-0950

Supporting Facilities: Specialty Electronic Materials and Sensors Cleanroom (SEMASC) (ALC)

This 15,000 gross square feet Class 10 and 100 cleanroom facility houses a comprehensive set of semiconductor fabrication tools—including specialty material deposition, etch, lithography, and thermal—and research characterization systems for the next generation of sensors and electronic devices for the Soldier. These systems enable the fabrication of advanced micro and nanoscale devices using an extremely broad set of device materials including silicon; III-V and IIVI semiconductors; silicon carbide; quartz; lead zirconate titanate (PZT) and aluminum nitride piezoelectrics; many metals and oxides; and graphene and carbon nanotubes. Support applications fabricated with these devices range from bio- and trace gas detection; secure communication (radiofrequency [RF] switches, filters, varactors, and tunable inductors); improvised explosive device (IED) detection (RF switches and filters); mobile sensor platforms for Soldier Intelligence, Surveillance, and Reconnaissance (bio-inspired microflight and terrestrial actuation, ultrasonic motors, bio-inspired sensors); traumatic brain injury (shock sensor, G-switch); RF (resonators, switches); power generation (microturbine, energy harvesting); infrared, ultraviolet, and optical detectors and emitters (imagers, lasers, LEDs); on-chip energetic devices (microthrusters, fuzing); and next-generation flexible, transparent, and high performance electronics and devices based on graphene and other 1D and 2D materials.

Sciences for Maneuver

The Sciences for Maneuver area is focused on gaining a greater fundamental understanding of advanced mobility technologies that enable innovative vehicle configurations and subsystem architectures. This area heavily relies on ARL's research expertise and facilities devoted to combustion research, drives research, fuel reformation, high altitude small engine testing, high temperature propulsion materials, tribology, power conditioning, prognostics & diagnostics, sensors & autonomous systems, microsystems aeromechanics wind tunnel, robotics research, and decision support sciences. With interagency agreements with NASA, ARL researchers also have access to unique hover test facilities, turbine engine component facilities, and transonic dynamics tunnel.

Discoveries, innovations, and developments made in maneuver sciences are expected to significantly impact the Army of the future by greatly enhancing the future Army's movement, sustainment, and maneuverability. Knowledge gained through these research efforts will lead to technological developments that make it possible to design, fabricate, integrate, control, and support platforms that will have a significant impact on Power Projection Superiority for the Army of 2030.

ARL's basic and applied research in the Sciences for Maneuver area specifically emphasizes Energy & Propulsion, Platform Mechanics, Platform Intelligence, and Logistics & Sustainability.

Energy & Propulsion concentrates on understanding and exploiting innovations in energy generation, storage, conversion, transmission and management specific to ground and air maneuver. The goal of this research is to provide energy and power applications that enhance Army operational effectiveness, improve efficiency, and accelerate development of critical military platform systems ensuring Army Power Projection superiority.

Platform Mechanics focuses on fundamental research that enables the development of the highly maneuverable platforms for the Army of the future. Knowledge gained in this area is expected to impact a wide array of vehicle systems, including the ground, air, and maritime domains, as well as vehicle scales from large to micro-scales.

Platform Intelligence focuses upon fundamental research that enables effective teaming of Soldiers and robots to conduct maneuver and military missions. ARL's activities are centered upon enhancing the autonomous capabilities of unmanned systems. Research compliments other research performed within the Information Sciences area but focuses exclusively on vehicle systems in real world environments. Knowledge gained in this area is expected to impact a wide array of vehicle systems, including the ground, air, and maritime domains, ranging from micro- to macro-scales.

Logistics & Sustainability focuses on fundamental and applied research to enable the rapid and reliable assessment of future Army platform reliability, health, and usage. Knowledge gained in this area is expected to impact a wide array of vehicle systems, including the ground, air, and maritime domains, ranging from micro- to macro-scales.

Active research areas and specific projects seeking Open Campus collaborative engagement include as follows:

Energy & Propulsion

Power Electronics for Tactical Energy Networks and Mobile Platforms

Enabling technologies and materials are critical to enhance the performance of future Army systems through the efficient utilization and distribution of electrical power across the spectrum of Army vehicles and tactical energy networks. Collaborations are sought for (a) power system controls and algorithm development; (b) mid- to large AC grid test platforms with multiple generators/sources; (c) renewable energy sources for dynamic environments; (d) nanocystalline, soft magnetic ribbon production, (e) high-voltage, hybrid energy storage technologies for compact systems; and (3) wide-band gap device fabrication (e.g., SiC, GaN, AIN).

Principal Investigators: Bruce Geil bruce.r.geil.civ@mail.mil (301) 394-3190
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Soldier and Small System Energy Harvesting

Enabling intelligent power systems are required to enable extended duration, expeditionary-type missions with minimal physical burden to Soldiers and with the need for resupply. ARL seeks collaborative partners in several areas: (a) novel transduction materials, batteries or fuel cells to be integrated on chip with MEMS devices; (b) energy harvesting devices for characterization and modeling in Army relevant scenarios; (c) devices and topologies that exploit multi-modal energy transduction for more power dense and predictable generation; (d) thermal to electric materials development; and (e) solid-state thermodynamic systems modeling.

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Patrick Taylor patrick.j.taylor36.civ@mail.mil (301) 394-1475

High-Efficiency gas Turbine Engine Components (APG and Army NASA Glenn Research Center Field Element)

ARL collaborators are sought to conduct experimental and computational investigations supporting innovative new technologies enabling next generation propulsion systems for Army air platforms. Possible areas of study include extending the current state-of-the–art in compressors, combustors and turbines. Research may also include evaluation of hybrid systems, adaptive engine/power system architectures, and novel architectures/cycles. Conduct of bench and component-level studies will focus on technologies to optimize future Army Vertical Lift mission performance (fuel consumption, range, time on station, etc.) across the full spectrum of ambient conditions (high hot, high cold, etc.)

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Tribology and Lubrication Science for High Performance Power Transmission (APG)

Innovative approaches are needed to create material and tribological solutions for high performance and extreme lubrication conditions. We aim to increase our understanding of the physics and chemistry of extreme lubrication conditions, thermomechanical degradation, and material failures at moving interfaces to support the development of robust vehicle drive trains with increased power density capabilities. Collaborations are sought in the study of new materials, development of improved modeling, and integration of new measurement method such as:

(a) Innovative approaches are needed to create material and tribological solutions for high performance and extreme lubrication conditions. These approaches may consist of engineered surface structures, solid films, functional coatings, modified surface chemistry, nanoscale or colloidal lubricant additives, and novel lubricant chemistry.

(b) Collaborations are sought to improve lubrication modeling in high speed tribological contacts throughout the regime from elastohydrodynamic to boundary lubrication, particularly under adverse conditions.
(c) New methods are sought which can measure high speed tribological contacts in situ, particularly fluid film properties and physical/chemical changes of the surfaces in contact.

Tribological studies of rotorcraft transmission components for improved survivability under loss-of-lubrication condition are of particular interest. Experimental and computational studies on helicopter and ground vehicle drive systems components including gears, bearings, and transmissions, as well as coupon-level fundamental studies focusing on physical failure mechanisms for helicopter transmission under loss-of-oil conditions.

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Supporting Facility: Tribology Lab (APG)

This lab evaluates fundamental friction, wear and lubrication technologies for improved, robust and power-dense vehicle transmissions. Facility explores innovative methods to extend efficiency and durability of mechanical components such as gears, bearings, splines, clutches, and seals.
Equipment Available: High-speed ball-on-disc tribometer. Gear and bearing rigs for experimental validation and empirical model input.

Spray and Combustion Science for Advanced Combustion Systems

ARL seeks collaborative researchers to achieve new discoveries in fuel spray and combustion sciences to innovate and enable small engine performance and fuel efficiency. Research for various fuel injectors and fuels in high-temperature and high-pressure conditions is needed to advance spray and combustion models which will be embedded in commercial engine codes to facilitate advanced engine development. ARL is also interested in working in collaboration to develop advanced optical diagnostic methods. Such methods are sought to investigate the detailed spray and combustion processes of various fuel injector designs and fuel properties (diesel, JP-8, Jet A, alternative JP-8, ATJ fuels) to further the fundamental understanding of the fuel physical and chemical effects on engine combustion.

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Matthew Kurman matthew.s.kurman.civ@mail.mil (410) 278-8971

Supporting Facility: Spray Combustion Research Laboratory (APG)

ARL has a world-class operating high-temperature pressure vessel system with various laser diagnostics to measure liquid spray and combustion processes. Three different fuel benches (one common-rail fuel bench, one hydraulically-actuated electronically-controlled unit injector fuel bench, and one air pump-driven fuel bench) can deliver fuels to an injector at various fuel pressures (over 2000 bars with the air pump-driven fuel bench) with different injector types. An injector analyzer bench is available to characterize and map an injector, and various injector samples. The high-temperature pressure vessel has the capability of up to 150 bar chamber pressure, 1000 K chamber temperature, and 0 to 21% oxygen concentrations in the test section. All three parameters can be independently controlled. This lab is established to (a) provide the understanding of the injector performance under ‘realistic’ operating conditions for various injector parameters, (b) provide the understanding of the impact of fuel properties on the detailed spray and combustion processes, and (c) generate the database of spray and combustion measurements. Collected data are used in 3D computational fluid dynamics models to simulate real engine spray and combustion processes that include piston motion and in-cylinder turbulence.

Equipment Available: High-temperature pressure vessel system, high-speed Mie and Schlieren imaging, shadowgraph imaging, planar laser-induced fluorescence (PLIF), laser-induced fluorescence (LIF), laser-induced incandescence (LII), Raman spectrograph, Raleigh thermometry, high-speed CMOS camera, CCD camera, and various other optics, LaVision Davis packages, IAV injection analyzer, common-rail fuel bench, HEUI fuel bench, and air-driven pump fuel bench.

Probabilistic-diagnostic Informed Innovations for Power Transmission Lightweighting

Innovative design concepts are sought to optimize power density in drive systems of Army vehicles. Leveraging advancements in health state awareness using a probabilistic and damage tolerance-based framework are of particular interest. ARL is especially interested in collaborative partnerships for helicopter drive trains & mechanical components, planetary gear dynamics, probabilistic life estimation, and modeling & simulation for damage progression & failure prediction.

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Michael Shiao chi-yu.shiao.civ@mail.mil (410) 278-4780

Platform Mechanics

Aeromechanics for Rotorcraft and Unmanned Aerial Systems

Computational and experimental investigations of aeromechanics for rotorcraft and unmanned aerial systems are critical to enable the development of the Army's first ever rotorcraft capable of supersonic speeds. Designs thus far have been unable to increase top speed without unacceptable compromises in range, efficiency and useful payload. Active and passive technologies for flow control and structural shape control to minimize performance trade-off penalties in different flight regimes remain technical challenges. Complimentary expertise, facilities and capabilities are sought in these areas: (a) co-axial rotor test stand for experiments on rotors in hovering flights; (b) wind tunnel for rotorcraft scaled experimental research with a test section area greater than 50 sq ft and capable of speeds greater than a 0.2 Mach number; (c) anechoic chamber for rotor aero-acoustics experiments; (d) capability for active flow control experiments using plasma; (e) expertise in active shape morphing structures; (f) expertise and capability in shape memory alloys for morphing rotor concepts; and (g) water towing tank for aerodynamics research.

Principal Investigator: Rajneesh Singh rajneesh.k.singh.civ@mail.mil (410) 278 4022
Matt Floros matthew.w.floros.civ@mail.mil (410) 278 7752

Advanced Rotorcraft Aeromechanics Research (APG and NASA Langley)

ARL conducts foundational aeromechanics research to enable future Army rotorcraft with combinations of enhanced performance and low maintenance burdens that are currently infeasible. Research interests include novel approaches for enabling advanced concepts that may currently be considered to be "radical" from an aeromechanical/aeroelastic stability and/or response perspective. Novel concepts from a structural dynamics, aerodynamic performance, coupled fluids/structures, and/or nonlinear dynamics theoretic perspectives are of interest. Current research activities include hybrid nanocomposite structural dynamics, aerodynamic flow control, and morphing structures.

Principal Investigator: Bryan Glaz bryan.j.glaz.civ@mail.mil (410) 278 8037

Supporting Facility: Transonic Dynamics Tunnel (via an Interagency Agreement with NASA Langley)

The Langley Transonic Dynamics Tunnel (TDT) is the only sub-scale facility in the world in which the scaling parameters (i.e., Mach and Froude scaling) necessary to assess both rotorcraft performance and aeromechanical/aeroelastic stability may be achieved simultaneously. This facility is a continuous-flow pressure tunnel capable of speeds up to Mach 1.2 at stagnation pressures up to 1 atm. The tunnel has a 16-ft square slotted test section that has cropped corners and a cross-sectional area of 248 ft^2. Either air or R-134a (a heavy gas) may be used as the test medium. Finally, this facility is also uniquely suited to testing future Army rotorcraft configurations that are expected to achieve significantly greater flight speeds than currently fielded Army helicopters. The wind tunnel facilities in which rotorcraft models are tested currently are incapable of reaching the desired speeds for these future Army vehicles. The TDT, being a transonic tunnel, has no such limitation. Use of this facility for collaborative research with ARL will require special coordination with NASA.

Mechanics of Handheld Aerial Mobility

Develop technologies and understandings to enable and enhance the performance of man-portable aerial systems. Activities are in the areas of Aeromechanics, Actuation, Flight Dynamics and Controls. Specific interests include the development of flight dynamics and control for handheld aerial mobility. Design and implement controllers for handheld aerial systems. Perform system ID on existing vehicles. Complimentary expertise is sought in unsteady & low Reynolds number aerodynamics; novel actuation for constrained size, weight & power; approaches to stability & control of non-linear, time varying systems; novel manufacturing/integration capabilities; and biomechanical understanding of animals.

Principal Investigator: Christopher Kroninger christopher.m.kroninger.civ@mail.mil (410) 278-5690

Supporting Facility: Microsystems Aeromechanics Wind Tunnel (APG)

This wind tunnel advances the study of fundamental flow physics relevant to micro air vehicle flight and assesses vehicle performance in terms of flight efficiency, stability and control to improve range, endurance, payload and maneuverability of handheld aerial platforms. It is slow speed, closed return wind tunnel. The test section is designed to be highly modular and a traversable rail super-structure allows for mounting experimental hardware around the test section. Currently supported experimental techniques include digital particle image velocimetry, hot-wire anemometry, static pressure measurement, force and moment measurement.

Supporting Facility: Oil Tank (APG)

This is a low Reynolds number (<2500) facility designed for the aerodynamics scaling of insect wings. Currently, six component force measurements can be measured from arbitrarily prescribed two degree of freedom (DoF) wing kinematics.

Rotorcraft Capability Assessment and Tradeoff Environment

ARL researches, develops, and employs tradespace exploration, technology insertion analysis, and decision analysis techniques to explore tradeoffs between requirements, technologies, and design parameters of conceptual-level rotorcraft. Collaborating researchers are sought to investigate: (a) surrogate model creation and rapid updating techniques; (b) application of multi-stakeholder interactions and value negotiation into the portfolio selection algorithm; (c) methods for including multiple discipline areas and multiple levels of modeling & simulation fidelity in the tradespace exploration process; (d) transition of a stand-alone environment to a collaborative web-based environment; (e) techniques for addressing uncertainty in the description of technology model elements; and (f) techniques for alerting decision makers to important technology research areas early in design.

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Rajneesh Singh rajneesh.k.singh.civ@mail.mil (410) 278-4022

Mission-Driven Microsystem Design and Validation (APG and ALC)

ARL researches, develops, and employs advanced design and validation methodologies for micro-autonomous systems that can improve military battlespace awareness. Our objective is to enable in situ rapid manufacturing of unmanned aerial ISR platforms using a minimal set of components and 3D printing technology. Collaborating partners are sought to: (a) investigate hardware and software allocation and optimization techniques; (b) perform microsystem experiments to validate virtually designed vehicles and operational environments; (c) investigate parameterization of CAD files; (d) perform mapping of system measures of suitability, performance, and effectiveness down to the hardware component level; (e) investigate how model-based systems engineering can enhance a conceptual design process and enable a collaborative web-based environment; (f) investigate application of DoD Manufacturing Readiness Assessment techniques to the conceptual design process; and (g) investigate application of multi-stakeholder interactions and value negotiation in the conceptual design process.

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Aerospace Power Transmission Component Research (APG and NASA Glenn Research Center Field Element)

Conduct experimental and computational investigations supporting innovative new technologies enabling next generation power transmission for military propulsion. Possible areas of study include extending the current state-of-the-art in alternative bearing concepts for both low speed and high speed applications. Research may include evaluation of potential coatings, hybrid material systems, surface modifications, and new materials for use in geared systems.

