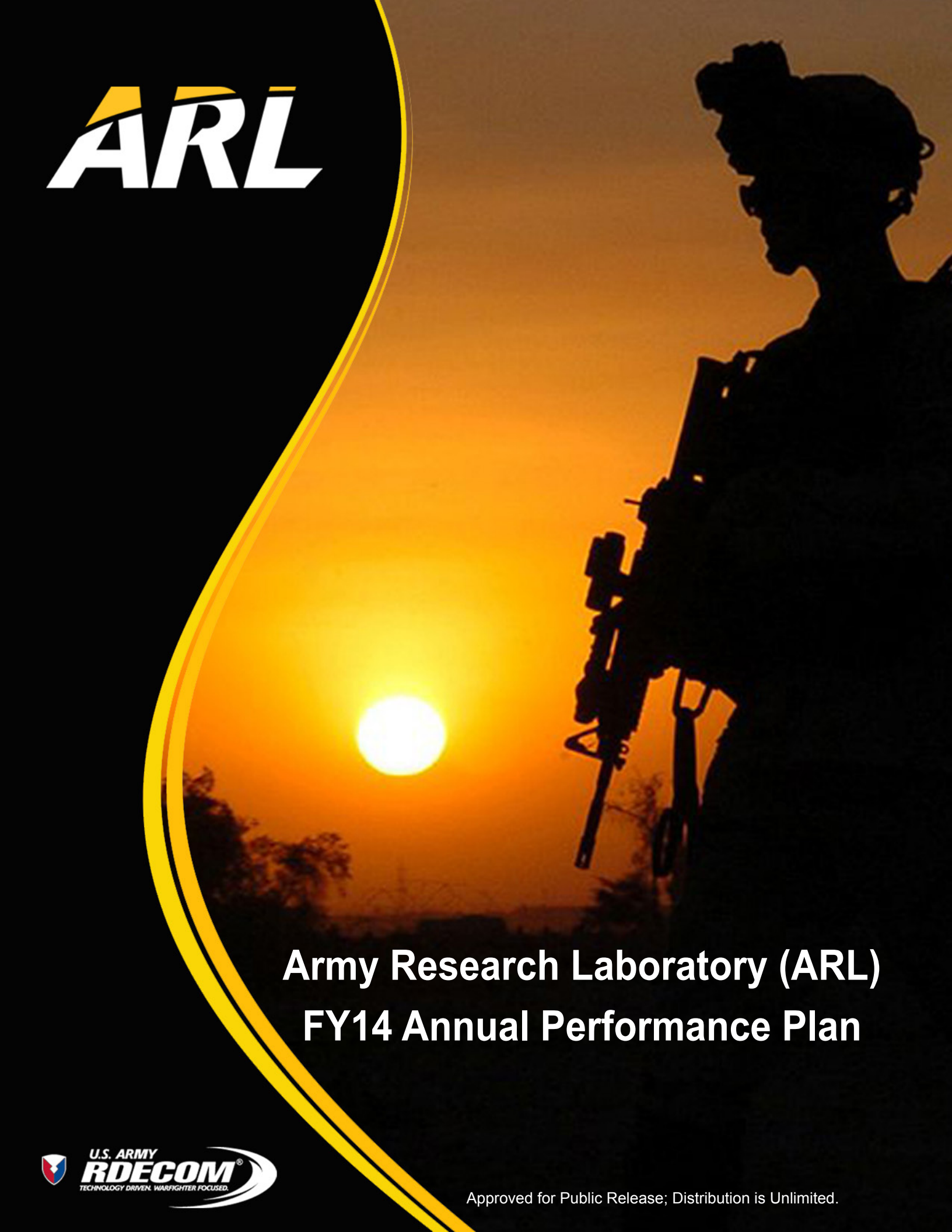

Army Research Laboratory (ARL)
FY14 Annual Performance Plan

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FY14 Annual Performance Plan

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FOREWORD

The ARL mission is to ***"Provide innovative science, technology, and analyses to enable full spectrum operations."*** We provide the technological underpinnings to the systems being developed by our customers and perform the research that will result in new product lines and technology breakthroughs to ensure the Army's technological superiority.

