MANY MINDS, MANY CAPABILITIES, SINGLE FOCUS ON THE SOLDIER

2010 ANNUAL REVIEW
U.S. ARMY RESEARCH LABORATORY

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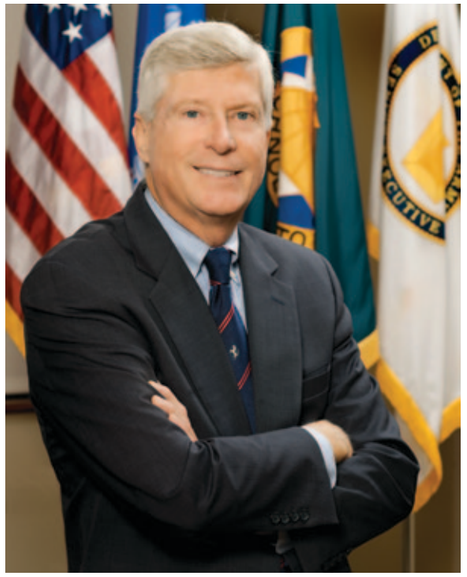
Foreword

Welcome to the Fiscal Year 2010 edition of the U.S. Army Research Laboratory (ARL) Annual Review. This publication briefly describes who we are and highlights some of our significant scientific and technical achievements of the last year. The size of this organization – seven distinct laboratories and offices with over two thousand military and civilian members – and the scope of research and analysis in which we are involved, limits us to select only a few items to present here as a representative sample of our overall accomplishments. ARL's research continuum stretches from early, long-term, basic research to evolving new technologies to supporting current operations. We organize our research and analysis efforts within nine Major Laboratory Programs (MLPs); Extramural Basic Research, Networks, Human Dimension, Lethality, Protection, Mobility, Power and Energy, Sensors, and Survivability/ Lethality Analysis. With the addition of the Simulation and Training Technology Center, the list of MLPs will expand to include an appropriately named MLP: Simulation and Training Technology.



John M. Miller
Director, U.S. Army Research Laboratory

While we list the MLPs as separate entities, the challenges our Warfighters face necessitate that we collaborate across multiple fields of science and technology to provide them the solutions they need to succeed on the battlefield. The Army's increasing demand for more technically complex capabilities and combat technological superiority, drive a need for multi-disciplinary technologies to meet these requirements. Over the last few years we have embarked on a process to address high-priority, transformational topics that intersect more than one traditional technical discipline with multidisciplinary/multi-directorate research programs to attain solutions based on more holistic understandings. A prime example of this collaboration includes our on-going effort in autonomous systems. We are leveraging our in-house expertise across the spectrum of sensors, networks, materials and mobility to arrive at a complete technological solution that will meet the operational requirements of the Soldier in the field.

This review begins with an introduction that includes an overview of our organization, personnel, infrastructure, awards and other recognition earned by ARL and its personnel, along with a brief look at our support to current operations. The remainder of the publication is structured around the nine MLPs identified above. Again, the accomplishments presented here, while only small sample of our efforts over the past year, are representative of the skill, dedication, and teamwork of our in-house staff and our partners in academia and industry.

Many Minds, Many Capabilities, Single Focus on the Soldier

Overview

The U.S. Army Research Laboratory (ARL) of the U.S. Army Research, Development and Engineering Command (RDECOM) is the Army's corporate, or central, laboratory. Its diverse assortment of unique facilities and dedicated workforce of government and private sector partners make up the largest source of world-class integrated research and analysis in the Army.

By combining its in-house technical expertise with those from academic and industry partners, ARL is able to maximize each dollar invested to provide the best technologies for our Soldiers. ARL's program consists of basic and applied research (6.1 and 6.2) and survivability/lethality and human factors analysis (6.6). ARL also applies the extensive research and analysis tools developed in its direct mission program to support ongoing development and acquisition programs in the Army Research, Development, and Engineering Centers (RDECs), Program Executive Offices (PEOs)/Program Manager (PM) Offices, and Industry. ARL has consistently provided the enabling technologies in many of the Army's most important weapons systems.

Technology and analysis products are moved into RDECOM RDECs and to other Army, Department of Defense (DoD), government, and industry customers. The Army relies on ARL to provide the critical links between the scientific and military communities. The Laboratory must marshal internal and external science and technology assets to fulfill the requirements defined by or requested by the Soldier. Equally important, the Laboratory must assist the Army user in understanding the implications of technology on doctrine and in defining future needs and opportunities.

Mission

The mission of ARL is to "Provide the underpinning science, technology, and analysis that enable full-spectrum operations." Within ARL we have teams working in partnership with the RDECs, Rapid Equip Force (REF), Joint Improvised Explosive Device Defeat Organization (JIEDDO), and others on the following tasks: current operational technical challenges facing Soldiers in Iraq (OND – Operation New Dawn) and Afghanistan (OEF – Operation Enduring Freedom), maturing and transitioning technologies in the two- to five-year timeframe for existing systems, and generating scientific discoveries that will provide the foundation for Soldier capabilities 15-20 years in the future.

Our team members understand our mission and they are proud of the contributions they are making for our Soldiers. Providing new or enhanced capabilities for our Soldiers dictates our research program content, recruitment and development of human capital, investments in technical infrastructure, and refinement of our business processes.

Vision

ARL's vision is articulated in a theme statement with three integral elements. It is used to guide organizational alignment and provide a comprehensive framework for critical review of our investments in research programs, technical infrastructure, and workforce development. Performance standards at all levels reflect the focus of each employee on achieving the goals.

The theme statement is: *Many Minds, Many Capabilities, Single Focus on the Soldier*

The elements are:

Acknowledged for scientific, technical, and analytic excellence;

Recognized as the bridge between the nation's S&T communities and the Army;

Leader in providing innovative solutions for the current and future Army.

Organizational Role

ARL is a subordinate element of the U.S. Army Research, Development and Engineering Command. We are a $1.9 billion a year organization that provides the underpinning basic and applied research for the Army and supports the efforts of a wide variety of customers ranging from the Army's Life Cycle management Commands, our sister Services, DoD and other government agencies. Of the total revenue received in FY10, over 56 percent ($1.1 billion) came from ARL customers. Through its partnerships with academia and industry, ARL also leverages several billion additional dollars of research.

Research, Development and Engineering Command (RDECOM)

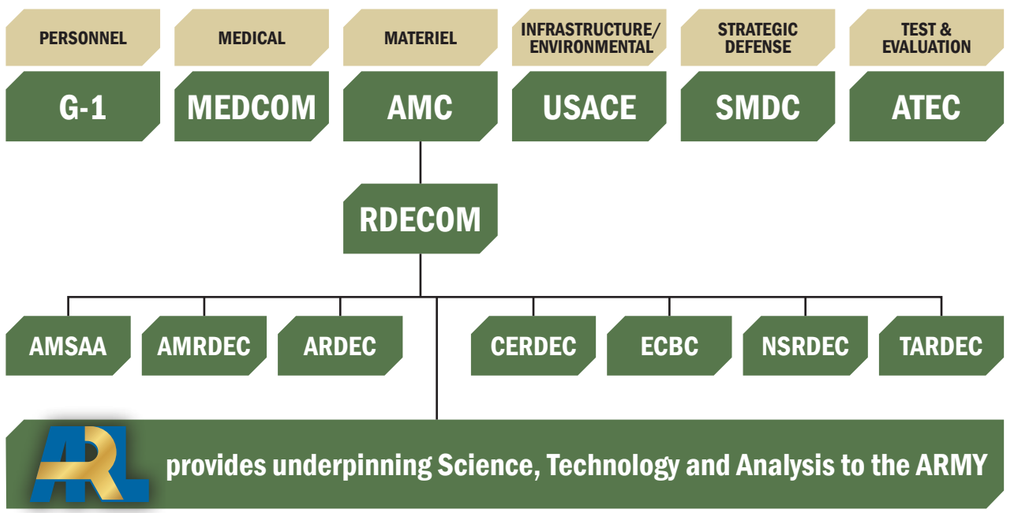
Mission Statement:

Empower, unburden, and protect the Warfighter to enable the dominance of the Army.

Vision Statement:

To be the Army's primary source for integrated research, development and engineering capabilities.

Army RDT&E Performing Organizations



The diversity and complexity of ARL's research and analysis programs (near, mid, and far term) present unique management and scientific challenges. ARL's endeavors must be aligned with the Army Strategic Planning Guidance, the Army Transformation Roadmap, Program Objective Memoranda guidance, Defense Planning Guidance, Defense Research and Engineering Goals, Defense and Army Science Board results, future capability requirements from the Training and Doctrine Command (TRADOC), analysis needs from Army Test and Evaluation Command (ATEC), TRADOC, and the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG-ME); and technology needs of the Research, Development and Engineering Centers (RDECs), Program Executive Offices/Program Managers, other Services, Defense Advanced Research Projects Agency (DARPA), Special Operations Command (SOCOM), Intelligence and Security Command (INSCOM), Rapid Equipping Force, industry, and others to whom ARL transitions technologies. ARL has continuously developed innovations relevant to planning and evaluation processes applicable to complex research and analysis organizations.

ARL Technical Assessment Board

Since 1996, ARL has had a relationship with the National Research Council (NRC), of the National Academy of Sciences, whose mission is to improve government decision making and public policy, increase public education and understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health.

The work of the NRC is made possible by 6,000 of the world's top scientists, engineers, and other professionals who volunteer their time without compensation to serve on committees and participate in activities.

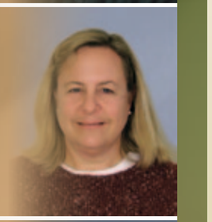
As part of this relationship with the NRC, ARL has in place a Technical Assessment Board. The charge of this Board is to provide biennial assessments of the scientific and technical quality of ARL. These assessments include the development of findings and recommendations related to the quality of ARL's research, development, and analysis programs. We use their input to ensure our work is at the leading edge.

The ARL TAB consists of leading scientists and engineers whose experience collectively spans the major topics within the scope of ARL. Six panels, one for each of ARL's directorates report to the board. Each board member sits on a panel, six of them as panel chairs (pictured here). The number of members on each panel varies, but their members' expertise is tailored to the technical fields covered by the directorates they review. Approximately 90 subject-matter experts participate across all panels.

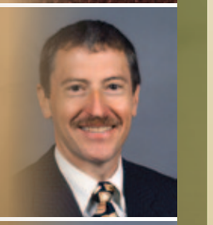
LYLE H. SCHWARTZ
Director (retired)
Air Force Office of Scientific Research

DONALD M. CHIARULLI
Professor of Computer Science and Computer Engineering
Department of Computer Science
University of Pittsburgh

MARJORIEANN ERICKSONKIRK
President
Phoenix Engineering Associates, Inc.



GEORGE T. GRAY, III
Laboratory Fellow
Fellow of ASM International
Fellow - American Physical Society
Los Alamos National Laboratory, FASM



PETER M. KOGGE
Professor of Computer Science and Engineering
Concurrent Professor of Electrical Engineering
University of Notre Dame

DAVID E. CROW
Senior Vice President of Engineering (retired)
Pratt and Whitney

JEREMY M. WOLFE
Professor of Ophthalmology
Visual Attention Laboratory
Harvard Medical School
Brigham and Women's Hospital

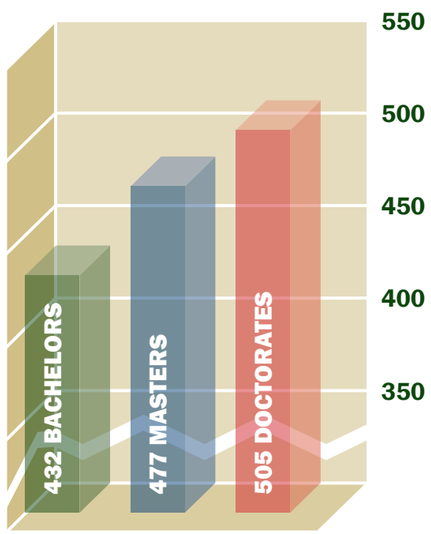
The ARL Team

ARL accomplishes its mission through the work of a highly educated and trained technical and support staff of 2,041 individuals. Of the 2,041 employees, 1,414 are classified as Scientific and Engineering (S&E), 982 of whom hold advanced degrees.

An organization is only as strong as the summation of the skills, expertise, and dedication of its workforce. ARL understands that our intellectual capital is our most critical resource. All research staffing decisions include a critical evaluation regarding generation or continuance of an internal capability vice reliance on external research partners and collaborators. Our goal continues to be a preeminent, multi-disciplinary, adaptive, and learning ARL team capable of meeting the challenges associated with the Soldier's technology requirements.

ARL recruits for and fills positions with the highest caliber applicants. Our interaction with ARL's network of research partners provides the opportunity to interact with graduate students and post-docs with the required expertise from which to recruit and our Personnel Demonstration Project allows starting pay to be negotiated in a competitive range.

1,414 Scientific & Engineering Employees



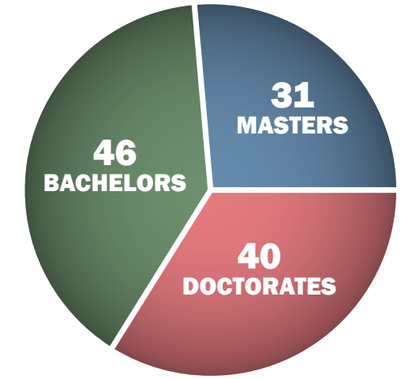
1,668 Technical Staff

321	Electrical/Electronics Engineers
212	Physicists/Physical Scientists
189	Mechanical Engineers
103	General/Industrial Engineers
46	Aerospace Engineers
77	Materials Engineers/Metallurgists
56	Engineering Psychologists
93	Chemical Engineers/Chemists
13	Biologists
7	Neuroscientists
56	Operations Research Analysts
168	Computer Scientists/Engineers
42	Mathematicians/Statisticians
18	Meteorologists
2	Physiologists
2	Biomedical Engineers
9	Other E&S
254	E&S Technicians

ARL's technical staff must be highly skilled to accomplish our mission and our leadership stresses the importance of advanced technical degrees. In FY10, the ARL scientific and engineering staff was composed of 505 (36 percent) doctorates, 477 (34 percent) Master of Science degrees, and 432 (30 percent) Bachelor of Science degrees.

Key performance indicators for quality of the research staff include metrics reflecting the attitudes and technical opinions of the external research community essential for achieving the first element of our vision. For FY10, ARL performed exceptionally in the number of presentations/proceedings (966), refereed journal articles (267), technical reports (507), books published (11), chapters of books written (25), patents awarded (32), and invited talks (136). The ARL staff holds 526 memberships in professional organizations and societies; in those organizations there are 62 ARL scientists and engineers who are Fellows, and 51 of our scientists and engineers hold prestigious posts.

The strength of ARL truly lies in its intellectual diversity. Through focused recruiting efforts, we attract scientists and engineers from a large number of academic institutions worldwide. As a result of these efforts, ARL hired 117 new scientists and engineers in FY10 including 40 with doctorates and 31 with Master of Science degrees, with 43 from Tier 1 schools. ARL strives for diversity of intellectual thought in its new hires and actively recruits from a wide range of schools.



New Hires
Degrees Awarded by:

Arizona State University
Brown University
Bryant and Stratton College
Carnegie Mellon University
Case Western Reserve University
Cornell University
CUNY Queensborough Community College
Delaware State University
Embry Riddle Aeronautical University
Franklin University
George Mason University
Georgetown University
Georgia Institute of Technology
Hendrix College
Indiana University
Institute of Physical Research in Armenia
Johns Hopkins University
Loyola College
Maria Regina College
Memorial University of New Foundland
Naval Postgraduate School
New Mexico State University
New York University
North Carolina State University
North Carolina Wesleyan College
Northeastern University
Norwich University
Ohio Northern University
Ohio State University
Old Dominion University
Oregon State University
Our Lady of the Lake University-San Antonio
Penn State University
Purdue University
Rice University
Rutgers University
Stevens Institute of Technology
SUNY - Binghamton
Taras Shevchenko University of Kiev
The University of Texas at El Paso
Towson University
Tuskegee University
U.S. Army War College
University of Baltimore
University of California-Berkeley
University of California-San Francisco
University of California-Santa Barbara
University of Central Florida
University of Cincinnati
University of Delaware
University of Florida
University of Idaho
University of Illinois at Chicago
University of Illinois at Urbana-Champaign
University of Kansas
University of Maryland-Baltimore County
University of Maryland-College Park
University of Maryland-University College
University of Massachusetts
University of Mississippi
University of Missouri
University of Missouri-Columbia
University of Nebraska at Lincoln-Cotner College
University of New Mexico
University of Notre Dame
University of Pennsylvania
University of Southern California
University of Texas
University of Virginia
University of Wisconsin-Madison
Utah State University
Villanova University
Virginia Polytechnic Institute and State University
Wake Forest University
Washington State University
West Virginia University
Wright State University

At ARL, we understand that science and technology have been and will remain the engines of economic growth and national security in the United States. In addition, we understand that excellence in discovery and innovation in science and engineering are the direct result of a well-educated workforce. It is a workforce that is being challenged by two trends: the global competition for science and engineering talent that impacts the pool of available scientists and engineers (S&Es) available in the United States; and the declining number of native-born S&E graduates entering the workforce. ARL is poised to intervene and improve the success in educating S&E students from all demographic groups, especially those that have been historically underrepresented in S&E careers.

With these national concerns and challenges in mind, ARL has made a corporate commitment to help develop the next generation of Army scientists and engineers by establishing an Outreach Program (OP) Office. The OP was expressly designed to address the projected shortfall of scientists and engineers among diverse populations of the 21st Century, to leverage technical capabilities of academia (including Historically Black Colleges and Universities/Minority Institutions (HBCU/MIs)) to fulfill ARL requirements, and to expand the involvement of HBCU/MIs in ongoing research at ARL. The objective of ARL's OP Office is to develop and execute programs that provide learning and teaching aids, incentives, and rewards for students and teachers while ensuring opportunities for socially and economically disadvantaged students.

For more information about ARL's extensive outreach programs, visit: www.arl.army.mil/outreach

Students Participate in GEMS Program at WSMR

Two sessions of the Gains in the Education of Mathematics and Science (GEMS) program were held at White Sands Missile Range (WSMR) in June and July. More than 80 students from Las Cruces and El Paso area high schools participated in the week-long program, which was organized by personnel from Computational and Information Sciences Directorate and Survivability/Lethality Analysis Directorate.

The GEMS program provides students a unique opportunity for exploring science, math, and technology alongside some of ARL's top scientists and engineers. The program encourages students to pursue higher education in the sciences by exposing them to exciting research and technology occurring in the lab and teaching them about the importance of such work, particularly to the Army.

"What we're trying to teach is that this is for the Soldier, we're not just doing this for ourselves," said Tom Maxwell, a GEMS coordinator and electrical engineer in the Information and Electronic Protection Division.

A GEMS student participates in a rocket demonstration at ARL's White Sands Missile Range location.

While at WSMR, students receive instruction from scientists and engineers about rockets, optics, robotics, radios, antennas, probability and statistics, computers, high speed imaging and electrical design. Each topic is complemented by a tour of an advanced test or research facility, a technology demonstration, or a hands-on laboratory experience in which students are able to build their own devices.

The students were especially impressed with the tour of ARL's Electromagnetic Vulnerability Assessment Facility (EMVAF) and the Army's largest radio frequency anechoic chamber. The EMVAF is equipped with state-of-the-art rooms that block out or isolate electromagnetic waves, and the students used the chamber to build and measure the patterns of their own WiFi antennas.

"Most people on WSMR, much less the general public, don't ever get to see inside a facility like that," Maxwell said. "The kids are getting to see it."

Spending time with ARL's scientists and engineers as well as Soldiers at WSMR provided students with a unique summer experience that exposed them to elements of science and technology that cannot be found within a typical high school classroom.

ALC and APG Host GEMS Summer Program

As part of the Army Education Outreach Program (AEOP), the Gains in the Education of Mathematics and Science series provided students the opportunity to receive hands-on science, technology, engineering and mathematics (STEM) education at Aberdeen Proving Ground (APG), Md. and the Adelphi Laboratory Center (ALC), Adelphi, Md.

Students learn some meteorology basics during the 2010 summer GEMS program at the Adelphi Laboratory Center, Md.

At APG, the GEMS program is geared towards students between grades 7-12. Participants broaden their knowledge level with exposure to composites, instrumentation, digital circuits, computer science, environmental and robotics.

Students at ALC are afforded the opportunity to discover the latest cutting-edge research on hydrogen electrolysis, flexible displays, and fuel cell technology. They also learn about photovoltaics and generators and build fuel cell cars and crystal radios.

All of the activities and experiments are designed by ARL scientists who also oversee the work as it is carried out by the students in the lab.

Students use a spectrometer to analyze the ingredients in gum. The GEMS program targets students in middle school and high school.

Materials Engineer Dr. Sandra Young works with the GEMS students at APG and said the program is designed to capture what students are interested in based on the wide range of projects covered.

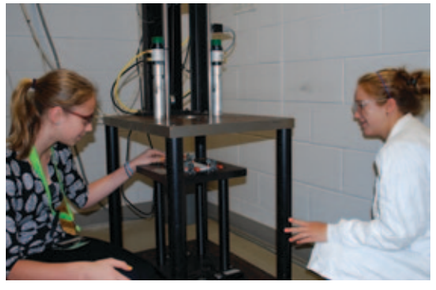
"These students work hands-on with experiments all week long," said Young. "GEMS combines mentoring by older students and scientists as well as team work and dialogue about the experiments they are working on, résumé writing, and careers in STEM.

"The students are getting to see real scientists work in the lab – they get to learn different things they won't get in a traditional school setting," Young added.

GEMS is not only open to students, but also to local schools and organizations. In addition to student participation, the program also welcomes teachers and assigns them to teams, with the hope that they can use some of the lessons from the program in their own classrooms.

Valerie Hawkins, a technology education teacher at Deep Park Middle Magnet School in Randallstown, Md., worked with the robotics team and obtained valuable information to take back with her for the upcoming school year.

"I have robotic kits back at my school, and being afforded the opportunity to see how it is naturally done gives me a better idea and provides a comfort level I wouldn't have gained without the program," said Hawkins.



Students evaluate impact samples as part of the Aberdeen Proving Ground GEMS program. Participation in the program allows students to gain hands-on education that they may not receive in a traditional classroom setting.

Partnerships and Collaborations

ARL is partnering and collaborating with academia, industry, and other government organizations through a variety of continuing and new innovative programs. Our intent is to maximize the use of our limited research dollars by leveraging the resource investments of our partners using a variety of approaches ranging from single investigator grants with individual university faculty, to large centers with groups and consortia, to direct collaborations between university research personnel and ARL in-house scientists, engineers and analysts.

COLLABORATIVE TECHNOLOGY ALLIANCES

- MICRO AUTONOMOUS SYSTEMS & TECHNOLOGY
- ROBOTICS
- NEUROERGONOMICS
- NETWORK SCIENCE

UNIVERSITY AFFILIATED RESEARCH CENTERS

BIOTECHNOLOGY

ICB
Institute of Collaborative Biotechnologies

Biologically-derived:
- Sensors
- Electronics
- Information Processing

NANOTECHNOLOGY

ISN
Institute of Soldier Nanotechnologies
- Protection
- Performance Enhancement
- Injury Intervention and Cure

ELECTROMECHANICS & HYPERVELOCITY PHYSICS

IAT
Institute for Advanced Technology
- EM Launch
- Pulsed Power
- Electric Armaments

IMMERSIVE ENVIRONMENTS

ICT
Institute for Creative Technologies
- Full Sensory Immersion
- 3-D Mobility
- Compelling Interactive Stories

PARTNERSHIP PROGRAMS

Single Investigator Program
Multidisciplinary University Research Initiative Program
Collaborative Technology Alliances
Centers of Excellence
HBCU/MI ARO Core Grants
Battlefield Capability Enhancement Centers of Excellence
SBIR/STTR
University Affiliated Research Centers
Defense Experimental Program to Stimulate Competitive Research
Short Term Innovative Research

Centers of Excellence

THE FLEXIBLE DISPLAY CENTER AT ARIZONA STATE UNIVERSITY

The U.S. Army established the Flexible Display Center at ASU in February 2004 to spearhead the next revolution in information displays. The Center is a partnership where academia, industry, and government collaborate on rapid technology development, innovation and integration to create a new generation of innovative displays that will be flexible, lightweight, low power, and rugged. These revolutionary displays will usher in a new era of powerful real-time information sharing through ubiquitous commercial and military application in everything from portable pocket-held and vehicle-mounted devices to permanent and temporary conferencing/command rooms.