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Technology Improvement Studies of Rotorcraft Transmission Components for Improved Efficiency, Durability, Vibration, or Acoustic Performance (APG and Army NASA Glenn Research Center Field Element)

Experimental and computational studies will be conducted on helicopter and ground vehicle drive system components including gears, bearings, and transmissions. systems, surface modifications, and new materials for use in geared systems. Methodologies for characterizing ultra high-cycle fatigue failure mechanisms and control technologies for efficiently performing these experiments are of interest.

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Platform Intelligence

Mobility and Manipulation for Next-Generation Unmanned Systems

Development of theory, controls, and mechanisms (morphology, actuation, propulsion, etc) to provide unmanned systems the physical capabilities required to efficiently navigate and perform work in dynamic 3D environments as an integral part of missions in which they are teamed with Soldiers. Theoretical and experimental studies are needed. These include extensive use of modeling and simulation tools for development of algorithmic and computational capabilities to describe the kinematics and dynamics of rigid and deformable multi-body systems and their interaction with the environment. Research emphasis is on advanced robotic systems and biological systems which exhibit unique (ambulation, brachiation, jumping), airborne, and wheeled mobility and dexterous manipulation of their bodies, limbs, and objects within the environment.

Principal Investigator: Harris Edge harris.l.edge.civ@mail.mil (410) 278-4317

Meta-Cognition, Self-reflection and Proprioception

Develop novel techniques that enable autonomous systems track performance on assigned tasks, recognize failures and adapt or adjust performance. Develop adaptable robotic behavior algorithms that enable autonomous robots to participate in small human/robot team missions with minimal human oversight utilizing techniques from the fields of statistical learning theory, artificial intelligence, and perception. Two topics of particular interest are recognizing and understanding team behaviors from visual and other sensory information; and adapting autonomous performance to dynamically changing conditions.

Principal Investigator: MaryAnne Fields mary.a.fields22.civ@mail.mil (410) 278-6675

Semantic Spatial Understanding

Develop novel techniques that enable autonomous systems to describe objects and their relationships in human understandable terms, including the relationships between objects and places. Surpass the state-of-the-art in object and place recognition through the integration of advanced learning techniques, motion estimation, visual localization & mapping, and spatially organized object graphs. Complimentary expertise is especially sought in unsupervised learning & feature discovery, scene understanding, knowledge representation, object recognition and statistical relational learning.

Principal Investigator: MaryAnne Fields mary.a.fields22.civ@mail.mil (410) 278-6675
Jason Owens jason.l.owens.civ@mail.mil (410) 278-7023

Autonomy

Develop novel techniques that enable the teaming of autonomous systems with Soldiers. These behaviors include autonomous 3D mapping, positioning, and exploration in urban environments; heterogeneous teaming; and semantic scene and activity understanding.

Principal Investigator: Stuart Young stuart.h.young.civ@mail.mil (301) 394-5618

Mapping 3D Indoor Environments with Hetrrogenous Robot Teams (ALC)
Perform autnomous navigation and exploration using unmanned aerial vehicles and unmanned ground vehicles in unknown environments. Considered scenarios relate to reconnaissance and persistent surveillance using hetrogenous teams of mobile robots. Complementary expertise is sought to effectively increase scalability to enable the conduct of larger experiments, methodologies to efficiently share & distribute global map computation in real time; and extension of task allocation mechanisms to reason about capabilities of heterogeneous platforms in executing exploration tasks.

Principal Investigator: John Rogers john.g.rogers59.civ@mail.mil (301) 394-1811

Supporting Facility: Sensors & Autonomous Systems Experimental Facility (ALC)

This facility enables the evaluation of emerging robotics and sensor systems by providing capabilities to assess autonomous navigation in complex and confined 3D and urban environments using a three-story high urban terrain replica.
Experimental Capabilities: Verification and validation of physical hardware that results from the virtual processes. The facility includes a fully integrated camera and GPS system for ground truthing; a dark room to simulate cave-like environments; a control room; lab environments for system repair, development & experimental control; diverse urban environment features; a three-foot deep sand bed; and a 120-foot long above ground computer-controlled trolley track system for evaluating optical systems and radars.

Automated Vehicle Routing (WSMR)

ARL seeks collaborators to test with its software package, the Automated Impacts Routing (AIR) application in simulated operational environment. This test would help to increase the technology readiness level of this software. AIR calculates optimized paths in 3D space, avoiding adverse atmospheric conditions and any other obstacles/volumes during planning or mission execution phases of an operation. The application is suitable for path optimization of air or ground platforms/systems. It has been found that some routing applications have limitations, such as finding a path using pre-defined networks. Pre-defined networks limit the solution space for the routing result. AIR overcomes this limitation by allowing entire grids for multiple levels (3D) to be ingested at any resolution, temporally or spatially. Based on the A* best-first search algorithm, AIR execution results in an optimized path not necessarily along a pre-defined network, lending a complete solution that may not have otherwise been considered. ARL's AIR application is platform independent (written in Java), has been developed as a web service as well as a standalone desktop application, and has been successfully tested on Windows and Linux platforms.

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Terry C. Jameson terry.c.jameson.civ@mail.mil (575) 678-3934

Logistics & Sustainability

Multifunctional Vehicle Structures

The future force will rely on small highly mobile unmanned vehicles to provide perimeter intelligence, surveillance and reconnaissance for small soldier units deployed in hostile unfamiliar environments. There will also be a need for highly mobile manned vehicles to deploy soldier teams to harsh, isolated, remote rural locations. Research on multifunctional vehicle structures will improve the payload capacity, mobility, and operational readiness of future Army vehicles by adding new functionality or consolidating existing single-purpose functionality into multi-role vehicle structures. Currently, material multifunctionality encompasses structural materials that can provide one or more of the following functions: structural health monitoring, energy harvesting or storage and actuation/morphing.

Principal Investigators: Mark Bundy mark.l.bundy2.civ@mail.mil (410) 278- 4318
Jaret Riddick jaret.c.riddick.civ@mail.mil (410) 278-9831

Supporting Facility/Equipment: Materials Processing Lab (APG)

Equipment Available: Fume hood, glove box, probe sonicator, spin coater, ball mill, balance, vacuum oven, Keithley 4200 semiconductor characterization and Cascade Microtech probe station, Arbin supercap and battery analyzer, Quantum Design Versalab vibrating sample magnetometer, Newport Solar Simulator, JAZ UV-Vis Spectrometer, Instron 5965 tensile tester, Deben Microtensile Stage, electrospinning system.

Advanced Sensor for Fusing

Develop an advanced sensor fusion framework for anomaly detection, health monitoring, and life prediction of dynamic rotorcraft components. Combine information from physical damage models and heterogeneous sensor data to provide accurate state estimation.

Principal Investigators: Mulugeta Haile mulugeta.a.haile.civ@mail.mil (410) 278-5289
Jaret Riddick jaret.c.riddick.civ@mail.mil (410) 278-9831

Supporting Facility: Sensing & Prognostics Lab (APG)

Equipment Available: Acoustic Emissions, Optical Fiber Bragg interrogator, Eddy Current Flaw detector, Ultrasonic Flaw detector, Digital Image Correlation, Pulsed Thermography, Acoustic (ToF) flaw detector with SMART sensors and actuators, 22-kip servo-hydraulic Mechanical testing Machine, High speed oscilloscope, LabView data acquisition systems.

Extremely Lightweight, Adaptive, Durable, Damage Tolerant Structures for Future Vertical Lift

Investigate novel concepts for extremely lightweight, adaptive, durable, damage tolerant structures enabled by advanced materials and designs for Army Future Vertical Lift. Apply novel nonlinear computational methods and new physics-based models to notional structural concepts to simulate the response of metallic and composite structures, as well as failure initiation and propagation to produce robust validated modeling capability. On-going research encompasses a wide range of basic research to address the following topics: durable, high strength composite/metallic and multifunctional damage tolerant structural configurations and designs; non-linear and physics-based computational methods; advanced probabilistic algorithms for fatigue life management with increased prediction accuracy and reduced computational time; and additive manufacturing of multifunctional fatigue-resistant lightweight components. Complimentary collaboration is especially sought with advanced characterization and modeling of precursors to damage with particular emphasis on fatigue failure initiation and advances to enable self-healing structures.

Principal Investigators: Jaret Riddick jaret.c.riddick.civ@mail.mil (410) 278-9831
Robert Haynes robert.a.haynes43.civ@mail.mil (410) 278-8035

Supporting Facility: Structural Integrity and Durability Laboratory (APG)

Equipment Available: 22-kip servo-hydraulic Mechanical Testing Machines with assortment of ASTM standard test fixtures, 1-kHz, 5-kip "High Cycle Fatigue" servo-hydraulic mechanical testing machine, 5 kN electromechanical testing machine with environmental chamber, digital image correlation, Stratasys Dimension Elite Performance 3D printer.

Virtual Risk-informed Agile Maneuver Sustainment (VRAMS)

Enable an integrated cap Enable an integrated capability embedded within vehicles (air, ground, and autonomous systems) to automatically gauge changes in their functional state, assess that functionality in the context of upcoming or even ongoing missions, and react accordingly to achieve mission requirements; increase materiel availability; and reduce assets' life cycle costs.

Principal Investigators: Ed Habtour ed.m.habtour.civ@mail.mil (410) 278-8042
Dy Le d.d.le.civ@mail.mil (410) 278-9829

Supporting Facility: Sensing and Prognostics Laboratory (APG)

Equipment Available: Hover cage/stand, full-size air/ground vehicle transmission diagnostics, outdoor vehicle fatigue and combat damage assessment facilities, acoustic emission, electromagnetic and piezoelectric shaker system for vibration generation, fatigue testing, failure analysis, seeded fault diagnostics and flight test evaluation, health and usage monitoring system (HUMS), structural health monitoring (SHM), and damage detection and data collection system.

Information Sciences

The Information Sciences area is focused on gaining a fundamental understanding of information generation, collection, assurance, distribution, and exploitation; high-performance electronic components and devices; and synthetic biological systems. This area heavily relies on ARL's research expertise and facilities in network science; decision support sciences; electronic & information warfare vulnerability; electronic materials synthesis, component fabrication, and device characterization; and manipulation of synthetic biological systems. Discoveries and innovations made in this area are expected to exert a significant impact on the Army embodied as improved sensing capabilities, improved tactical networks, improved commander's decision support aids, and robust computational resources leading to information supremacy.

Information Sciences research emphasis areas include Battlefield Information Sensing and Effecting, System Intelligence and Intelligent Systems, Human and Information Interaction, Networks and Communications, and Cyber Security research. These areas collectively comprise ARL's Information Sciences research campaign, which heavily relies on ARL's research expertise and facilities in network science; human cognitive and decision support sciences; physical and software intelligent systems; electronic & information warfare vulnerability; electronic materials synthesis, component fabrication, and device characterization; sensing and modeling of complex battlefield environments; high-performance computing; and cyber defense and forensics. Discoveries and innovations made in this area are expected to exert a significant impact on the Army embodied as improved sensing capabilities, enhanced tactical networks, effective decision support aids, intelligent systems that team with Soldiers, and robust computational capabilities leading to information supremacy.

Sensing and Effecting research concentrates on understanding and exploiting information gained through sensing exploiting data to drive effectors. Both sensing and effecting necessitate detailed understanding of corresponding physical behaviors that generate and utilize data, as well as effective means for storage, retrieval, and manipulation of data.

System Intelligence and Intelligent Systems research concentrates on understanding and exploiting interactions between information and intelligent systems, such as robots and software agents, wherein information is transformed between different levels of abstraction and roles within the intelligent system's cognitive processes—recognition, reasoning, predictions, and decision-making.

Human and Information Interaction research concentrates on understanding and exploiting interactions between information and humans, which involves complex mixed-initiative processes of information acquisition, transformation between levels of abstraction and relevance, comprehension, negotiation and interactive tasking, mutually between humans and Army information systems.

Networks and Communications research concentrates on understanding and exploiting information's interactions with socio-technical networks, particularly communications, and command & control networks, both formal and social. Such interactions are heavily influenced by complex channels and protocols requiring complex analyses to understand and predict emergent behaviors of networks.

Cyber Security research concentrates on understanding and exploiting interactions of information with cyber attackers—human and/or intelligent agents. These interactions involve friendly operations against adversary information systems and networks, defense of friendly information systems and networks, and assurance of persistent information support to Soldiers even when parts of the friendly systems and networks are compromised.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

Biological, Chemical, and Atmospheric Aerosol Detection and Characterization Algorithms

Methodologies are developed to detect, characterize, classify, and identify hazardous biological, chemical, and atmospheric aerosols

Principal Investigators:	Yongle Pan	yongle.pan.civ@mail.civ@mail.mil	(301) 394-1381
	Steven Hill	steven.c.hill32.civ@mail.mil	(301) 394-1813
	Gorden Videen	gorden.w.videen.civ@mail.mil	(301) 394-1871

Raman Spectra of Single Trapped Airborne Aerosol Particles

A technology is under development that can trap individual atmospheric aerosol particles out of a continuous air flow sample, precisely characterize their chemical composition through Raman spectroscopy, and distinguish hazardous chem/bio agents from naturally occurring constituents.

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	Steven Hill	steven.c.hill32.civ@mail.mil	(301) 394-1813

Infrasonics

Develop models that predict infrasonic propagation, accurately accounting for environmental effects on the signal. Additionally, models are developed that allow the design of wind screens that optimize infrasonic antenna performance.

Principal Investigator: John Noble john.m.noble.civ@mail.mil (301) 394-5663

Cloudlet-Based Processing

Develop optimization approaches to allow for self-forming "cloudlet"-based processing configurations with HPC assets providing key processing and offloading support for constrained hand-held devices. Develop models to account for network connectivity and offered computing load as mapped to a dynamic computing infrastructure (computing capacity). Develop new methodologies or apply existing concepts related to scheduling to achieve balance in transient and unstable networks common in Army operational realms.

Principal Investigator: David Bruno david.l.bruno4.civ@mail.mil (410) 278-8929

Verification and Validation of Cloudlet Provisioning Using EMANE (APG)

The Extendable Mobile Ad-hoc Network Emulator (EMANE) is a useful system to verify and validate network-based protocols. This project will investigate how to extend the system for models under development at ARL and also test current models being proposed for non-ad-hoc networks for scalability and performance.

Principal Investigator: David Doria david.l.doria.civ@mail.mil (410) 278-2310

Scheduling and Provisioning within Army Cloudlets (APG)
This research involves investigating new model developments to couple mobile ad hoc networking with computing assets deployed in the field. Approximation methods will be investigated to facilitate provisioning and scheduling in real time.

Principal Investigator: David Bruno david.l.bruno4.civ@mail.mil (410) 278-8929

Domain-Specific Languages

Perform research into the utility of domain-specific languages to achieve high efficiency on advanced computing architectures to promote portability and longevity while reducing the burdens on computational scientists to develop software. Develop quantitative and qualitative assessment methodologies to assess performance.

Principal Investigator: David Bruno david.l.bruno4.civ@mail.mil (410) 278-8929

Investigation of Terra-Lua Approach for DSLs (APG)
ARL and Stanford University are working on the creation of DSLs targeting, in this case, finite element codes. This project will perform analysis of the Terra-Lua approach as it maps to a large-scale hybrid computing system using standard cores and GPU-based technologies.

Principal Investigator: Dale Shires dale.r.shires.civ@mail.mil (410) 278-5006

Information Architectures

Develop agile, auto-adaptive data dissemination and extraction techniques for hybrid tactical networks to enable small unit situation understanding.

Information to the Edge (ALC)
Develop adaptive methods for data dissemination and extraction in hybrid tactical networks. Explore machine learning and dynamic workflow techniques to dynamically allocate and configure sensing and processing assets to enhance small unit decision making.

Principal Investigator: Laurel Sadler laurel.c.sadler.civ@mail.mil (301) 394-1221

Natural Language Processing (NLP)

This effort will focus on adaptive machine translation (MT) research using predictive modeling techniques that leverage lexical, syntactic, and semantic natural language processing (NLP) resources against large-scale, heterogeneous document collections.

Principal Investigator: Melissa Holland virginia.m.holland6.civ@mail.mil (301) 394-3001

Bot-Language (ALC)

Using formal logic specifications built from natural language mission descriptions, generate reactive controllers that govern low-level robot behaviors. Explore the application of these specifications to enhance Soldier-machine interfaces.

Principal Investigator: Melissa Holland virginia.m.holland6.civ@mail.mil (301) 394-3001

NLP for Cultural Understanding (ALC)

Automation of the processing, analysis, and interpretation of text, including very low-resource foreign languages and social media, to support social network construction and relationship discovery from text toward new dimensions of socio-cultural insight.

Principal Investigator: Melissa Holland virginia.m.holland6.civ@mail.mil (301) 394-3001

Network Science

Apply non-equilibrium statistical physics to complex networks.

Principal Investigator: Bruce J. West bruce.j.west.civ@mail.mil (919) 549-4257

Network & Information Sciences: Quality of Information

Development of foundational framework, including ties with semantic information theory, and propagation of information in composite dynamic networks.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Greg Cirincione	gregory.h.cirincione.civ@mail.mil	(301) 394-4809

Supporting Facility: Mobile Network Modeling Institute (APG)

Facility for fine-grained simulation and emulation of communication networks.