The FY14 Annual Performance Plan (APP) articulates ARL's key FY14 technical objectives aligned to our Major Laboratory Programs (MLPs). The FY14 APP represents a transition year for ARL planning as we are currently in the process of revising the ARL long term Science & Technology (S&T) strategy based upon a series of S&T campaigns designed to shape and ensure Army land dominance in the near, mid and far term (i.e., 2030). As the FY14 APP is published, ARL is concurrently developing both the corporate strategy and specific S&T focused campaigns. The S&T planning documents will be completed in late spring of FY14, such that the FY15 APP will complete the transition and fully align with the new S&T campaigns and strategies.

The Performance Plan is organized into six sections. After an introductory section that describes our approach to business planning and performance evaluation, Section 2 contains ARL's key technology mission objectives and, wherever possible, the quantifiable deliverables against which our performance can be objectively verified and validated. Section 3 contains ARL's personnel objectives to maintain a high quality staff. Section 4 describes infrastructure and equipment objectives. Section 5 is a summary of the ARL FY14 budget. Section 6 describes ARL's performance evaluation approach and contains corporate performance metrics.

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1. Introduction

The Army Research Laboratory (ARL) of the Army's Research, Development and Engineering Command (RDECOM) is the Army's corporate or central laboratory for material technology. Its diverse assortment of unique facilities and its 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 primarily of basic and applied research (6.1 and 6.2), advanced technology development (6.3), 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 assist the Army Research, Development, and Engineering Centers (RDECs), Program Executive Offices (PEOs)/Program Managers (PMs), and Industry in supporting ongoing development and acquisition programs.

ARL consists of six directorates, the Army Research Office and the WIAMan program office. These offices focus on the following technology areas which are critical to strategic land dominance across the entire spectrum of operations:

- **Army Research Office (ARO)** – initiates the scientific and far-reaching technological discoveries in extramural organizations: educational institutions, nonprofit organizations, and private industry.

- **Computational and Information Sciences Directorate (CISD)** – conducts a broad spectrum of research, focuses on corporate information architecture, and manages ARL's business and high performance computing assets. Scientific research areas include network and information science, high bandwidth communication, advanced command and control techniques, battlefield visualization, weather decision aids, and defensive information operations.

- **Human Research and Engineering Directorate (HRED)** – conducts a broad-based program of scientific research and technology development directed into three focus areas: (1) enhancing the effectiveness of Soldier performance and Soldier-machine interactions in mission contexts; (2) providing the Army and ARL with human factors integration leadership to ensure that Soldier performance requirements are adequately considered in technology development and system design; and (3) enhancing the Soldier experience in training environments, increasing training system performance and cost-effectiveness, and increasing Army analysis capability through advanced simulation technology capabilities.

- **Sensors and Electron Devices Directorate (SEDD**) – scientific research and technology in electro-optic smart sensors, multifunction radio frequency (RF), autonomous sensing, power and energy, and signature management directed towards reconnaissance, intelligence, surveillance and target acquisition (RISTA), fire control, guidance, fuzing, survivability, mobility, and lethality applications.

- **Survivability/ Lethality Analysis Directorate (SLAD)** – integrated survivability and lethality analysis of Army systems and technologies across the full spectrum of battlefield threats and environments as well as analysis tools, techniques, and methodologies.

- **Vehicle Technology Directorate (VTD**) – scientific research and technology addressing vehicle propulsion, platform mechanics, autonomous systems, and reliability for air and ground vehicles to enhance Army mobility and logistics capabilities.

- **Weapons and Materials Research Directorate (WMRD**) – scientific research and technology in the areas of weapons, protection, and materials to enhance the lethality and survivability of America's ground forces.

- **WIAMan Project Management Office -** execute RDECOM-led project to develop and transition an improved injury assessment capability for mounted Soldiers subjected to the effects of under-body blast. This capability is intended for use in DoD Live Fire Test and Evaluation but research products will also enable enhanced means for Soldier protection. Project elements include biomechanics research, an Anthropomorphic Test Device (ATD, a.k.a. crash-test dummy) that is purpose built for use in the military under-body blast environment, data acquisition system technology, signal processing, and human injury analysis techniques.

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 Research, Development, and Engineering Centers (RDECs) and to other Army, Department of Defense (DoD), government, and industry customers.

The Army relies on the Army Research Laboratory (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.