Arizona State University

MATERIALS CENTER OF EXCELLENCE

The Materials Center of Excellence (MCOE) is an integral part of the Army's strategy to provide advanced materials to enable lightweight, durable, and survivable solutions for the range of Army applications. The Centers are a partnership between ARL and leading materials research universities providing for mutual exchange of personnel and sharing of research facilities. Lightweight, multi-functional composites, advanced armor ceramics, dynamic response of metals, protective polymers, and hybrid systems are emphasized. The program has been widely acclaimed and recognized for its technical excellence and impact on Army programs.

University of Delaware
Johns Hopkins University
Rutgers University
Drexel University
Virginia Tech

THE ARMY HIGH PERFORMANCE COMPUTING RESEARCH CENTER

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

Stanford University
New Mexico State University
Morgan State University
University of Texas, El Paso
High Performance Tech, Inc.
NASA - Ames

International Technology Alliance Providing Greater Understanding of Networks

U.S. Army Research Laboratory researchers, working in collaboration with researchers from the United Kingdom's Ministry of Defense and a consortium of industry and academic partners in both the U.S. and U.K., were able to gain a greater understanding of the fundamental theoretical underpinnings of network theory, network system security, and information processing and delivery.

The reliability of network operations is highly dependent on the robustness of paths and the protocols and subsequent trade-offs used to ensure information delivery. The trade-offs include the burden of increased overhead for routing protocols against the increase and frequency of data gathering.

Theoretical results indicate that there is a sharp transition between the value of the information and the need for the maximum available information.

ARL Director John Miller signs documents establishing the International Technology Alliance.

Protecting the information flow from unintended disclosure while ensuring trustworthiness and fidelity of the information when delivered was explored using a description-logic based approach with results that will allow network architects to improve end-to-end security in future designs.

Using a hybrid approach, researchers developed a capability to allocate sensor resources to support mission requirements that uses a semantic approach to define tasks so that software agents can determine what resources are needed.

These advancements will have impacts on current network system operations as well as future network architecture designs.

The U.S. and U.K. government team that was involved in the two-year process to establish the International Technology Alliance.

Obama Reviews ARL Funded Research

President Barack Obama toured laboratories at the Massachusetts Institute of Technology and reviewed ARL-funded research.

Obama's visit, which took place on Oct. 23, 2009 as part of a larger visit to the university to see the MIT Energy Initiative, brought him to the laboratory of Institute of Collaborative Biotechnologies (ICB) researcher Dr. Angela Belcher.

Belcher's research team is working with ARL to apply recognized needs from the battlefield toward better technologies for the Army. This research could reduce the weight load for Soldiers and aircraft after optimization, transitioning, and advanced development are complete.

Dr. Angela Belcher discusses her latest research with President Barack Obama when he visited the Massachusetts Institute of technology in October 2009. Lt. Col. F. John Burpo, currently working in the Department of Biological Engineering at MIT, is also pictured. Burpo is pursuing his doctorate in Biological Engineering and will become a U.S. Military Academy professor in 2011.

While most lithium-ion batteries are relatively bulky and must be enclosed within a hard shell, these efficient, flexible, lightweight biological micro-batteries were created using genetically-engineered viruses as templates for the battery material.

Belcher recalled that Obama was "very impressed" when she described "how much better [these] batteries were than conventional batteries." The new batteries could be used to reduce the load carried by Soldiers or allow unmanned aerial vehicles to fly longer with a larger payload.

Obama also visited several investigators within the Institute of Soldier Nanotechnologies (ISN) who have leveraged their work in nanoscience to provide unexpected applications in energy, thereby increasing the payoff for Army investment in this research.

Prior to presenting a speech on energy policy, Obama toured the laboratory of ISN Professor Vladimir Bulovic, where they discussed ARL-funded research in quantum dot LED lights, which could lead to more efficient lighting technology.

Obama later reviewed ARL-funded research in the laboratories of ISN Professors Marc Baldo and Paula Hammond. Baldo and Hammond demonstrated potential applications of their ISN-funded research in electron transport and layered materials assembly.

The presentation included research in self-assembled solar cells and a demonstration of a system that bridges ICB and ISN research by employing a biologically created solar cell to charge a biological battery developed from Belcher's research.

President Barack Obama toured laboratories at the Massachusetts Institute of Technology and reviewed ARL-funded research.

Empire Challenge 2010

Empire Challenge is U.S. Joint Forces Command's (JFCOM) annual live, joint and coalition intelligence, surveillance and reconnaissance (ISR) interoperability demonstration under the sponsorship of the Under Secretary of Defense for Intelligence (USD/I).

The focus of this past year's effort, Empire Challenge 2010 (EC-10), was ISR interoperability in Afghanistan, concentrating on persistent sensing over key terrain in both rural and urban complex environments.

Analysis - Soldiers from the 3rd MI conduct analysis.

The heart of this effort was to provide solutions-based assessments of the Distributed Common Ground/Surface System (DCGS) Enterprise; multinational, capability-based interoperability; and Intel-Ops Fusion capabilities.

Through ARL's Initiative for Integration and Interoperability of ISR Assets (I4A), using both network and analytic solutions, and providing support across the asymmetric warfighting front, I4A used activity detection sensors to conduct activity-based analysis across sensor modalities and network domains.

Specific achievements included:

- Conducting cross platform tipping and cueing
- Disseminating multi-source data into DCGS
- Demonstrating new sensor technologies
- Integrating disparate air and ground ISR assets into an integrated collection posture
- Sharing data and products across domains
- Demonstrating event-driven air/ground cross cueing
- Providing activity-based collection posture assessment

Notable accomplishments included the first ever push of Constant Hawk/Wide Area data to the tactical edge via a ROVER transceiver, integration of unattended ground sensors (UGS) and Constant Hawk data into a common picture, the successful demonstration of new UGS technologies and the development of new collection assessment methodologies.

Based on the results of EC-10, novel UGS systems are now being improved based on lessons learned during the exercise, with the goal of fielding the improved systems in a limited operational assessment.

ARL partnered with, and will share EC-10 information with JFCOM, the U.S. Marine Corps, Defense Threat Reduction Agency, Defense Intelligence Agency, Air Force Research Laboratory, Intelligence and Security Command, Program Manager for Aerial Common Sensors, Night Vision Laboratory, 3rd Military Intelligence Battalion, and 513th Military Intelligence Brigade.

I4A HQ - Constant Hawk Analyst Trailers and I4A Headquarters.

Army Leverages Private Industry, Academia to Advance Robotics Research

Developing smart robots with the ability to work for and alongside Soldiers is the ultimate goal of the Army's new robotics cooperative agreement with industry and academia.

The Robotics Collaborative Technology Alliance is expected to push the research needed to make autonomous robots accomplish more missions and take some of the burden off Soldiers on the battlefield, said ARL's Jon Bornstein, chief of the Robotics Autonomous Systems Division and CTA manager.

"I would like to see the CTA research demonstrate an unmanned system that can adapt to a dynamic environment and learn from its experiences," said Bornstein. "I'm really looking forward to this research moving unmanned systems as a tool for the Soldier."

Bornstein said he compares his vision of the future use of robots in the Army with the way Warfighters work with dogs in K-9 units.

"They're part of the team, and we want these unmanned systems to be part of team. There must be an intuitive bond between the Soldier and robot - a trust ... and a certain level of compatibility to develop that capability," he said.

Through the agreement, ARL will be working with a consortium of leading research organizations to break through basic scientific barriers in perception, intelligence, human-robot interaction, dexterous manipulation and unique mobility.

"Developing technology in these critical areas is crucial to the advancement of future unmanned systems possessing a significant level of autonomy," said Bornstein. "Robots can't be dumb. They must be able to work on their own."

While the Army drives the research direction, it chose a consortium of eight organizations, led by General Dynamics Robotic Systems, to perform under the cooperative agreement.

Boston Dynamics, Carnegie-Mellon University, California Institute of Technology Jet Propulsion Laboratory, Florida A&M University, QinetiQ North America, the University of Central Florida, and the University of Pennsylvania will all work as partners to delve into the cutting-edge research.

ARL uses cooperative agreements to develop and execute research plans that share financial, intellectual, personnel and infrastructure resources from both the government and private sector, and the new agreement is the third robotics-centered CTA the laboratory has leveraged.

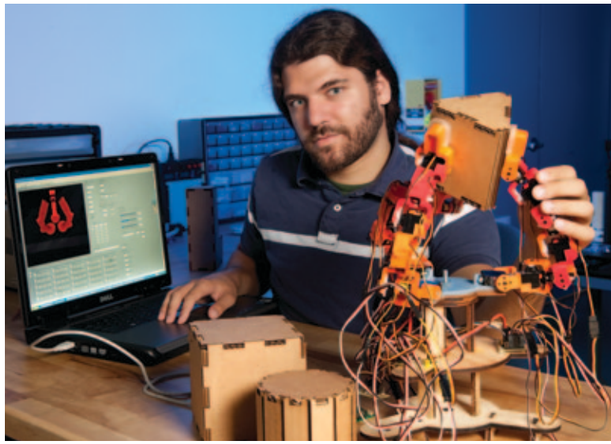
Bornstein managed a previous eight and a half years of CTA robotics research. The original CTA focused on command and control of robotics while the newly announced agreement is reaching into intelligence, learning and robotic-human interaction.

"We accomplished a significant amount of research in our previous CTA," said Bornstein. "We see (that research) filtering into the Army's autonomous systems now."

The Micro Autonomous System Technologies CTA was the second ARL alliance, which focuses on small, hand-held robotics research.

The broader robotics-research picture falls under the auspices of the laboratory's enterprise that focuses on four key areas: perception, intelligence, human-robot interaction and manipulation and mobility.

"This robotics CTA will be a key part of ARL's Autonomous Systems Enterprise that combines ARL's internal research efforts with external research," said Bornstein.



VTD's Miles Pekala displays the robotic tentacle manipulator.

ARL and Other RDECOM Organizations Recognized with Army Superior Unit Award

Gen. Ann Dunwoody, Maj. Gen. Nick Justice and ARL Director John Miller gather after the award ceremony.

The U.S. Army Research Laboratory was one of several Research, Development and Engineering Command subordinate organizations that received a Superior Unit Award Sept. 16 at Aberdeen Proving Ground, Md.

ARL Director John Miller accepted the award on behalf of the laboratory from Army Materiel Command's Commander Gen. Ann Dunwoody.

Gen. Dunwoody presented Miller with a lapel pin and streamer during the ceremony.

The Army Superior Unit Award was established by the Secretary of the Army in 1985 to recognize outstanding meritorious performance of a unit during peacetime, or in a difficult and challenging mission under extraordinary circumstances. Through a coordinated command-wide effort, RDECOM developed nine of the ten Army's Greatest Inventions in 2007.

Gen. Dunwoody spoke to the crowd of over 2,000 people on Fanshaw Field and said the work of over 17,000 RDECOM employees has saved countless lives on the battlefield.

"You can't be Army strong without being smart and focused," said Dunwoody. "RDECOM has made a difference and done all this in the midst of Base Realignment and Closure (BRAC).

Maj. Gen. Nick Justice, Gen. Ann Dunwoody and Command Sgt. Maj. Hector Marin stand at attention at the beginning of the Superior Unit Award ceremony at APG.

ARL Director John Miller stands with the colors on Fanshaw Field during the Superior Unit Award Ceremony.

"The new center of gravity for AMC is here at Aberdeen...the employees of RDECOM manage to do amazing things day in and day out," she said.

RDECOM Commander Maj. Gen. Nick Justice said the history of technology development and testing could be found at APG – from using horse-drawn cavalry to the birthing of the information age at a facility right down the road. With BRAC, he expects the pace of change to increase further.

"The award is not a culmination of the event," Justice said. "We are challenged to become more effective, innovative and dedicated to the nation and armed forces in everything we do."

An award streamer was added to ARL's colors signifying the award.

Research and Development Achievement Awards

Army Research Office:

- Dr. Bruce J. West

Computational and Information Sciences Directorate:

- Dr. Brian J. Henz
- Dr. Raju R. Namburu
- Song J. Park
- Dale R. Shires

Sensors and Electron Devices Directorate:

- Dr. Sarah S. Bedair
- Dr. Gregory N. Brill
- Dr. Yuanping Chen
- Dr. Nibir K. Dhar
- Dr. Ronald Green
- Dr. Ellen L. Holthoff
- Dr. Brian C. Morgan
- Dr. Paul Pellegrino
- Dr. Priyalal S. Wijewarnasuriya
- John Bender
- Lauren M. Boteler
- Roberto Innocenti
- Gail Koebke
- Dimeji Ibitayo
- Christopher D. Meyer
- Lam H. Nguyen
- Damian Urciuoli

Weapons and Materials Research Directorate:

- Dr. Chiung-Chu Chen
- Dr. Margaret M. Hurley
- Dr. Michael J. McQuaid
- Dr. Patrick J. Taylor
- Peter T. Bartkowski
- Kestutis G. Chesonis
- John A. Escarsega
- Valerie S. Hernandez

Defense Standardization Program Outstanding Achievement Award

- Dr. Jonathan Montgomery - WMRD
- Matthew Burkins – WMRD
- Bill Gooch - WMRD
- Richard Squillacioti - WMRD
- Kirk Stoffel – WMRD

Department of the Army Lean Six Sigma Certifications

Green Belt

- Anthony Johnson – ARO

Black Belt

- Marc Pepi - WMRD

Excellence in Federal Career Awards

Gold:

- Dr. Sara Bedair – SEDD
- Thomas C. Adkins - SLAD

Silver:

- Demiji Ibitayo - SEDD

Bronze:

- Dr. Sandra Young - WMRD
- Margaret Denkins – CISD
- Natalie Eberius - SLAD
- Bonney G. Gietz – CISD
- Ricky Grote - SLAD

Women of Color Technology Award - Technology All-Star

Peggy Lacewell - ARO

Value Engineering Achievement Award

Battlefield Environment Division – CISD

MANPRINT Practitioners Special Achievement Award

Anna Mares – HRED

Wilbur B. Payne (Small Group) Memorial Award for Excellence in Acquisition

Survivability/Lethality Analysis Directorate

LEGION OF MERIT

COL. BOBBY SMITH

MERITORIOUS SERVICE MEDAL

LT. COL. MARJORIE GRANTHAM
LT. COL. FREDRICK LUDDEN
LT. COL. KATHALEEN MOSES
MAJ. ANTHONY DOUGLAS
MAJ. JEFFREY JURAND
MAJ. RICHARD MOYERS
STAFF SGT. WETZEL BOUSHIE

ARMY COMMENDATION MEDAL

SGT. 1ST CLASS JAMES RATLIFF
STAFF SGT. COLLIN MOORE

ARL Fellows: An Elite Group

The Fellows of the Army Research Laboratory play a vital role at the laboratory. Their overall mission is to achieve, promote and maintain technical excellence in science and engineering at ARL. The Fellows serve as advisors and consultants on technical matters to the ARL Director and the Directorate Directors.

They are carefully chosen from the ARL community, itself a distinguished collection of some of the top scientific minds in our Nation. Only a small percentage of the scientist and engineer workforce at ARL can be Fellows. The selection criteria include an emphasis on nominating those researchers performing the very highest quality ongoing S&E work that also has an extremely high impact on Army needs, the mission, and their field of endeavor. The first ARL Fellows were elected in 1993. The Fellows endeavor to be representative of ARL as a whole. To this end, the ARL Fellows Charter provides procedures that assure a field of candidates drawn from the entire laboratory. There are currently 28 Fellows, 29 Fellows emeriti, and two Honorary Fellows.

U.S. Army Research Laboratory Holds Summer Student Research Symposium

The fourth annual Summer Student Research Symposium was held at Aberdeen Proving Ground, Md. on Aug. 10. Each year summer student interns conduct research projects and compose technical reports recounting their internship work. The reports are evaluated by directorate judging panels, and the top submissions are selected as symposium finalists. Finalists provide presentations at the symposium, and gold, silver, and bronze cash prizes are awarded to the top three presentations in both undergraduate and graduate student categories.

In the undergraduate category, Jamie Huang, a student at the Massachusetts Institute of Technology, received the gold award. “All of the presentations were outstanding and it’s an honor to be selected as the winner,” Huang said.

In the graduate student category, Daniel Cannon received top honors. Cannon is a doctoral student at Carnegie Mellon University. “I was shocked and pleased when my name was announced,” Cannon said. “I’m glad that my work impressed the judges and that they viewed my project as practical and important to the Warfighter.”

Symposium Group: Director John Miller stands with the symposium finalists, their mentors, and some of the ARL fellows after the awards ceremony. Front Row (L-R): Betsy Rice, Irene Val-Addo, Jamie Huang, Ann Ploskonka, Director John Miller, Janea Lowery, Daniel Smith, Katherine Bagley, Gabriella Rose, James McCauley, Melanie Cole, John Powell. Back Row (L-R): Tomasz Letowski, Jan Andzelm, Dattatraya Dandekar, Shashi Karna, Rose Pesce-Rodriguez, Brad Forch, Daniel Cannon, Collin Becker, John Dykes, Lynn Munday, Volker Weiss.

ARL Colloquium

The ARL Colloquium Series, inaugurated in 2009, continued to provide a forum for the exchange of ideas throughout the year. The goal of the ARL Colloquium is to bring distinguished individuals in the sciences, engineering, arts, humanities, innovative technologies, military, and government affairs to ARL as Colloquium speakers, augmenting the many technical seminars and distinguished technical lectures that already occur throughout ARL. For the Colloquium, plenary-type topics are selected to be of exciting, broad interest relevant to current or future ARL research interests, and speakers are selected for their ability to highlight exciting developments in a broad context and explain national/international or broad scientific context. The Colloquium provides:

- A venue for timely and stimulating ideas relevant to ARL staff, contractors, postdoctoral fellows, and student interns
- A regular opportunity for cross-disciplinary interaction of ARL’s scientists and engineers
- Opportunity for external leaders to become more familiar with ARL’s mission and capabilities

During the year, ARL hosted several distinguished lectures including:

November 2009 – Col. (Ret.) Douglas Macgregor, Ph.D. Topic: Developing the Nation’s Forces - Predicting a Hazardous Future.

January 2010 - Dr. George Dieter, University of Maryland. Topic: Engineering Education in the United States.

March 2010 - Dr. Sommerer, Johns Hopkins University Applied Physics Laboratory. Topic: Impact of Technology Globalization: Challenges and Opportunities for National Security.

May 2010 - Ambassador Goodwin Cooke, Syracuse University. Topic: Nations and States, and the Issue of Ethnicity in International Relations.

July 2010 - Dr. David Lovell and Dylan Rebois, Engineers, University of Maryland. Topic: Engineers Without Borders: Delivering Sustainable Solutions to Engineering Problems in the Developing World.

Dr. George Dieter, University of Maryland, discusses the state of engineering education during January’s colloquium.

Dylan Rebois, chapter president for Engineers Without Borders at the University of Maryland, addresses the ARL workforce during July’s colloquium.

Key Facilities

ARL has seven primary sites: Adelphi, Md.; Aberdeen Proving Ground, Md.; White Sands Missile Range, N.M.; Raleigh-Durham, N.C.; Langley, Va.; Glenn, Ohio; and Orlando, Fla. Unique facilities at our primary sites provide our scientists and engineers access to world-class research centers.

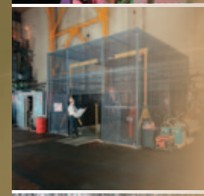
ELECTROMAGNETIC VULNERABILITY ASSESSMENT FACILITY
The new facility addresses the complete electromagnetic threat being encountered in theater and anticipated for the Future Force.

NOVEL ENERGETICS RESEARCH FACILITY
This facility contains a processing complex with energetics processing and manufacturing labs, an explosives casting lab, and it also has explosives x-ray capability.

SHOOTING SIMULATOR
An indoor small arms shooting performance simulator with a high-speed weapon tracking system that provides real-time continuous weapon aim point data.

ROBOTICS RESEARCH FACILITY
This 13-acre course is used for unmanned vehicles and indirect driving studies. Driving paths include straightaways, slaloms, tight turns, and straight and broad paths in which obstacles such as logs and rocks must be avoided.

LASER OPTICS TESTBED
This laboratory is equipped to support sophisticated investigations in adaptive and nonlinear optics, advanced imaging and image processing, and laser communications for ground-to-ground applications.



PULSE POWER FACILITY
This facility provides a full-scale testbed for development, evaluation and demonstration of continuous power components.

MOBILITY/PORTABILITY RESEARCH FACILITY
The Army standard for measuring the effects of various equipment configurations and loads on Soldier mobility and physiological performance.

VERTICAL IMPULSE MEASUREMENT FACILITY
Facility for measuring accurately the combined debris and blast impulse produced in landmine detonations. Data are used to validate models and develop technologies for improved survivability of future lightweight tactical and combat vehicles.

TACTICAL ENVIRONMENT SIMULATION FACILITY
This facility integrates, under one roof, the Omni-Directional Treadmill (ODT) into virtual visual and auditory environments to enable laboratory controlled investigations.

RODMAN MATERIALS RESEARCH LABORATORY
The Rodman has nearly 300,000 sq. ft. of laboratories that enable the pursuit of disruptive and challenging research and characterization in advanced materials technologies for potential applications in Army weapon systems.

TRANSONIC EXPERIMENTAL RESEARCH FACILITY
Among other things, this facility evaluates aerodynamics and fluid dynamics of projectiles, smart munitions systems, and sub-munitions dispense systems.

ZAHL PHYSICAL SCIENCES LABORATORY
The Zahl's cornerstone is its clean room. The lab enables basic and applied research and analysis in nanobiotechnologies; flexible electronics; advanced specialty electronics material growth; nonlinear material research and characterization; and power electronics.

SIMULATION AND TRAINING TECHNOLOGY CENTER
The facility is located in Orlando, Fla. and houses engineers and scientists from the Simulation and Training Technology Center.

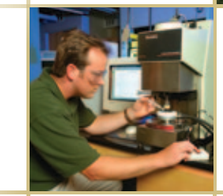
DSRC AND SCIENTIFIC VISUALIZATION FACILITY
This facility features state-of-the-art scalable parallel architectures and large vector-parallel systems supporting both classified/unclassified missions throughout the DoD's RDT&E community.