Tactical Optical Communications

Study of unconventional free-space optical communication systems (employing, e.g., ultraviolet or visible light-emitting diodes), including communication channel model development, the analysis of system design tradeoffs, experimental validation, and prototype system development.

Principal Investigator: Robert Drost robert.j.drost6.civ@mail.mil (301) 394-0158

Network & Information Sciences: Co-evolution of Networks

Development of empirical and theoretical models; tools for discovery, inference, prediction and control; and experimental validation.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Bruce J. West	bruce.j.west.civ@mail.mil	(919) 549-4257

Quality of Information (ALC)
Develop a foundational framework, including ties with semantic information theory; develop models for propagation of information in composite dynamic networks; and experimental validation.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Greg Cirincione	gregory.h.cirincione.civ@mail.mil	(301) 394-4809

Group Structures in Composite Networks (ALC)
Empirical study of group structures in multiple collaboration and other social networks and development of models of evolution.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Terrence Moore	terrence.j.moore.civ@mail.mil	(301) 394-1236

Network Science (ALC)
Develop theories and experimentally validated models for the structure, dynamics, and interactions of co-evolving networks; develop metrics for composite dynamic networks; determine how processes and parameters in one network affect and are affected by those in the co-evolving networks; predict and control individual and composite behavior of these complex interacting networks.

Principal Investigator:	Hasan Cam	hasan.cam.civ@mail.mil	(301) 394-2871

Network Tomography (ALC)
Development of theories, fundamental performance bounds, algorithms, and performance guarantees for inference of network state and topology from partial and inaccurate information in dynamic and stochastic settings; and detection of changes.

Principal Investigator:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486

Co-Evolution & Dynamics of Networks (ALC)
Develop framework for modeling co-evolution and dynamics in inter-genre networks, including large and adversarial network. Characterize co-evolution of structural vs. functional/behavioral traits. Develop tools for discovery, inference, and prediction in inter-genre networks.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Terry Moore	terrence.j.moore.civ@mail.mil	(301) 394-1236

Models of Information Propagation in Composite Networks (ALC)
Model social influence using probabilistic graph models; exploit tensor decomposition to transform graphical models into structurally simpler graphical models; and develop inference and prediction techniques (for both static and dynamic networks).

Principal Investigator:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486

Quality of Information (ALC)
Development of foundational framework, including ties with semantic information theory; development of an appropriate theory of information. Extensions of subjective logic for fusion for QoI.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Greg Cirincione	gregory.h.cirincione.civ@mail.mil	(301) 394-4809
	Lance Kaplan	lance.m.kaplan.civ@mail.mil	(301) 394-0807

Supporting Facility: Network Science Research Laboratory (ALC)
Integrated framework for experimentation on networks.

Quantum Information Science

Investigate advanced tactical and long-range atmospheric laser communication and imaging technologies to achieve high-bandwidth communication and high-fidelity visualization. Investigate and develop novel processing techniques to provide tactically superior quantum imaging and battlefield communications particularly in obscured, obstructed, or adverse tactical environments. Research topics include experimental and theoretical research in quantum entanglement, quantum imaging, quantum multiphoton interference, quantum information processing, and quantum communications.

Principal Investigator: Ronald Meyers ronald.e.meyers6.civ@mail.mil (301) 394-2111

Sensor Fusion and Biometrics

Develop new mathematical tools for multimodal fusion of homogenous/heterogeneous sensor data for display as well as identification. Provide algorithms to identify individuals from their biometrics data.

Principal Investigator: Nasser Nasrabadi nasser.m.nasrabadi.civ@mail.mil (301) 394-0806

Video and Imaging Understanding

This effort will focus on developing machine learning algorithms in analyzing and labeling image and videos for detection and identification of faces and people's activities. Research in computer vision, machine learning, and statistical techniques for developing new methods for object classification and identification. Emphasis on developing new methods to analyze full motion video for tracking individuals or a group of people. Machine learning techniques will be investigated to recognize people's activities in an unconstrained environment.

Principal Investigator: Nasser Nasrabadi nasser.m.nasrabadi.civ@mail.mil (301) 394-0806

Anomaly Determination

This effort will focus on research and development of a robust and flexible framework, context-aware feature extraction and anomaly determination algorithms in order to determine anomalous activities and analyze patterns of life. Focus will be on exploiting and processing disparate structured and unstructured data including sensor data, video data and social media data.

Principal Investigators:

Thyagaraju Damarla	thyagaraju.damarla.civ@mail.mil	(301) 394-1266
Tien Pham	tien.pham1.civ@mail.mil	(301) 394-4282
Michael A. Kolodny	michael.a.kolodny.ctr@mail.mil	(301) 394-3110

Applied Anomaly Detection

Visualization tools are being developed to aid the Warfighter in identifying IED emplacements, hostile UAS encroachment, and other battlefield hazards. The project is being transitioned from a training tool environment to a tactically-available decision support application.

Principal Investigator: Adrienne Raglin adrienne.j.raglin.civ@mail.mil (301)394-0210

Anomaly Detection Algorithms (ALC)

Research and develop multi-modal sensor and fusion algorithms for anomaly detection. Bayesian and non-Bayesian methods will be explored.

Principal Investigator: Thyagaraju Damarla thyagaraju.damarla.civ@mail.mil (301)394-1266

Anomaly Determination Testbed (ALC)

Develop software and analysis tools for a networked testbed to collect and process multi-modal sensor data and social media data for anomaly determination algorithm development.

Principal Investigator: Michael A. Kolodny michael.a.kolodny.ctr@mail.mil (301) 394-3110

Sensor Ontologies (ALC)

Research and develop sensor ontologies to link disparate sensor assets to human-directed taskings.

Principal Investigator: Tien Pham tien.pham1.civ@mail.mil (301) 394-4282

Semantic Data & Information Processing (ALC)

Research and develop semantically-aware processing algorithms to discover, extract, correlate, combine and/or fuse text, photo, sound, image and video data/information to enable computer applications to intelligently understand the context in which data/information was generated and stored and to extract logical conclusions and establish relationships.

Principal Investigator: Tien Pham tien.pham1.civ@mail.mil (301) 394-4282

Multi-modal Sensor Data Analysis & Fusion for Target Detection, Classification and Tracking

This effort will focus on the development of novel algorithms for multi-modal sensor data analysis based on sensor phenomenology. Effort will focus on robust feature extraction engines for various types of targets, e.g., human, animal and vehicle. Exploitation of compressive sensing techniques to learn new approaches for signal representation and analysis will be considered. Distributed sensor detection and classification of correlated and un-correlated data will be dealt with. In addition, feature extraction of other types of information sources such as electronic signals and social media will also be investigated for better situational awareness. New tracking algorithms using distributed sensors will be explored.

Principal Investigator: Thyagaraju Damarla thyagaraju.damarla.civ@mail.mil (301)394-1266

Multi-modal Processing & Fusion Algorithms for Unattended Sensors (ALC)
Research and develop robust and efficient multi-modal algorithms for resource-constrained unattended ground sensors.

Principal Investigator: Thyagaraju Damarla thyagaraju.damarla.civ@mail.mil (301)394-1266

Distributed Signal Processing

This effort will focus on the development of signal processing algorithms in various areas including distributed detection, localization, and state estimation. Focus will be on developing algorithms for sensor networks, which guarantee robust performance and network consensus.

Principal Investigators:	Jemin George	jemin.george.civ@mail.mil	(301) 394-3977
	Gene Whipps	gene.t.whipps.civ@mail.mil	(301) 394-2372
	Tien Pham	tien.pham1.civ@mail.mil	(301) 394-4282

Fully Distributed Multi-Target Localization (ALC)
Develop fully distributed multi-target localization algorithm using average consensus and modeling the individual measurements as Finite Point Processes.

Principal Investigator: Jemin George jemin.george.civ@mail.mil (301) 394-3977

Robust State Estimation and Fault Detection in Network (ALC)
Develop robust algorithms for state estimation and fault detection in networked nonlinear-systems. Developed algorithm should be distributed and robust against model uncertainties.

Principal Investigator: Jemin George jemin.george.civ@mail.mil (301) 394-3977

Machine Learning for Signal Processing (ALC)
Research and develop distributed algorithms geared toward dimensionality reduction and learning of probabilistic data distributions for data with inherently low-dimensional embeddings. Focus will be on social media and traditional sensors with high rates of data inputs.

Principal Investigator: Gene Whipps gene.t.whipps.civ@mail.mil (301) 394-2372

Uncertainty Management Across Networks

This research effort will focus uncertainty characterization through information fusion processing and knowledge synthesis. There is a need to understand data and information is transformed by the different fusion processing methods and how to choose the methods to achieve desired quality of information (QoI) and robustness.

Principal Investigator: Lance Kaplan lance.m.kaplan.civ@mail.mil (301) 394-0807

Trust in Fused Information (ALC)

Research how will focus on how different strands of knowledge can be processed, analyzed, and combined to model trust in information and how such models can be exploited to improve the trustworthiness of the fused information.

Principal Investigator: Lance Kaplan lance.m.kaplan.civ@mail.mil (301) 394-0807

Spectral-Spatiotemporal Sensor Data Analysis for Target Detection and Identification

This effort will focus on the research and development of advanced autonomous decision methods for target detection and identification, using multivariate sensor data, longitudinal data analysis techniques, and sensor phenomenology. Focus will be on exploiting and processing correlated and uncorrelated spectral-spatiotemporal imageries of a particular site continuously recorded over a period of an entire year in the longwave infrared (LWIR) region of the spectrum.

Principal Investigators: Dalton Rosario dalton.s.rosario.civ@mail.mil (301) 394-4235
Patrick Rauss patrick.j.rauss.civ@mail.mil (301) 394-1075

Algorithms for Daytime and Nighttime Target Detection and Identification (ALC)

Focus are threefold: (1) conduct a rigorous spectral-spatiotemporal, longitudinal data analysis of a LWIR hyperspectral dataset, aimed at statistically quantifying the evolution of spectral patterns of multiple materials in a target site as a function of short-term and long-term time periods, and through various weather conditions naturally occurring in four meteorological seasons; (2) determine sources of performance degradation using state of the art algorithms to process the dataset; and (3) leverage results from (1) and (2) to introduce new algorithmic concepts for daytime/nighttime target detection and identification. Parametric, nonparametric, and semiparametric methods will be explored.

Principal Investigator: Dalton Rosario dalton.s.rosario.civ@mail.mil (301) 394-4235

Phenomenology of LWIR Hyperspectral Signatures (ALC)

Focus on working with LWIR hyperspectral imageries collected on approximately hourly basis of a fixed area over a long period of time (currently a year). Effort will specifically focus on identifying, characterizing, and understanding the phenomenology of the spectral signatures of the materials in the scene (both man-made and natural) and how they are affected over time and various atmospheric and weather conditions.

Principal Investigator: Patrick Rauss patrick.j.rauss.civ@mail.mil (301) 394-1075

Text and Video Analytics

Investigate joint optimization of semantic information of text and video to enable Soldiers at the tactical edge. Develop hierarchical semantic structures that can make tradeoff between specificity and generality that can provide a broad perspective of text and video. Develop semantically adaptive analytics approaches that can deliver optimal information over constrained multigenre networks. Develop a content based semantic information theory.

Principal Investigators: Heesung Kwon heesung.kwon@us.army.mil (301) 394-2501
Shuowen Hu shuowen.hu.civ@mail.mil (301) 394-2526

Acoustic/Infrasonic Sensor Concepts

Research will be focused on the development of unique, high dynamic range, low noise sensors for acoustics and infrasound. Sensors that measure acoustic pressures and those that resolve the acoustic particle velocity will be included. These devices must be robust and be able to survive for extended use in an outdoor environment. Acoustic anechoic chamber, speakers, array configurations, instrumentation microphones and data acquisition are resources that can be applied to this research area.

Principal Investigators: Stephen Tenney Stephen.m.tenney2.civ@mail.mil (301) 394-3080
Kirk Alberts William.c.alberts4.civ@mail.mil (301) 394-2121

Direction of Arrival Estimation

This research will be on developing direction of arrival (DOA) estimation algorithms for non-stationary signals, noise and interference. The focus will be on processing acoustic signals collected using either traditional microphone arrays or novel vector sensing concepts.

Principal Investigators:
Geoffrey Goldman Geoffrey.h.goldman.civ@mail.mil (301) 394-0882
Latasha Solomon Latasha.i.solomon.civ@mail.mil (301) 394-2180

Robust Multi-target Tracking

This effort will focus on developing multi-target detection and tracking algorithms in the presence of non-stationary interference and noise. The focus will be on processing acoustic signals generated from aerial targets in a noisy environment using one or more arrays of microphones.

Principal Investigator: Geoffrey Goldman Geoffrey.h.goldman.civ@mail.mil (301) 394-0882

Classification of Acoustic Signals

This effort will focus on developing algorithms to classify targets of military significance from acoustic signals. The research will include preprocessing the data, extracting robust features, and classification. Algorithms that offer efficient processing requirements are most favored.

Principal Investigators: Duong Tran-Luu Tungduong.tran-luu.civ@mail.mil (301) 394-3082
Geoffrey Goldman Geoffrey.h.goldman.civ@mail.mil (301) 394-0882

Acoustic Array Signal Processing

Work here will focus on signal processing techniques to handle multi-sensor microphone arrays for infrasonic as well as acoustic applications. Array signal processing for wind noise reduction, time difference of arrival and beam forming techniques are of interest. Exploiting the benefits derived from microphone arrays including the determination of optimum numbers of microphones within an array is of interest.

Principal Investigator: Stephen Tenney Stephen.m.tenney2.civ@mail.mil (301) 394-3080

Wind Noise Reduction

This effort is focused on the development of novel acoustic and infrasonic wind noise reduction technologies, e.g. investigating various porous materials and windscreen sizes both theoretically and experimentally. There is a need to minimize the size of both acoustic and infrasonic windscreens while maximizing their sound transmission capabilities and their environmental robustness. Further, this research will also address signal-processing methods to extract infrasonic signals from data corrupted by wind noise.

Principal Investigators: William Alberts william.c.alberts4.civ@mail.mil (301) 394-2121
Latasha Solomon Latasha.i.solomon.civ@mail.mil (301) 394-2180

Ground Effect Mitigation

This research will focus on directly estimating and mitigating the adverse effects of interfering ground-reflected acoustic waves measured by three-dimensional microphone arrays. The thrust of the research is to improve estimated source elevation angles by removing the phase- and amplitude-altering effects of the porous ground.

Principal Investigators: William Alberts william.c.alberts4.civ@mail.mil (301) 394-2121

Magnetics Research

This effort focuses on the research and development of magnetic sensors, devices and materials that include improving our ability to detect, locate, and identify magnetic objects and power sources. Other goals are lower power communications and information storage.

Principal Investigator: Alan Edelstein alan.s.edelstein.civ@mail.mil (301) 394-2162

Magnetic Anomaly Detection Algorithms (ALC)

Research and develop magnetic algorithms for magnetic anomaly detection and the location and identification of objects of interest.

Principal Investigator: Alan Edelstein alan.s.edelstein.civ@mail.mil (301) 394-2162

Magnetic Sensors and Devices (ALC)

Develop and fabricate magnetic low cost, sensitive magnetic sensors and methods for evaluating the performance of magnetic sensors for detecting various magnetic sources in different environmental conditions. Develop and fabricate magnetic devices that include devices using magnetic tunnel junctions and spin valves for application such as spin torque oscillators and non-erasable and high density memory

Principal Investigator: Alan Edelstein alan.s.edelstein.civ@mail.mil (301) 394-2162

Metal Detectors (ALC)
Enhance the performance of traditional metal detectors through improved sensors, fusion, and advanced signal processing techniques. Develop metal detectors that are lighter and/or have a narrower detection bandwidth.

Principal Investigator: Alan Edelstein alan.s.edelstein.civ@mail.mil (301) 394-2162

Communications (ALC)
Investigate magnetic devices and materials that are lower cost, smaller and/or have improved performance in communicating information with special emphasis on energy efficiency.

Principal Investigator: Alan Edelstein alan.s.edelstein.civ@mail.mil (301) 394-2162

Quasi-static 3D Electric- & Magnetic-field Modeling and Simulation

This effort will focus on research and development of robust and flexible state-of-the-art solvers for quasi-static boundary-value problems. Particular codes may include in-house Method of Moments, Boundary-Element Methods, Fast Multipole Methods as well as commercial codes using Massively Parallel Processors, GPUs, HPC, ad hoc arrays, etc.

Principal Investigators: David Hull david.m.hull6.civ@mail.mil (301) 394-3140
Stephen Vinci stephen.j.vinci.civ@mail.mil (301) 394-0418

Quasi-static Modeling (ALC)
Create simulation models for studying electrostatic and magnetostatic fields on objects under varying conditions with multi-physics parameters. Applications include design of improved E-field generators and/or sensors, models of people, vehicles, unmanned air systems (UAS), power lines, bullets, rockets, plasmas, arcs, lightning, etc.