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, Army Top Challenges, Program Objective Memoranda guidance, Defense Planning Guidance, Defense Research and Engineering Goals, Defense and Army Science Board results, future capability requirements from Training & Doctrine Command (TRADOC), analysis needs from the Army Test and Evaluation Command (ATEC), TRADOC, and Joint Technical Coordinating Group for Munitions Effectiveness **(**JTCG-ME); and technology needs of the RDECs and Centers, the PEOs/PMs, other Services, Defense Advanced Research Projects Agency (DARPA), Special Operations Command (SOCOM), US Army Intelligence & 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. We have implemented a performance evaluation approach to measure the outcomes and outputs of research, and a comprehensive business planning process specifically tuned to our unique environment.

The purpose of the ARL performance evaluation approach is to measure (1) relevance, (2) productivity, (3) quality, and (4) the research environment. Peer Review, Customer Evaluation (feedback) and Metrics are the three performance measures that are used. Peer review is performed on primary mission areas by a Technical Assessment Board (TAB) from the National Research Council (NRC) of the National Academies of Science and Engineering. The extramural basic research program undergoes peer review by technical Boards of Visitors, one for each of ten scientific disciplines. Customer evaluation is performed by a formal customer survey process and the metrics' process. Figure 1.1 shows the application and relationship of performance measures to areas being measured. More detail about ARL performance evaluation can be found in Section 6, Performance Evaluation.

Figure 1.1

ARL has developed a comprehensive business planning process that is tied to specific executive reviews and the annual budget cycle. Business planning consists of four phases. First, strategic planning lays out ARL's mission, vision, corporate strategic goals, and organizational technology thrusts. Here, the external environment is laid against our internal strengths and weaknesses in order to validate corporate-level decisions. Next, long-range planning addresses in detail the five-year Program Objective Memorandum (POM) period. This phase expands on the strategic goals by aligning resources to major elements of the planned ARL program. This final plan, the Annual Performance Plan, describes tasks and deliverables expected from each of our directorates over the next 12 months as a result of our planning. The Annual Performance Report, published after the end of the year, assesses how well the specific plans outlined in this Annual Performance Plan were met. Figure 1.2 shows the four phases of the planning process.

Figure 1.2 ARL Planning Process

2. Mission Accomplishment

ARL's fundamental mission is to provide technologies that revolutionize the capabilities of America's Soldiers now and into the future.

To achieve this objective, ARL will pursue the following six goals to strengthen the Army's research program:

- Provide scientific leadership for a collaborative research enterprise.
- Attract the Nation's best S&Es to contribute to and lead Army research.
- Ensure coherence and balance in the ARL research portfolio.
- Foster connections between Army researchers and the Army community.
- Maximize the discovery and innovation potential in the ARL research environment.
- Identify and execute opportunities to transition technologies for the Future Force.

Aggressive and innovative technology solutions are required to transform the Army into a force that is more strategically responsive and dominant across the entire spectrum of operations. ARL plays a key role in providing the technologies necessary to support the Army's Current and Future Force. The products of this technology development and analysis will be used by the RDECOM RDECs, PEOs, PMs, and other customers. ARL supports the Army's Test and Evaluation strategy as reflected in the Army Test Resources Master Plan (ATRMP). ARL supports the Army's Science and Technology strategy as reflected in the Army Science and Technology Master Plan (ASTMP).

ARL also identifies technology objectives through Technology Program Agreements (TPAs). TPAs are developed cooperatively by ARL and its principal direct customers, the RDECOM RDECs (and specified equivalents). They describe the products, schedules, and resources required to satisfy the customers' technology and analysis needs. ARL corporately commits to apply 40 to 60 percent of its annual 6.1 and 6.2 mission funds to the TPA program.

FY14 ARL mission accomplishment performance goals follow:

- Meet 80% of Major Laboratory Program technical objective goals.
- 40-60% of mission program covered by TPAs with substantive deliverables and effective schedule.
- Meet 90% of TPA performance goals.
- Mission-funded research program shows evolution as evidenced by at least 10% of resources reprogrammed to new / reoriented research goals.
- Effective Director's Research Initiatives (DRI) program executed with 20% of projects transitioning into mission research effort.
- Effective Director's Strategic Initiatives (DSI) program executed with 50% of projects transitioning into mission research effort.

a. Major Laboratory Programs (MLP)

ARL's long-term direct mission investments are aligned with ARL's ten MLPs to address the Army's capability gaps and requirements as identified by the Army Training and Doctrine Command (TRADOC). Each MLP is further subdivided into tier 2 competencies as shown in Figure 1.3.