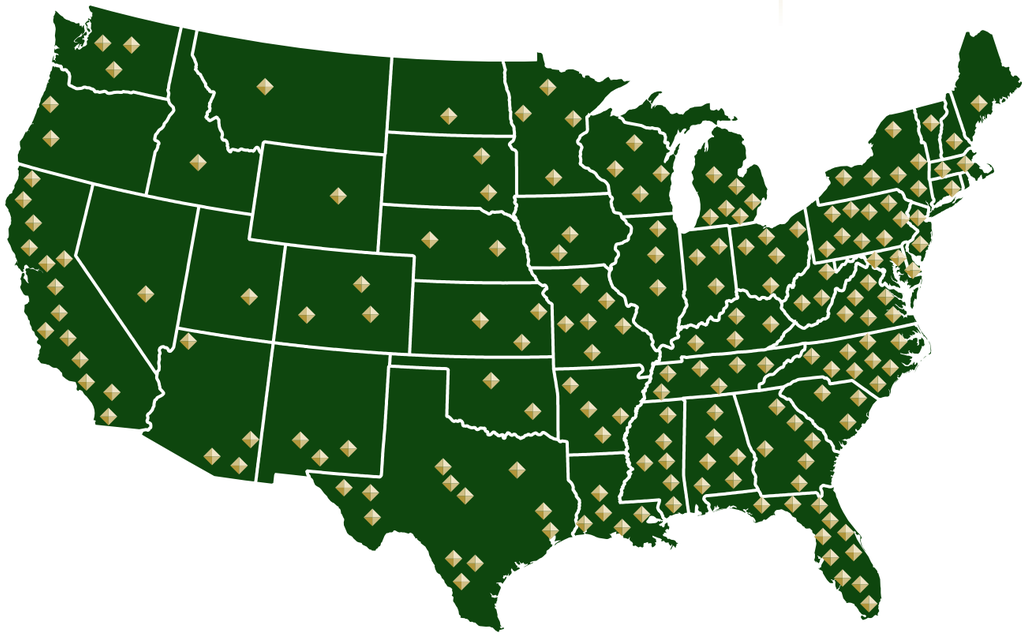
AIRBASE EXPERIMENTAL FACILITY #6
This modern, centralized complex provides analysts, program managers, and decision makers with experimental data that addresses the SLV of air and ground combat systems.

THE ARMY RESEARCH LABORATORY IS THE RDECOM LEAD AGENCY FOR PLANNING AND EXECUTING RESEARCH OPPORTUNITIES WITH ACADEMIA.

ARL has a number of complementary mechanisms for academic partnering, ranging from single investigator grants with individual university faculty, to large centers with groups and consortia, to direct collaborations between university research personnel and ARL in-house scientists, engineers and analysts.

ARL is actively engaged in funding research with over 250 universities and colleges located in all 50 states.





Simulation and Training Technology Center Dedication

On Nov. 7, 2003, the Simulation and Training Technology Center (STTC) was dedicated to Sgt. 1st Class Paul Ray Smith for valor and bravery during Operation Iraqi Freedom. Smith was selected by the center to represent all Soldiers from the State of Florida who have Fallen in America's war against terrorism. On May 13, 2005, the Center was rededicated after Smith was posthumously awarded the Congressional Medal of Honor. His citation reads:

"For conspicuous gallantry and intrepidity at the risk of his life above and beyond the call of duty: Sergeant First Class Paul R. Smith distinguished himself by acts of gallantry and intrepidity above and beyond the call of duty in action with an armed enemy near Baghdad International Airport, Baghdad, Iraq on 4 April 2003. On that day, Sergeant First Class Smith was engaged in the construction of a prisoner of war holding area when his Task Force was violently attacked by a company-sized enemy force. Realizing the vulnerability of over 100 fellow Soldiers, Sergeant First Class Smith quickly organized a hasty defense consisting of two platoons of Soldiers, one Bradley Fighting Vehicle and three armored personnel carriers. As the fight developed, Sergeant First Class Smith braved hostile enemy fire to personally engage the enemy with hand grenades and anti-tank weapons, and organized the evacuation of three wounded Soldiers from an armored personnel carrier struck by a rocket propelled grenade and a 60mm mortar round. Fearing the enemy would overrun their defenses, Sergeant First Class Smith moved under withering enemy fire to man a .50 caliber machine gun mounted on a damaged armored personnel carrier. In total disregard for his own life, he maintained his exposed position in order to engage the attacking enemy force. During this action, he was mortally wounded. His courageous actions helped defeat the enemy attack, and resulted in as many as 50 enemy Soldiers killed, while allowing the safe withdrawal of numerous wounded Soldiers. Sergeant First Class Smith's extraordinary heroism and uncommon valor are in keeping with the highest traditions of the military service and reflect great credit upon himself, the Third Infantry Division "Rock of the Marne," and the United States Army."

Sgt. 1st Class Paul Ray Smith Simulation and Training Technology Center

On Oct. 1, 2010, the Simulation and Training Technology Center (STTC) officially became part of ARL. This realignment began when ARL assumed operational control of the center on April 23, 2010. The merger of the organizations serves to strengthen the Research, Development, and Engineering Command's research and engineering core. It will allow the organizations to build a more cohesive Human Dimension and Training research program and to leverage technologies more effectively.

Organization

The STTC employs approximately 80 military, civilian and direct contractor personnel.

Customer Relationships

The STTC takes a partnership approach to mission success. Many organizations call on the STTC for their unique expertise. For example, the STTC supplies lead technical guidance to the Program Executive Office Simulation, Training and Instrumentation (PEO STRI) for programs such as the generation of synthetic natural environments, live training tracking systems, support of computer generated forces and the establishment of eighteen Medical Simulation Training Centers throughout the world. Additionally, the STTC provides other agencies including the Department of Defense and Department of Homeland Security with state-of-the-art applied research and development of simulation technologies in areas such as human agent, and teams, in a system of systems environment.

Current Research Highlights

Counter-Improvised Explosive Device (C-IED) Training

One of the latest STTC products, jointly developed by the STTC, the Joint Improvised Explosive Device Defeat Organization (JIEDDO) and the Institute for Creative Technologies (ICT), is the delivery of the Mobile Counter-IED Interactive Trainer (MCIT) prototype suite. The MCIT is a mobile system designed to provide the training and experience necessary for U.S. forces to recognize and defeat an emplaced IED under a variety of complex attack scenarios in the contemporary operating environment. The MCIT seeks to prepare Soldiers mentally for hostile encounters through interactive exercises, and also reinforces key learning objectives and concepts.

Sgt. 1st Class Paul Ray Smith Simulation and Training Technology Center, Orlando, Fla.

Severe Trauma Simulation and Synthetic Tissue

The STTC is conducting research and development in severe trauma simulation technologies to better prepare the Soldiers to deal with injuries encountered on the battlefield. Current technologies do not simulate the proper look, feel, smell or actions of real trauma and therefore, do not properly prepare the trainee for the horrific injuries he/she will treat in a combat environment. The prototype will provide stress inoculation training such that Soldiers will be physically and emotionally prepared to deal with treating severe wounds.

Multinational Training

The Multinational Environment for Training Evaluation and Research (METER) is using Virtual World technology to create a distributed simulation environment that could support training for a wide range of Joint Interagency, Inter-governmental, and Multi-national (JIIM) operations, including Coalition Warfare. Under the METER project, the STTC and the United Kingdom's (U.K.) Land Warfare Centre, are conducting experimental training exercises to evaluate virtual world technology for Coalition Warfare training. The goal of the research is to leverage the scalability, as well as the social and distributed nature of virtual worlds to provide a large terrain area where U.S. and U.K. forces could conduct a collaborative mission in a cluttered urban environment.

Virtual Worlds and Gaming Research

The STTC is carving a path forward in the exploration of virtual worlds for low-cost collaboration and expansion of distributed learning potential. Virtual worlds offer the power of immersive learning, engagement and analytical workspace, which is persistent and broader than gaming today. In 2009, the STTC designed and executed the inaugural Federal Virtual Worlds Challenge (FVWC). More information on the FVWC can be found at www.fvwc.army.mil.

The STTC is pursuing virtual worlds research and development to support various Army applications (collaboration, training, public relations, prototype application development, and geospatial).

Moving Forward

It is the STTC's goal, as a part of ARL, to continue to be recognized as the preeminent world leader in research, development and engineering of training systems and transitioning the right technology in the shortest time to Soldiers. The STTC, as part of Team Orlando, engages with its sister services, academia and industry to develop critical simulation and training technologies to increase Warfighter battlefield readiness and performance.

Army Research Lab's Newest Analysis Facility Helps Ensure Aircraft Safety, Design

The Army Research Laboratory unveiled its latest efforts in ensuring the military's aircraft are safe and effective on the battlefield during a ribbon-cutting ceremony Sept. 8, 2010.

The ARL Rotorcraft Survivability and Assessment Facility (RSAF) will give the Department of Defense accurate and timely test and evaluation information that could lead to improvements in aircraft design and reduce injury and death, said John Miller, ARL director.

The state-of-the-art facility will "address an immediate need for evaluation and assessment," said Miller, by testing "all the kinds of threats that our Soldiers and Warfighters in theater have to deal with."

The RSAF provides a full spectrum of aircraft survivability assessment services, including support to advanced system developments, quick responses to new threats, and live-fire testing and experimentation.

Costing about $12 million, the facility construction began in October 2007 and was completed in July with the first helicopter, an AH-64D Apache Longbow Block III attack helicopter, arriving in late August.

The Apache Block III will be the first system tested at the RSAF. The Block III is an upgrade that will allow pilots the ability to view real-time unmanned aircraft systems feeds in the cockpit, among other network and multi-role weapon system improvements, according to Army statements.

The upgrade is expected to be applied to all Apaches, but they must be fully evaluated on how they will hold up in war before they're fielded.

"When the Army upgrades something (or acquires a new system), it's mandated by law that it undergoes realistic ballistic vulnerability testing," said Fred Marsh, RSAF team leader. "That's what we do for aircraft."

Co-located with ARL's Airbase Experimental Facilities 6 and 7, which execute about 20 evaluation projects a year, the RSAF will add additional investigative resources to improve helicopter and Warfighter survivability for the Army and the DoD.

"It overall provides us with an additional advanced test site," said Marsh. "That's a significant improvement to our mission in itself."

An AH-64D Apache attack helicopter is mounted to the ARL Rotorcraft Survivability and Assessment Facility's tilt-table for later live-fire and other tests and evaluations. The new RSAF facility tests U.S. military and foreign rotor aircraft to help keep Warfighters safe from threats.

Not only does it bring additional capabilities, it also brings new ones. The site is equipped with a tilt-table system that allows the test engineers to fire at the helicopter at multiple angles, including from below – something that couldn't be easily done before.

"The ability to maneuver the target gives us a lot more opportunity to position (the aircraft) at previously unachievable elevations, significantly expanding our test capabilities," said Marsh.

It's also equipped with standard and high-speed video camera systems that will supplement more than 400 other points of data collection to include temperature, blast pressure, strain and stress. Small arms, anti-aircraft artillery, high-explosive warheads and several non-conventional munitions are just some of the live-fire testing capabilities.

The critical information gathered from the live-fire tests is mostly used by program managers, the Army Evaluation Center, other DoD decision makers as well as being used to support mathematical modeling and analysis.

And sometimes real-time assessments are also needed, said Marsh. Recently an aircraft was believed to be shot down by enemy fire in Afghanistan, and to understand what happened, the Army and Air Force turned to Marsh and his team to recreate the scenario.

Whether the information is used in models or to recreate a battlefield scene, Marsh said, he knows who he ultimately is working for.

"This all directly supports the Warfighter," said Marsh.

Newest ARL Supercomputer Expands Army's Computational Sciences Footprint Across DoD

ARL Associate Director Reed Skaggs, third from left, is joined by Harold J. Breaux and Charles Nietubicz during a ribbon cutting ceremony recognizing the dedication of ARL's newest supercomputer.

High performance computers, like those housed within the Defense Supercomputing Resource Center that ARL manages at Aberdeen Proving Ground (APG), help the Army solve some of the toughest scientific challenges of our time, develop new applications for proven systems like up-armored combat vehicles, and expand military medical research.

ARL dedicated its newest supercomputer, the Harold, on June 29 at the historic Ballistic Research Laboratory Hall, now a conference center that pays homage to the hallmark organization responsible for helping to create the Electronic Numerical Integrator And Computer (ENIAC), the world's first general-purpose electronic computer.

Named in honor of Harold J. Breaux, a Defense Department supercomputing resourcing pioneer, the new system is a SGI Altix ICE 8200 Linux cluster and the largest of its kind ever deployed at the ARL DSRC. It offers 10,752 Intel Xeon 5500 series processor cores and higher memory bandwidth than other high performing computers here and across the DoD HPCMP, enabling more of the peak processing capability to be delivered with less code optimization. The computer arrived in June 2009 and has been in production use since October 2009.

Critical to defense research projects is the maturation and expansion of computational sciences coupled with standard engineering disciplines, said Charles Nietubicz, director of ARL's DSRC and chief of the Advanced Computing and Computational Sciences Division within CISD. He noted that today, ARL researchers cannot do basic and applied research without high performing computers because such capability, along with theory and experimentation, introduces relevant computational power needed to do physics-based research.

The Harold is one of three ARL supercomputers that bring the DSRC's total processing power to more than 350 Teraflops, or trillion floating point operations per second. Nietubicz said this significantly enhances DoD scientists' and researchers' ability to investigate challenging projects involving increased fidelity by applying more computational cycles. The other two supercomputers are the Tow, which has 6,656 cores with 52.2 TB system memory and 400 TB of local storage capacity, and the TI-09 cluster, acquired in 2009, which is a test and development system with 96 cores that supports the other two larger systems.

Breaux said he was humbled that the system shares his name; to him, it is a permanent and public reminder of the "good ride" he has experienced in his career with the Army. One of his most significant contributions to supercomputing came through his lead role as an Army representative on a DoD working group in 1992, which founded the multi-billion dollar HPC Modernization Program.

Breaux entered federal service in 1962 first as a second lieutenant assigned to the Ballistic Research Laboratory, ARL's predecessor organization. He spent 33 years as a civil servant, which included 21 years as a research mathematician involved in mathematical analysis and computer modeling and simulation of ballistics, including helicopter fire control and phenomena such as laser propagation and effects associated with military systems.

During his last 12 years as a civil servant, he served as chief of the High Performance Computing Division, and as manager of ARL HPC Systems, which included computer operations, network development, applications research and outreach initiatives aimed to expand and modernize HPC capability throughout ARL, the Army and DoD.

Breaux is recognized for writing the proposal that resulted in ARL's designation as one of the first three DoD laboratories chosen as a Defense Supercomputer Resource Centers. In 2005 he was given a "HERO" award by the Defense Department for his long term contributions to the High Performance Computing Modernization Program.

Contract for the Heat Engine Systems Altitude Test Facility (HESATF) Symbolizes Progress

As Base Realignment and Closure (BRAC) progresses, ARL's ability to initiate and develop future scientific discoveries grows stronger. As part of the BRAC legislation, a new facility for the Vehicle Technology Directorate (VTD) is under construction at Aberdeen Proving Ground (APG). Recently, a design-build contract for the Heat Engine Systems Altitude Test Facility was awarded and will serve as one of six major components in the VTD facility upon completion.

The HESATF will have multi-component capability consisting of an altitude engine test chamber and equipment necessary to supply air to the chamber, create altitude conditions and remove exhaust. There will also be systems in place to simulate air craft power loads and rotor blades for helicopters.

According to Gary Klann, who works for VTD at NASA-Glenn, creating the necessary simulated flight conditions in this facility requires the use of specialized air-handling systems that provide exact dryness levels, pressures and temperatures.

The contract includes a computerized facility control and monitoring system where everything will be operated locally from an adjacent reinforced control room located within the facility, Klann noted. "The bottom line is that the engines and propulsion systems operated in this facility will 'think' they are operating under actual flight environments."

When the VTD construction is complete, the building will house five other major laboratories specializing in flow physics, integrity and durability, mechanical components, high temperature and universal drive. The new HESATF will be located within the Engine Components and Engine Systems laboratory.

The new VTD facility is located behind the Rodman Laboratory and is expected to be completed by May 2011.

The HESATF further enhances ARL's ability to continually research, develop, test and evaluate across multiple disciplines including propulsion, structure, aeroelasticity, and autonomous control of air and ground vehicle systems.

VTD Director Dr. Mark Nixon said the overall facility at APG will be a cost saving measure and greatly augment the mission of the directorate.

"The Propulsion Systems Lab at NASA-Glenn provides the Army's only access to ground-based test facility capable of true flight simulation for experimental research on air-breathing propulsion systems," he said. "The new facility at APG will have similar capabilities to that of the PSL, but will be tailored to smaller engines and will be more cost effective for both basic and applied research in this technical area."

Stakeholders Gather to Sign Final Steel Beam for New VTD Facility

A group of stakeholders in the construction of the new Vehicle Technology Directorate (VTD) facility met on April 15 at Aberdeen Proving Ground (APG) for an informal signing of the building's final steel beam.

The facility's purpose will be to research, develop, test, and evaluate across multiple disciplines including propulsion, structure, aeroelasticity and autonomous control of air and ground vehicle systems. It is located behind the Rodman Laboratory and is expected to be completed by May 2011.

Representatives from the Army Corps of Engineers and contractor Walbridge Aldinger attended the ceremony. ARL's Mark Nixon, director of VTD, and Gary Klann, Base Realignment and Closure facility lead, were also present to discuss the progress of the VTD facility.

Michael Cygan, project manager for Walbridge, the primary contractor, estimates that one-third of the project is already complete, and it is scheduled to be finished by the deadline. The steel portion of construction began in January, and the team will continue to work towards completion by adding unique concrete blast walls and other distinctive features.

"We had some challenges to overcome with the snow this past winter, but we are moving forward and have overcome any challenges from the bad weather," Cygan said. "We are working hard with the subcontractors to ensure that our work is nothing short of high quality."

When VTD employees relocate from NASA-Glenn and NASA-Langley, they will have new and improved opportunities with their new facility, said VTD Director Dr. Mark Nixon.

"The site at APG will have customized, unmanned systems," he said. "We will have a better utilization of space without having to worry about making use of other facilities. This allows scientists to leave long-term experiments in the lab and not have to worry about time constraints."

According to Nixon, the new building will greatly benefit the directorate's mission. New specialized equipment will be brought in and the overall way scientists are able to approach their projects will be improved.

"Overall, this new facility will enable us to form research that allows us to be more continuous in our efforts," said Nixon. "While we will still have some reach back capability, this is a cost-saving effort in both facility utilization and personnel time."

VTD employee Stephen Wilkerson participated in the ceremonial signing of the final beam.

The U.S. Army has evolved into a high-technology fighting force, relying on cutting-edge research and analysis to maintain its dominance. The research ARL performs to sustain such a force is inherently long-term in nature and may require 10-20 years of research and development before delivering innovative capabilities to our Warfighters. We have selected seven high-payoff Strategic Research Initiatives (SRIs) depicted below that can expand existing or establish new core competencies in support of our Technology Focus Areas.

The ARL Director's Strategic Initiatives (DSIs) are two-year funded efforts ($500,000/year) for emerging (revolutionary) research areas in support of SRIs to potentially expand or establish new Core Competencies. DSIs support higher risk research that is collaborative, multi-disciplinary multi-directorate. These initiatives present the opportunity to attract new researchers and develop new infrastructure and have long-term potential to deliver unprecedented capabilities for the Soldier.

MATERIALS IN EXTREME ENVIRONMENTS
- Multi-Scale Initiative
- Inverse Materials Design
- Nanoscience
- Disruptive Energetics
- Hierarchy: Translation Between Scales

BATTLEFIELD NEUROSCIENCE
- Neuro-Cognitive Measurement
- Cognitive/Information – Decision Making
- Neurally Inspired Systems
- Brain Structure-Function Coupling

NETWORK SCIENCE
- Cognitive/Information – Decision Making
- System of System Analysis

HIERARCHICAL COMPUTING
- Commodity Computing
- Non-linear HPC
- Multiscale Chemistry, Physics & Mechanics M&S

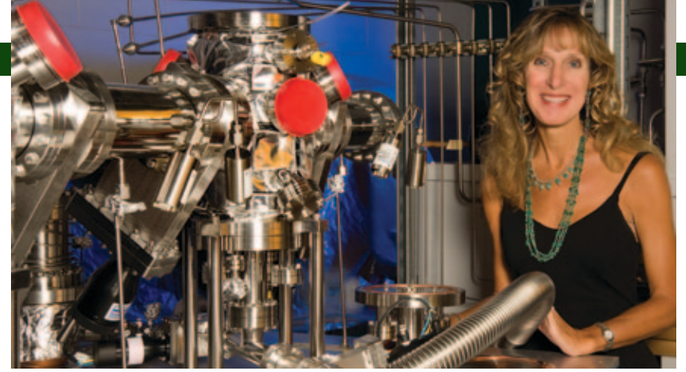
HETEROGENEOUS ELECTRONICS
- Heterogeneous Devices
- Graphene Nanoelectronics
- Biologically Enabled

EXTREME ENERGY SCIENCE
- Nano to Micro Generators & Convertors
- Energy Harvesting & Scavenging
- Novel Energy Storage
- Biologically Enabled

AUTONOMOUS SYSTEMS TECHNOLOGY
- Autonomous Tactical Navigation
- Cognitive Robotics
- Scalable Autonomy

In FY10, ARL funded nine DSIs in the areas of Bioscience, Neuroscience, Network Science of Decision Making, Nanoscience, GaN High Power Electronics, Power for Microsystems, Graphene Nanoelectronics, Multi-scale Modeling of Non-Crystalline Ceramics and Quantum Research. Success of the ARL DSIs will help ensure decisive warfighting superiority for our Soldier and enhance the foundation of our world-class laboratory.

The Director's Research Initiative (DRI) program, established in 1993, identifies funds, and implements innovative, original research outside of current mission funded work (of sufficient novelty that is not a simple continuation or enhancement of an existing program or graduate work). The DRI process provides an opportunity for the ARL Director to encourage high-risk research in certain areas that offer outstanding potential to the ARL mission.



Dr. Melanie Cole, an ARL Fellow, led a team of scientists that received award recognition for work done under their Director's Research Initiative.

Groundbreaking Army Research Helps Soldiers Send, Receive Information on Battlefield

Research being done at the U.S. Army Research Laboratory is leading to significant improvements in how Soldiers send and receive data – including videos, voice transmissions, and other communications – on the battlefield.

Dr. Melanie Cole, an ARL Fellow, led a team of scientists that received award recognition for work done under their Director's Research Initiative in UV-photon irradiation. Their work has enabled technology essential to the Army's communications-on-the-move (OTM) initiative, which focuses on mobile communications platforms that connect Soldiers, sensors and weapons systems to a global grid.

The DRI research concentrated on the development of a novel materials technology solution to achieve high-Q tunable complex oxide thin-film materials to enable enhanced performance, low cost, tunable Ka-band filters for the next generation communications platforms. The team's work has since resulted in a funded research initiative for the U.S. Army Special Operations Command. This DRI technology development has enabled ARL, in collaboration with Robert Romanofsky, a senior scientist in the Antenna and Optical Systems Branch at NASA, to design and develop a novel tunable, high efficiency miniaturized antenna system containing an impedance matched balun/antenna feed on a single affordable, semiconductor-industry standard wafer substrate.

Army Investment in Sensors Research Leads to Advances in Soldier Protection

Just months after the tragic attacks of September 11, 2001, the U.S. Army Research Laboratory launched an aggressive, innovative research project that has been instrumental to the development of low-cost, lightweight sensors capable of providing novel approaches to the detection of manmade threats to Soldiers, including biological agents, small arms fire, and missile plumes.

The Edgewood Chemical and Biological Center's Tactical Biological Detector, an ultraviolet, light-emission diode (LED)-based bioaerosol detection device, can trace its heritage to the intellectual capital in wide bandgap semiconductors built from ARL's nearly decade-old research initiative. This device emerged after combined efforts with the Defense Advanced Research Projects Agency and ARL under the Semiconductor Ultraviolet Optical Sources (SUVOS) program.