Principal Investigator: David Hull david.m.hull6.civ@mail.mil (301) 394-3140

3D Graphics and Visualization Tools (ALC)
Development of 3-D graphics editing tools, aided meshing tools, iterative tools for dynamic (time-varying) models, etc.

Principal Investigator: David Hull david.m.hull6.civ@mail.mil (301) 394-3140

Real-time and In-situ Parametric Electric and Magnetic Model-based Fitting (ALC)
Research and develop algorithms to fit live data from electric and magnetic field sensors to previously-generated or in-situ generated quasi-static boundary element models. Applications include mobile platform (vehicle, UAS) analysis of sensor data and fitting in real-time to on-the-fly generated models.

Principal Investigator: David Hull david.m.hull6.civ@mail.mil (301) 394-3140

Quasi-static Electric-field Generator Facility

This effort will focus on the continued development, improvement, and operation of ARL's unique uniform-field electric-field generator facilities. Work to include improvements to the IEEE standard 1308-1994, including 2-D and 3-D field generation, larger volumes, specified accuracy, development of data acquisition systems, characterization procedures, and experimental verification. Applications include sensor characterization and calibration, electric-field lenses for focusing space charges and/or charged-particle beams, and electric safety.

Principal Investigators:	Simon Ghionea	simon.j.ghionea.civ@mail.mil	(301) 394-1844
	David Hull	david.m.hull6.civ@mail.mil	(301) 394-3140
	Stephen Vinci	stephen.j.vinci.civ@mail.mil	(301) 394-0418

Supporting Facility: Electric-field Generator Laboratory (ALC)

Unique uni-axial quasi-static electric-field generator facility. Patented design controls fringing fields and provides a large 1 m^3 working volume with <2% deviation from ideal parallel plate electric field. This facility is intended to encourage and foster development of ambient electric-field sensors and outside collaborators are encouraged to bring their sensors and systems to characterize in this unique ARL facility. Measurements performed are dynamic range, linearity, frequency response, field-referred noise floor, etc. Frequency range and field strength presently available is DC – 20 kHz and up to 4 V/m over the full (>20 m3) cage volume; 10-100 V/m can be generated in smaller volumes, and upgrades are possible to operate at up to 1 MHz and 1000 V/m.

Equipment Available: National Instruments PXI chassis, precision ac and dc power supplies, signal generators, amplifiers, data acquisition cards, PCB design workflows, Ansys Electromagnetics, Integrated Engineering Software suite, in-house codes.

Phase-synchronous Non-conducting Data Acquisition System Design (ALC)

Design of a fully-isolated data acquisition system for use in the ARL Electric-field Generator. Galvanic connections are subject to interactions with the generated electric-field thus reducing accuracy of the measurement. The challenge is in maintaining phase synchronicity to the field generation equipment. Options to be investigated will include methods with minimal metallic footprint at the device under test and no metallic wiring, such as optical, wireless telemetry, or combinations of both.

Principal Investigator: Simon Ghionea simon.j.ghionea.civ@mail.mil (301) 394-1844

Control System Design for High-Field and/or High-Frequency (up to ~1 MHz) Operation (ALC)

Investigate safety requirements and propose and design solutions to operate the facility at higher field strength. Develop models and LabView GUI's to support testing. Specify programmable laboratory equipment (amplifiers, function generators) and design appropriate safety interlock systems and standard operating procedures. Calculate and measure the upper frequency-limit for electric-field generator, and propose modifications to improve to ~1 MHz range.

Principal Investigator: Simon Ghionea simon.j.ghionea.civ@mail.mil (301) 394-1844

Development of Electric- and Magnetic-field Arbitrary Vector Chamber (ALC)

Electric and magnetic design of novel 2-D and 3-D electric and magnetic-field generation facilities and improvements to IEEE 1308-1994. Control of fringing fields, application of a separate quasi-static magnetic field in the same time and space, including minimization of cross-domain coupling.

Principal Investigator: David Hull david.m.hull6.civ@mail.mil (301) 394-3140

Electric-field Transducers and Sensor Systems

This effort will focus on the development of electric-field transducers and sensor systems, including vector and scalar (total-field) sensors, operating from DC to ~1 MHz (or some subset of this range). Applications include physiological sensors (EEG, ECG), bullet detection and tracking, power-line field sensing, as well as study of high-voltage arcs and plasmas, corona, space charges, etc

Principal Investigator: David Hull david.m.hull6.civ@mail.mil (301) 394-3140

Sensor Characterization (ALC)
Perform experiments in the ARL electric-field generator facility to test in-house and collaborator sensor systems. Properties to be studied include sensitivity, size, weight, power, stability, linearity, dynamic range, cross-domain sensitivity,etc.

Principal Investigator: Simon Ghionea simon.j.ghionea.civ@mail.mil (301) 394-1844

Smart Sensor System Design (ALC)
Design of unique application-specific sensor systems at the transducer, board, and firmware level. The focus is on multi-modal high dynamic range, low distortion, and low power analog signal conditioning.

Principal Investigator: Simon Ghionea simon.j.ghionea.civ@mail.mil (301) 394-1844

Novel Electric-field Transducers (ALC)
Design, test, and characterization work on novel electric-field transducers and sensing concepts. Efforts to include transducers based on high electric impedance, MEMS, optical, charged particles, and stress/strain measurements.

Principal Investigator: Simon Ghionea simon.j.ghionea.civ@mail.mil (301) 394-1844

Energy and Signature Analysis for Microgrids: Prognostics, Diagnostics, Energy Savings, and Stability

This effort will focus on research to analyze and study characteristics voltage and current waveforms on the supply line to a device under test (DUT) for purposes of predicting the onset of subsystem component failures or wears and prescribing preventative maintenance to address the issue. Techniques may be utilized to study energy efficiency of equipment that may not be operating at optimal efficiencies due to age or wear. Also addresses microgrid stability where limited power may be available.

Principal Investigators: Stephen Vinci stephen.j.vinci.civ@mail.mil (301) 394-0418
David Hull david.m.hull6.civ@mail.mil (301) 394-3140

Prognosticating Equipment Failure From Energy Consumption Signatures (ALC)
Study the correlation between equipment failure/wear with it's power (voltage and current) waveforms. Use automated analysis algorithms to prescribe diagnostics to maintain equipment health.

Principal Investigator: Stephen Vinci stephen.j.vinci.civ@mail.mil (301) 394-0418

Energy Savings (ALC)
This work focuses on intelligent algorithms and to empower users and organizations to save energy. Identifying and reporting top power consumers and unknown or "vampire loads" which can drastically reduce the organization's energy usage.

Principal Investigator: Stephen Vinci stephen.j.vinci.civ@mail.mil (301) 394-0418

Microgrid Stability and Energy Reporting (ALC)
Use intelligent energy usage information to make informed decisions, such as load shedding, and quality of service, in a microgrid operating environment.

Principal Investigator: Stephen Vinci stephen.j.vinci.civ@mail.mil (301) 394-0418

Science of Cyber Security

Develop a fundamental understanding of cyber phenomena, including aspects of human attackers, cyber defenders, and end users, so that fundamental laws, theories, and theoretically grounded and empirically validated models can be applied to a broad range of Army domains, applications, and environments.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Alex Kott	alexander.kott1.civ@mail.mil	(301) 394-1507

Networked Trust and Its Impact on Security (ALC)
Develop models of networked trust and its impact on cyber security, and experimental validation with a mixture of agent models and HiTL testing.

Principal Investigators:	Ananthram Swami	ananthram.swami.civ@mail.mil	(301) 394-2486
	Jin-Hee Cho	jin-hee.cho.civ@mail.mil	(301) 394-0492
	Kevin Chan	kevin.s.chan.civ@mail.mil	(301) 394-5640

Supporting Facility: Cyber Lab (ALC)

Live test bed for monitoring, collecting, and testing computer networks.

Sciences for Lethality & Protection

The Sciences for Lethality and Protection area is focused on gaining a fundamental understanding of armor, under body, scalable effects, electronic warfare, and human injury mechanisms. This area heavily relies on ARL's research expertise and facilities in terminal effects; impact physics; weapons physics, guidance and aerodynamics; and ballistic vulnerability. Knowledge gained through these research efforts will lead to technological developments in a broad array of lethality systems as well as resilient and robust vehicle protection systems.

Research emphasis areas include Lethality Research for Soldiers and Army Platforms, Protection Research for Soldiers and Army Platforms, and Battlefield Injury Biomechanics.

Lethality Research for Soldiers and Army Platforms concentrates on understanding and exploiting the fundamental aspects of launch and control, electronic attack, directed energy mechanisms, and target effects.

Protection Research for Soldiers and Army Platforms concentrates on understanding and exploiting the fundamental aspects of protection against ballistic threats, directed energy threats, and CBRNE threats.

Battlefield Injury Mechanisms concentrates on understanding and exploiting the fundamental aspects of human combat injury mechanisms.

Key challenges required to enable disruptive advances in this area include:

- Understanding the interaction of extreme fields with matter.
- Understanding the controlling mechanisms of human ballistic injury and performance.
- Understanding the relationship between aerodynamics and algorithms for navigation and environment constraints including measurement/processing/flight time/GPS denied.
- Understanding robust, reliable, and recoverable nonlethal mechanisms to shut down or dissuade humans.
- Understanding the coupling of physical phenomena—mechanical, electromagnetic, and biological—across the range of military interest.
- Understanding and discovery of very high-energy storage mechanisms and controlled release on desired timescales.
- Understanding the fundamental aspects of frequency agile, high-energy, and short pulse laser interaction with organic, biological, and inorganic materials.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

Dynamic Failure of Materials

Discover the underlying mechanisms associated with material fracture and failure that occur at very high loading rates, create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

Principal Investigator: Todd Bjerke todd.w.bjerke2.civ@mail.mil (410) 278-5819

Supporting Facility: Dynamic Fracture Laboratory (APG)

High-rate loading device and state-of-the-art instrumentation to isolate and probe individual fracture/failure mechanisms.

Equipment Available: Gas gun, coherent gradient sensing device, high-powered laser, method of caustics, ultrafast 64 channel IR detector array for measuring thermal emissions furing propagating cracks, strain gages, Hadland cameras.

Modeling of Dynamic Fracture (APG)

Discover the underlying mechanisms associated with material fracture and failure that occur at very high loading rates, create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

Principal Investigator: Todd Bjerke todd.w.bjerke2.civ@mail.mil (410) 278-5819

Flight Dynamics/Guidance, Navigation, and Control

Flight dynamics and guidance, navigation, and control of guided precision munitions with emphasis on development of new algorithms of novel guided munitions.

Principal Investigator: Frank Fresconi frank.e.fresconi.civ@mail.mil (410) 306-0794

High-G Environment

Understanding and simulating a structural response to a high-acceleration environment are critical to the effective design of gun-launched projectiles. Development of detailed models of high-g simulation that can be used to tailor test environment.

Principal Investigator: Morris Berman morris.berman@us.army.mil (301) 394-4188

Interior Ballistic Structural Models (APG)

Use high-fidelity FE modeling methods to simulate structural response to the interior ballistic environment.

Principal Investigator: William Drysdale william.h.drysdale.civ@mail.mil (410) 306-0945

Supporting Facility: High-G Environment Simulation Facility (ALC)

Laboratory creation of millisecond-duration high-g environments.

Equipment Available: 3" Airgun, 4" Airgun, 7" Airgun.

High-Rate Experimental Mechanics of Materials at Different Length Scales and Loading Rates

Exploring and understanding the relationship between mechanical, electrical, and chemical response of materials to mechanical loading by identifying associated micro-mechanisms through quantitative in-situ visualization. Investigations are designed to unravel the deformation, failure and injury mechanisms at loading rates and length scales with focus on Army-relevant materials including bio and bio-mimetic materials.

Principal Investigator: Tusit Weerasooriya tusit.weerasooriya@us.army.mil (410) 306-0969

Deformation and Failure Mechanisms for Army-Relevant Materials (APG)
Understanding the relationship between mechanical, electrical, and chemical response of materials at different length scales to mechanical loading with focus on rates experienced by Soldiers on the battlefield. Developing in situ experimental methods and conducting investigations to identify associated micro-mechanisms through quantitative visualization.

Principal Investigator: Tusit Weerasooriya tusit.weerasooriya@us.army.mil (410) 306-0969

Supporting Facility: Multi-Scale and Multi-Rate Experimental Mechanics Laboratory (APG)

The laboratory has developed many unique in-situ experimental methods at different length-scales to explore the rate-dependent response of materials (including bio materials) using novel loading methods at different rates. Response measuring diagnostics include wide-field, fluorescent, confocal, electron microscopy, macro/micro-DIC methods and micro-CT methods. This lab is in the process of developing in situ X-ray diffraction microscopy (SAXS and WAXS) methods. Mechanical loading devices include specially designed Hopkinson bars and other specialized loading devices to apply Army relevant loading to materials scaling from centimeters to sub-micrometers.

Humans in Extreme Environments

Understanding the mechanisms of human response to high rate ballistic loading. Develop experimental methods and computational techniques to understand the human response to ballistic loading. Current research focuses include understanding the response of the brain and the body to ballistic loading conditions including accelerative loading conditions. Experimental investigations in the response of the brain are designed to elucidate neuronal responses from mechanical loading at different rates. Computational techniques are required to accurately represent the rate-dependent response of tissue to applied loading.

Principal Investigators: Christopher Hoppel christopher.p.hoppel.civ@mail.mil (410) 278-8878
Tusit Weerasooriya tusit.weerasooriya@us.army.mil (410) 306-0969

Supporting Facility: Multi-Scale and Multi-Rate Experimental Mechanics Laboratory (APG)

The laboratory has developed numerous unique in situ experimental methods at different length-scales to explore the rate-dependent response of materials (including bio materials) using novel loading methods at different rates. Response measurement diagnostics include wide-field, fluorescent, confocal, electron microscopy, macro/micro-DIC methods and micro-CT methods. We are also in the process of developing in situ

X-ray diffraction microscopy (SAXS and WAXS) methods. Mechanical loading devices include specially designed Hopkinson bars and other specialized loading devices to apply Army relevant loading to materials scaling from centimeters to sub-micrometers.

Understanding the Mechanisms of Traumatic Brain Injury (APG)

Develop in situ experimental methods to characterize the neuronal response to different rates of loading including ballistic loading. Develop computational techniques to represent the electrical, mechanical, and chemical responses of the brain to stress waves applied to the body.

Principal Investigators:	Christopher Hoppel	christopher.p.hoppel.civ@mail.mil	(410) 278-8878
	Tusit Weerasooriya	tusit.weerasooriya@us.army.mil	(410) 306-0969

Diagnostic Development for Ballistic Experiments

Develop diagnostics capable of measuring material response during ballistic impact events.

Principal Investigator:	John Runyeon	john.w.runyeon.civ@mail.mil	(410) 278-6568

Diagnostic Development for Ballistic Experiments (APG)

Enhance diagnostic techniques for use in ballistic experiments. The intent is to implement these diagnostic techniques at large scale experimental facilities capable of handling up to 20 lb of high explosive. The goal of this focus area is to increase both the quantity and fidelity of data typically captured during ballistic experiments as well as explore entirely new diagnostic methods. Examples of potential collaborative efforts include development of a) multi-color flash x-ray tomography and b) modern cineradiography capability.

Princpal Investigator:	Michael Zellner	michael.b.zellner.civ@mail.mil	410-306-2565

Supporting Facility: Multiple Experimental Facilities that Utilize the Following (APG)

- Flash radiography sources including 150, 300, 450, and 1000 KeV
- Computed radiography using Kodak imaging plates and imaging plate scanner
- Lasers; IPG 2 watt 1550 nm laser and Spectral Physics 6 watt 532 nm laser
- High speed oscilloscopes (numerous 1 GHz bandwidth and one 16 GHz bandwidth)
- Numerous delay generators and timing equipment
- Four channels of 10 GHz Photonic Doppler Velocimetry
- Cordin 222-16 intensified gated framing camera (16 images); SIM 8 frame intensified gated framing camera
- Four Photron high speed cameras;
- High voltage firing set capable of setting off numerous detonators (RP-80 like)

Protection Technologies

Understanding conventional and unconventional methods for defeating combinations of chemical energy warhead anti-armor threats including rocket propelled grenades (RPG), anti-tank guided missiles (ATGM), explosively formed penetrators (EFP) and related improvised explosive device (IED) threats. Explore and develop hybrid and/or adaptive protection technologies to defeat a range of anti-armor chemical energy warhead threats. Investigations would involve a using a wide range of available resources including analytic models, scalable continuum mechanics codes, high performance computing assets, and multiple ballistic experimental facilities

Principal Investigator: John Runyeon john.w.runyeon.civ@mail.mil (410) 278-6568

ATGM, RPG, EFP and IED Defeat (APG)

Explore and develop hybrid and/or adaptive protection technologies to defeat a range of anti-armor chemical energy warhead threats. Investigations would involve a using a wide range of available resources including analytic models, scalable continuum mechanics codes, high performance computing assets, and multiple ballistic experimental facilities.