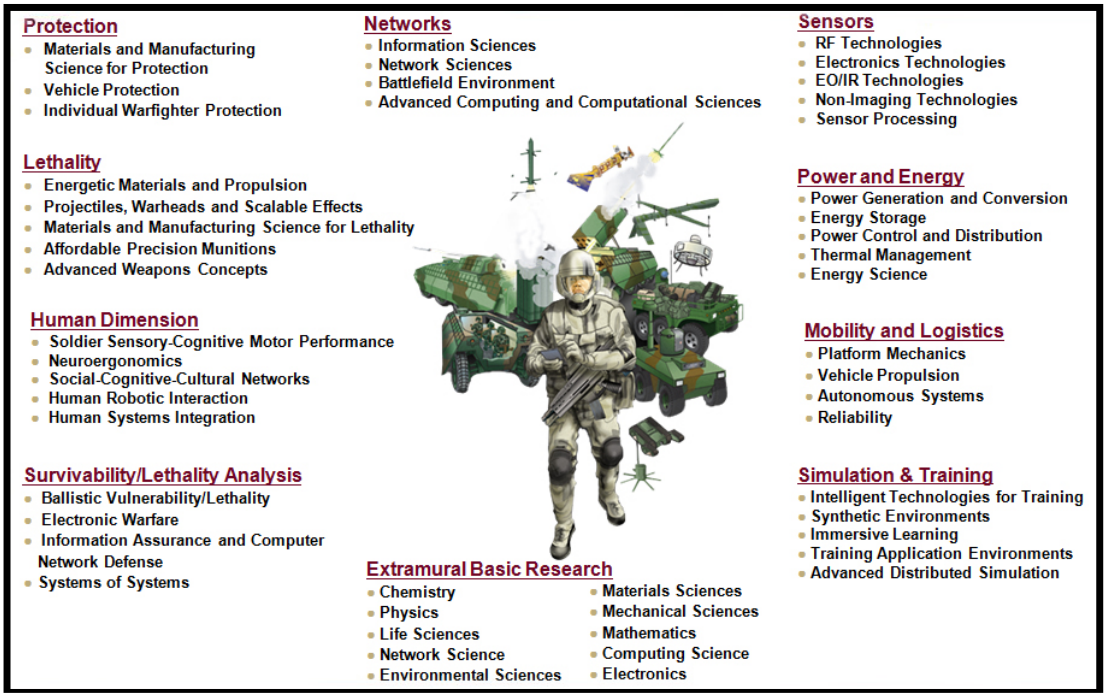


Figure 1.3 ARL Major Laboratory Programs

b. S&T Campaigns

As the FY14 APP is being published, ARL is in the process of developing a series of S&T Campaigns, which will focus our future S&T to create new foundations for disruptive technologies and solve formerly unsolvable problems. The eight S&T campaigns are:

- ***Extramural Basic Research***
- ***Human Sciences***
- ***Information Sciences***
- ***Sciences for Lethality and Protection***
- ***Sciences for Maneuver***
- ***Material Sciences***
- ***Computational Sciences***
- ***Assessment and Analysis***

Because these campaigns are still under development, the FY14 APP is not fully aligned to them. However, it is planned that the FY15 APP will be fully aligned to ARL's newly developed S&T campaigns, and the ARL Major Laboratory Programs taxonomy will no longer be used.

c. Corporate Initiatives

As the FY14 APP is being published, ARL has developed new Corporate Initiatives designed to focus on the most important strategic areas for the laboratory. Corporate Initiatives will typically start with a study led by a senior leader to investigate a specific area deemed to be of critical interest to the laboratory, and then will be followed by an implementation plan focused on executing the recommendations from the study. The length of the study will generally not be longer than 9 – 12 months, and the implementation plan should cover not more than a three (3) year period. As examples, the first of the Corporate Initiatives include an ARL-wide skill sets analysis, an examination of ARL's Business Intelligence posture, an assessment of ARL's methodology for research portfolio development, and the initiation of actions that could lead to a new "open campus" environment.

d. Director's Strategic & Research Initiatives (DSI & DRI)

The DRI Program is a small, "out-of-the-box" effort that annually identifies and provides seed funds for bold, high-risk research ideas proposed by ARL researchers. Projects are rigorously evaluated, and approximately 25% of the most promising ideas are selected for funding in an annual competition. Funding for each DRI project is $250K/year maximum for up to three years.