In 2002, Chief researcher Dr. Michael Wraback, ARL Fellow, along with a team of researchers was awarded a small seed investment. Today, it has resulted in several million dollars of DARPA, Homeland Security Advanced Research Projects Agency, and Defense Threat Reduction Agency funding over the past decade, as well as the initiation of an ARL mission program with current assets of $1 million per year. In addition, ARL has helped initiate a new DARPA-funded project for fiscal year 2010 that will look even deeper into the ultraviolet range, with the goal of not only detecting the presence of chemical and biological agents but also identifying them.

Dr. Michael Wraback, ARL Fellow, launched radical research in ultraviolet LEDs, laser diodes and detectors that have enabled revolutionary technology developments.

Soldiers assigned to the Army Research Laboratory fill a unique niche not only in the organization but also in the Department of Defense. When they're not helping out in the operation center, working in the labs or training, they may deploy to Afghanistan as part of a Science and Technology Acquisition Corps Advisor (STACA) team or Iraq as a member of the Science and Technology Assistance Team (STAT) / Field Assistance in Science and Technology (FAST) team. In these positions they work as a link between Soldiers in the field and with the military scientists giving them the tools that keep them alive and make them effective fighters. By getting face-to-face feedback from Warfighters about new and existing equipment, ARL Soldiers helped scientists improve the comfort, safety and lethality of the nation's fighting force.

ARL Soldiers Deployed as Part of FAST Teams or STACAs

SSG Dashawna Wingate, Multi-national Corps – Iraq (MNC – I) STACA (OIF) (June 13, 2009/March 9, 2010)

LTC Keith Harvey, CJTF Paladin J9/RDECOM Science & Technology Advisor Team 8 (OEF) (September 26, 2009/March 24, 2010)

SFC Brian Verderber, CJTF Paladin J9/RDECOM Science & Technology NCOIC CJTF Paladin Team 10 (OEF) (August 14, 2010/February 9, 2011)

LTC Blake Stringer, RDECOM FAST 23 (April 17, 2010/October 13, 2010)

SFC Rodney Pittman, RDECOM FAST 24 (September 17, 2010/March 15, 2011)

SFC Garry Reese, CJTF 82/101 S&T Team 2 (OEF) (August 29, 2009/February 24, 2010)

MAJ Ryan Howell, S&T Team 3, RC SOUTH (OEF) (July 17, 2010/January 12, 2011)

SFC (P) Jemall Pittman, S&T TEAM 3, RC SOUTH (OEF) (July 17, 2010/January 12, 2011)

SFC Jimmie Smith, S&T Team 1, RC South (OEF) (August 29, 2009/February 24, 2010)

LTC Clark Frederick, Fielding OIC, Radiant Falcon (Iraq and Kuwait) (July 13, 2010/TBD)

SFC Robert Hopkins, NCOIC, Radiant Falcon (Iraq and Kuwait) (September 10, 2010/TBD)

No longer with ARL: MAJ Anthony Douglas CJTF 82/101 S&T Team 2 (OEF) (August 29, 2009/February 24, 2010)

ARL Soldiers Bridging Technology Gaps on the Battlefield

ARL Soldiers are on the front lines of conflict bridging the gap between Warfighters and the scientists who support them.

As part of a science and technology team, SLAD's Sgt. 1st Class Jemall Pittman and WMRD's Maj. Ryan Howell joined up with a medical researcher to find capability gaps and relay information from troops in Afghanistan.

They are investigating ground maneuver, support, air and medical units' technology capabilities and enabling RDECOM and medical scientists and engineers understand what's needed on the battlefield.

"Our greatest asset (for troops) is our ability to reach back into the research, development and engineering world to help solve some of the most robust problems here in Afghanistan," said Pittman.

Along with their primary mission of communicating the needs of the Soldiers, they also find themselves educating the units on what the R&D community is and how it helps.

"(The team) gives units and their Warfighters another weapon in their arsenal that, unfortunately most units don't know exists," said Pittman. "In addition to getting capabilities to the Warfighter, we fight to ensure commanders know we're here and what we provide them."

The team arrived in theater in late July and is expected to return in January. Pittman said as a Soldier, the best part of the six-month deployment so far is "being in the fight - bringing the right technology to the right Soldiers at the right time on the battlefield."

"If we are able to put any technology in a Soldier's hand that saves his or her life, it would be a great accomplishment," he added.

Civilian Scientists and Engineers Deploy to Iraq to Support Soldiers

As part of a the Field Assistance in Science and Technology (FAST) Program, three ARL scientists and engineers (S&Es) volunteered to deploy to Iraq for 179-day tours. Their mission was to provide operational commanders with immediate access to RDECOM laboratory and engineering capability, expedite the delivery of critical technology solutions to Soldiers, and, on a more personal note, directly support the Soldier.

One S&E served a tour as the III Corps Science and Technology Acquisition Corps Advisor (STACA) assigned to the Multi-National Corps-Iraq, and the other two S&Es served separate tours as Science Advisors on Science and Technology Assistance Teams (STAT) assigned to the 402nd Army Field Support Brigade.

The STACA and STAT S&Es gathered feedback directly from Soldiers to learn how well fielded equipment is meeting mission needs and to identify capability and technology gaps that remain unmet. As a result, they identified, documented, and funneled over 75 Soldier issues to the FAST headquarters, which were the forwarded to ARL or to one of the Research, Development and Engineering Centers (RDECs) and to Program Managers (PMs) for resolution and/or information. Issues covered a broad range of topics from the clothing and gear worn by Soldiers to the vehicles and equipment used by them.

MRAP towbar storage was one of over 75 Soldier issues.

STAT members used a range of techniques to uncover issues and capability gaps. They traveled to Soldier locations to talk with them one-on-one or in small groups, and in some cases directly observed modifications that Soldiers had made to their equipment. These observations then prompted the S&Es to conduct contextual interviews to identify the requirements driving the need for the modification.

Contextual interviews are a type of ethnographic research and are conducted in a Soldier's work environment with the actual equipment they use. This technique was effective for identifying system requirements as well as the root cause of system design issues. During interviews, Soldiers were also asked to assess how well field modifications were meeting their needs and to identify design changes that they believed would prevent issues from reappearing in future systems.

Mine Resistant Ambush Protected (MRAP) vehicle tow-bar stowage is one example of a fix in the field that was sent back to RDECOM for a permanent solution. Upon noticing that Soldiers were using a variety of methods to secure towbars to the outside of their MRAPs, one team learned that these vehicles have no external mounting brackets for securely stowing a towbar.

Stowing tow bars inside MRAPs is not recommended because if they came loose during a rollover or attack, they would pose secondary missile threats potentially trapping individuals inside the vehicle. To overcome this design limitation, Soldiers fabricated brackets and installed them on their MRAPs only to learn that mounting them below the front grill reduced the angle of the grade that the vehicle could traverse. They looked to RDECOM to design and fabricate a better bracket that would meet their needs and overcome the limitations inherent in their field-expedient solution. Furthermore, they recommended that future vehicles be equipped with built-in towbars that operate like the Janney coupler that automatically interlocks with its mate on contact when connecting railroad freight cars.

Once an RDECOM or PM solution is fielded, however, the STACA and STAT S&Es continue their support. After receiving several weapon-mounted light kits in response to an earlier STAT team's request, one unit of combat engineers who were conducting route clearance operations were asked if they would like to use the kits and assess their combat effectiveness. The STAT assisted Soldiers with installation, setup, and initial operational issues. After one month of use, the STAT returned to obtain Soldier feedback and to ensure that the kits were fully operational.

ARL researcher Dr. Pamela Savage-Knepshield traveled to Soldier locations for discussions.

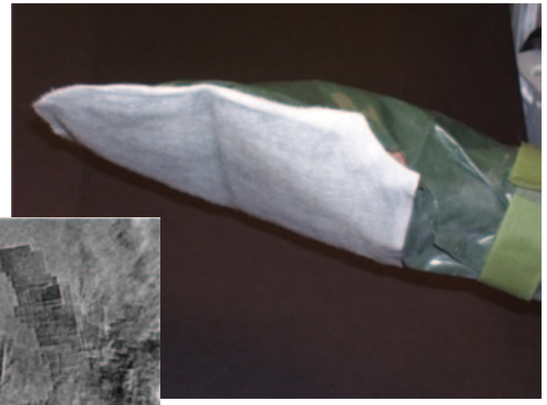
Soldier feedback is critical. Questionnaires and interviews are the primary methods.

Combat engineers completed questionnaires designed by the team to capture feedback on critical system attributes and were interviewed to gather critical qualitative data that would enable the team to understand which attributes were most important and why as well as what was working well and what was not. They analyzed the data collected and prepared a report which was shared with each kit's manufacturer so they could understand how best to modify their designs to better meet our Soldiers' mission needs.

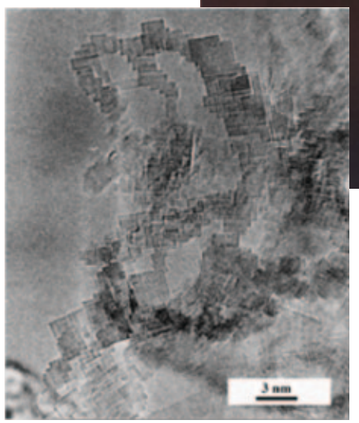
When asked if they would volunteer again for this assignment, one ARL employee replied, "This was the most rewarding assignment in my civilian career, and the most humbling. The ability to serve and support our Soldiers in the combat zone and genuinely serve our country is something that I will never regret and would do again in a heartbeat." As ARL S&Es, they provided a critical link from the Soldier to the lab and back again.

Nanostructured Materials Basic Research Leads to ARL Supported Program to Supply M295 Individual Equipment Decontamination Kits Through 2014

ARL sponsored basic research discoveries in catalysis and nanomaterials at Kansas State University led to the creation of NanoScale Corporation and their development of state-of-the-art decontamination technologies. The basic research breakthroughs led to a successful new decontaminant program, and eventually to the ability to manufacture the M295 Individual Equipment Decontamination Kit. The M295 Kit enables Soldiers to rapidly and effectively decontaminate their individual equipment through physical removal and absorption of chemical agents. NanoScale Corporation was recently awarded an Army contract to supply the M295 individual equipment decontamination kit through 2014.



M295 wipe-down mitt.



TEM image of nanomaterial.

ARL Crosswalk Analyses Validate Lessons from Live-Fire Tests

In 2010, ARL was able to apply our decades of test and evaluation experience to improve the designs of vehicles being used in Iraq and Afghanistan, help operational and intelligence units in theater assess more accurately the threat and combat damage, as well as improve and validate Army practices in live-fire test and evaluation (LFT&E).

ARL performed the first-ever analysis comparing LFT&E results with assessments of combat damage from incidents in Iraq and Afghanistan. This analysis, known as a crosswalk, provided insights into the critical injuries produced during combat incidents, resulting in new instrumentation and criteria for capturing data and assessing similar injuries during live fire testing. This analysis also resulted in vehicle design changes to the underbody, a redesigned crew floor and new crew seats in existing fielded Mine Resistant Ambush Protected (MRAP) platforms. These design changes were later tested and proven to reduce the potential for crew injury. This crosswalk also showed that LFT&E results (for both crew incapacitation and vehicle damage) were very similar to those observed in corresponding operational incidents.

ARL has been able to improve on live-fire test procedures through its crosswalk analyses.

ARL performed additional crosswalks, including events involving several variants of MRAP. For these crosswalks, ARL used operational, intelligence, and medical data from the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) program. The comparisons, which addressed both vehicle damage and occupant incapacitation, illustrated the efficacy of a number of design improvements that ARL had recommended based on live-fire testing (and which the MRAP program is in the process of incorporating), specifically, re-design of the seats, Remote Weapon Station (RWS) integration, and vehicle floor and hull design changes.

These crosswalk results have been briefed to representatives of the user, test and evaluation, and acquisition communities, including the Director of Operational Test and Evaluation and the Secretary of Defense.

ARL has been able to increase Soldier survivability in the theater through its crosswalk analyses.

ARL analyses have helped the Army assess modifications to current and future vehicle systems to increase crew survivability.

Mission Specific Armor Packages

Department of Defense vehicles face a myriad of ballistic threats. A reactive approach of continuing to layer armor adds considerable weight and thickness to vehicles, impacts mission loads, hinders mobility and reduces overall systems durability.

To reduce these impacts, the Army Research Laboratory continues to research and develop new armors that are more weight and space efficient.

ARL's research and development of new armors is providing increased protection for the family of Mine Resistant Ambush Protected (MRAP) vehicles.

Integrated armor protection package for current operations support.

New modular armors matured in 2010 use cutting-edge ballistic protection mechanisms to deliver the same protection at a fraction of the weight and thickness of fielded armors.

Armor designs were transitioned to the Tank Automotive Research, Development and Engineering Center for packaging design, system integration and prototype fabrication. Integrated products are now undergoing end use trials.

Statistical Machine Translation for Security Assistance to CENTCOM

Work on ARL's Statistical Translation Engine for English-to-Dari (STEED) was strongly endorsed by U.S. Navy doctors serving in Afghanistan as embedded training teams (ETT) with the medical corps of the Afghan National Army. During a visit by the ARL project lead, team leaders discussed the need for follow-on projects as well as the challenges in providing Afghan doctors with sufficient training and reference materials. Communications between ARL and the ETT leadership slowed progress on the target translation but there was time for improvements to methods and analysis of research results.

The project programming lead compiled experimental data and methodology into a useful interim report, which has attracted interest beyond ARL in the deliberate pursuit of aligned, parallel data in tandem with the accomplishment of translation tasks. Similarly, the compilation of a technical term base, which started with the team's resident language expert manually selecting technical terms with their translations and copying them into a spreadsheet, was re-examined in the light of automated term management techniques as practiced by the National Library of Medicine. Semi-automatic extraction of technical terms, combined with extraction of candidate translations contextualized using concordance techniques, is being researched by the ARL project team. STEED and the original translation task both received a boost via the recruitment of an Afghan medical doctor and former translator in the service of the ETT who was granted a special visa and who now resides in the U.S. STEED updates are back on track and a full translation of the Critical Care Support manual is expected by the end of FY11.

First product of new ARL method of human-in-the-loop machine translation.

Mission Accomplishments

The remainder of this review is structured around our nine major laboratory program areas of Extramural Basic Research, Networks, Human Dimension, Lethality, Mobility, Power and Energy, Sensors, Protection, and Survivability/Lethality Analysis.

The accomplishments presented here, while only a small sample of our efforts over the past year, are representative of the skill, dedication, and teamwork of our in-house staff and our partners in academia and industry.

Extramural Basic Research

- Video Microscopy of Living Cells to Drive Development of New Therapeutics
- Laser Cooling of Molecules to Drive Revolutionary New Research Areas and Sensor Applications
- 1000X Reduction in Required Number of Grid Points for Droplet Interaction Model
- Harnessing Bacteria for Micro-Scale Transport and Manipulation

Networks

- Trust in Networks
- Discovering Network Behaviors
- Quantum Imaging Information Science and Technology

Human Dimension

- Revealing Variation in Brain Structure Using Diffusion Weighted Imaging
- Army's World Class EAR Facility Raises the Bar in Auditory Research
- Development of an Auditory Localization Model: The Effects of a Second Sound
- Stereoscopic Camera Integration with Small Robotic Vehicles

Lethality

- Materials and Processes for Improved Gun Barrel Wear Resistance
- Green Ammunition
- Disruptive Energetics

Mobility

- Multi-Functional Flapping Wing Technology for Micro Air Vehicles
- Autonomous Unmanned Systems
- Variable Speed Power Turbines for Improved Fuel Efficiency

Power and Energy

- Batteries and Battery Development
- Fault Protection in Electronic Systems
- Wide Bandgap Power Devices

Sensors

- UV Sources and Detectors
- Microautonomous Systems
- Flexible Displays and Electronics

Protection

- Modeling and Simulation of 3-D Textile Fabrication Process for Protective Applications
- Transparent Spinel Armor Manufacturing Scale-Up
- Base Armor Alternatives
- A Simplified Model for Blast/Impulse of Buried Explosives

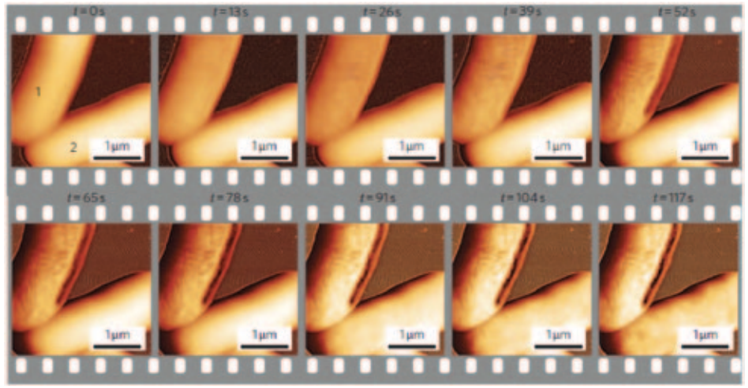
Survivability/Lethality Analysis

- Intelligent Munitions System Scorpion
- High Fidelity Threat Effects Integration
- Ground Combat Vehicle (GCV) Analyses of Alternatives (AoA)

Video Microscopy of Living Cells to Drive Development of New Therapeutics

ARL-funded researchers study bacteria using high-resolution video.

ARL-funded researchers at the Massachusetts Institute for Technology have developed an innovative, real-time microscopy method that provides a unique way to investigate the mechanisms of action of various antibacterial compounds. Under the direction of Dr. Angela Belcher, also of the Institute of Soldier Nanotechnologies (ISN), these researchers successfully adapted atomic force microscopy to produce real-time, high-resolution videos of bacteria under attack by small proteins called antimicrobial peptides (AmPs). Previous attempts to image the live, dynamic cellular processes of cells at a nanometer resolution have been unsuccessful, but this new method revealed that the AmPs kill bacteria through a disruption of the cell membrane in a series of phases. The investigators can use this new real-time imaging approach to better understand the mechanisms by which bacteria gain resistance to certain compounds, and then to test compounds that may have improved antibacterial efficiency and a low-propensity for bacterial resistance, relative to existing therapeutics. The long-term applications of this research for the Warfighter could include the development of a new class of highly-potent antibiotics, improved dressings for wound healing, bacterial-resistant clothing, and improved packaging for food preservation.



Time series of AmP antimicrobial action on E. coli (bacteria): *as shown in these selected frames from the video microscopy analysis, the normally smooth membrane surfaces of the bacteria (t=0s) begin changing to a rough, corrugated texture (t=26s for bacterium 1), with both bacteria in the image displaying significantly damaged membranes after nearly two minutes of exposure to an AmP (t=117s). A corrugated texture indicates that the cell membrane is damaged and the cell has died, as was confirmed by other analysis methods. It is noteworthy that a similar analysis using cells treated with a traditional antibiotic (ampicillin) revealed that only minor changes to the cell membranes were visible after a tiring 112 minutes (6,720s) of exposure.*

Laser Cooling of Molecules to Drive Revolutionary New Research Areas and Sensor Applications

Researchers sponsored through an U.S. Army Research Laboratory (ARL) single-investigator award have made a considerable breakthrough in the ability to cool and trap molecules that could enable revolutionary new capabilities in sensors and computers. This important achievement follows two decades of work in making and exploiting ultra-cold atoms.

Schematic of the ultra-high vacuum magneto-optical trap (MOT) chamber used for the successful laser-cooling of molecules: *the schematic illustrates (a) the full chamber geometry, including MOT coils and laser beams, as well as feeds for inserting and detecting microwave power in the cavity, and (b) a view of the interior of the chamber, showing the cavity geometry and various mounting fixtures. The potential trap volume is illustrated by the purple ellipsoid at the center of the panel. [Image credit: David DeMille]*

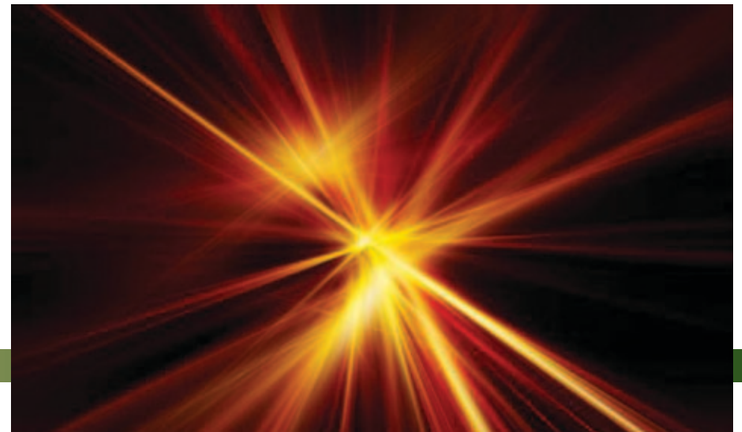
The creation of ultra-cold atoms (of a single element) in the 1980s demonstrated that when a gas of atoms becomes cold enough, they lose their identity and behave like a wave rather than a cloud of distinct particles. This discovery opened the door to powerful new areas in basic science research and many Department of Defense applications, as experiments and applications that were once only possible with light (i.e., optics) became possible with matter. Given the enormous civilian and military contributions made possible by the laser cooling of atoms, extending this work to the realm of molecules has become a holy grail of sorts in the physics community.

In contrast to atoms, molecules exist in specific rotational and vibrational states. This complex internal structure prevents a simple extension of atomic laser-cooling to the molecular realm; however, this increased complexity can also provide scientific opportunities not possible with atoms. For example, molecules cooled near absolute zero can enable phenomenally exquisite control over chemical reactions, opening the door to the future development of new functional materials with uses ranging from power generation to armor.

Led by Dr. David DeMille at Yale University, a team of physicists has discovered a method for laser cooling strontium monofluoride—the first ever demonstration of the laser cooling and trapping of molecules. The result indicates a clear path to further cooling and trapping improvements sufficient to access new realms of physics and enable unique capabilities.

In addition to the potential materials-development applications described above, the long-term applications of these fundamental physics advances will extend beyond the opportunities made possible with ultra-cold atoms. For example, ultra-cold dipolar molecules are an ideal system for developing quantum computing qubits. Even in the areas that are already enabled by ultra-cold atoms, molecules should do even better.

For example, interferometry with ultra-cold molecules can exceed the precision of atom interferometry, thereby further extending the capabilities of promising applications such as highly accurate and jam-proof gyros (for navigation), accelerometers (for inertial guidance), and sensors such as magnetometers (mine detection) and gravity gradiometers (remote tunnel/bunker detection) for use by the Soldier.



A new method for laser cooling could help pave the way for using individual molecules as information bits in quantum computing.

1000X Reduction in Required Number of Grid Points for Droplet Interaction Model

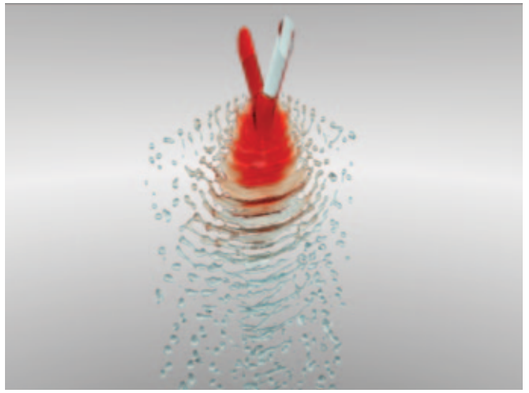
ARL-supported researchers at Georgia Tech have developed a new numerical technique that will allow, for the first time, chemical kinetics to be introduced in detailed reacting spray/droplet models for future rocket motor design.

Interacting droplet models are needed for future design of hypergolic fueled rocket motors.

The new numerical technique allows a three order of magnitude reduction in the required number of grid points to model interacting droplets and makes possible the tracking of the fluid interfaces through the interior as the two droplets mix.

Coupled with the reduction in grid points and its associated computational time, this will allow use of chemical kinetics in reacting spray models for motor design.