Principal Investigator: John Runyeon john.w.runyeon.civ@mail.mil (410) 278-6568

Supporting Facilities: Multi-Scale and Multi-Rate Experimental Mechanics Laboratory (APG)

- Multi-Threat Armor Branch Experimental Facility 7 and 7a (full-scale explosive events) with significant diagnostic capabilities for high-rate ballistic events
- DoD Super-Computing Resource Center with significant classified and unclassified computing capability
- Numerous related ARL, APG and Army facilities that provide support to protection research.

Dynamic Failure of Materials at Extreme States

Discover the underlying mechanisms associated with material fracture, failure, and high pressure transformations/instabilities that occur at very high loading rates, pressures, temperatures, and magnetic fields; create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

Principal Investigator: Todd Bjerke todd.w.bjerke2.civ@mail.mil (410) 278-5819

Modeling of Dynamic Failure at Extreme States (APG)

Discover the underlying mechanisms associated with material fracture, failure, and high pressure transformations/instabilities that occur at very high loading rates, pressures, temperatures, and magnetic fields; create engineering-level models of the underlying mechanisms, and structure the models in a manner consistent for implementation into advanced computational mechanics codes.

Principal Investigator: Todd Bjerke todd.w.bjerke2.civ@mail.mil (410) 278-5819

Supporting Facilities: Dynamic Fracture Laboratory (APG)

High-rate loading device and state-of-the-art instrumentation to isolate and probe individual fracture and failure mechanisms.

Equipment Available: Small diameter gas gun with customizable impact chamber, coherent gradient sensing equipment, high-powered laser, method of caustics, ultrafast 64- channel two-dimensional IR detector array for measuring thermal emissions during crack propagation, strain gages, ultra high speed imaging cameras.

Supporting Facilities: Shock and Impact Physics Laboratory (APG)

Impact laboratory for studying the effects of extreme shock pressures, temperatures, coupled electromagnetic fields, and ballistic penetration in materials.
Equipment Available: Suite of large diameter single and two-stage light gas guns, plate impact shock physics impact chambers, ballistic impact chambers, pulsed x-ray and high speed optical imaging systems, multi-point VISAR systems, simultaneous pressure-shear impact and shock-recovery capabilities, and extreme magnetic field coils.

Low-Cost Hyper-Accurate Weapons

Research estimation and control algorithms while leveraging high-performance, low-power computing capabilities to solve complex engagement problems that are currently not feasible.

Principal Investigator: Mark Ilg mark.d.ilg.civ@mail.mil (410) 306-0780

Supporting Facility: Guidance Navigation and Control Laboratory (GN&C) (**APG**)

Facility for developing GN&C systems for gun-launched munitions. Conduct hardware in-the-loop simulations and prototyping of guidance electronics and actuation systems.
Equipment Available: Sprient GNSS 8000 - Global Navigation Simulator; Antenna Characterization Chamber; Gun Shock Loading Table; MEMs IMU Calibration Equipment; Helmholtz Coil; Mechanical Prototyping Equipment; MyData PCB Assembly Equipment.

Modeling Development and Validation Via Novel Experimental Diagnostics

This work encompasses fundamental research in electromagnetism and solid mechanics. A close synergism between theory and experiment is continuously sought, and close collaboration between experimentalists and modelers is considered mandatory. The theoretical work can vary from largely analytical, which relies only on physics-based PC programs, to full-scale hydrocode simulations. The experimental work employs sophisticated diagnostics that can be used to measure electrical and thermodynamic properties for purposes of comparison with theory. Specific research projects in electrodynamics or plasma physics with an emphasis on conductors moving in EM fields, gasses under extreme conditions, and/or development of unique experimental diagnostics for physics-based model or hydrocode validation

Principal Investigator: Casey Uhlig willard.c.uhlig.civ@mail.mil (410) 278-3997

Supporting Facility: EM Laboratory and Experimental Ballistic Facilities (APG)

Experimental facilities with pulsed power production and measurement capabilities, and high-velocity impact events.
Equipment Available: Pulsed-power equipment, high-speed video (Photron, Phantom, Ultra 24, Shimatzu), video tracking, high-speed spectroscopic imaging.

Penetration Mechanics

High-velocity penetration into soft, brittle, and ductile materials. Fracture and failure behaviors.

Principal Investigator: Jim Newill james.f.newill.civ@mail.mil (410) 278-6004

Penetration Behavior of Brittle and Ductile Materials (APG)
Experimental and modeling and simulation for high-velocity impact.

Principal Investigator: Brian Schuster brian.e.schuster.civ@mail.mil (410) 278-6733

Supporting Facility: High-Velocity Impact Research Facility (APG)

Facility for studying the penetration behaviors of soft and hard targets, which are both brittle and ductile.
Equipment Available: Launchers, flash radiograph station.

Phase-Coherent Fiber Laser Arrays

Tactical and long-range atmospheric imaging, laser communications, and directed energy systems are under development. R&D includes advanced hybrid parallel live image acquisition and processing based on adaptive optical and analog/digital computation; maximizing tactical directed-energy laser beam irradiance through adaptive coherent beam combining and control techniques; and mitigation and adaptive turbulence correction in long-range atmospheric propagation for laser communication and directed energy weapon systems.

Principal Investigator: Jony Jiang Liu jony.j.liu.civ@mail.mil (301) 394-1442

Supporting Facility: Intelligent Optics Laboratory (IOL) (ALC)

The IOL is equipped to support sophisticated investigations in adaptive and nonlinear optics, advanced imaging and image processing, and laser communications for ground-to-ground and other applications. A variety of state-of-the-art adaptive optics, wave front diagnostics, and image processing tools are used to support advanced techniques for simulation, imaging, and laser communication system performance.

Principal Investigator: Chatt Williamson chatt.c.williamson.civ@mail.mil (301) 394-1771

Human Sciences

ARL's Human Sciences Campaign is focused on identifying, creating, and transitioning scientific discoveries and technological innovations underlying Human Behavior, Human Capabilities Enhancement, and Human-System Integration that are critical to the U.S. Army's future technological superiority. This campaign concentrates on high-risk and high-payoff transformational basic research; critically-focused, promising applied research; and selective advanced technology development that are expected to have revolutionary impacts on the Army's warfighting capabilities. In addition to significantly improving the Army's existing warfighting capabilities, it creates disruptive and game-changing Soldier-centric technologies for the Army, while also preventing technological surprises from potential adversaries.

The Human Sciences Campaign provides a critical assimilation point for Soldier-relevant technologies across all of the other ARL Campaigns. Human Sciences incorporates technologies and concepts from the other plans into multi-scale, human-centric research and advanced technology development, while concurrently feeding deep knowledge of human function, states, behavior, and performance, as well as human-based and human-systems technology concepts, into the other campaigns. Human Sciences is executed with ARL's in-house scientists and engineers who collaborate directly with world-class extramural researchers and technology developers. When unique and important opportunities exist, research is also executed in collaboration with industry, academia, not-for profit organizations, and other U.S. and international researchers.

ARL's Human Sciences emphasis areas include Human Behavior, Human Capability Enhnacement, and Human-System Integration.

Human Behavior encompasses basic and applied research, which aims to discover, understand, and predict human perceptual, cognitive, affective, physical, and social behaviors in settings ranging from individuals and teams to organizations and societies. Human Behavior research focuses on critical research gaps necessary to transition extant knowledge and new discoveries into innovative technologies that are expected to create revolutionary capabilities for the Army of 2030 and beyond. Innovations in this area are expected to generate capabilities to predict warfighter performance and provide fundamental enablers for enhancing Soldier capabilities and maximizing Soldier-system performance well beyond the capabilities of today's Army.

Human Capability Enhancement is a basic research, applied research, and advanced technology development effort, which aims to discover, innovate, and develop technologies that directly and indirectly enhance human perceptual, cognitive, physical, and social capabilities ranging from individuals and teams to organizations and societies for the Army of 2030 and beyond. Innovations in this area are expected to generate equipment and training technologies that will provide unprecedented capabilities for future warfighters and enable future leaders to make sound decisions effectively in complex socio-cultural contexts.

Human-System Integration includes basic and applied research that aims to discover, understand, exploit, and apply fundamental principles of human-system integration across domains, including but not limited to complex information systems, human-agent teams, cybersecurity, and organizational and social networks. Discoveries of fundamental principles governing networked communications and human-system relationships and dynamics are expected to lead to technological and methodological innovations critical in poising the Army of 2030 to quickly shape its operational environment. These discoveries are expected to be relevant across the full range of social and cultural environments.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

Human Behavior

Individual Differences and Human Variability

Research to understand the underlying properties, principles, and mechanisms governing the differences between individual humans as well as difference within the same individual based on state changes (e.g., fatigue, stress). To develop new methods, algorithms, and capabilities for predicting individual performance within a range of settings from small units to societies that can augment performance, training, and system design.

Principal Investigator: Jean Vettel jean.m.vettel.civ@mail.mil (410) 278-7431

Cortical Dynamics of Everyday Tasks in Real-World Environments

Research the influence of everyday events and environments on cortical processes. This research entails the investigation of the cortical processes associated with locomotion and the interaction between cognitive and physical loading on brain dynamics. In addition, this work also focuses on neuroimaging in real-world environments in order to study the neural response to both chronic and acute occupational stress and fatigue.

Principal Investigator: Dave Hairston william.d.hairston4.civ@mail.mil (410) 278-5925

Understanding Brain Structure-Function Relationships in Healthy Individuals (APG)

ARL's Neuroscience program seeks to enable revolutionary advances in Soldier-system performance by integrating modern neuroscience with computer science and engineering to both enhance our understanding of Soldier function in complex operational settings and develop novel and effective means to enhance systems design. ARL's neuroscience efforts focus on the scientific study of the brain and its interaction with technology. We are looking for post-doctoral colleagues to advance efforts in brain structure-function couplings. The brain structure-function couplings effort incorporates several neuroimaging methods to image structure (MPRAGE, diffusion imaging) and function (mostly EEG with some fMRI) to derive structural and functional networks for an individual. Ongoing research examines the sensitivity and reliability of reconstruction methods to derive structural tractography from diffusion-weighted imaging as well as the ability of functional connectivity measures to derive task-relevant, functional networks. The successful applicant will implement and evaluate metrics (e.g., network-level descriptions) that quantify individual differences in structural and/or functional connectivity.

Principal Investigator: Jean Vettel jean.m.vettel.civ@mail.mil (410) 278-7431

Advancing EEG Signal Processing Techniques

Refine methods for detecting and extracting neural artifacts from EEG data.

Principal Investigator: Scott Kerick scott.e.kerick.civ@mail.mil (410) 278-5833

Supporting Facility: BIERS Imaging Analysis Site Laboratory (APG)

Independently managed Linux (RHEL 6) high-end computing cluster with all workstations tied to dedicated central multicore server. Workstations use a wide variety of contemporary EEG and MRI analysis tools including, but not limited to Matlab, EEGLab, BCILab, FieldTrip, BrainStorm, Scan, FSL, AFNI, FreeSurfer, Connectome Mapper, and DSI Studio.

Equipment Available: Qty 13 Dell Precision T7500 workstations with 64-96 Gb RAM & 8-12 2.2Ghx cores. All use Matlab with several toolboxes. Qty 1 Dell PowerEdge R910 with 32 core, 512 Gb RAM running Matlab Distributed Computing Server, and Qty (2) Dell PowerVault storage arrays totaling > 36 Tb storage.

Supporting Facility: Mission Impact Neuro-Inspired Design (MIND) Laboratory (APG)

Laboratory facility including multiple electrically isolated, acoustically attenuated chambers (one large for large-group studies) and a central control room specifically designed for neurophysiological research. Facility includes access to a uniquely large, wide range of EEG systems from a variety of both established and recent start-up manufacturers (e.g., Biosemi, ABM, Emotiv, Mindo). Systems range in design from conventional low-noise amplified to ultra-portable, wireless, low-profile "dry" systems designed for use in freely-mobile applications.

Equipment Available: Several eye trackers, including FaceLab, SMI, TOBII, & SmartEye; Trigno full-motion EMG & Accelerometry; several EEG systems, including: Biosemi 64 Ch (qty 3), Biosemi 256 Ch (qty 2), ABM

X10, ABM X24, Emotiv Epoc (Qty 3), Quasar 9ch HMS, Mindo4, Mindo16 (Qty 2), Mindo 32 (Qty 3), and Mindo 64.

The Effects of Individual Factors on Performance

Individual factors (IF) are becoming increasingly important in the measurement and prediction of cognitive tasks. Equipment-based and task difficulty-based experimental designs without accounting for individual differences often lowers experimental power and increases error. Inclusion of IF such as working memory capacity and coping style, two very powerful cognitive and affective pre-measures have proven to be powerful predictors in addition to task difficulty for such cognitive tasks as simulated driving and shoot-don't shoot scenarios in dual-task environments. IF can include psycho-physiological measures and subjective measures of cognitive resilience (hardiness), self-efficacy, social and cultural factors, stress states and traits, and sleepiness or fatigue to name a few. To objective of this research is to find stable and validated IF measures that can greatly reduce error variability in applied laboratory and field studies, increase explained variance and statistical power through multi-theoretical approaches to experimental research in cognitive task domains. The supporting facility for this research is the System Assessment and Usability Laboratory (SAUL).

Principal Investigator: David Scribner david.r.scribner.civ@mail.mil (410) 278-5983

Soldier Performance - Interaction of Physical and Cognitive Performance

Perform research and analysis to understand the effects of physical and cognitive stress (and their interaction) on Soldier performance in laboratory and dismounted operational environments.

Principal Investigator: Michael LaFiandra michael.e.lafiandra.civ@mail.mil (410) 278-5973

Interaction of Physical and Cognitive Performance for the Dismounted Soldier (APG)

The project investigates the effects of physical and cognitive stress on Soldier performance and determines new ways of measuring these stressors in operational environments.

Principal Investigator: Michael LaFiandra michael.lafiandra@us.army.mil (410) 278-5973

Biomechanics for a Dismounted Warrior (APG)

Our biomechanics program focuses on understanding the effects of equipment on the Solider and Soldier-system performance. Specifically, we examine Solider-equipment issues for dismounted Soldiers (i.e., Soldiers not riding in vehicles). Biomechanical analyses are used to minimize the negative effects of this equipment and to provide design guidance for maximizing the positive effects. Our current biomechanics laboratory is being replaced by a state-of-the-art 2700 square foot biomechanics lab with an integrated force plate treadmill, portable cardio-pulmonary and EMG systems, and motion capture system.

Principal Investigator: Michael LaFiandra michael.e.lafiandra.civ@mail.mil (410) 278-5973

Supporting Facility: Soldier Performance and Equipment Advanced Research Facility (APG)

Facility designed to impose and measure the effects of physical and cognitive stress on Soldier performance in a dismounted operational environment.

Equipment Available: 3000 sq-ft biomechanics lab with 12 camera motion capture system, 2 x 16 channel EMG systems, 2 portable oxygen consumption measurement devices, inertial measurement units, fully instrumented 500 meter obstacle course with 22 obstacles, WiFi network.

Supporting Facility: C4ISR Laboratory (APG)

Immersive environment for evaluating effects of cognitive stress on Soldier performance.

Equipment Available: Nine individual rooms (whisper rooms) each housing a large-screen monitor connected to a networked gaming system capable of allowing Soldier subjects in each room to interact in the virtual environment.

Supporting Facility: Tactical Environment Simulation Facility (TESF) (APG)

Immersive environment for evaluating effects of physical and cognitive stress on Soldier performance.

Equipment Available: Immersive cave (4 sides, completely enclosed CAVE) with OmniDirectional Treadmill (ODT) capable of immersing Soldier subjects in simulated environment and allowing them to walk freely in that environment.

Similarity Metrics for Multimodal Cueing (APG)

Develop frameworks for understanding human perception of complex, multimodal events in naturalistic environments based on similarity relationships among stimulus features. Empirical and theoretical investigations aim at quantitative, predictive and/or adaptive models and novel methodological approaches for objective assessments of multimodal perceptual similarity. The development of methods and analytic techniques to account for changes in perceptual similarity across short and long time scales are sought.