To promote collaborative, multi-disciplinary, higher risk fundamental research, ARL's Director has established the DSI program. DSIs are annually identified as opportunities/future areas that can expand or establish core competencies in support of ARL's Major Laboratory Programs. DSIs provide an opportunity to attract new researchers and allow for growth opportunities, which, if successful, would be funded in follow on years by a Directorate's mission program.

These initiatives will have the long-term potential to deliver unprecedented capabilities for the Solider.

A DSI project is funded by the ARL Director, at $500K - $1000K/year, for up to three (3) years for newly evolving (revolutionary) research areas resulting from either new starts or branches from existing investments within the Director's Strategic Research Initiative Topics (SRI). The new and continuing DSI projects for FY14 are:

Continuing DSIs

1. A Quantum Network with Atoms and Photons (QNET-AP)
2. High Temperature Thermal-to-Electric Energy Conversion
3. Metamaterial and Metastructural Architectures for Novel Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Sensors and Devices with New Capabilities Spanning the Frequency Range from Microwaves to the Infrared (IR)
4. Understanding and Exploiting the Electronic Interface in Stacked 2D Atomic Material Layers
5. Understanding Effects of Traumatic Insults on Brain Structure and Function

New DSIs

1. Heterogeneous Systems in Information Variable Environments (HIVE)
2. Field-Induced Texturing of Ceramic Materials for Unparalleled Properties

e. Partnerships and Collaboration

The Army Research Laboratory (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 among which are contracts, grants, cooperative agreements, Cooperative Research and Development Agreements (CRADAs), etc. Our interactions can be with individual organizations or with multiple organizations across the S&T community. Approximately 70% of ARL's total revenue is executed with external partners.

- **Extramural Research** – ARL has a strong linkage to the academic community through the Single Investigator Program, the Multidisciplinary University Research Initiative (MURI) Program, and University Affiliated Research Centers (UARCs). In FY14, ARL anticipates an extramural basic research program with over 1100 Single Investigator and

59 MURI grants associated with over 250 university partners in all 50 states. This extramural research seeks to discover and exploit new scientific opportunities and technology breakthroughs in the physical sciences (physics, chemical sciences, life sciences and social sciences), the engineering sciences (mechanical, electrical, materials, environmental), and information sciences (network sciences, mathematical sciences, and computing sciences). ARL will continue to work closely with its three University Affiliated Research Centers (UARCs) partners addressing basic research in Nanotechnology, Biotechnology, and Creative Technology (immersive training technology) and its two Centers of Excellence (COEs) in Flexible displays, and the Army High Performance Computing Research Center (AHPCRC).

- **Collaborative Technology Alliances and Research Alliances** – ARL has four Collaborative Technology Alliances (CTAs) in the areas of Network Science, Micro-Autonomous Systems and Technology, Neuroergonomics, and Robotics. The CTAs involve partnerships between industry (lead), academia, small business, Historically Black Colleges and Universities/Minority Institutions (HBCU/MIs), and ARL. They leverage the large investments being made by the commercial sector in basic research areas of interest to the Army. As part of the ARL Enterprise for Multiscale Research of Materials, ARL initiated two academia led Collaborative Research Alliances (CRA) - Materials in Extreme Dynamic Environments (MEDE) and Multidisciplinary Modeling of Electronic Materials (MSME). In late FY13, ARL established the Cyber Security CRA. ARL and the UK Ministry of Defense (MOD) have also joined in a landmark collaborative venture known as the International Technology Alliance (ITA) in Network Sciences.

- **Small Business Innovative Research (SBIR)** – ARL works with the small business community through the Small Business Innovative Research (SBIR) program. The SBIR program provides small business an opportunity to provide high-quality research of innovative concepts to solve Army/Department of Defense (DoD) related scientific or engineering problems, especially those concepts that also show high potential for commercial use. ARL will execute an approximate total of 105 SBIR actions for Phase I, II, and IIE efforts in FY14.