It is anticipated that global reaction kinetics will be introduced into the model late in 2010. The researchers at Georgia Tech are part of a Multidisciplinary University Research Initiative (MURI) team led by Penn State.



Visualization of mixing resulting from two impinging jets of different fluids.

The team is one of two investigating the physics of hypergolic gelled propellants and is working closely with ARL researchers and the Air Force Research Laboratory Propulsion Directorate.

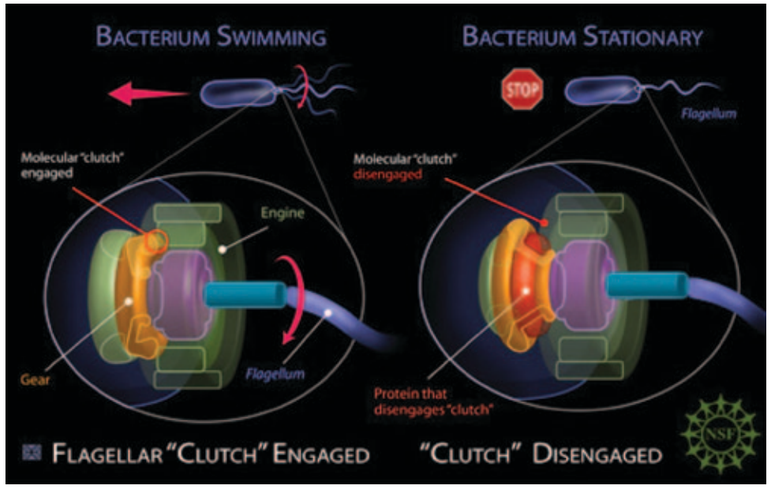
Partnerships with academic institutions such as Georgia Tech maximize ARL's investments for the benefit of Soldiers.

Partnerships with Academic Institutions Produce Breakthroughs.

Harnessing Bacteria for Micro-Scale Transport and Manipulation

ARL sponsored researchers at the University of Pennsylvania, led by Professor Vijay Kumar, have, for the first time, constructed a stochastic model for micro-scale locomotion and manipulation using flagellated bacteria for actuation, which lends itself to controlling the trajectory of bacteria propelled micro-structures for engineering of micro-manipulators and micro-robotics in the next five years.

Instead of using manmade structures that are modeled after biological systems, this research uses the actual micro-organisms as micro-actuators.

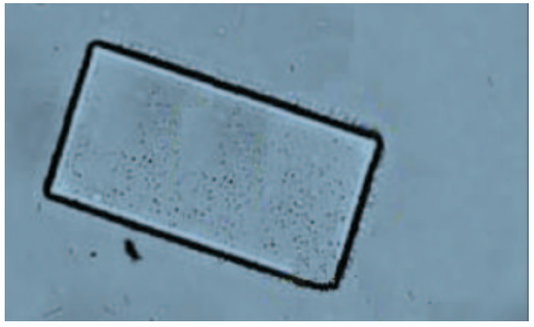


Model showing two propulsion modes and flagellated bacteria.

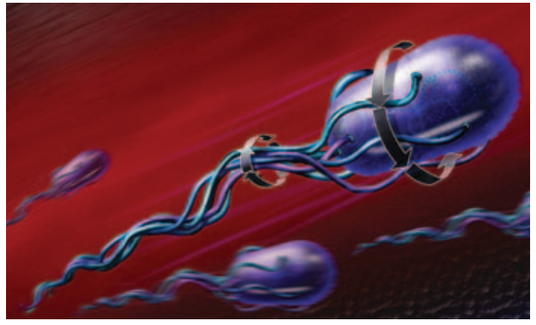
The micro-organisms offer several advantages over alternative means of locomotion using manmade micro-motors; they are inexpensive and easily produced, and do not require a separate energy source to power their locomotion.

Like other biological based organisms, the bacteria harness energy from the nutrient-rich environment in which they reside. A blotting procedure is used to attach flagellated bacteria to a neutrally buoyant plate called a micro-barge that is used for deployment of micro-structures, like robotic drug delivery.

Researchers have constructed a micro-barge powered by a swarm of bacteria and they have shown that their theoretical model accurately predicts the behavior of the micro-barge's motion and further can provide the means for controlling the swarm.



Blotting procedure used to attach flagellated bacteria to buoyant plate — called a micro-barge.

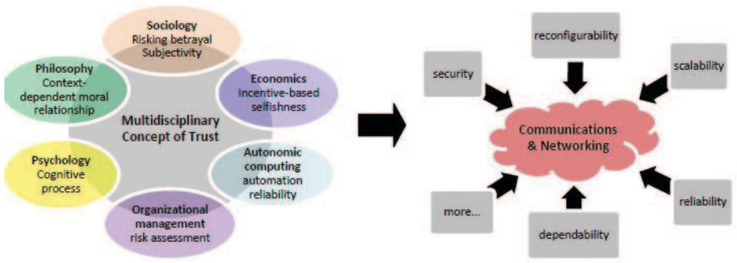


Bacteria depiction — four flagellae.

Trust in Networks

Our trust in our own network is a lucrative target for the enemy. In an operation, as networks adapt and enemies attack, the Warfighter needs to know the extent of trust he can place in all network elements including nodes, links, people, and information.

Trust Management Systems (TMS) for Mobile Ad Hoc Networks (MANET) must consider the interactions between the composite cognitive, social, information and communication (CIS) networks, and take into account the severe resource constraints, dynamics, and inaccuracy and incompleteness of network state information. ARL has developed a composite trust metric taking into account the multi-dimensional attributes of the composite networks, developed a trust management protocol, and investigated trade-offs in the proposed protocols. A TMS is critical for bootstrapping trust, for example, with dynamically forming communities of interest, particularly in cases involving coalition forces and non-government organizations. Timely distribution of trust and maintenance of trust can ensure information flow, enabling timely and accurate decision making and thus mission success.



Summary how trust is defined in various disciplines and how they translate into various aspects of a composite trust metric for a group communication system for a MANET.

The broad questions underlying this study are how are trust relationships between social/cognitive entities (humans or agents) affected by the characteristics of underlying CIS networks? What is the impact of information flow and network structure upon trust? What are effective definitions of a trust metric that capture the interactions among the component CIS networks and enable effective decision making?

The relationship between communication and social networks was investigated through a command and control experimental platform called ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust). This platform was modified to represent a distributed information-sharing and distributed server scenario; and the effects of communication loss and delays on the completion of an information-sharing task were investigated. ARL researchers also studied the impact of network size and connectivity of the communications network on the performance of the social network. These experiments were conducted using human-agent models and provide insight into prediction and modeling of Soldier performance, which can be applied towards the design of future tactical networks.

ARL researchers devised a composite trust metric that takes into account attributes such as node capability, selfishness, proximity and node degree. The trust metric reflects unique characteristics of trust such as subjectivity, incomplete transitivity, asymmetry, dynamicity, and context-dependency. Using the proposed composite trust metric, we develop and analyze a trust management protocol for mission-driven group communication systems in MANETs. Since the underlying model is Markov, we used stochastic Petri nets techniques for analytical evaluations.

Central to our work is the concept of a trust web among peers. A larger web enables collection of trust information from and about more entities, but also suffers from increased delay and uncertainty. Researchers investigated the trade-offs between trust availability and path reliability as a function of the size of the web.

In continuing work, researchers will use ELICIT and other experimental platforms to validate and refine the composite trust metrics. We will identify critical trade-offs so that fine-tuning of critical design parameters and strategies can be automated. This will enable Warfighters or their "agents" to make effective tactical decisions in a distributed manner where resources are limited, information is incomplete or uncertain.

Discovering Network Behaviors

ARL researchers studying cyber threats and network intrusions for more than a decade have emerged with a new perspective in observing network activity. U.S. Army networks are targeted by focused adversaries determined to extract information to diminish the Army tactical and technological advantages. Army computer assets are protected by designated personnel who use very expensive and complex tools to battle this amorphous and nimble foe. By studying the methodology and techniques used by the adversary in successful breaches, Army defenders aim to modify their future defenses but by focusing on very specific aspects of successful attack methodologies, the resulting adjustments are very specific and short-lived.

Developers of 2I's network understanding capability, ARL Computer Scientists Peter Guarino and Kerry Long, stand next to the computer cluster that performs the network mapping functions.

Taking a broader perspective on successful adversary behavior, researchers realized that adversaries devote significant time and resources to mapping and understanding the behavior and structure of Army computer networks. Laboratory experts already knew that computer defenders often have little usable knowledge of the makeup and function of protected networks. In previous projects that attempted to scan networks and produce their diagrams, the results often proved unreliable. Was it possible that the adversary had a better way of gaining knowledge of Army networks?

The Sourcefire RNA product, the open source project POF, and NSA Trickler have also demonstrated that networks can be understood through passive observation of traffic as it exits a boundary. The passive listening processes in these products identify network host operating systems, currently running network services, and when coupled with an open source vulnerability database like the MITRE CVE, sometimes even predict successful attack avenues. Hypothetically, an adversary could use one or all of these tools to build network understanding just by monitoring traffic leaving a protected enclave.

The researchers assumed the role of a hypothetical adversary determined to build a useful understanding of Army networks by passively monitoring network traffic leaving the protected confines. They leveraged its existing intrusion detection architecture, Interrogator, and 30 monitored network enclaves to profile network behaviors. Just as previous researchers and adversaries, ARL found that by carefully observing the characteristic network traffic performing common services, it was possible to derive signatures that could automatically classify network assets. Scientists are taking this concept much further by coupling these basic network profiling techniques with the extensive Interrogator network traffic database which is mined to enrich the characterization of monitored enclaves. Rather than just identifying network assets based on traffic that passes onto the Internet from Army networks, ARL designed a profiling technology that analyzes not just what is being communicated, but also to whom, for how long, and how often. More importantly, they discovered that over time it is possible to infer more subtle and more accurate network details based upon fusing multiple independent session observations. Because of the laboratory's efforts, the Interrogator user interface has evolved to allow the most sophisticated asset, the ARL network analyst, to interact with the profiling observations to supplement findings, creating even more reliable network behavior maps. By using this network understanding, ARL is drastically revising both its existing intrusion detection tool suite and its analytical methodology, in a new project called Interrogator 2I.

This intrusion detection architecture seeks to stay ahead of the ever changing cyber threat through a concerted collaboration of operational analysis and research applications that will provide protection and ensure fidelity of military communication assets.

Quantum Imaging Information Science and Technology

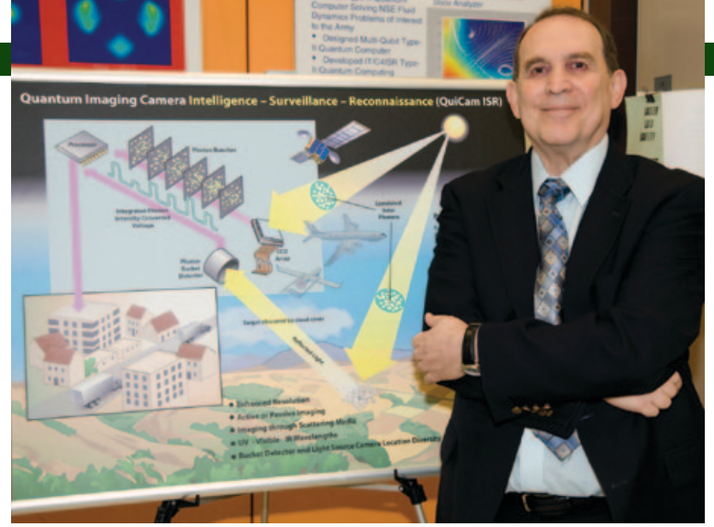
The ARL Quantum Imaging Information Science and Technology (QUIIST) program has made impressive strides exploiting the quantum ghost imaging (QGI) phenomena for development of a new generation of novel high-resolution battlefield imaging devices capable of imaging through atmospheric obscurants and turbulence.

In FY10 ARL's QUIIST team developed novel QGI techniques with potential for improved imaging in normally adverse imaging conditions. The Turbulence-Free Ghost Imaging (TFGI) and the Quantum-Inspired Ghost Imaging (QIGI) capabilities were developed at ARL from laboratory experiments and quantum theory. The ARL researchers also extended QGI to the infrared and began performing nonlocal entangled photon QGI experiments. Entangled photons have the nonlocal quantum property that Einstein called "Spooky action at distance."

The FY10 basic research extends the ARL QUIIST invention of remote QGI (Meyers, et al., Ghost imaging experiment by measuring reflected photons, Physical Review A, 2008), which has the potential to produce increased resolution images with enhanced signal to noise ratios beyond the capability of conventional military optics.

Unlike single sensor conventional imaging, QGI usually takes advantage of two advanced sensors. In QGI, when a natural or manmade light source illuminates the target, a single-pixel photon bucket detector counts the photons reflected by the target object and an array sensor measures the spatial distribution of the light source photons. A computer recovers the image of the object from quantum relations between the two sensed photon beams.

The QUIIST research has shown that the quantum properties are important for military applications and result from a non-factorable symmetric quantum wave function that characterizes the quantum joint probabilities of two distant photons The two-photon QGI imaging, using near field quantum properties, not only has the potential to hunt IEDs in adverse imaging scenarios, but can also be exploited for enhanced spacecraft and astronomical imaging.



QUIIST PI Ron Meyers with ARL aerial Quantum Imaging Camera (QuiCam) design.

A Turbulence-Free Ghost Imaging (TFGI) capability developed by the ARL QUIIST team is virtually free from the adverse impact of index of refraction fluctuations of the media. TFGI was demonstrated in laboratory experiments at ARL and showed images without distortion as viewed through strong turbulence. In comparison, classical images measured through the same turbulence exhibited pronounced distortion and smearing.

Quantum-Inspired Ghost Imaging (QIGI) is being developed by QUIIST as a low weight and bandwidth active imaging solution for a Soldier or robot in adverse imaging conditions. The QIGI method uses only a remote single-pixel photon detector and a diffraction-free structured light source to image target objects. QIGI experiments at ARL showed high resolution and high contrast images as viewed through obscured and turbulent media. A related DRI won Top Honors (Meyers; Diffraction Free Ghost Imaging Light Source for Ghost Imaging Viewed through Obscuring Media, ARL-TR-5095 (2010)).

The ARL QUIIST program leverages extensive collaborative interactions with ARO, the ARO Quantum Imaging MURI, DoD agencies, and the scientific community. QUIIST research has resulted in key ARL quantum imaging, quantum communication and quantum computing patents and publications. The transformative QGI basic research resulted in a Department of the Army R&D Award for Technical Excellence in November 2009.

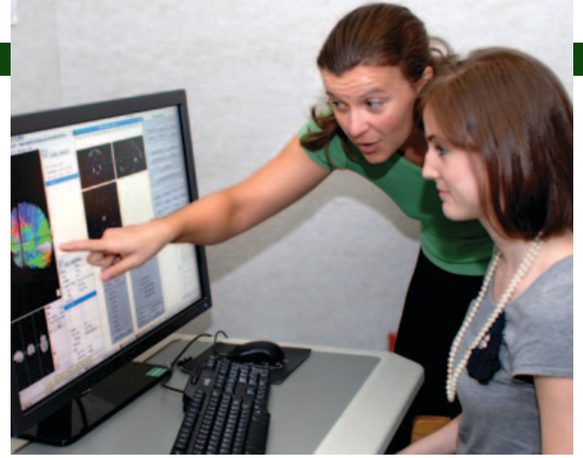
Revealing Variation in Brain Structure Using Diffusion Weighted Imaging

Every Soldier has a unique set of talents and skills, and many of these individual differences are likely related to the structure of their brains. The brain consists of an estimated 10^{15} fiber tract pathways, where each tract contains bundles of neurons.

Images of a person's fiber tracts can be obtained using a Magnetic Resonance Imaging (MRI) scanner with a technique known as diffusion-weighted imaging. This imaging technique reveals the direction that water is moving in different regions of the brain, and this directional movement reveals the local brain structure since water moves, or diffuses, in the same direction as the local fiber tract. To estimate the direction of water movement, this technique divides the entire brain into smaller cubes, similar to the pixels of a picture image, and records whether any water is moving within that small cube. From the water movement estimates for each cube, a complete image can be reconstructed by integrating data from nearby cubes to identify the direction of each fiber tract. Consequently, the output of this reconstruction procedure produces a whole brain image of a person's fiber tract structure.

One of the critical parameters for a diffusion-weighted MRI scan is the number of diffusion directions that can be measured in the brain. Classically, an MRI scan images a few millimeters at a time from bottom to top, left to right, or front to back. In a diffusion-weighted MRI scan, however, the brain images are taken at many different angles in order to better obtain an estimate of water diffusion since the fiber tracts can cause the water to flow at any angle. Currently, there are two techniques for diffusion-weighted imaging, and they differ based on the number of orientations they image of the brain. The traditional method, Diffusion Tensor Imaging (DTI), typically images 30-60 orientations, while a newer, more recently proposed method, Diffusion Spectrum Imaging (DSI), typically images 180-275 orientations.

ARL researchers study the human mind to optimize Soldier performance.



Dr. Jean Vettel discusses the pattern of neural tracts for one of the study participants with Michaela McBride, pointing out the density of tracts in the region of the brain involved with motor movements.

A collaborative project between ARL and the Cognitive Neuroscience Team at the Institute for Collaborative Biotechnologies investigated whether the most recent advance in structural brain imaging, DSI, provides more reliable estimates of brain fiber tracts. The design facilitated the investigation of two important questions. First, can a given technique produce a comprehensive structural mapping of a single individual's brain? Second, can a given technique estimate the same brain structure across different imaging sessions?

Results demonstrated that these two questions were best addressed by different imaging techniques. DSI was found to provide a more comprehensive mapping of individual brain structure, as it identifies 2-5 times more fiber tracts than DTI. The traditional DTI method, however, was found to provide reliable metrics of a particular individual's fiber tracts across the three sessions, thus producing a more stable description of a person's anatomical structure. Combined, these results indicate that each method has unique strengths for different types of structural imaging research studies.

Future research will aim to link individual variations in brain structure in Army officers with their performance on several tasks and may enable us to engineer systems that better account for the particular talents and skills of individual Soldiers. This research will enable systems to be tailored to particular Soldiers and optimize their performance in operational settings.

Army's World Class EAR Facility Raises the Bar in Auditory Research

The importance of a Soldier's ability to hear a wide range of sounds is critical to survival and mission success on the battlefield. In today's military environment, the harshness of various sounds produced by both military and non-military activities makes it difficult for the Soldier to separate useful signals from background noise. A Soldier's ability to hear can be corrupted by physical barriers such as ballistics helmets, mission-oriented protective posture headgear, communications headsets and hearing protection devices.

With the ultimate need for Soldiers to accomplish their mission, it is critical to determine both the limits of human hearing and the effects of Soldier equipment on perception of sounds encountered on the battlefield. In order to facilitate research in this area, the U.S. Army Research Laboratory (ARL) recently completed the Environment for Auditory Research (EAR) at Aberdeen Proving Ground, Md. The concept and blueprint of the EAR were developed by ARL Fellow Tom Letowski and Bruce Amrein, chief of the Visual and Auditory Processes Branch.

A team of ARL researchers conducts basic and applied auditory and speech perception research, aiding situational awareness and survivability of ground troops. Areas of research include the perception of acoustic signatures produced by military-relevant sound sources, speech communication in adverse environments, effects of mental and physical workload on performance of the human auditory system, effects of various types of headgear on detection, and identification and localization of specific acoustic signatures.

Phuong Tran configures an experiment in the Control Room. Rack-mounted equipment is used to control the stimulus presentations in the research space.

In order to support this research, the EAR facility has been designed to be reconfigurable to simulate a wide range of indoor and outdoor acoustic environments. A researcher's ability to re-create soundscapes from both urban and rural surroundings is an important property and just one example of the many capabilities of the facility.

"The use of controlled space is imperative in order to integrate certain conditions," explained Amrein. "For example, sound sources, reflective surfaces and head-mounted equipment must all be emulated in the controlled setting. The capability to mix in relevant military sounds and have an actual body present to give feedback quantifies the effects and impacts of auditory research."

EAR is a distinctive and flexible research facility. The combination of the research spaces and capabilities is unmatched at any military, academic or industrial facility worldwide. The facility currently covers four indoor areas including the Sphere Room, Distance Hall, Dome Room and Listening Laboratory, as well as one outdoor space, OpenEAR. All spaces are controllable from one room, and the facility can accommodate up to three independent experiments simultaneously.

The OpenEAR was designed for auditory research in real outdoor environments.

Two of the first completed experiments involved localizing a target sound from a distance and estimating the direction of footsteps. ARL researchers are also collaborating with several external organizations such as the Missouri University of Science and Technology and Starkey Laboratories.

Development of an Auditory Localization Model: The Effects of a Second Sound

Military operations in urban areas involve complex auditory environments. Most models of how listeners identify the location of sounds predict performance in response to a single sound in a quiet, non-reflective environment.

This is an oversimplification of the situation faced by our Soldiers in urban combat areas. Although it is necessary to know the localization ability of a Soldier in this environment, it is impossible to reproduce these environments in even the most sophisticated laboratory setting and field studies can be cost and time prohibitive. Using a model, populated with the best possible data, to predict how changes in equipment or acoustic environment can impact a listener's ability to know the location of a sound source is the most economical and least labor-intensive approach. A validated, predictive model of auditory localization performance is essential for determining the effects of Soldier equipment (such as helmets, hearing protection and protective gear) on localization performance in complex environments.

A Director's Research Initiative (DRI) aimed to develop and evaluate a model of human sound localization that could provide accurate predictions of human localization performance for multiple sound sources. The vast majority of empirical and modeling work in auditory localization has focused on performance with single sound sources presented in quiet environments. Studies and models that use more complex, realistic stimuli are more representative of real-world environments.

The investigators began with an existing auditory localization model, published in the literature, which was shown to be accurate for identification of single sound source locations in non-reverberant environments. From this, they worked to expand the model to the localization of two sounds under two conditions—with and without headgear. Human perceptual data on the identification of the location of one sound source when two sounds were presented simultaneously were collected on 12 adult listeners with normal hearing in the Environment for Auditory Research (EAR).

Jim Faughn in the Dome Room of the Environment for Auditory Research (EAR).

Dr. Paula Henry with Lt. Col. Marjorie Grantham in the Dome Room of the Environment for Auditory Research (EAR).

Data for the model were recordings of the same stimuli presented to an acoustic manikin. The acoustic characteristics of these recordings were used to predict human performance. The model generated localization responses based on two sub-factors: the signal's acoustic information arriving at the two ears and models of the auditory processing that occurs between the ear canal and the brain.

The model's predictions were then compared to actual performance of human listeners. Error rates were generally comparable between the experimental and simulated data, which is a critical first step in model validation. A second step in model validation involves understanding where the model did not fit the data. In this case, although the general pattern of results was comparable, the model did not accurately predict a decrease in localization error with an increase in angular separation between the two sounds. The inaccuracy of the model in this case may be due to the fact that it only labels a single location estimate rather than indicating the location of each of the two sound sources.

The researchers are expanding the model so that it can localize a larger number of sound sources (not just one or two) to represent human behavior in urban environments with even greater fidelity. The important outcome of this project was improvement in a model that can make useful predictions about auditory performance, opening the door to many Army-relevant applications, including the assessment of prototype headgear.

Stereoscopic Camera Integration with Small Robotic Vehicles

Soldier operating a TALON robot on a simulated mission using the fully integrated 3-D display.