Principal Investigator: Jeremy R. Gaston jeremy.r.gaston.civ@mail.mil (410) 278-3644

Audio Simulation via Loudspeaker Arrays (APG)

The Army Research Laboratory conducts research on how Soldiers hear sounds in complex auditory environments. In order to best do this research, realistic spatial sound fields must be created that simulate what a Soldier would hear while performing listening and communication tasks in the field. A world-class facility, the environment for auditory research (EAR), contains four indoor loudspeaker arrays and one outdoor array for displaying simulated auditory environments to human listeners. The EAR’s arrays are circular, spherical, linear, and custom-shaped to afford studying different processing capabilities of the human auditory system. The research challenge is two-fold. One engineering challenge is to accurately record and reproduce soundscapes over several different loudspeaker arrangements. The geometry of the recording microphone array and its mapping to a given spatial loudspeaker array needs to be properly transposed to recreate veridical sound fields. A number of spatial partitioning techniques, including beamforing and spherical harmonic decomposition, as well as spatial reproduction techniques, such as wave field synthesis and high-order ambisonics, could be explored. A second behavioral challenge is to determine when changes in the soundscape can be detected, identified, and localized. Changes include modifications of existing sound sources in a given soundscape and the addition of novel blue and red force sounds into given soundscape. Once battlefield acoustics can be realistically simulated, a Soldier’s auditory performance can be quantified in very complex military sound fields.

Principal Investigator: Mark A. Ericson mark.a.ericson.civ@mail.mil (410) 278-4089

Object Identification and Cognitive Fatigue during Visual Target Search

Recent research has identified how target features (e.g., t-junctions, occlusion vs. deletion, etc.) affects object identification and how target familiarity affects target detection. The objective of this project is to examine how the target feature space impacts initial detection (prior to final object identification verification). In addition, various aspects of the task (e.g., time-on-task, low target prevalence, etc.) can increase cognitive fatigue resulting in degradations of performance. This research is intended to determine how cognitive fatigue interacts with target properties to impact detection.

Principal Investigator: Joshua Rubinstein Joshua.s.rubinstein.civ@mail.mil (410) 278-5461

Omnipresent and Multi-Aspect Human Assessment

Develop techniques to estimate human states and confidence measures in those state estimates from multi-modal physiological and behavioral data to assess state-based changes in performance over time.

Principal Investigator: Kaleb McDowell kaleb.g.mcdowell.civ@mail.mil (410) 278-1453

Technologies Enabling Collection of Pervasive Real-World Neuroimaging Data

Research into hardware and software solutions enabling pervasive, mobile neuroimaging investigation. This work includes the development of novel electrode and system technologies to enable long term, mobile recording of high-density electroencephalography from the scalp, including multi-aspect, multi-modality methods. Work additionally includes algorithms and methods for artifact rejection, filtering, and source separation of data collected from real-world neuroimaging data, and novel schemes for validating the efficacy of new, unproven methods of physiological data collection.

Principal Investigator: Dave Hairston william.d.hairston4.civ@mail.mil (410) 278-5925

Soldier Auditory Situation Awareness

Models of auditory detection, identification, and localization that incorporate communications devices and personal protective gear and inform design and development of such devices.

Principal Investigator: Angélique Scharine angelique.a.scharine.civ@mail.mil (410) 278-5957

Identification of Military-Relevant Sound Events in Complex Operational Environments (APG)

Auditory information is often the first alert to events occurring in an environment. Recognition of sound sources can inform the Soldier of relevant events occurring in his surroundings. However, the science of sound identification is still relatively unexplored and highly dependent on context. In order to develop Soldier training and military aids, we seek to characterize auditory scenes by identifying auditory events important in the spectrum of military operations. This requires that we understand the features that allow the listener to recognize and identify aspects of relevant sound-source events. Models of these source and sound feature relationships have several applications. They can be used to predict Soldier performance in complex environments as well as develop training paradigms, either to train Soldiers in the identification of sounds themselves or to design realistic virtual training simulations. This work may include studies in sound source identification, development of sensory training tools and paradigms, and perception modeling of auditory and multimodal perception.

Principal Investigator: Angélique Scharine angelique.scharine@us.army.mil (410) 278-5957

Stealth Military Operations and Force Protection (APG)
The object of this research is to identify ways to reduce the auditory information available to enemy forces about individual Soldier and squad activities by minimizing and manipulating one's (individual or squad) auditory signature. This research involves various methods of manipulating the surrounding environment in order to hide the Soldier's presence, deceive the enemy by simulating the Soldier’s presence at a different location, and project false information about the strength of the actual force. Data obtained could guide the creation of devices and procedures that mask, multiply, or misdirect the auditory information available to the enemy. This requires the extension of the current understanding of sound identification principles and their application within different contexts. In addition, this may include an understanding of the perceptual principles that induce change deafness. This understanding must include the multimodal cues that drive the real-world processing of one's operational environment.

Principal Investigator: Angélique Scharine angelique.scharine@us.army.mil (410) 278-5957

Auditory Situation Awareness in Complex Acoustic Environments (APG)
ARL is investigating the effects of complex acoustical environments on Soldier performance. Acoustic signals are often the first evidence of activity or a presence, and they are the only type of information about the surrounding environment that is available to the Solider regardless of the time of day and from all directions. Detection of acoustic signals and recognition of acoustic signatures, and the directions from which they come, are critical because they may mean the difference between life and death. The primary research goal is to describe and predict the effects of auditory features present in urban military operations on Soldier auditory awareness and to quantify these effects on performance. Auditory situation awareness is defined as the ability to detect, recognize, and localize sound events. Urban acoustic environments include the effects of reverberation, direct and indirect sound pathways, background and impulse noise, movement, and mutual masking of multiple sound sources, including self-made Soldier sounds. Perception and high-level mental processing of these events are also dependent on the Soldier’s mission, knowledge of the physical environment, and attentional workload. This research addresses issues not traditionally considered separately in auditory research because the complexities of the military auditory environment demand it. Data obtained from this research form the basis for determining the effects of Soldier equipment and spatial situation on auditory performance and feed various models of Soldier performance.

Principal Investigator: Angélique Scharine angelique.scharine@us.army.mil (410) 278-5957

Effect of Signal Processing on Auditory Spatial Perception (APG)
Increasingly, Soldiers are being provided with radios and headsets for use with their radios. Because these headsets provide hearing protection from loud noises and some form of hearing restoration via externally mounted microphones, these tactical communications and protection systems (TCAPS) are viewed by many as a significant improvement. Soldiers, historically reluctant to wear hearing protection, may increase their compliance with hearing conservation guidelines if they are provided with communications capability. Further, the “ambient situation awareness” capability provided by the microphones is sometimes touted as “enhanced

hearing” or as “combat hearing aids” because they allow the user to set the level and even provide some amplification. However, these devices also alter the cues used for auditory spatial perception. Most notably, the level of sounds passed through the headset from the ambient microphones is limited to prevent the user from being exposed to unsafe noise levels. This is achieved in various ways. The system can simply shut off and not transmit sounds above a certain intensity level. Or it can compress the range of levels transmitted, passing lower levels through unchanged but reducing the level as a function of intensity for higher levels. This compression changes the relative level cues that are the main source of distance perception cues. It is unknown the degree to which this occurs or the operational effect of such changes. The object of this research is to understand the degree to which sensitivity to distance cues is affected, the degree to which this is a function of experience, and the operational impact of such changes.

Principal Investigator: Angélique Scharine angelique.scharine@us.army.mil (410) 278-5957

Human Capability Enhancement

Training and Soldier Performance

Develop a fundamental understanding of the effects of training with physical augmentation technologies on the enhancement of Soldier performance.

Principal Investigator: Kathy Kehring kathy.l.kehring.civ@mail.mil (410) 278-5894

Training Effectiveness and Soldier Performance with Physical Augmentation Technologies (APG)
Physical augmentation technologies are being developed with the goal of enhancing Soldiers’ physical performance by enabling them to move and act more quickly and decisively, provide stability, and sustain peak performance over longer periods while carrying a load. As new concepts are being developed to provide this physical augmentation, the training required to achieve the maximum benefit from the systems remains undefined. There is also the potential that in some cases a lack of training or improper training may result in inhibiting performance while using the system or that the use of these systems may have an effect on performance when not using them. This research will seek to define optimal training methods and parameters as well as the measures of effectiveness to ensure the systems provide the maximum benefit of amplifying movements and actions, while increasing control, reducing the impacts of load carriage, and increasing endurance to enhance their impact on the battlefield. It will also explore potential indicators of performance and whether training can be tailored to these indicators. Additionally, the effects of these devices on other critical operational tasks will be studied.

Principal Investigator: Kathy Kehring kathy.l.kehring.civ@mail.mil (410) 278-5894

Supporting Facility: Soldier Performance and Equipment Advanced Research Facility (SPEAR) (APG)

Facility designed to impose and measure the effects of physical and cognitive stress on Soldier performance in a dismounted operational environment.

Equipment Available: 3000 sq-ft biomechanics lab with 12 camera motion capture system, 2 x 16 channel EMG systems, 2 portable oxygen consumption measurement devices, inertial measurement units, fully instrumented 500 meter obstacle course with 22 obstacles, WiFi network.

Supporting Facility: Tactical Environment Simulation Facility (TESF) (APG)

Immersive environment for evaluating effects of physical and cognitive stress on Soldier performance.
Equipment Available: Immersive cave (4 sides, completely enclosed CAVE) with OmniDirectional Treadmill (ODT) capable of immersing Soldier subjects in simulated environment and allowing them to walk freely in that environment.

Supporting Facility: Shooter Performance Research Facility (M-Range) (APG)

Outdoor, live-fire, small arms shooting facility for investigating the interaction between equipment and weapon design and human performance via state-of-the-art marksmanship evaluation.
Equipment Available: Pop-up targets at distances from 25 to 1,000 meters programmable for varied exposure times, intervals, and order of presentation. Acoustical sensors for real-time location of rounds fired through or near the target.

Control Systems for Physical Augmentation Systems

This research aims to identify the control parameters that affect human gait so that effective control algorithms can be developed for exoskeletons and other personal augmentation systems for Soldiers. Effort focus on understanding the parameters used to control human gait under the conditions and in the environments in which dismounted Soldiers operate (e.g., carrying a heavy rucksack and walking up and down hills or tactical movements on uneven terrain).

Principal Investigator: Philip Crowell harrison.p.crowell.civ@mail.mil (410) 278-5986

Noise Stimulation to Improve Soldier Shooting Performance

This research aims to determine whether sub-sensory vibratory or electrical noise applied to the skin can elicit a stochastic resonance (SR) effect to improve weapon aim stability and resulting marksmanship performance.

Principal Investigator: Courtney Webster courtney.a.webster2.ctr@mail.mil (410) 278-9528

Bone Conduction (BC) Perception and Communication Systems

Analyze sound pathways, brain response, and/or factors that influence bone conduction effectiveness. Examine BC in novel contexts. Improve devices and mounting systems.

Principal Investigator: Kimberly Pollard kimberly.a.pollard.civ@mail.mil (410) 278-5842

Bone Conduction Perception: Physiology (APG)

Humans can hear sounds through air conduction (the pathway that starts with the external ear) and bone conduction (through vibrations of the skull). While air conduction is the dominant mode of hearing, bone conduction can be very useful in various military and security operations. Radio and audio signals can be converted into skull vibration by vibrators located on the head, and skull vibrations during speech production can be picked up by bone microphones (accelerometers) and transmitted over audio and radio channels. There is some evidence that air- and bone-conducted signals may be processed differently at the cochlear and retrocochlear levels, but it is not clear. Similarly, it is not clear if there are any differences in brain processing of sounds conducted by bone stimulation of audible and ultrasound stimuli. This research opportunity may involve analysis of bone conduction pathways in the head, collection of brain recordings during auditory task, implementation of advanced brain signal processing methods, and optimization of air- and bone-conducted signals for speech recognition and comprehension under various operational conditions.

Principal Investigator: Piotr Franaszczuk piotr.j.franaszczuk.civ@mail.mil (410) 278-8003

Tactile Communication

Investigate the effects of alternative forms of communication in military environments, specifically, head tactile communication and phenomena for Soldier and squad communications. Develop, advance, and miniaturize head tactile equipment for field experimentation. Investigate tactile and BC synergy.

Principal Investigator: Kimberly Myles kimberly.p.myles.civ@mail.mil (410) 278-5998

Tactile & Bone Conduction Communication

Tactile displays can provide information to Warfighters when other sensory modalities, such as hearing and vision, are cognitively overloaded. ARL is investigating the use of tactile displays for enhancing communication in adverse military environments, including a head-mounted application. A head-mounted tactile device would intuitively present directional or collective stimulation and would quietly warn or aid in navigation without competing for visual or auditory attention. In addition, current tactile transducers can provide both a tactile and an auditory sensation depending on the excitation frequency used such as from slow (10 Hz) and fast (250 Hz) mechanical stimulation of specialized receptors in the skin. Research may include the optimization of tactile signals, determining the most efficient operation mode (displacement, velocity, acceleration) for tactile transducers, miniaturization of head-mounted tactile devices, and person-to-person communication.

Principal Investigator: Joel Kalb joel.kalb@us.army.mil (410) 278-5977

Medical Technologies

Conducts research to prototype the most realistic and effective medical simulation-based training systems. Research is conducted into key enabling technologies that include silicon and synthetic biological tissues; embedded odors; blood and other body fluids; variable physiology; sensors; after action review capabilities; 3D anatomy; virtual tissue; and virtual patient visualization. HRED-STTC has a Medical Lab supporting this research area. Internships and Postdocs are available. There is currently one Intern working in this research area.

Principal Investigators: Christine Allen christine.allen2@us.army.mil (407) 384-5119
Tere Sotomayor teresita.sottomayor@us.army.mil(407) 384-3969

Adaptive Tutoring

Investigate methods to enable computer-based tutoring systems to adapt instruction based on learner states (cognitive, affective, and competence). Experimentally assess learner state variables (self-reported, observed, physiological, and behavioral) to accurately model the learner's cognitive / affective state and adapt content and interactions to meet learner needs. The Learning in Intelligent Tutoring Environments (LITE) Laboratory supports a wide range of research into adaptive tutoring. There is one current postdoc student working in this technology area

Principal Investigator: Robert Sottilare robert.sottilare@us.army.mil (407) 384-3007

Adaptive Computer-Based Tutoring Research (Orlando, FL)
The goal of this research is to develop methods to assess the cognitive and affective states of trainees in near–real time and then use this state data to adapt computer-based instruction to enhance/accelerate learning outcomes (e.g., knowledge and skill acquisition, retention). The research program has three thrusts: trainee modeling, authoring and expert modeling, and instructional strategy selection. Trainee modeling includes assessment techniques for determining cognitive and affective states through behavioral and physiological sensing techniques and machine learning algorithms. Authoring and expert modeling research explores the automated development of instructional content and expert models used as standards to define the trainee's performance level. Finally, instructional strategy selection research develops and assesses machine learning techniques to automatically guide the tutor's performance (e.g., interaction with the trainee, selection of instructional content and feedback, pace, and challenge level of instruction).

Principal Investigator: Robert Sottilare robert.sottilare@us.army.mil (407) 616-1860

Advanced Simulation

The purpose of the Soldier-Centered Army Learning Environment (SCALE) is to research and prototype a technology-enabled, data-driven learning environment for integrated training across multiple platforms (personal computers, mobile devices, games, virtual worlds, social media, and classroom teaching methods). Research is conducted to determine how and when Soldiers learn best in collaborative environments and to assess performances; capture and share individual expertise and lessons learned; and develop user-friendly authoring tools that support rapid development of content across several platforms.

Principal Investigator: Chris Gaughan chris.gaughan@us.army.mil (407) 384-3323

Live Training Technologies

Conduct research into training and operational simulations in the Army Live Training Domain. Technologies being researched include hybrid position and navigation sensors, next-generation lasers, embedded simulations in operational systems, enemy predictive technologies, micro-cloud architectures, and tracking technologies inside structures. A laser lab supports this research area.

Principal Investigators: Frank Tucker frank.tucker@us.army.mil (407) 384-5448
Bonnie Eifert latika.effert@us.army.mil (407) 384-5338

Virtual Worlds

Research into modeling all aspects of Massively Multiple Online Gaming (MMOG). ARL has an in-house laboratory supporting virtual world research.

Principal Investigator: Tami Griffith tami.griffith@us.army.mil (407) 384-3636

Virtual Humans

Conduct research to assess the social effects of virtual humans / artificial intelligence. Areas of research include natural language processing, gestures, responses, emotion, and photo-realistic graphics. Objective is to rapidly create virtual human characters.

Principal Investigator: John Hart john.hart@us.army.mil (407) 384-3012

Dismounted Soldiers

Conduct research into technologies to blend live and virtual training simulations. Research technologies include virtual locomotion, avatar group behaviors, visual stimulates, positioning sensors, artificial intelligence, and see-through helmet-mounted displays. ARL has a Dismounted Soldiers lab that supports this research area.

Principal Investigators: Pat Garrity pat.garrity@us.army.mil (407) 384-3663
Frank Dean frank.dean@us.army.mil (407) 384-3877

Human-System Integration

Human-System Integration – Cybernetics

Application of the concepts, insights, and methods of cybernetics and related disciplines to enhancement of human human-system integration. The work focuses on identifying and elucidating general principles that may apply across levels of analysis and can enable technology development and designs that exploits the dynamic nature of human behavior to enhance the effectiveness of human-system integration in technology designs for human perceptual, cognitive, and sensorimotor performance.