- **Cooperative Research and Development Agreements (CRADA)** – In FY14, ARL expects to have about 50 active traditional CRADAs and about 25 short form CRADAs, but additional amendments will increase the total number of projects. New starts for FY14 CRADAs will include, but are not limited to, the following subject matter: Enhanced Autonomy Using a Self-Contained Rotorcraft; Mobile Landing Platform and Dexterous Manipulator Package**;** Development of Contoured Transparent Armor System; Micrometeorological Modeling and Measurements; and Diagnostics for Imaging of Key Chemical Species in High-Pressure Combustion; Multi-task CRADAs with ATK, Johns Hopkins U./Applied Physics Laboratory, BAE, Boeing, and DuPont will continue to produce many additional projects.

- **Test Service Agreements (TSA)** – Based on previous year's performances, ARL will execute approximately 20 TSAs in FY14, and will actively seek partnering opportunities to enable industry leveraging of ARL's extensive unique test facilities and capabilities.

The technological focus for FY14 continues to be centered on ARL's ballistic and materials capabilities.

- **International Collaboration** – International armaments cooperation has the potential to significantly improve interoperability for coalition warfare, leverage other program resources, and obtain the most advanced, state-of-the-art technology from the global technology and industrial base.

  ARL recognizes that armaments cooperation programs offer unique opportunities for promoting U.S. security and technology advancement. To meet these objectives ARL has collaborated with traditional foreign allies and reached out to new foreign partners. RDECOM is the proponent for over 300 Data Exchange Annexes (DEAs), Project Agreements (PAs) and Memorandums of Understanding (MOUs) with foreign partners that are used to augment current R&D efforts and future military platforms. ARL is the proponent for a subset of these programs in the RDECOM portfolio but leverages all means to engage with foreign partners.

  ARL leverages international programs and fora to help foster personal relationships, solidify future collaborations between nations, and enable Army systems with cutting edge technologies. ARL is an active participant in the Engineer and Scientist Exchange Program (ESEP), Coalition Warfare Program (CWP), Foreign Technical Assessment Support (FTAS) Program, Foreign Comparative Testing (FCT) programs, The Technology Cooperation Program (TTCP), and North Atlantic Treaty Organization (NATO) S&T working groups.

  ARL provides support to the nine RDECOM International Technology Centers (ITC) located around the globe. These offices are staffed with engineers and scientists that execute RDECOM's tech search and international S&T engagement missions. The ITCs offer boots on the ground visibility to identify novel/emerging technologies as well as coordination of subject matter expert/distinguished visitor (SME/DV) engagement opportunities.

  ARL is developing a comprehensive, pro-active approach to international collaboration. The International Strategy Group (ISG) has laid the ground work to support long-term cutting-edge collaborative research partnerships. This body is aligned with the DRI and DSI programs to promote international collaboration on approved in-house projects. ARL will conduct surveys of global state of the art programs and research facilities relevant to its new Collaborative Research Alliances on Materials in Extreme Dynamics Environments (MEDE) and Multi-scale Modeling of Electronic Materials (MSEM). ARL shall seek to further expand its global outreach through an increase in basic research investments in foreign academia. This will be facilitated by the placement of ARL program managers in strategically located OCONUS (Outside the Contiguous United States) offices.

  New project agreements are anticipated with Singapore on Soldier-portable fuel cells; with Germany on lightweight magnesium body armor and tactical information processing; and with Israel on radio frequency (RF) fiber links for sensor processing, novel solid-state lasers, and blast testing on the Namer armored vehicle with

anthropomorphic test dummies. Collaboration under the new Project Arrangement (PA) with Germany on Weapons Effects in Urban Terrain will be actively pursued through computational studies and complementary experimental investigations at German facilities during the year. The Netherlands also wishes to participate in this project, and it is expected to be expanded into a trilateral effort involving all three countries under a new Memorandum of Agreement.

ARL will continue to benefit from the extensive research in network science performed by the Network and Information Science Consortium formed under the International Technology Alliance (ITA) with the United Kingdom (UK). This program is now in its second five-year phase. The success of the basic research program has led to several spin off applied research programs and field tests, including two CWP funded collaborative research programs demonstrating the interoperability of disparate US/UK intelligence, surveillance and reconnaissance assets, and policy-controlled data/information sharing in a realistic coalition operational environment.

f. Technical Objectives (by MLP)