Enhanced visual perception and precision tele-manipulation are desired capabilities for Soldiers employing the current generation of small unmanned ground vehicles (SUGVs) to deal with threats such as improvised explosive devices (IED) in theater. These small robots provide a means to execute dangerous missions at standoff distances. A significant challenge that Soldiers must overcome when operating these robots at the required standoff distances is the reliance upon the perspective presented to them via the robot's standard 2-D cameras and displays, rather than the 3-D perception that they get from their personal senses. In lieu of other feedback, this 2-D imagery can hamper task performance for missions such as threat interrogation that are primarily visual in nature. The Army Research Laboratory led an effort to develop and test stereoscopic (3-D) cameras and displays that could "plug-and-play" with the widely used TALON robot system. Building upon ARL's expertise in the visual perception sciences, the researchers have been closely working with industry partners over the last several years to leverage recent developments in commercial stereoscopic display technologies such as those that have contributed to the recent resurgence of 3-D entertainment. Through an ARL cooperative agreement, a prototype camera and display were produced and evaluated by experienced Soldiers. This upgrade kit is a field-upgradable set of two stereo-cameras and a flat panel display using only standard hardware, data and electrical connections existing on the TALON robot. In a comparative study with the standard 2-D vision system, improvements were found in the Soldiers' mission performance and the operators' confidence in manipulating objects with the robot. Most notably, for missions requiring conducting operations in reduced visibility or performing manipulation intensive tasks, TALON operators were able to complete these simulated missions an average of 25 percent faster while using the 3-D system. This could translate to shortening real-world mission times by several minutes per threat interrogation. With the 3-D system, Soldiers demonstrated an 18 percent higher success rate in precision sensor placement, as well as made fewer unintentional collisions while driving or manipulating objects. Soldier feedback was overwhelmingly in support of pursuing 3-D vision systems, such as the one evaluated for fielding to combat units.

TALON robot system equipped with 3-D cameras on the arm and rear mast.

An additional challenge that Soldiers must overcome when operating robots, specifically those equipped with manipulator arms, is the lack of tactile feedback. If a Soldier is able to "feel" what is happening at the end of the manipulator arm, his or her ability to perform the mission will be enhanced. ARL plans to test the effectiveness of a bilateral force feedback manipulator arm, with both standard 2-D and 3-D cameras. It is hypothesized that integrating a bilateral force feedback manipulator arm with a 3-D camera system will dramatically improve a Soldier's situational awareness.

TALON robot preparing to investigate for potential threats in a road culvert.

Materials and Processes for Improved Gun Barrel Wear Resistance

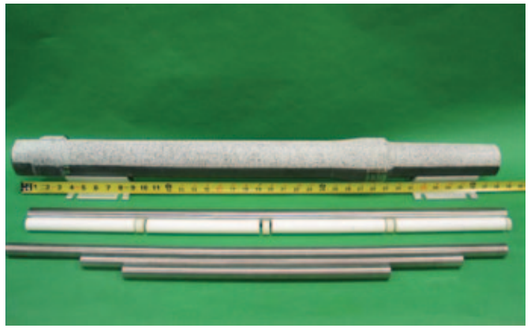
New materials and manufacturing processes are needed to enhance the service life and performance of Army gun systems. Chromium has been used for decades as the coating to increase service, but that process is being phased out of the military due to the carcinogenic waste stream. Added to this is the fact that chromium has limitations that prevent the utilization of higher energy propellants which would increase muzzle velocity and lethality of the system. Current research is identifying new materials that exhibit superior erosion and wear resistance, and concurrently developing new manufacturing processes to emplace these materials at the bore surface.

Cold spray consolidation of a tantalum tube.

ARL has identified a new cobalt-chromium-molybdenum alloy (BioDur® CCM alloy from Carpenter Technologies) that has demonstrated improved thermal shock resistance. This alloy has been transitioned to Benet for an FY11 ManTech program for explosively cladding liners into medium and large caliber gun tubes.

In another breakthrough, supersonic particle deposition (or cold spray) has demonstrated the capability to create seamless liner tubes of Tantalum (Ta) and Tantalum-Tungsten (Ta-W) alloys. Tantalum tubes have been cold sprayed, annealed, and successfully emplaced by explosive cladding.

Liner and Barrel: *The Stellite 25 liner was bonded to the truncated M242 gun barrel with the GLEEM process.*



GLEEM Hardware: *In the background is the truncated M242 gun tube (the speckle pattern applied is for optical strain measurements). The steel rods in the foreground are used to apply pressure to the elastomeric material and seals (white rods) as they are inserted one at a time into the liner.*

In order to enable low strain bore liners, ARL has developed a new process called Gun Liner Emplacement using Elastomeric Materials (GLEEM), and has a patent pending for emplacing liners and increasing service life via beneficial pre-stress development in gun tubes. Stellite 25 has been selected for the GLEEM process and the liner and barrel sections have been prepared. Further subscale testing is currently underway, and lining of a 3-foot section has been completed.

Green Ammunition

The need for higher performance small caliber ammunitions was evident in Somalia, Afghanistan and Iraq with Fort Benning reporting numerous sporadic performance issues seen during engagements.

In addition, the U.S. Army is mandated to be an environment custodian and to consider environmentally friendly options to replace lead in its systems.

ARL researchers routinely work with Soldiers to test new equipment, weapons and ammunition.

In order to address these issues, ARL partnering with Program Manager – Maneuver Ammunition Systems (PM-MAS) and the Armament Research and Development, Engineering Center (ARDEC) and Alliant Tech Systems Lake City Army Ammunition Plant pursued a non-traditional path for small caliber ammunition.

In this approach, ARL researchers borrowed from large-caliber, direct-fire systems focused on "purpose built" ammunition and used the latest simulation and experimental tools available.

The approach showed that there were opportunities to resolve the issues seen in combat along with improving the hard target capabilities of the projectile.

Some of the advanced tools employed by ARL include computational fluid dynamics to address the aerodynamic designs, explicit finite element dynamic simulations to develop the in-bore launch mechanics, advanced 3-D computation fluids with reacting chemistry codes for development of the propulsion and state-of-the-art terminal effects experiments and lethality analysis.

This non-traditional path resulted in an innovative design, the M855A1 Enhanced Performance Rounds (EPR). The M855A1 EPR is an environmentally friendly 5.56mm cartridge that enables superior small arms defeat capability for the Warfighter.

Pictures of the M855A1 projectile and its internal components.

Picture of the M855A1 cartridge.

The M855A1 EPR provides consistent performance, increases effectiveness at extended distances and significantly increases the range of hard target performance with no increase in cartridge weight.

The M855A1 EPR cartridge delivers an improvement to the legacy M855 cartridge and incorporates environmental requirements as well as a new propellant that increases velocity and reduces muzzle flash. The M855A1 EPR was fielded in June 2010.

Disruptive Energetics

In FY10, the Army Research Laboratory (ARL) initiated a new mission program to design, synthesize, characterize, formulate, and test novel materials which may fill the considerable energy gap that exists between conventional energetics and nuclear events.

Recent computational and experimental studies of materials such as nanodiamonds and nitrogen under thermomechanical extremes of pressure, temperature, and strain have revealed extraordinary physical and chemical behavior accompanied by unexpectedly complex structures with large amounts of structural energy, which can be stored in metastable states.

It is widely accepted that such materials have increased energy density and would yield between three to ten times the energy release relative to conventional energetic materials, if the energy can be rapidly liberated through exothermic chemical reactions. Using state-of-the-art quantum mechanical calculations performed at ARL as a guide, ARL experimentalists have successfully demonstrated the recovery and increased energetic performance of disruptive energetic materials.

For the first time, a novel high-energy-density nitrogen/hydrogen liquid was recovered to near ambient conditions, after QM simulations showed that passivation of the terminal ends of amorphous polymeric nitrogen resulted in increased stability (Figure 1).

Simulations on nanodiamonds showed a rapid liberation of stored structural energy leads to significant spall and fragmentation with a highly reactive surface, which may be related to experimental observations of significant increases in the thermal output of conventional energetics mixed with trace amounts of nanodiamonds (Figure 2).

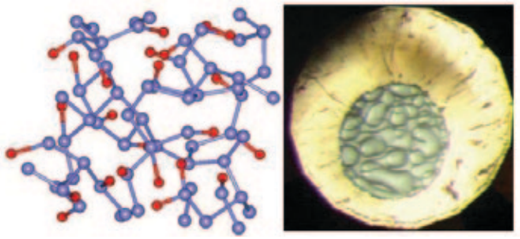


Figure 1. (left) Quantum mechanical passivation of amorphous nitrogen (blue) with hydrogen (red). (right) Experimentally realized amorphous nitrogen/hydrogen liquid recovered from high-pressure diamond anvil cell experiments to 0.5 GPa.

Figure 2. (left) Quantum mechanical simulations of two colliding nanodiamond particles, showing the significant spall and surface fragmentation. (right) Laser ignition of a conventional energetic material mixed with nanodiamonds.

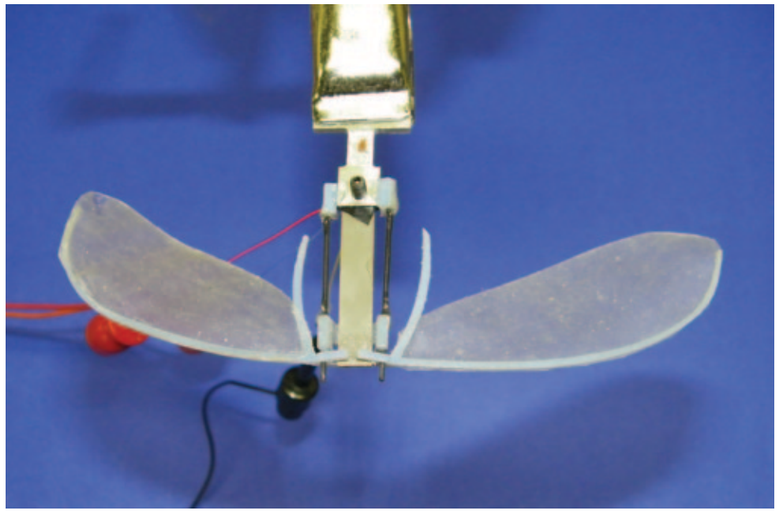
Although in its infancy, the combined computational and experimental Disruptive energetics program has already provided deeper insight into the underlying fundamental interactions at the atomic, molecular, and microstructural levels and direct experimental evidence of increased energy density.

Multi-Functional Flapping Wing Technology for Micro Air Vehicles

Army combat operations have placed a high premium on reconnaissance missions for unmanned aerial vehicles (UAVs) and micro air vehicles (MAVs).

UAVs and MAVs provide situational awareness that will shape the decisions of the squad command, such that these platforms are designed to be the eyes and ears for the Soldier.

One approach for accomplishing this mission is to develop a biologically inspired flapping wing insect that can maneuver into confined areas and possess hovering capabilities.



Wing frame for flapping micro-air device.

However, due to the size limitations of MAVs (typically less than 15 centimeters in dimension and less than 100 grams in mass), it is a challenge for the flapping wing vehicle to perform in adverse weather conditions (i.e., indoor or outdoor air gusts and precipitation).

One tactic is to provide adaptability or shape control of the wing structure that can create effective aerodynamic forces such that the MAVs can navigate in difficult weather conditions.

Propulsion via motors works well for larger UAVs, but for small MAVs capable of stealthy exploration of confined spaces, and envisioned to execute bioinspired insect-like flapping motion, motors may not be the best choice.

MAV actuation through the use of piezoelectric actuators is an actively pursued research area.

However, piezoelectric actuator applications are currently limited by conventional form factors.

A main advantage of pursuing this research project is to explore a newly designed piezoelectric actuator, one that will specifically produce insect-like motion by actively coupling bend and twist movements within the wing structure, thereby demonstrating a camber effect.

In FY10, the Army Research Laboratory developed an analytical model of layered $Pb(Zr_{0.55}Ti_{0.45})O_3$ (PZT) to introduce bend-twist motion in flapping wing response and have performed parametric studies to select layered PZT configurations with the desired biaxial actuation through introducing off-axis (angled) PZT segments onto a PZT bimorph to produce a functionally-modified actuator. Further developments include an actuator-to-wing hinge that mechanically couples and amplifies the bend action of the bimorph into the wing.

The creation of analytical models will allow efforts to be concentrated on the optimization of the actuator design and wing morphology.

If successful, the novel actuator designs can offer a unique contribution to the evolving MAV technology by providing for a more robust flapping wing.

Autonomous Unmanned Systems

Rapid advances in robotics technology over the last several years have enabled future unmanned ground vehicles that will provide increased awareness, extended reach, and multiplication of force for the Warfighter. Over the past eight years the Robotics Collaborative Technology Alliance (RCTA) has developed and transitioned technologies that enable unmanned ground vehicles (UGVs) to autonomously operate in dynamic, unstructured environments.

Detection, tracking, and avoidance of humans by an autonomous UGV during experiments conducted at the National Institute of Standards and Technology facility in Gaithersburg, Md.

During fiscal 2010, the U.S. Army Research Laboratory (ARL) concluded the RCTA with capstone experiments involving autonomous unmanned vehicles. As part of the capstone, the detection, tracking and avoidance of humans by an autonomous UGV was demonstrated. Additionally, ARL demonstrated mixed mode hierarchical planning in unknown environments wherein the vehicle selected appropriate algorithms based on what it experienced during the mission. Autonomous maneuver with bi-directional flow of terrain feature and mission level perception information in a complex and dynamic environment was also demonstrated. It showed autonomous interaction of a UGV with moving vehicles. In order to examine workload implications, two UGVs were simultaneously supervised by one human operator. ARL also examined multiple sources of sensed data, to include mid-range sensing, water detection, and unmanned aerial vehicle fly-over data which were incorporated into a world model in real time for dynamic planning. ARL has successfully transitioned technology to Advanced Development programs and Joint Capability Technology Demonstrations.

Unknown obstacles are sensed and data is incorporated for hierarchical planning as part of the Robotics CTA capstone experiment at Fort Indiantown Gap, Pa.

Autonomous detection, tracking, and avoidance of vehicular traffic by a UGV in an urban environment during a portion of the Robotics CTA capstone experiment at Fort Indiantown Gap, Pa.

Variable Speed Power Turbines for Improved Fuel Efficiency

The V-22 Osprey is a multi-mission, military tiltrotor aircraft capable of vertical take-off and landing (VTOL).

The need for increased military rotorcraft lift capability is evidenced by the ever-increasing payload capabilities of growth versions of existing helicopters (e.g., the Army CH-47F and the Navy CH-53K). Mission studies for the next generation of vertical take-off and landing (VTOL) capable, heavy-lift, long-range vehicles have concluded that, for maximum efficiency of operation (and reduced casualties), high-speed, high-altitude flight during the cruise leg of the missions is essential.

To achieve high efficiency at both the hover near ground and high-speed forward flight, the speed of the main rotor must be varied substantially. This requirement poses a severe challenge for turbo-shaft engines, which nominally operate efficiently over a narrow speed range.

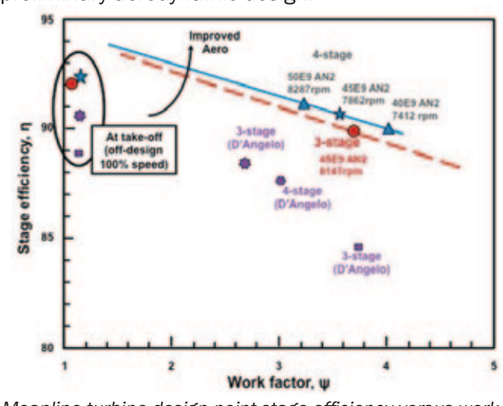
The key aerodynamic challenges required for a variable-speed power turbine are related to the attainment of efficiency at high work factors at cruise, the wide incidence variation associated with the speed change from take-off (100 percent speed) to cruise (54 percent speed), and operation at low chord Reynolds (Re) numbers encountered at high altitude cruise.

A CH-47F sling loading an up-armored HMMWV.

Collaboration with the Army Aviation Applied Technology Directorate, the NASA Subsonic Rotary Wing Project and industry partners was established. Preliminary trade studies to optimize basic power turbine characteristics such as stage number, solidity, loading, incidence angle range, and Reynolds number effects were completed and are ongoing.

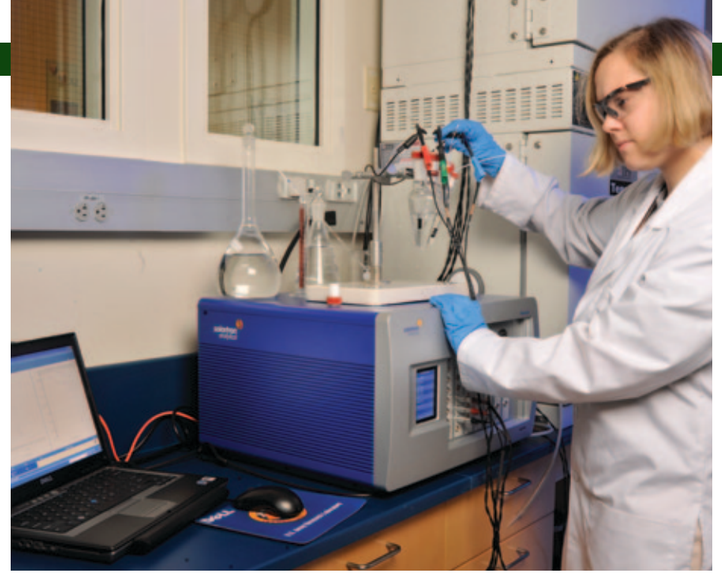
Mean-line and 3-D computational fluid dynamic analyses have produced the first of several incidence tolerant turbine blade designs that will be evaluated in a transonic turbine cascade that is being upgraded to provide the wide inlet flow angle range needed to evaluate incidence tolerant blade designs.

The aerodynamic technology foundation for enabling efficient (>88 percent adiabatic) wide variable-speed power turbine operation has been demonstrated and the performance potential validated via computational analyses of a 50 percent variable-speed power turbine preliminary aerodynamic design.



Meanline turbine design-point stage efficiency versus work factor for a conceptual military design compared with previous designs by D'Angelo.

Batteries and Battery Development



Michelle Marx analyzing impedance spectra from high power Li-ion batteries.

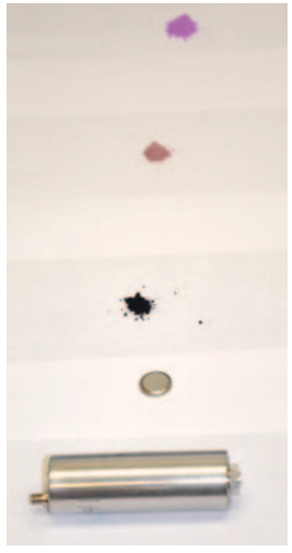
Batteries of higher energy and power density that can be operated over a wide temperature range and many cycles and with long storage life are critical to meet the demands of the Army's present and future electrified systems. In order to increase the energy density of state-of-the-art Lithium-ion (Li-ion) batteries, ARL is taking the approach of developing cathodes that operate at higher voltages since the energy density is proportional to the voltage of the cell.

At the same time, ARL is utilizing safer cathode materials that will result in batteries with improved safety as compared to current Li-ion batteries. Layered structure cathodes such as lithium nickel cobalt aluminum oxide and lithium nickel manganese cobalt oxide operate at 3.7 Volts (V) with energy densities of 680 and 740 Watt-Hours per kilogram (Wh/kg), respectively. Safer cathodes of olivine structure such as lithium iron phosphate operate at 3.4 V with an energy density of 580 Wh/kg. Higher voltage olivine structured cathode material such as lithium cobalt phosphate operates at 4.8 V with an energy density of 820 Wh/kg.

The use of higher voltage cathodes requires the development of electrolytes capable of operating at those higher voltages. ARL researchers have recently made a significant breakthrough in developing an electrolyte that can operate at 5 V.

Advanced batteries with high specific energy being developed and evaluated for Soldier and communication applications.

This was accomplished through a fundamental understanding of the surface/electrolyte interface (SEI), which allowed ARL researchers to tailor an additive that is particularly effective in protecting cathodes. This additive allows the operation of high voltage lithium nickel manganese spinel oxides at 4.7 V with 99 percent coulombic efficiency and 85 percent capacity retention after 200 cycles. The modified voltage lithium cobalt phosphate can also be cycled with little capacity fading after 20 cycles.



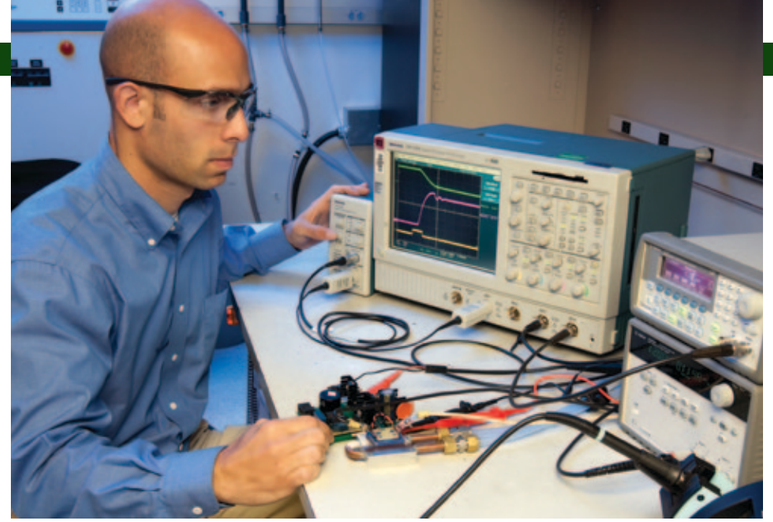
Advanced cobalt phosphate cathode materials synthesized by ARL Scientist Dr. Jan Allen for high voltage Li-ion batteries.

Further work to characterize high voltage electrolytes and cathodes in full cells, evaluate operation over wide temperature ranges, and measure rate performance are in progress.

Fault Protection in Electronic Systems

ARL has developed and demonstrated scalable bi-directional solid-state circuit breakers (SSCBs) for fast fault protection in power electronic systems having bi-directional current flow.

In addition to alternating current systems, direct current power electronic systems such as those of hybrid electric vehicle drives stand to benefit from this technology. Bi-directional SSCBs provide important advantages over their conventional mechanical counterparts.

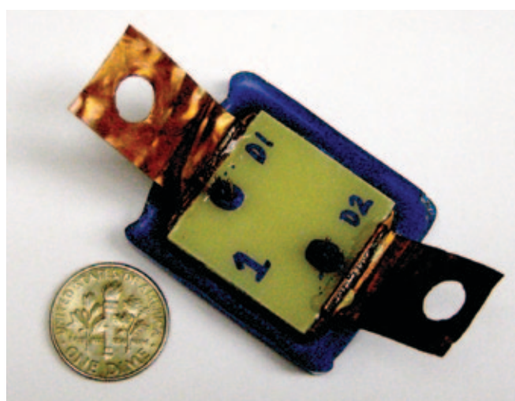


Damian Urciuoli tests the bi-directional solid-state circuit breaker.

Even coupled with transient voltage suppression components, they can achieve actuation times that are three orders of magnitude lower. Bi-directional SSCBs also offer dramatic improvements in reliability and operating life, resulting in superior system protection and reduced maintenance. Silicon carbide 0.1-cm^2 1200-Volt (V), 10-Amp (A) rated Junction Field Effect Transistor (JFET) devices were designed for the application. An array of devices was used to demonstrate current scalability and symmetric 600-V, 60-A bi-directional SSCB operation.

For a 36-kilowatt fault condition, repeatable fault suppression times of approximately 10 microseconds were observed in both directions with 6-meters of series cabling having approximately 20 microhenries of inductance. A novel gate driver has also been developed for inherent temperature compensated SSCB over-current protection and has been demonstrated for bi-directional current flow. ARL is collaborating with Northrop Grumman on bi-directional SSCB SiC device development to support this effort.