Principal Investigator: Kelvin S. Oie kelvin.s.oie.civ@mail.mil (410) 278-5960

Human multisensory integration and perception (APG)

Investigate fundamental principles and adaptive mechanisms underlying the integration of multisensory information in human perception. This effort seeks to advance empirical and theoretical conceptualizations of human multisensory processing, emphasizing mechanistic and predictive computational models of human behavior in multimodal behavioral contexts. Modeling efforts focus on cybernetic, control theory, or dynamical approaches conceptualizing the processes of multisensory integration at the systems level (or higher) with an emphasis on nonlinear, adaptive, closed-loop models.

Principal Investigator: Kelvin S. Oie kelvin.s.oie.civ@mail.mil (410) 278-5960

Enhanced closed-loop perception: algorithms and applications (APG)

Develop computational algorithms for multisensory fusion and augmented perception applications. Empirical approaches focus on developing and utilizing novel technology platforms to examine new multimodal combinations that augment human perceptual capabilities. Model-based approaches are sought to address critical issues of multisensory integration in real-world environments. Innovative experimental tasks and paradigms, as well as novel stimulation and display models, including biofeedback approaches, are sought in proof-of-concept implementations and demonstration systems.

Principal Investigator: Kelvin S. Oie kelvin.s.oie.civ@mail.mil (410) 278-5960

Supporting Facility: Multisensory Augmented Reality Testbed Platform (APG)

Wearable, highly-immersive multisensory testbed platform with augmented reality capabilities. Includes: head-mounted display (HMD) (dual 1920 x 1080 resolution screens with ~130° field of view with ~75% binocular overlap) with integrated head tracking capabilities; dual HDMI video inputs; integrated stereo audio inputs; and binocular eye tracking integrated in HMD. Augmented reality capabilities include: two high-resolution, high-speed cameras; HMD mounting platform; SDK; digital mixing and real-time digital overlays; and integrated sensor for depth sensing, including hand and finger tracking.

Human Sociocybernetics (APG)

Research the impact of social variables and sociocultural influences in human interactions with technology. Conceptual and computational cybernetics models are sought to identify general principles of human sociotechnical interactions that can enable advanced control and communication through feedback coupling of human-system capabilities and behavior. Empirical and theoretical investigations at neural, neurocognitive, and socio-cognitive levels of analysis are sought in the context of individual and team behavior, as well as interactions with autonomous agents.

Principal Investigator: Kelvin S. Oie kelvin.s.oie.civ@mail.mil (410) 278-5960

Social Cognitive Network Science

We are conducting a cross-disciplinary basic and applied research program to significantly advance the state-of-the-art in how communication networks influence and are influenced by human behavior in the context of military decision making. The research will contribute to the development of theory, methods, measures, models, and understanding of networked communications and the social-cognitive implications of those networks. Research environments range from computational modeling, to networked simulations in a laboratory environment, to field exercises. Studies will look at the effects of technology on cognitive workload, team collaboration, organizational effectiveness, and decision making. Cyber security is also a major topic.

Principal Investigator: Norbou Buchler norbou.buchler.civ@mail.mil (410) 278-9403

Network Science: Social Networks and Cognitive Factors (APG)

Communication and information technology has transformed military capabilities to engage in network-centric operations. To an unprecedented degree, Soldiers collaborate in distributed networks across areas of operations often using specialized information systems and communication platforms to manage the imperative to collect and analyze intelligence, secure a populace, deliver supplies, and wage war. Our interdisciplinary approach leverages convergent methodologies to include experimental psychology (experimental design), cognitive science (modeling), human factors (usability, work domain analysis), and network science (social network analysis). The emerging interdisciplinary field of network science is of particular interest to our research efforts to address a preeminent challenge posed by the sheer complexity of human-in-the-loop networks and may serve to guide the systematic convergence of technology, information, and people. The objective of our research is to understand the effects that networked systems have on human cognition and team dynamics, and to develop models, theories, and analytical approaches to examine cognitive processes, information properties, and to identify key network dynamics across the social-cognitive-technological levels. Networked systems do not necessarily take into account the processing capabilities and limitations of the human brain. Cognitive performance—evidenced by effective distributed collaboration and decision making— may or may not be well-supported by our networks and Soldier technologies. It is imperative that we understand what aspects of network operations cause an undue cognitive burden to the command staff and dismounted Soldiers who collaborate with and pull information from media such as radios, text messages, emails, battle command systems, sensors, and ground and air unmanned assets. The objective is to develop decision aids to help integrate information management for users who especially are required to rapidly and efficiently process information from sources at multiple levels. A better understanding is required of system usage on communication flow, information transfer, cognitive workload, situational awareness, expertise, individual differences, and their effects on performance. This knowledge is instrumental to the development of battle command decision support tools that improve information relevance (data aggregation), and team collaboration and synchronization (alert/aiding capabilities). This work should ultimately result in networked information systems well-aligned to the needs of the Warfighter by matching system requirements to Soldier cognition and collaborations through an enhanced understanding of human-system team interactions.

Principal Investigator: Norbou Buchler norbou.buchler.civ@mail.mil (410) 278-9403

Supporting Facility: Cognitive Assessment, Simulation & Engineering Laboratory (APG)

Stand-alone behavioral sciences lab that has capabilities for a variety of research topics, especially multidisciplinary topics.

Equipment Available: Isolation, sound attenuated research chambers; robotics lab; simulated mission command centers (various levels); VirTra 300 degree immersive simulation facility, with tetherless rifle firing capability and threat-fire shock belt for realism; psychophysiological measures.

Human-Robot Interaction

This research area is of critical importance to the Army for its understanding of the complexities and dynamics of human interaction with unmanned systems across domains (e.g., land, air) and capability levels (e.g., autonomy, manual control). We are developing programs to carry out fundamental research involving complex equipment, emerging technologies, and scientific phenomena pertaining to humans and autonomous systems. The work applies methods and techniques of cognitive and experimental psychology, human factors engineering, and/or computer science to the understanding and solution of human factors issues involving unmanned systems across a range of military operations. The research will contribute to the development of theory, models, methods, and measures for understanding the interdependencies between the cognitive, social, information, and communication aspects of interaction with unmanned autonomous systems and ultimately to help align Soldier and system capabilities in real time to support effective performance across a broad spectrum of military operations.

Principal Investigator: Susan Hill susan.g.hill.civ@mail.mil (410) 278-6237

Enhancing Performance of Human-Robot Interaction (HRI) Teams (APG)
Military operations depend more and more on an array of unmanned technology, such as ground vehicles, air vehicles, sensors, and microsystems. The inclusion of unmanned systems, information networks, and advanced sensor suites is intended to enhance operational performance and Soldier safety. However, the implications of these technologies for human use are not always fully understood nor are they always considered during design. The Soldier's role for interaction with unmanned systems is broad, ranging from robot operator to information manager to information consumer. The goal of our HRI program is to maximize the effectiveness of integrating unmanned technology into the Soldier team through the development of state-of-the-art Soldier-system interactions. We seek to identify tools, techniques, and measures that can improve and assess performance with unmanned systems across multiple environments. Specific issues to be addressed include unmanned and manned vehicle autonomy, intuitive communications and interfaces, supervisory control, teaming, situation awareness, and strategies for workload management. ARL's Human Research and Engineering Directorate is currently conducting HRI research at APG, MD. Research environments include laboratory, simulation, and field environments.

Principal Investigator: Susan Hill susan.g.hill.civ@mail.mil (410) 278-6237

Human-Robot Interaction and Advanced Displays for Human-Vehicle Interaction (Orlando, FL)
ARL is conducting research on human-robot interaction (HRI) and advanced displays for human-vehicle interaction (HVI). HRI and HVI are both complex work environments where the human operator engages in multiple simultaneous goal-oriented tasks (e.g., communication, navigation, reconnaissance, security, and control of other systems while on the move). Other HRI research involves experiments on live and simulated robot teleoperation; specific research areas include display technologies (e.g., multimodal displays and stereoscopic displays) and automation techniques (e.g., adaptive automation) to enhance the robotics operator's performance in multitasking environments. Our research on advanced displays for HVI focuses on augmented/overlaid information on vehicle vision block for indirect-vision driving and embedded training. State-of-the-art simulators and equipment are used in both research areas.

Principal Investigator: Jessie Chen jessie.chen@us.army.mil (407) 384-5435

Supporting Facility: Cognitive Assessment, Simulation & Engineering Laboratory (APG)

Stand-alone behavioral sciences lab which has capabilities for a variety of research topics, especially multi-disciplinary topics.

Equipment Available: Isolation, sound attenuated research chambers; robotics lab; simulated mission command centers (various levels); VirTra 300 degree immersive simulation facility, with tetherless rifle firing capability and threat-fire shock belt for realism; psychophysiological measures.

Manned-Unmanned Collaborative Teaming

Investigate factors that determine effective teams, decision making, and performance, specifically for manned/unmanned teams in ground and aviation systems.

Principal Investigator: Tom Davis thomas.w.davis.civ@mail.mil (256) 876-2048

Manned and Unmanned Collaborative Systems Integration

Advancement in technology has greatly improved the capability of military systems. Mission requirements are now dictating system interoperability levels that go beyond the traditional human-machine interface. Asymmetric threats are dictating collaborations among a mission system now defined by multiple systems. These higher-order system-of-system interactions are introducing challenges to the way technology is designed, constructed, measured, and evaluated. The Collaborative Unmanned System Integration Laboratory (CUSIL) is conducting research to expand our Nation's understanding of the dynamic human-machine relationships already deployed and underway with the military's fleet of optionally piloted vehicles. Core research initiatives address the demands placed on the Soldiers' mental resources required to manage attention, make decisions, and coordinate crew activities and communication.

Principal Investigator: Tom Davis thomas.w.davis.civ@mail.mil (256) 876-2048

Supporting Facility: Manned-Unmanned Systems Integration Laboratory (Huntsville, AL)

Manned-Unmanned Collaborative Teaming Laboratory dedicated to investigating factors that impact teams and their decision making.

Equipment Available: Eight (8) networked distributed team workstations with virtual battle space, EEG and EKG monitoring, head motion and eye tracking, six-DOF Pholemus Motion Tracking.

Decision Fusion for Human-autonomy Interactions

Develop general techniques for fusing decisions from both human and autonomous agents in order to improve performance at joint human-autonomous tasks. Investigate active transfer learning thorugh brain computer interaction by using novel machine learning methods to better identify artifacts in unlabeled neural data. . Advance development of machine learning and classification techniques for increasing the robustness of Army-relevant brain-computer interaction technologies (BCIT), using statistical classification and machine learning methods, semisupervised graphical learning, analysis of large-scale data sets, advanced signal processing, multivariate statistics, computer programming, experimental design, EEG, and physiological recording and analysis. Emphasis on translational research and technology development that will leverage years of research andidate will support the short-term goal (5 years) of developing a working proof-of-concept system to demonstrate the viability BCITs in operational environments.

Principal Investigator: Brent Lance brent.j.lance.civ@mail.mil (410) 278-5943

Medical Human Factors

The ARL Field Element at Fort Sam Houston, TX, conducts medically-related human factors engineering research and consults with the Army Medical Department Center and School. Lines-of-study include attrition during medical Advanced Individual Training; performance modeling; evaluation and design of advanced technologies to ensure ease of use, display congruency, efficiency and effectiveness; an examination of mindfulness based stress reduction delivered through a virtual world (teaching mindfulness [meditation] to Soldiers and veterans in-person and via Second Life); study of the interactive metronome as an effective intervention to enhance performance; study of devices to help identify mild TBI cases
.

Principal Investigator: Valerie Rice valerie.j.rice.civ@mail.mil (210) 221-2007

Cognitive Robotics

This research aims to use cognitive architectures to improve robotics control and interactions with other humans and move beyond cCurrent robots, whose abilities are scripted or task specific and do not generalize to new domains.

Principal Investigator: Troy Kelley Troy.D.Kelley6.civ@mail.mil 410-278-5869

Human System Integration - Modeling and Simulation

Research, develop, and apply human systems integration (HSI) techniques, tools, and technologies to ensure MANPRINT goals, constraints, and human performance measures are achieved.

Principal Investigators: Diane Mitchell diane.k.mitchell.civ@mail.mil (410) 278-5861
Jock Grynovicki jock.o.grynovicki.civ@mail.mil (410) 278-5956

Supporting Facility: System Assessment and Usability Laboratory (SAUL) (APG)
Research, develop, and apply human systems integration (HSI) techniques, tools, and technologies to ensure MANPRINT goals, constraints, and human performance measures are achieved. Conduct MANPRINT assessments on graphical user interface (GUI). Execute usability studies on software user interfaces. Research various individual factors on various cognitive tasks including driving, Unmanned Ground Vehicle operations, Unmanned Aerial Vehicle operations, convoy operations, and route reconnaissance.
Equipment Available: HSI-Tools: IMPRINT enhanced with automation and library of activities and micromodels, Job Assessment Software System (JASS) to define and measure human aptitudes; MIL-STD-1472 Physical Accommodation Companion Software; C3TRACE - Command, Control, and Communication Environment. VBS3 to provide simulated environments to with samples of various military relevant tasks such as C4ISR, UGV and UAV operations, convoys, mine detection, dismounted and mounted operations with various communications in either individual participant or teamed scenarios.

Assessment and Analysis

The Assessment and Analysis research area is focused on development and application of analytical tools and methodologies to quantitatively assess the military utility of Army, DoD, and select foreign combat systems. In addition to the development of novel assessment and analysis capabilities, knowledge and understanding drawn from ARL's other technical campaigns are leveraged to help influence requirements for future Army systems. Exemplary of Army and DoD-relevant high-interest areas supported through these efforts include ballistic effectiveness, personnel armor susceptibility; platform armor susceptibility; information systems vulnerability; system-of-systems analyses; and human performance enhancement assessment.

ARL's Assessment and Analysis research emphasis areas include Assessment of Science and Technology, Science and Technology of Assessment, Assessing Mission Capability of Materiel, and Materiel Capable of Assessing Mission Capability. These areas collectively comprise the Assessment and Analysis area, which heavily relies on ARL's research expertise and facilities in intelligent systems, cyber security, information sciences, human sciences, materials, and lethality & protection. The Assessment and Analysis area is focused on guiding the development and integration of technologies, substantially broadening the range of issues that can be addressed with analytical rigor, improving the throughput and responsiveness of the analytical processes, and developing ruggedized and ready-to-employ applications that make the full power of the laboratory's internal analysis capabilities available directly to the Army's operational force.

Assessment of Science and Technology concentrates on understanding the costs and benefits of R&D efforts, their readiness levels, risks, potential payoffs, and integration challenges.

Science and Technology of Assessment concentrates on understanding the key types of analytical problems likely to confront the Army of 2030, exploiting the latest developments by our academic and industrial partners, and performing basic and applied research to develop the powerful new tools required.

Assessing Mission Capability of Materiel concentrates on understanding and exploiting systems' technologies, design, and employment together with current—and likely future—state of the art to optimize future designs and to inform evaluation and acquisition decisions with analyses that are both technically sound and practically efficient. Key to this effort, are methodologies to integrate technical assessments into the science and engineering domain with considerations of mission effectiveness for the materiel's operational user.

Materiel Capable of Assessing Mission Capability concentrates on understanding and exploiting developments in the other S&T campaigns to evolve assessment and analysis itself from a laboratory service to a technology that we transition to the Warfighter.

Active research areas and specific projects seeking Open Campus collaborative engagement include:

Augmenting Threat Analysis Capabilities Using Intelligent Threat Agents

Computer and network vulnerability is tested by having evaluators attempt to penetrate the systems under test. During these penetration tests, an evaluator must typically gather information about the system under test. This is a critical, time consuming step that involves tracing through large amounts of complex data, and then decide the next-course of action. Decisions are dependent on evaluator experience, time constraints, and the availability of public vulnerability data. We are researching ways of reducing the time, evaluator interaction, and evaluator experience needed to adequately characterize computers and computer networks so that the time needed for vulnerability analyses can be reduced. Researcher will provide fundamental research and analysis to develop algorithms, models, and tools that are capable of learning and evolving from observations of computer interfaces and networks that will lead to more thorough, scientifically-based vulnerability assessments.

Principal Investigator: Jaime Acosta Jaime.c.acosta.civ@mail.mil 575-678-8115

Kill Assessment for Ballistic Missile Intercepts

Several types of data from optical sensors may potentially provide key indicators to a kill assessment system, including spatial, temporal, and spectral data. ARL is designing, constructing, and using advanced optical sensors that operate in the visible through mid-wave infrared spectral regions to record data from exo-atmospheric intercepts of ballistic missiles. We are developing pattern recognition algorithms that allow assessment of the intercept in near-real time, and analyzing their efficacy in determining the degree of intercept.Researcher will provide fundamental research and analysis to support in the design, construction, and characterization of sophisticated electro-optical sensors for use during live-fire intercept testing. Opportunities also exist for the development and testing of pattern recognition algorithms that uses electro-optical intercept data to make interceptor kill assessment in near-real time.

Principal Investigator: Bryan Holtsberry bryan.l.holtsberry.civ@mail.mil 575-678-4225

Statistical Methods in Ballistic Modeling and Simulation

Modeling and simulation (M&S) is used to address the survivability and/or lethality of Army aviation, ground combat, Soldier and munitions systems against the full spectrum of battlefield threats. In the Ballistic Vulnerability/Lethality Division of SLAD, M&S-based analyses include determination of ballistic penetration through materials, failure of vehicular components, loss of subsystem functionality and impact of damage on a vehicle's ability to conduct military missions. Researcher will conduct fundamental research and analysis to develop mathematical and probabilistic methods to validate the complete spectrum of algorithms and sub-models within its core ballistic M&S tool.

Principal Investigator: Joseph Collins joseph.c.collins38.civ@mail.mil 410-278-6832

Modeling Techniques to Enable Interactive Visual Analysis

ARL researches methods by which to improve the timeliness, and quality of simulation models of kinetic and electromagnetic interactions. These models are used to evaluate existing Army assets against ballistic and directed electromagnetic threats and to analyze the relative effect of design changes on these assets' survivability versus kinetic and electromagnetic threats. These models are also used to establish doctrine on how assets are to be employed. Our research focuses on novel visualization and massively-parallel computational techniques. Through these means we hope to establish a cognition-driven simulation experience where the user can engage in computational steering and have their understanding intentionally shape the information presented by the simulation as it occurs. It is our intent to maintain this visually interactive environment from the moment the user sets out to construct the model to the final conclusion of the simulation. Researcher will provide fundamental research and analysis to support 1) optimizations of the computation of projectile/target interaction through ray tracing or *n*-body simulation techniques, 2) visualization of combined volumetric and surface data representations to communicate the concept of radiative or ballistic dosage within a physical environment, 3) methods of expressing massively parallel computation that assure ease of expression, highest performance, and utilization of current and near-term computational architectures, 4) new and novel computing architectures for massively parallel computation in non “data-center” platforms.

Principal Investigator: Lee Butler lee.a.butler6.civ@mail.mil 410-278-9200

Small Unit Modeling and Architecture

ARL requires the capability to assess the mission impacts of new or revised technology or tactics by modeling small unit combat at an engineering level of detail. An ARL –Physical Sciences Laboratory of New Mexico State University (PSL/NMSU) team has significant expertise in engineering-level modeling with unique expertise in threat modeling and effects for ballistics, electronic warfare, and cybersecurity, but important challenges remain. Simulated decision-making processes have been developed for many military functions, but ARL requires these to be more easily tailor able by end users. ARL also requires improved methods for speeding up the process of trading time with technical fidelity while small unit studies are scoped.

Principal Investigator: Phil Simpson phillip.b.simpson.civ@mail.mil (575) 678-2324

Laser Vulnerability of Optics and Electro-Optics

A critical concern on the modern battlefield is the vulnerability of Army optical and electro-optical systems, as well as the soldier, to lasers. The Army is continually introducing new and innovative optical systems operating in bands from the visible to the far infrared which are integral to the concept of a lighter, faster military. These advanced sensors require an ever-evolving approach to hardening to reduce active laser signature as well as jamming and damage vulnerability to lasers without reducing the optical systems’ performance.
We develop concepts and designs for better laser hardening and we improve capabilities to evaluate the laser vulnerability of Army optics. This includes characterizing laser vulnerability of optical and electro-optical equipment and developing advanced predictive models. Researcher will provide fundamental research and analysis to support laser, optical, and electro-optical measurement and characterization, leading to the development of improved laser hardening designs and concepts as well as improved capabilities to evaluate the laser vulnerability. These capabilities include the development of modeling and simulation techniques as well as the design of laser-based laboratory and field experiments leading to the improvement of optical and electro-optical hardening to laser energy.

Principal Investigator: Norman Comer norman.d.comer.civ@mail.mil 575-678-9276

Advanced Electromagnetic Measurement

ARL administers a complex of electromagnetic anechoic chambers, reverberation chambers, and TEM cells for the Army. The main anechoic chamber contains a wide variety of radioactive elements and sensors to include GPS satellite and radio emission simulators, and a cell phone base station.

Research opportunities exist in advanced electromagnetic measurement methods, hardware and software measurement automation, and advanced electromagnetic experiments and results interpretation.

Principal Investigator: Christos Maragoudakis christos.e.maragoudakis.civ@mail.mil
575-678-3145

Supporting Facilities: Electromagnetic Vulnerability Assessment Facility (EMVAF), **(WMSR)**

The EMVAF is a major radio-frequency (RF) measurement facility developed by RDECOM to perform all types of secure RF/microwave measurements. The EMVAF specialty is measuring and developing susceptibility profiles on US Army weapon systems and foreign systems. Additionally, the facility has significant capability and skills in measuring RF/microwave emissions, coupling, and validating electromagnetic codes.

Electro-Optical Vulnerability Assessment Facility (EOVAF) **(WSMR)**

The EOVAF is a DoD unique facility for evaluating laser vulnerability of Army optical/electro-optical systems. The properties evaluated include eye protection, optical-augmentation signatures, and laser jamming and damage vulnerability of sensors. Working across the threat spectrum from the visible through the far infrared, the EOVAF accommodates laboratory and field experiments as well as theoretical modeling.

Military Injury Biomechanics

The goal of our research area is to enhance Soldier protection by understanding the entire spectrum of human injuries including causation, frequency, prevention, mitigation, sequelae and performance. By investigating injuries from conflict and the biomechanics of injury we can improve our understanding of the risk and mechanism of human injury to consequently increase protection and prevention of injuries to our warfighters. Our focus is on applied research and analysis that examine materiel solutions and their effect on performance effectiveness. Our work develops novel methods for exploring in simulated environments of combat threats the vulnerability of humans to blast and ballistics. Researcher will provide fundamental research and analysis that involve analysis of raw computed tomography for biological targets, biosimulants, and protective materials to examine material properties under high-strain rate environments and model trauma. The researcher will conduct ballistic experiments while exploring experimental and novel instrumentation configurations, including explosively driven shock tubes.

Principal Investigator: Patrick Gillich patrick.j.gillich.civ@mail.mil 410-278-6332

Systems Engineering and Experimentation

Perform ballistic experimentation and testing that relates to the vulnerability, lethality and survivability of air and ground systems and personnel.

Supporting Facilities: Experimental Facility 20 (Peep Site) **(APG):**

Researchers at the Peep Site facility primarily focus on executing developmental tests, with concentration on soldier survivability issues. Typical efforts include assessing personnel armor, incapacitation from small-arms projectiles, transient deformation of materials, blunt trauma involving personnel armors, and helmet performance, as well as experimental support to improve and validate inputs to modeling and simulation.
Equipment Available: To acquire, record, and process data, the Peep Site utilizes such state-of-the-art equipment as Phantom 7 high-speed video and digital x-ray. It has the manufacturing capability to produce gelatin targets to simulate muscle tissue for use in assessing incapacitation.

Point of Contact: John Polesne; 410-278-3353; john.t.polesne.civ@mail.mil

Airbase Experimental Facility 6 and 7 (AB6/7) **(APG):**

AB 6/7, an integrated group of firing locations and support facilities managed by SLAD at APG, MD, provide to the Army, DoD, and DoD contractors essential capabilities and services in ballistic and high-explosives test and experimentation.

Equipment Available: The facilities enable ballistic experimentation with targets from components through full-scale operating aircraft (and other combat vehicles) against direct-fire munitions up to 120 mm caliber and warhead-charge weights up to 30 pounds. Facility 6 includes a main test pad with an environmentally friendly system for fluid collection and recycling a fully enclosed, hardened building for vulnerability/lethality (V/L) research on classified targets, and a partially enclosed test pad for experiments with operating power plants and drive-train subsystems. Facility 7 includes several sites for small-caliber tests, including an indoor ballistic-firing location rated for calibers up to 14.5 mm.

Point of Contact: Frederick Marsh; 410-278-9271; frederick.a.marsh2.civ@mail.mil

FREQUENTLY ASKED QUESTIONS

Q: Where would I be working?

ARL is headquartered in Adelphi, MD, and occupies major sites at Aberdeen Proving Ground, MD; Research Triangle Park, NC; White Sands Missile Range, NM; and Orlando, FL. Unique facilities at our primary sites provide scientists and engineers access to world-class research centers. Opportunities currently exist at several of our major sites:

- ADELPHI LABORATORY CENTER (ALC) is located approximately 10 miles north of the center of Washington, DC, and approximately 26 miles southwest of Baltimore, MD. The center is within one mile of both I-495, also known as the Capital Beltway, and I-95. ALC is located in Montgomery and Prince George's Counties, MD.
- ABERDEEN PROVING GROUND (APG) is the Army's oldest active proving ground established on October 20, 1917, six months after the United States entered World War I. It remains one of the Army's most active and diversified installations. Situated at the head of the Chesapeake Bay, APG is surrounded by some of the best natural resources that Maryland has to offer. Located along the I-95 corridor, APG is approximately 74 miles to Philadelphia, 71 miles to Washington DC, and 32 miles to Baltimore.
- ORLANDO, FL, is the home of ARL's Simulation and Training Technology Center. It is located approximately 15 miles east of downtown Orlando, FL.
- WHITE SANDS MISSILE RANGE (WSMR) is located in the Tularosa Basin of south-central New Mexico. The headquarters area is 20 miles east of Las Cruces, NM, and 45 miles north of El Paso, TX. The range boundaries extend almost 100 miles north to south by 40 miles east to west. At almost 3,200 square miles, the range is the largest military installation in the country.

Q: Are there security requirements for working with ARL?

All personnel working at ARL must undergo a basic background check of his or her criminal and credit histories to ensure that they are "reliable, trustworthy, of good conduct and character, and loyal to the United States." The length and depth of the background investigation will depend on the position's requirements, as well as the type of security clearance if needed for a particular job, visiting scientist exchange, postdoctoral fellowship, or internship. If selected for a position that requires a security clearance, the individual will be required to complete an SF 312 Nondisclosure Agreement in accordance with Executive Order 13526 as part of their responsibility to protect sensitive information. In order to help speed the process along, candidates should begin to gather relevant information now. The forms for background checks (SF-85: Questionnaire for Non-Sensitive Positions) and (SF-86: Questionnaire for Non-Sensitive Positions) are on the Office of Personnel Management's website and can be found at http://www.opm.gov/forms/standard-forms/.

For U.S. Citizens: In addition to forms SF-85 and SF-86, a fingerprint card will need to be completed at the local Intel & Security Office.

For Non-U.S. Citizens: In addition to forms SF-85 and SF-86, the following is needed:

- Fingerprint card must be completed.

- Two forms of picture identification must be presented (one of which must be a valid Passport/VISA, or Resident Alien Card).

Q: I am a foreign visiting scientist, postdoc, graduate student, or intern. Can I work at ARL?

YES.

Non-U.S. citizen employees will be issued a Foreign National “V” Escort Required Badge as well as a Foreign National DoD Common Access Card (CAC). This badge authorizes access to designated ARL Buildings/Rooms from 8:00 am to 5:00 pm, Monday through Friday only, except Federal holidays. Access during other times and to other ARL facilities requires prior approval of the ARL Foreign Disclosure Officer (FDO).

- The ARL badge will be prominently displayed on an exterior garment above the waist, with photo and/or markings visible from the front, at all times while inside restricted areas.
- The ARL badge will need to be renewed every 30 days by visiting the Visitor Control Center and completing the necessary paperwork. The designated escort(s) are required to sign for the badge.
- The ARL badge will not be worn outside of the ARL campus. Badges will not be used for identification purposes outside of the ARL installation and facilities, and will not be used for private purposes, such as cashing checks.
- The individual bearers shall be responsible for the care and safeguarding of badges issued to them. The loss of a security badge must be reported at once, in writing, to the Intelligence and Security Division, Access Control/Badging Office.
- Visitors to ARL are subject to the restrictions used by federal law, statutes, Army, IMCOM, ALC regulations, policies and procedures, and this memorandum.
- All other activities, meetings, or events at other locations within ARL, as well as access outside the core working hours, require an escort at all times. Prior approval must be granted by the Foreign Disclosure Officer.

FOREIGN NATIONAL ACCESS TO ARL FACILITIES:

Foreign Nationals are welcome to ARL facilities but require prior approval or precoordination. In order to enter the facilities, Foreign National visitors must complete the following:

- Unofficial Visit request Form — 7-10 days prior to stay
- Official Visit request Form — 30 days prior to stay

After completion of the ARL form, the request will be sent to the Foreign Disclosure Officer for approval. Once approved the individual must provide 2 forms of identification to receive the Foreign National ARL Badge.

Entrance into ARL installation typically requires:

- Entry onto ARL by any motor vehicle or other wheeled device, subjects the operator and occupants to a search of their person and vehicle by law enforcement authorities assigned to ARL as authorized by law.
- No person will drive a privately owned vehicle on the installation without having on his/her person, a valid state driver’s license, vehicle registration, and proof of insurance. The owner of the vehicle is also responsible for

ensuring that any other person operating his/her vehicle is properly licensed and carries a valid license on his/her person while operating the vehicle.

- Entry will be admitted upon display of appropriate Common Access Card (CAC) or Civilian Identification Card and Civilian driver's license. Employees/Guest Researchers without a DoD ID will be stopped, their vehicle inspected, and instructed to obtain a temporary vehicle pass for that day. ARL is working to establish identification cards/processes for collaborating partners.
- Access for drivers will be at the main gate, where their vehicles may be inspected prior to entry. Parking is authorized in any of the available lots.

Q: Will I still be able to publish my research if I work with ARL, or will my work be classified?

Much of the work conducted at ARL is basic or applied research that can be published in open literature unless it has been determined to be "classified." Generally speaking:

- All publishable and releasable material prepared or jointly prepared by ARL employees must be reviewed and approved by the responsible supervisor; undergo a security classification, quality assurance and OPSEC review (ARL Form 1) and be approved for public release (Distribution A: Approved for public release) by the ARL Public Affairs Office.
- All publishable and releasable material prepared by a contractor or a researcher under contract to the U.S. Government must be reviewed and approved, if required by the terms of the contract, by his or her Contracting Office Technical Representative; undergo a security classification, quality assurance and OPSEC review (ARL Form 1); and be approved for public release (Distribution A: Approved for public release) by the ARL Public Affairs Office.
- ARL's Quality Assurance and OPSEC Review policy does not apply to basic research conducted by a visiting researcher that is not under contract with ARL as long as an ARL employee or qualified contractor is not a coauthor of such material. Authors or organizations not subject to mandatory reviews may submit their material to ARL to obtain advice on national security concerns.

Q: How will the creation and assignment of any intellectual property be handled?

Under the Bayh-Dole Act, the outside collaborator has first opportunity to file a patent for jointly created inventions. If that party decides that they don't want the "invention," they must notify ARL, and then ARL can decide if it would like to go forward and pursue patenting or other means of protecting the intellectual property.

Q: What are government "march-in" rights?

Government march-in rights are one of the most contentious provisions in the Bayh-Dole Act. This applies only when ARL funds the research. That is not the usual situation under Open Campus efforts. It allows the funding agency (ARL) to ignore the exclusivity of a patent awarded under the act and grant additional licenses to other "reasonable applicants." This right is strictly limited and can only be used under very specific circumstances. As of 2012, NO FEDERAL AGENCY has ever exercised these rights.

Q: Will any intellectual property (IP) that I bring to the collaboration be protected?

Any IP a non-Federal party brings to the collaboration MAY be protected. The non-Federal party should clearly indicate the proprietary data or property that they are claiming ownership to. ARL may or may not want to protect jointly made IP by filing a patent or other means. The non-Federal party has first election under Bayh-Dole and can file for patent protection. Under all circumstances, non-Federal IP disclosed to Federal employees during the collaboration results in a duty by the Federal employees not to disclose the information (plans, diagrams, etc.) to any non-party to the project.

Q: Does working with a DoD lab affect one's ability to file for a patent?

NO. Working at ARL does not affect your ability to file a patent; however, there will be additional paperwork requirements. The non-Federal party MUST fill out a DD882 report of invention form. ARL would then make a rights determination. Normally the non-Federal party (either solely inventing or jointly with ARL personnel) will have the first opportunity to file for patent protection. The rights the Government will obtain will vary with the instrument (CRDA, Cooperative Agreement, contract, etc.).

Q: What other regulations do I need to know about to work with ARL?

The specific regulations and policies that may apply to any person or group working with ARL will depend on what authority is being used to support the project and/or collaboration. Details concerning the relationship, cost sharing (if applicable), protection of resulting IP, identification and protection of proprietary data, facility/equipment use, and security measures will need to be identified and defined in the implementing agreement.