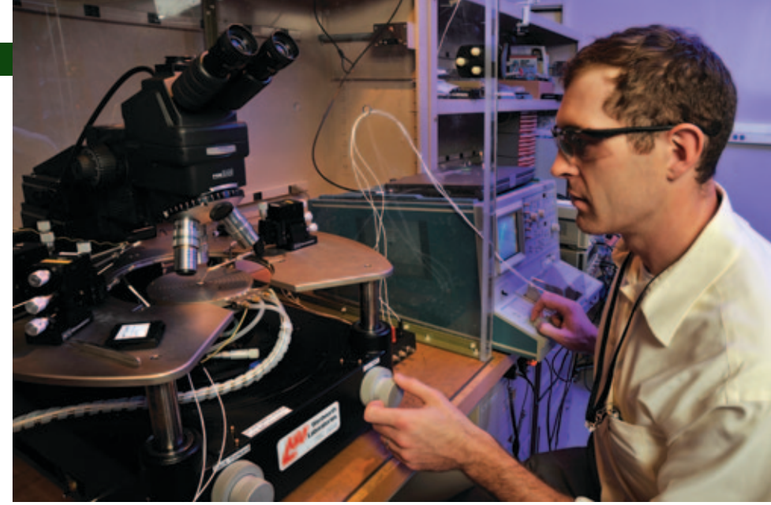
Bi-directional solid-state circuit breaker substrate populated with silicon carbide JFETs and silicon carbide gate resistors.



Packaged solid-state circuit breaker device capable of handling up to 30 amperes of current.

Wide Bandgap Power Devices

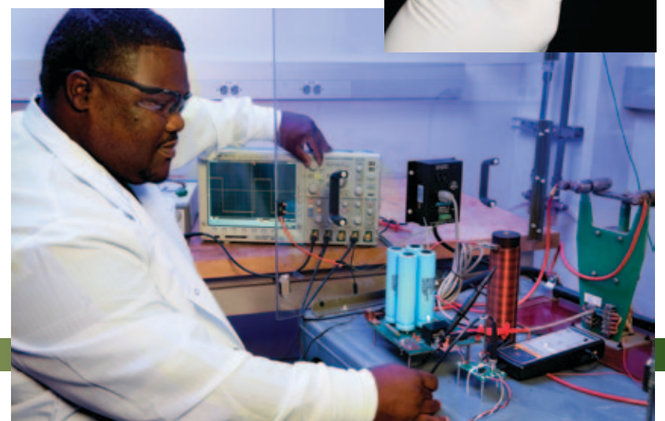
Silicon carbide (SiC) and gallium nitride (GaN) are the primary wide bandgap (WBG) semiconductor materials to replace silicon for the development of efficient high-power, high-temperature electronic devices to meet significantly increased requirements for electrical power generation, distribution, and control for current force and future Army vehicle platforms to provide advanced mobility, survivability and lethality capabilities.



Dr. Timothy Walsh tests gallium nitride diodes in a probe-station to ascertain current-voltage behavior.

The ARL device physics team collaborates with the main U.S. manufacturers (including Cree Inc. and General Electric Corp.) of WBG power devices as well as a multi-disciplined consortium of in-house and university researchers (including the National Institute of Standards and Technology, the University of Maryland, the State University of New York-Albany, and Auburn, Rutgers, Purdue, North Carolina State, and Pennsylvania State Universities).

Areas of collaboration include materials analysis, electrical characterization, multi-scale physics-based device and material modeling, and process improvement studies. Being a more mature technology, the focus of our SiC device physics team's efforts is on both identifying failure mechanisms and determining proper test methods for assessing the reliability of state-of-the-art SiC power Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs); as well as on identifying, understanding, and reducing process-induced material defects, in both the conducting channel and adjacent insulating gate oxide, that limit present device performance.



Dr. Ron Green operates the clamped-inductive load switching characterization testbed to evaluate new silicon carbide MOSFETs as a function of temperature, current, and voltage. ***Inset photo:*** *A 1200-V, 100-A silicon carbide MOSFET module used for characterizing dynamic device performance.*

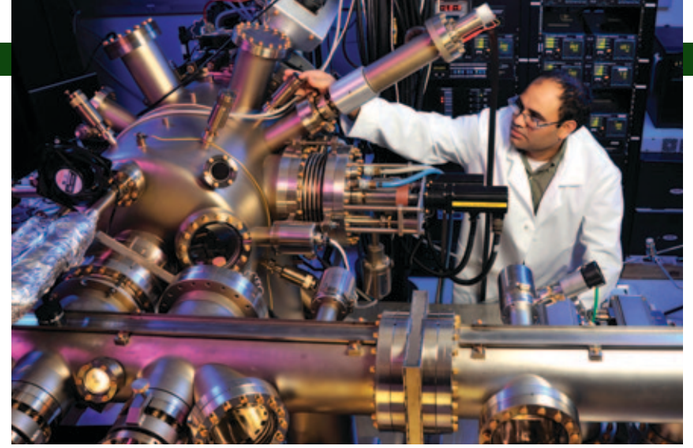
GaN power device technology is less mature than that of SiC because until very recently large crystals of GaN could not be grown, requiring GaN films to be grown on other substrates, which has led to devices with a large number of material defects. However, GaN power devices continue to be investigated as well because of their theoretically superior performance compared to SiC, and could be the path to aluminum gallium nitride devices, which along with diamond could possibly meet the demands of pulsed power applications that SiC and GaN devices cannot meet.

Recent accomplishments for SiC include the identification of a serious failure mechanism in the OFF-state, which could lead to excess leakage current and device failure—likely due to a near-interfacial oxide trap related to an oxygen vacancy, which causes a bias and temperature dependent instability of the threshold voltage.

Recent accomplishments for the GaN Power Electronics DSI include quantifying how reducing the carbon and the dislocation concentration in GaN films improves the properties of Schottky diodes; and achieving the lowest ever contact resistance to n-type GaN using ARL's patented ion-implantation process to improve device efficiency.

UV Sources and Detectors

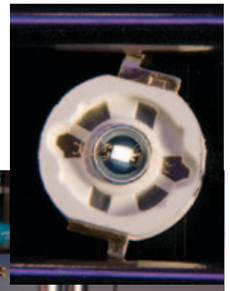
Semiconductor ultraviolet (UV) radiation sources (LEDs and laser diodes) and avalanche photodiode detectors (APDs) based on the indium aluminum gallium nitride (InAlGaN) material system can be used as compact, lightweight, low-cost, low-power-consumption components in sensors for bioagent detection and identification, water sterilization, solar-blind non-line-of-sight (NLOS) covert communications for unattended ground sensors, and rocket propelled grenade/sniper UV flash detection. ARL's research addresses fundamental issues in the fabrication of group III-V nitride semiconductor materials and devices.

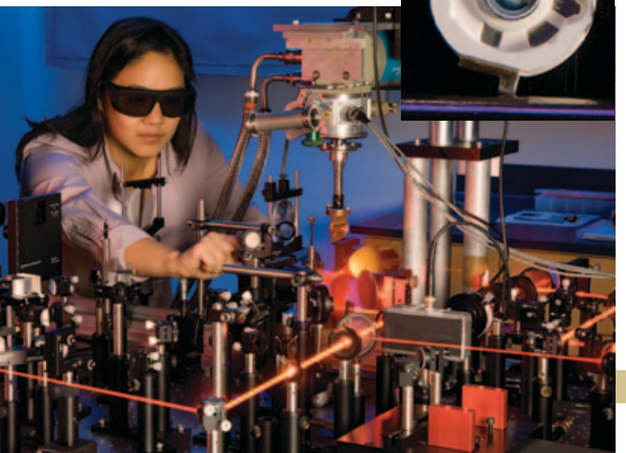


Dr. Anand Sampath opening the reflection high energy diffraction gun shutter on the III-Nitrides semiconductor molecular beam epitaxy reactor during growth.

Using ARL's unique time-resolved UV photoluminescence and reliability studies to guide device design, ARL and its industrial partners are collaborating on the development of UV LEDs in the 240-280 nm range with output power greater than 10 mW required for many of these applications that are being studied by the Edgewood Chemical and Biological Center (ECBC) for potential incorporation into the next generation Tactical Biological (TAC BIO) sensor for bioagent detection. Further improvement in LED performance may be attained through incorporation of spontaneously forming nanostructures such as ARL's patented nanoscale compositional inhomogeneities (NCI) into the AlGaN active regions, which has led to internal quantum efficiencies exceeding 30 percent in the 270-280 nm range. In addition, ARL has developed the first periodically poled AlN for frequency doubling of visible InGaN lasers into the 240-250 nm range and potential use in bioidentification by resonance Raman spectroscopy.

Dr. Grace Metcalfe performing UV pump and terahertz probe spectroscopy measurements to study carrier dynamics in ARL-grown nanometer-scale compositional inhomogeneous AlGaN materials. ***Inset photo:*** *Electroluminescence from a deep ultraviolet light emitting diode packaged on a surface mount header.*



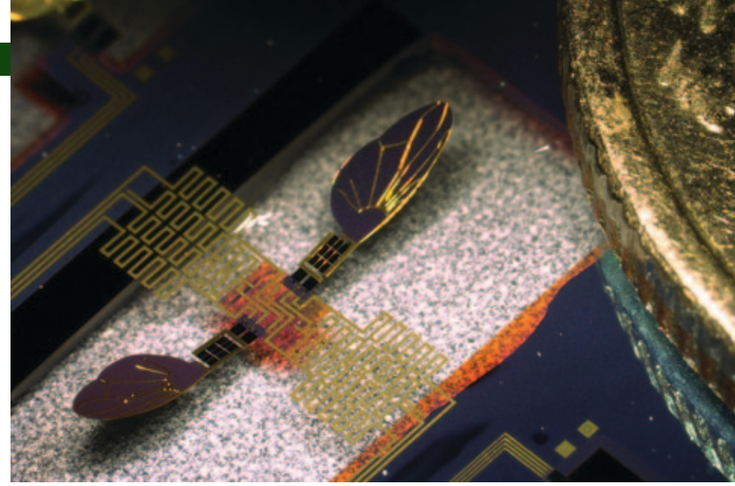


ARL has improved UV detector performance by extending the spectral range of high performance silicon carbide (SiC) APDs through incorporation of nitride semiconductors as absorbers for separate absorption and multiplication (SAM) APDs that combine the high quantum efficiency and bandgap tunability of nitride semiconductors with the proven high performance avalanche multiplication properties of SiC. GaN/SiC SAM APDs with high gain and low dark current have been demonstrated that provide higher quantum efficiency than SiC APDs at wavelengths longer than 330 nm required for bio-flourescence detection. AlN interface charge control layers may also be used to reduce surface recombination in SiC APDs, thereby improving the short wavelength (< 260 nm) performance for hostile fire detection. The high gain and low dark current of the III-Nitride/SiC APDs make them excellent candidates for replacement of fragile, expensive, and bulky photomultipliers currently used for these applications.

These UV sources and detectors will contribute to the sustainability of our Soldiers by helping in the reduction of the logistics footprint, while providing new solutions for protection, information, and potable water at the individual Soldier level, aiding the survivability, lethality, and deployability of the current and future force.

Microautonomous Systems

ARL is developing Micro Autonomous Systems Technology (MAST) to support Soldiers in the last 100 meters of complex environments such as urban settings and caves. Small man-portable robotic platforms, currently in the field, are Soldier teleoperated, require multiple Soldiers per platform, and have limitations in mobility and the capabilities that they can perform while in these environments.



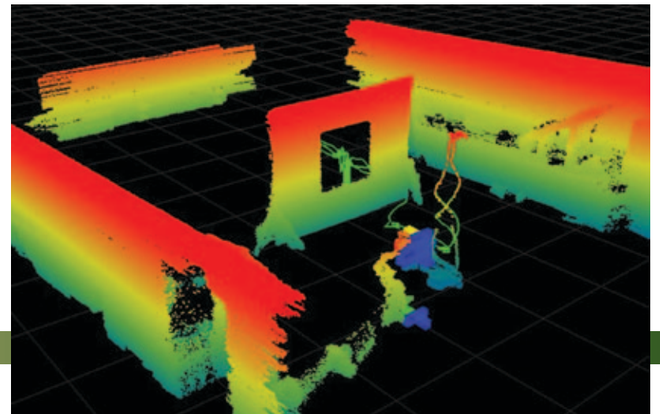
MEMS fabricated insect inspired multi-degree of freedom wing actuators for microflight (ARL).

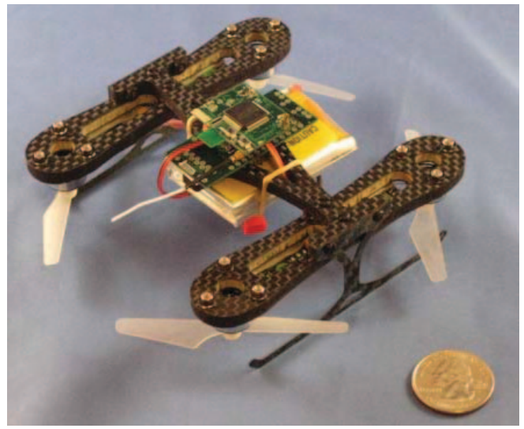
ARL awarded a MAST Collaborative Technology Alliance to a consortium of industry and academia to address these issues by developing small, hand-held sized, autonomous, crawling, flying and hybrid robotic platforms and the fundamental microelectronics, autonomous behavior, mechanics, and integration technologies required to make such systems a reality in the future.

These systems, through size and autonomy, will invert the Soldier to platform ratio and free up the Soldier for other duties; work autonomously and collaboratively to perform building and cave search and mapping; and autonomously set up mobile sensor and communication networks in complex RF environments such as buildings and caves.

The MAST Consortium is led by BAE Systems and has centers based at the University of Maryland for Microsystem Mechanics, The University of Pennsylvania for Processing for Autonomous Operation, the University of Michigan for Microelectronics, and the Jet Propulsion Laboratory for Platform Integration and includes general members at Georgia Tech, UC-Berkeley, CalTech, University of New Mexico, North Carolina A&T, and MIT.

The Consortium is working collaboratively with ARL's in-house robotics enterprise research to perform basic research to address the many fundamental challenges associated in making MAST a reality. These include understanding and designing the controls necessary for MAST scaled platforms to fly and hover autonomously through complex environments, especially internal to buildings and in wind. Some examples of technology developed within the last year are integrated antennas on MAST scaled platforms, development of radio repeaters for autonomous deployment of sensor and communications networks, a 35-gram mini-quad rotor autonomous platform, a 10-gram flapping wing platform capable of hover along with detailed fluidics modeling for winged flight, demonstrated distributed autonomous mapping and RF communications within buildings, and multi-degree freedom MEMS-based flapping wings for future insect inspired microflight.





35-gram miniature quad rotor (University of Maryland).

3-D Perception for Flight in Cluttered Environments (University of Pennsylvania and MIT).

Flexible Displays and Electronics

The U.S. Army established the Flexible Display Center (FDC) at Arizona State University in partnership with the state of Arizona to accelerate the development of flexible display technology to meet emerging information technology needs for the Soldier.

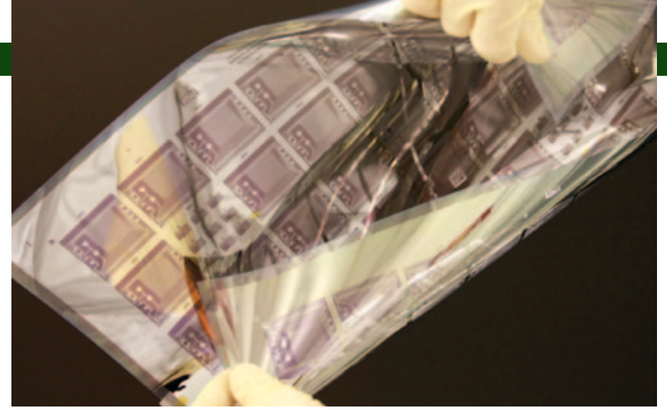
The Center was formed through a cooperative agreement with the U.S. Army Research Laboratory, Army partners, and the current 28 Industrial partners to achieve the common goal of lightweight, rugged, ultra-low power flexible displays and electronics developed with high yield manufacturing processes. The program has Army partners to ensure the technology has system-level applications that include Natick Soldier Research Development and Engineering command (NSRDEC), Tank-Automotive RDEC, Communications-Electronics RDEC, Armament RDEC, and the Aviation and Missile RDEC.

In the last year, the FDC and industry partners have significantly advanced color displays and processing at Generation II (GEN II). Full color organic light-

An array of flexible Color Emissive Displays developed at the Flexible Display Center. ARL contributed to the process development.

emitting diode displays have been demonstrated on the plastic. The flexible reflective displays have transitioned to industry for system level integration. These systems are being evaluated through two technology transition agreements (TTAs). In addition, the flexible substrate processing technology based on a bond debond technology has transitioned to the GEN II pilot line.

The Army has begun to leverage the developments at the Flexible Display Center to enable the broader



A generation II sized panel of displays in plastic fabricated at the Flexible Display Center.

applications across flexible electronics and elements. Leveraging the transistor backplane arrays for flexible displays enables two technology spaces: flexible electronics and flexible elements.

Flexible electronics are considered as large area distributions of electronic circuits, discrete elements, and sensors. Flexible elements include large-area individual elements such as solar cells, antennas, and solid state lighting. The Army is looking at applications that leverage the developments at the Flexible Display Center to enable the broader applications across flexible electronics and elements.

Recently, ARL developed and demonstrated organic compounds for organic LEDs, organic thin-film transistors, and organic solar cells that have applications across flexible electronics and elements. ARL transitioned organic light-emitting diode (OLED) knowledge to the FDC for integration into emissive flexible displays that includes charge transfer complex molecular systems to dramatically enhance the charge injection and transport properties for organic devices.

The early transition to flexible electronics is shown by system demonstrators that integrate flexible displays with flexible circuit boards and power, which are being developed by the FDC and Small Business Innovation Research (SBIR) programs. As flexible electronics technology matures, other application demonstrators are being investigated such as flexible MEMs, imaging arrays, and sensor array elements such as neutron detectors.

These longer term applications will demand higher performance thin-film transistor (TFT) arrays, novel sensor architecture and unique manufacturing paradigms that will enable large-area flexible electronics at low-costs to meet the ever increasing demands of the commercial and military needs.

Modeling and Simulation of 3-D Textile Fabrication Process for Protective Applications

ARL and university partners have developed a robust modeling capability to simulate the fabrication processes of three-dimensional (3-D) textile preforms for all levels of armor applications. Through these collaborations a sub-yarn level 3-D fabric model was successfully developed that is capable of quantifying the process effects on 3-D preform architecture. The user-friendly 3-D fabric architecture modeling code is being used by the textile industry for simulation of complicated 3-D weaving processes for both Army and commercial applications. The 3-D fabric code has ballistic modeling capability incorporated and has been used to develop highly efficient hybrid soft body armor. Recently, the code has also been extended to generate the micromechanical models of 3-D hybrid fabric composites. Figure 1 shows three typical high fidelity 3-D fabric architectures, which can be used to make composites for a wide range of structural and protective applications.

Development of highly efficient hybrid 3-D composite systems for various protective applications requires modeling the effect of fiber architecture on the material responding to dynamic loading. To accomplish this, a robust hierarchical procedure, shown in Figure 2, has been developed to establish the finite element micromechanical model for relating the effective composite properties to the 3-D fabric architecture. The results of progressive failure simulation for the representative volume elements of a 2-D plain weave layer and a 3-D orthogonal weave composite subjected to axial loading are shown in Figure 3. Developing a robust materials-by-design tool is ongoing at ARL for expediting the development cycle toward providing enhanced protection for the Warfighters, which will range from personnel protection to vehicle armor.

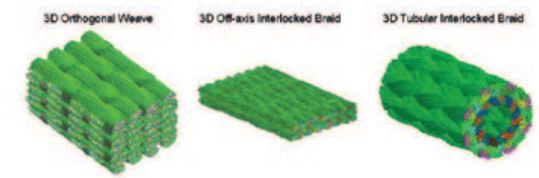


Figure 1: 3-D Fabric Fiber Architectures Generated by Using the Textile Process Simulation Code.

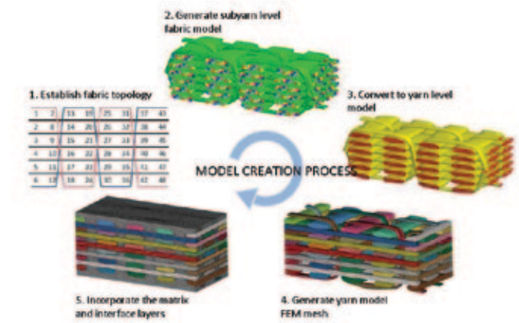


Figure 2: Schematic of Micromechanical Model Creation Process Starting from Fabric Topology Layout to Three Phase Finite Element Model.

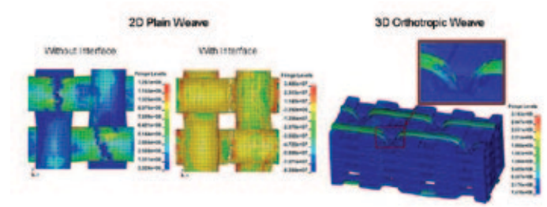
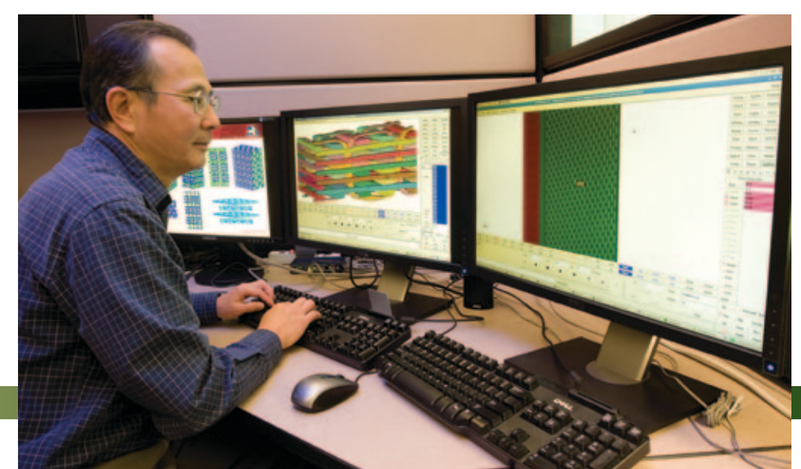


Figure 3: Progressive Failure Simulation Results of 2-D Plain-Weave and 3-D Orthogonal Weave Composites Subjected to High-Rate Axial Tensile Loading.



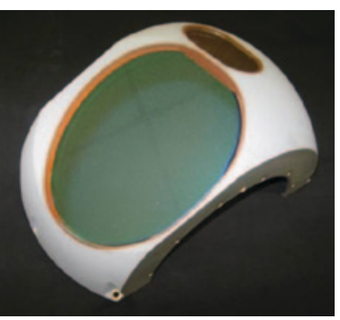
Dr. Chian-Fong Yen works on the 3-D fabric model. ARL and university partners developed this modeling capability.

Transparent Spinel Armor Manufacturing Scale-Up

Glass-plastic based transparent armors are growing prohibitively heavy to meet new requirements. Transparent armors based on spinel have been shown to reduce weight by 33 percent to 50 percent. The use of spinel in transparent armors has been pioneered by the Army Research Laboratory (ARL). The current method of hot-pressing spinel was developed at ARL and the technology was then transferred to Technology Assessment and Transfer (TA&T) under a CRDA (Cooperative Research and Development Agreement). The scale-up of this technology has continued under a Cooperative Research Agreement. The current state-of-the art fabrication capability for transparent ceramic spinel is optimized at 300 in^2 but tactical vehicle requirements need up to 600 in^2 panels. The goal of the program is to provide new manufacturing capability to produce sizes up to 600 in^2 transparent ceramic spinel armor for improved ballistic protection for tactical vehicle platforms defending against Long Term Armor Strategy (LTAS) objective threats.

Major accomplishments of this Army Manufacturing Technology Objective during this year include:

• Development of spinel/plastic transparent armor that is 35 percent lighter than traditional glass plastic armors and clearer than traditional transparent armor designs.



Hot-pressed spinel window for Advanced Targeting - Forward Looking Infrared targeting pod (AT-FLIR).

• Delivery of a segmented front window for Family of Medium Tactical Vehicles (FMTV) road test. Spinel transparent armor delivered to Tactical Wheeled Vehicle Army Technology Objective (ATO) for ballistic testing and vehicle tests and technology demonstrators.

• The size of hot-pressed spinel plates available for DoD applications has been increased from 170 square inches to 300 in^2.

• Advances in spinel powders and spinel powder processing have been transferred to sintering technology to make electromagnetic domes.

Spinel based transparent armor on FMTV 1083A1 P2 for TARDEC/ARL TWVS ATO demonstrator undergoing testing.

• The increase in the size and quality of hot-pressed spinel available has allowed the following:

- The Navy is flight testing hot-pressed spinel for a window for the new AN/ASQ-228 Advanced Targeting Forward Looking Infrared targeting pod (AT-FLIR) being developed for the F18. A spinel window was delivered and flight tested.

- Lockheed Martin is evaluating hot-pressed spinel for insertion as a lens into the aircraft mounted SNIPER XT Targeting Pod.

- The Navy is developing a hot-pressed spinel for IR window on new DDG-1000 destroyers.

Sintered spinel domes for Joint Air to Ground Munitions (JAGM) Army/Navy, and small diameter bomb dome Air Force.

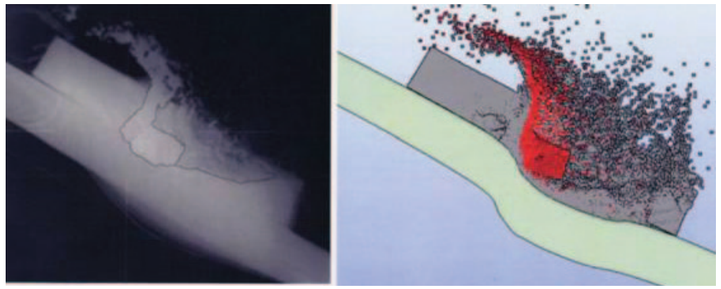
Base Armor Alternatives

Today's ground vehicles must be responsive to mission scenarios ranging from peacekeeping to major combat. This has made a tailored modular approach to armor beneficial, where mission specific packages can be added over a baseline level of protection.

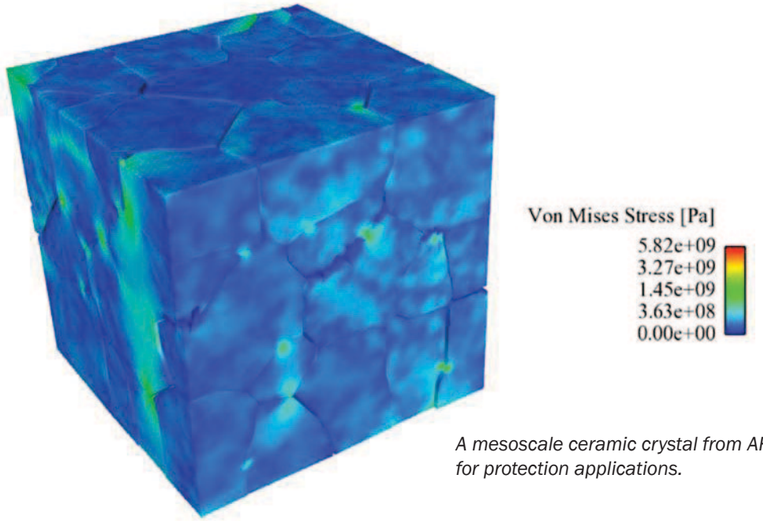
In 2010 ARL performed high performance computing simulations and conducted detailed experiments to advance designs that exploited multiple advanced materials and manufacturing approaches. This research effort led to the development of optimized baseline armor packages for ground platforms that were transitioned to industry through Cooperative Research and Development Agreements and to our TARDEC partners.

These different approaches provide the Army's vehicle designers and Original Equipment Manufacturers (OEMs) with potential trade-offs that balance size, weight, and cost requirements all while meeting the necessary level of baseline protection.

Jim Wolbert, composite laboratory lead technician, preparing materials for laminate armor applications.



A sample of a computational penetration simulation used in the modeling of armor materials as compared to a validating experiment.

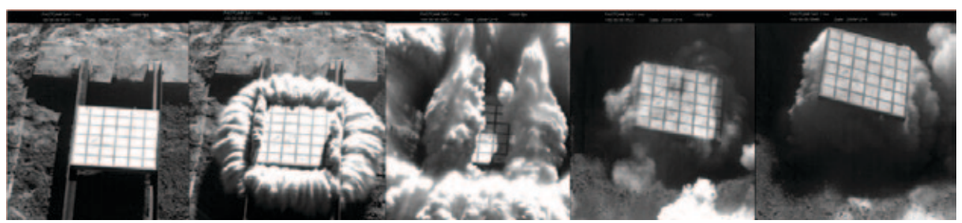


A mesoscale ceramic crystal from ARL modeling efforts of ceramic materials for protection applications.

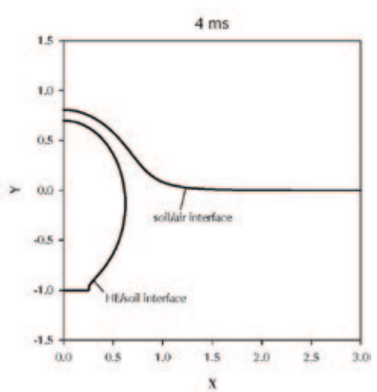
A Simplified Model for Blast/Impulse of Buried Explosives

ARL has developed a model for understanding the blast and impulse response of buried explosives. By incorporating tailored modeling assumptions, in conjunction with analytical-modeling constructs, the underlying model exhibits a size, structure, and performance that is much closer to an analytical model than a full-fledged general-purpose numerical code. Unlike many blast codes currently employed, the current model is able to separate out the contributions of both delivered soil impulse and residual high-explosive blast. Results are given as a function of both time and spatial location. The model will be used to carry out a variety of parametric studies of the buried explosive event, to include the effects of burial depth, explosive variation, and soil condition. ARL is currently assessing the potential use of the model for the purpose of vulnerability/lethality analysis.

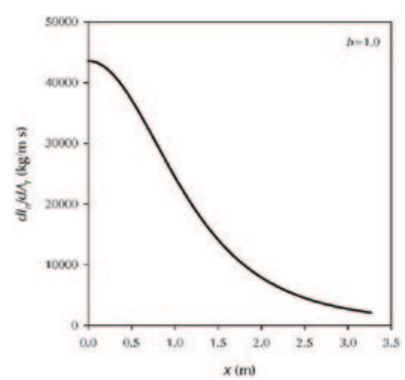
Buried explosive event in progress.



Explosive event in progress.



Calculation depicting formation of explosive bubble under dome of propelled soil.



Specific impulse delivered by soil impact upon barrier, as a function of location upon barrier.

Intelligent Munitions System Scorpion

Joe Churchman, IMS Scorpion System Leader, conducts a pre-flight check of a FLIR imager.

Intelligent Munitions System (IMS) Scorpion is a new anti-vehicular weapons system that allows trained operators to remotely control ground-emplaced munitions over a network via a portable control station (notebook-sized computer and radio). This system will level the battlefield against improvised explosive devices (IEDs), roadside bombs that commonly kill Soldiers and civilians alike, which have been among the most dangerous threats encountered by US troops in the Middle East.

The IMS Scorpion system provides the Soldier a capability that is generations ahead of IEDs in that the system's onboard sensors alert the operator to approaching traffic; once the operator visually identifies the approaching vehicle(s) he has the means to prevent the passage of enemy vehicles while allowing for the safe passage of friendly vehicles. The onboard sensors can even trigger the munition engagement automatically, if desired.

ARL worked closely with the IMS Scorpion Product Manager, Developmental Test Command (DTC) and Army Evaluation Center (AEC) to ensure developmental test events were designed to provide results that could be used to determine system performance for comparison to stated design requirements. ARL provided expertise and capability to supply electronic warfare (EW) countermeasure (CM) environments and ballistic performance analysis to IMS Scorpion DT events.

ARL's involvement in this program contributed in multiple ways. ARL analysis results are a critical aspect of AEC's evaluation of the system. ARL results will also be used by Training and Doctrine Command (TRADOC) to train system operators. ARL findings from warhead testing and its strategy of providing accredited threats during DT allowed PM IMS Scorpion to streamline both cost and test schedule. ARL's involvement directly contributed to ensuring that the system will be able to perform its mission when fielded.

Two T-72s are driven on a test track to measure the IMS Scorpion response.

An aerial view of an IMS Scorpion dispensing module in a test environment with its associated digital acquisition system.

High Fidelity Threat Effects Integration

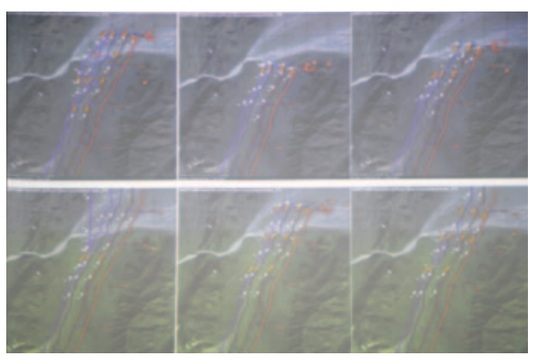
The Army Research Laboratory successfully developed the System of Systems Survivability Simulation (S4) to address the challenges and demands of modern digital battlefield operations. With technology advancing at a rapid pace and adversaries using threats asymmetrically to counter our forces, it has become crucial to develop new methodologies and analysis tools that will inform the Warfighter, Army evaluator and materiel developer decisions related to systems-of-systems (SoS) problem sets.

ARL's S4 Facility at White Sands Missile Range, N.M.

System of Systems is the Army's concept of a collection of systems that are organized, manned, equipped and trained to be more responsive, deployable, agile, versatile, lethal, survivable and sustainable across the spectrum of military operations. The SoS is a collection of networked and mutually dependent systems that has properties and capabilities beyond the attributes of individual systems. SoS represents a fundamentally new analysis problem that traditional Army analysis tools and methodologies were not designed to address. S4 provides the means to analyze and assess this new problem in an Army mission context.

S4 incorporates state-of-the-art representations of warfighting capabilities and key threats combat forces will encounter in the battlefield. These include effects of ballistic events, attacks on computer-network operations, and use of electronic warfare embedded within the cognitive, communication, and decision-making context that enables SoS decisions. This innovative combat and research aide is designed to address intense combat challenges in any environment. By implementing engineering-level threat effects, S4 enables the analyst to understand the consequences of vulnerability upon the Warfighter mission in a contemporary military operational environment.

ARL is collaborating with New Mexico State University Physical Sciences Laboratory, the Naval Post Graduate School, and the Training and Doctrine Command in the development of this capability to ensure that S4 uses the latest thinking in model development, intelligent agent technology, innovative tactics and operational experience to fully represent the modern battlefield.



Quick Look is a visualization analysis tool that allows the analyst to quickly scan through thousands of simulation runs and sort metrics of interest. This picture elucidates electronic warfare (EW) jamming in frames 2 and 3 (1-6 left to right/top to bottom).

The set of S4 capabilities fills a critical void in the Army's analysis community by providing the ability to conduct SoS analysis in a contemporary military operational environment. Analysis in this context initiates with the study question, articulation of a need, appropriate modeling to address the need, and analysis tools to provide credible, analytically sound operational outcomes.

Ground Combat Vehicle (GCV) Analyses of Alternatives (AoA)

When the U.S. Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC) was directed to perform an analysis of alternatives (AoA) for the first major milestone of the GCV, the Army Acquisition Executive's Milestone A decision as well as the AoAs for the Abrams and Bradley modernization programs, TRAC came to ARL for the ballistic vulnerability data crucial for their force-on-force models.

The GCV AoA team received the ARL 2010 Honorary Award for Analysis.

For an AoA, TRAC runs its high-level force-on-force models for a selected series of scenarios to compare conceptual and legacy vehicles with respect to Army requirements. Accurate and timely force-on-force analyses are required to support decision makers and ensure the Army spends its research and development dollars wisely. Most importantly, these analyses help the Army select and provide the best systems possible to our Soldiers.

ARL immediately went to work generating the ballistic vulnerability data sets for the systems requested by TRAC: GCV Infantry Fighting Vehicle (IFV) design concept prepared by the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), the M2A3 Bradley with reactive and add-on armor, and the M1A2 Abrams upgraded with the Systems Enhancement Package and the Tank Urban Survivability Kit. ARL analyzed a wide variety of threats against these platforms: small- and large-cal kinetic-energy munitions, shaped-charge jets, explosively formed penetrators, fragments and under-body blast threats.

To produce these ballistic vulnerability estimates, ARL built a highly collaborative environment by establishing an interactive objective-focused team that included armor technology scientists from ARL automotive and ground combat vehicle engineers from TARDEC and the platform Program Management offices, force-level analysts from TRAC, user representatives from TRADOC, system analysts from the U.S. Army Materiel Systems Analysis Activity, and intelligence analysts from the National Ground Intelligence Center. These technical collaborations provided ARL with sufficient data to perform ballistic vulnerability analyses of the relevant systems. This was done in parallel with closely coordinated efforts including the GCV IFV concept design and continued development, trade studies, technical readiness levels (TRL) assessments, and the source selection board process.

ARL provided vulnerability data in support of the AoA for the Bradley modernization program.

ARL provided vulnerability data in support of the AoA for the Abrams modernization program.

ARL developed design change recommendations for TARDEC. By providing these recommendations early in system development, ARL is enabling the Army to improve Soldier protection and produce a better product at a lower cost by improving the system design when it is relatively inexpensive to do so early in the acquisition lifecycle.

Glossary

AEC ..... Army Evaluation Center
AEOP..... Army Education Outreach Program
AHPCRC .... Army High Performance Computing Research Center
ALC..... Adelphi Laboratory Center
AmPs ..... Antimicrobial Peptides
AoA..... Analysis of Alternatives
APDs ..... Avalanche Photodiode Detectors
APG ..... Aberdeen Proving Ground
ARDEC ..... Armament Research and Development, Engineering Center
ARL ..... Army Research Laboratory
ARO ..... Army Research Office
ASU ..... Arizona State University
AT-FLIR ..... Advanced Targeting Forward Looking Infrared
ATEC..... Army Test and Evaluation Command
ATO..... Army Technology Objective
BRAC ..... Base Realignment and Closure
C-IED..... Counter-Improvised Explosive Device
CISD..... Computational and Information Sciences Directorate
CMT..... Composites Materials Technology
CRDA ..... Cooperative Research and Development Agreement
CTA..... Collaborative Technology Alliance
DARPA ..... Defense Advanced Research Projects Agency
DCGS ..... Distributed Common Ground/Surface System
DoD ..... Department of Defense
DRI ..... Director's Research Initiative
DSI ..... Diffusion Spectrum Imaging
DSIs..... Director's Strategic Initiatives
DSRC ..... Defense Supercomputing Resource Center
DTC ..... Developmental Test Command
DTI..... Diffusion Tensor Imaging
EAR ..... Environment for Auditory Research
EC-10 ..... Empire Challenge 2010
ECBC..... Edgewood Chemical and Biological Center
ELICIT ..... Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust
EMVAF ..... Electromagnetic Vulnerability Assessment Facility
EPR ..... Enhanced Performance Rounds
ETT ..... Embedded Training Teams
EW..... Electronic Warfare
FAST..... Field Assistance in Science and Technology
FDC ..... Flexible Display Center
FMTV..... Family of Medium Tactical Vehicles
FVWC ..... Federal Virtual Worlds Challenge
FY ..... Fiscal Year
GaN ..... Gallium Nitride
GCV ..... Ground Combat Vehicle
GEMS..... Gains in the Education of Mathematics and Science
GEN II..... Generation II
GIG ..... Global Information Grid
GLEEM ..... Gun Liner Emplacement using Elastomeric Materials
HBCU/MIs Historically Black Colleges and Universities/Minority Institutions
HESATF ..... Heat Engine Systems Altitude Test Facility
HMMWV .... High Mobility Multipurpose Wheeled Vehicle
HPC..... High Performance Computing
HRED ..... Human Research and Engineering Directorate
IAT ..... Institute of Advanced Technology
ICB ..... Institute of Collaborative Biotechnologies
ICT..... Institute for Creative Technologies
IED ..... Improvised Explosive Device
IFV..... Infantry Fighting Vehicle
IMS..... Intelligent Munitions System
InAlGaN ..... Indium Aluminum Gallium Nitride
INSCOM ..... Intelligence and Security Command
ISN ..... Institute of Soldier Nanotechnologies
ISR ..... Intelligence, Surveillance and Reconnaissance
JAGM..... Joint Air to Ground Munitions
JFCOM ..... U.S. Joint Forces Command
JFET..... Junction Field Effect Transistor
JIEDDO..... Joint Improvised Explosive Device Defeat Organization
JIIM ..... Joint Interagency, Inter-governmental, and Multi-national
JTAPIC..... Joint Trauma Analysis and Prevention of Injury in Combat
JTCG-ME .... Joint Technical Coordinating Group for Munitions Effectiveness
LED..... Light-emitting Diode
LFT&E ..... Live-Fire Test and Evaluation
Li-ion ..... Lithium-ion
LTAS ..... Long Term Armor Strategy
MANET..... Mobile Ad Hoc Networks
MAST ..... Micro Autonomous Systems Technology
MAVs..... Micro Air Vehicles
MCIT ..... Mobile Counter-IED Interactive Trainer
MCOE..... Materials Center of Excellence
METER..... Multinational Environment for Training Evaluation and Research
MI ..... Military Intelligence
MIT..... Massachusetts Institute of Technology
MLPs..... Major Laboratory Programs
MOSFETs ... Metal-Oxide-Semiconductor Field-Effect Transistors
MRAP..... Mine Resistant Ambush Protected
MRI ..... Magnetic Resonance Imaging
MURI..... Multidisciplinary University Research Initiative
NCI ..... Nanoscale Compositional Inhomogeneities
NDAA..... National Defense Authorization Act
NLOS ..... Non-Line-of-Sight
NRC..... National Research Council
NSRDEC..... Natick Soldier Research Development and Engineering command
OEF ..... Operation Enduring Freedom
OEMs ..... Original Equipment Manufacturers
OLED ..... Organic Light-Emitting Diode
OND..... Operation New Dawn
OP..... Outreach Program
OTM..... On-the-Move
PEOs ..... Program Executive Offices
PEO STRI ... Program Executive Office Simulation, Training and Instrumentation
PM..... Program Manager
PM-MAS .... Program Manager – Maneuver Ammunition Systems
PSL ..... Propulsion Systems Lab
QGI ..... Quantum Ghost Imaging
QIGI ..... Quantum-Inspired Ghost Imaging
QM ..... Quantum Mechanical
QUIIST..... Quantum Imaging Information Science and Technology
R&D ..... Research and Development
RCTA ..... Robotics Collaborative Technology Alliance
RDECOM ... Research, Development and Engineering Command
RDECs..... Research, Development, and Engineering Centers
RDT&E ..... Research, Development, Testing and Engineering
REF ..... Rapid Equipping Force
RSAF..... Rotorcraft Survivability and Assessment Facility
RWS ..... Remote Weapon Station
S4..... System of Systems Survivability Simulation
S&E ..... Science and Engineering
S&T ..... Science and Technology
SAM ..... Separate Absorption and Multiplication
SBIR..... Small Business Innovation Research
SEDD..... Sensors and Electron Devices Directorate
SEI..... Surface/Electrolyte Interface
SiC..... Silicon Carbide
SLAD ..... Survivability/Lethality Analysis Directorate
SOCOM ..... Special Operations Command
SoS..... System of Systems
SRIs ..... Strategic Research Initiatives
SSCBs..... Solid-State Circuit Breakers
STACA ..... Science and Technology Acquisition Corps Advisor
STAT ..... Science and Technology Assistance Teams
STEED ..... Statistical Translation Engine for English-to-Dari
STEM ..... Science, Technology, Engineering and Mathematics
STTC..... Simulation and Training Technology Center
STTR..... Small Business Technology Transfer Program
SUGVs..... Small Unmanned Ground Vehicles
SUVOS..... Semiconductor Ultraviolet Optical Sources
Ta..... Tantalum
Ta-W ..... Tantalum-Tungsten
TA&T ..... Technology Assessment and Transfer
TAC BIO..... Tactical Biological
TARDEC ..... Tank Automotive Research, Development and Engineering Center
TB..... Terabyte
TFT ..... Thin-Film Transistor
TMS..... Trust Management Systems
TRAC ..... Training and Doctrine Command (TRADOC) Analysis Center
TRADOC..... Training and Doctrine Command
TRL..... Technical Readiness Levels
TTAs ..... Technology Transition Agreements
UD-CCM..... University of Delaware-Center for Composite Materials
UGS ..... Unattended Ground Sensors
USD/I..... Under Secretary of Defense for Intelligence
UV..... Ultraviolet
VTD..... Vehicle Technology Directorate
VTOL..... Vertical Take-Off and Landing
WBG..... Wide Bandgap
WMRD ..... Weapons and Materials Research Directorate
WSMR..... White Sands Missile Range

Managing Our Portfolio

We live in a dynamic and rapidly changing world both in terms of scientific advancement and in the challenges our Warfighters face around the world. The pace of technological change is dramatic and is evident even to the casual consumer of electronics. At the same time, our adversaries on the battlefield are adapting their methods just as rapidly in response to our technology and rules of engagement. It is incumbent on us to constantly monitor the scientific and technology landscape to ensure our research is relevant and to capitalize on emerging areas of research and technology that can give our Soldiers the best chance to succeed and survive on the battlefield.

Surveying the field is important, but if we don't act on the information we have failed. We must maintain the flexibility to adjust our research programs to adapt to changing reality. Section 219 of the FY2009 National Defense Authorization Act (NDAA) provided much needed help to this end. This section, gives DoD laboratory directors the authority to use up to three percent of all available funds for the purpose of funding innovative research, transitioning technology to the field, and workforce development. The FY2010 NDAA added minor construction projects to that list.

ARL has taken full advantage of this authority. In particular, we use several different programs to fund new innovative, high-risk projects, interdisciplinary strategic initiatives and quick reaction projects to support the current fight. Funded projects that show promise are then moved into our core funding mix.

In addition to our efforts under Section 219, every year we take a hard look at how we might realign our limited resources to either enlarge our current investment in a research area or embark on something new. Two such areas into which we are moving additional resources are information assurance and data to decision. Our information assurance effort will focus on developing adaptive / self protective networks and applications against any type of cyber attacks while providing secure access to tactical Global Information Grid (GIG) applications with smart devices by utilizing clouds and pervasive computing services. Our data to decision effort will focus on developing the capability to structure and combine information from widely disparate sources that enables human understanding and decisions without causing information overload.

Our focus is on providing scientific and technological advances in support of the Warfighter. We do this best by maintaining a vibrant, evolving and relevant research portfolio.

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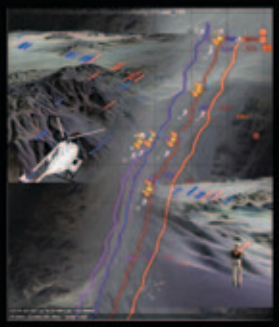

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