Protection

Materials and Manufacturing Science for Protection

The objective of this research is to develop and apply multi-scale, multi-disciplinary computational approaches to address the need for on-demand materials-by-design across all materials classes (i.e. metals, ceramics, polymers, and composites). In FY14, the goals are to: 1) develop advanced materials and manufacturing solutions for efficient ultra-lightweight protection of Soldiers in extreme environments and their equipment, including ground and air vehicles; 2) explore new characterization techniques for multi-axial high rate evaluation of single fibers, enabling rapid screening of potential high performance fibers; 3) validate experimental and computational methods for predicting failure in armor ceramics; 4) produce new computational tools for fabric armor simulation designed to predict the ballistic response of soft armors; 5) demonstrate unique material properties resulting from intense energetic fields; and 6) investigate material processing techniques utilizing these intense energetic fields and their ability to produce new materials with properties and functional behavior not achievable with conventional methods.

Vehicle Protection

The objective of this work is to develop multi-threat hybrid armor technologies incorporating both active and passive mechanisms for ground vehicle systems that are effective against future conventional weapons and evolving improvised threats. Research also involves experimental and computational development to create tools, techniques, and technologies for protection against mine/ Improvised Explosive Device (IED) blast threats, ballistic shock mitigation, and fuel/ammunition fires to enable survivability of current and future platforms. In FY14, the goals are to: 1) develop ceramic laminate technology, large improvised threat protection, and second generation multi-threat protection; 2) pursue a new understanding of encapsulated ceramic mechanisms capable of defeating advanced kinetic energy (KE) threats by coupling modeling and simulation techniques with experiments; 3) develop hardened vehicle hull designs using

advanced modeling tools developed by the Ballistic and Blast Loading Highly Scalable Software Institute; 4) mature long-stroke seat technology and multi-directional seating mechanisms to further enhance interior vehicle protection; 5) capture blast emissions across the Electromagnetic (EM) spectrum and match with appropriate sensors to provide pre-activation of active seats or exterior hull protection mechanisms; 6) begin exploration and concept development of novel adaptive protection, including counter measures, threat warning capabilities, and dynamic threat maps.

Soldier Protection

The objective of this work is to develop unique physics based models to quantify the relationship between blast and ballistic insult, injury, human response, and warfighter performance, with a primary focus on understanding the complex target interactions that occur between threats and personal protective equipment. Critical challenges to be addressed include maximizing mobility while dealing with expected threat growth, understanding terminal effects impact on biological processes, and providing protection in a complex ballistic and blast environment. In FY14, the goals are to: 1) demonstrate new techniques for measuring the response of biological materials at high rates of loading that cause severe deformation and failure; and 2) develop low technology readiness level (TRL) concepts for personnel protection equipment (PPE) that are based on computational simulations of the interaction of humans with the dynamic threat/PPE impact.

Lethality

Materials and Manufacturing Science for Lethality

The objective of this research is to refine our understanding of material behavior and properties at very high strain rates that often exceed failure limits and extremes of temperature. In FY14, the goals are to: 1) develop powder production technologies for reliable, cost-effective production of nano-crystalline tungsten; and 2) demonstrate environmentally friendly binder materials for tungsten carbide.

Lethal and Scalable Effects

The objective of this work is the creation of models and multi-purpose technologies aimed at reducing the energy and/or mass required to defeat emerging armor threats and to develop methods for scaling warhead lethality to enhance urban warfighting capabilities, including control of collateral damage. In FY14, the goals are: 1) conduct proof of principle experiments for man portable weapons that demonstrate capability to perforate wall targets, including double reinforced concrete and adobe; 2) conceptualize variations in novel penetrator deployment schemes and conduct laboratory experiments to understand how deployment variations affect lethality performance; and 3) explore novel ways of using the additional energy provided by new high velocity gun concepts against various targets.

Disruptive Energetics and Propulsion Technologies

The objective of this research is the discovery and invention of novel energetic materials and their use in explosives and propulsion technologies, with the overarching aim to provide the DoD with weapons possessing orders of magnitude enhancement in performance. In FY14, the goals are to: 1) synthesize two new energetic compounds (binder and explosive) that exhibit increased

energy compared to current CHNO (carbon, hydrogen, nitrogen, oxygen) compounds, such as trinitrotoluene (TNT); 2) experimentally quantify new energetic materials with new cost saving small scale techniques; and 3) demonstrate propellant improvements for small arms ammunition.

Low Cost Hyper Accurate Weapons

The objective of this research is to develop a basic understanding of the complex flow fields of maneuvering projectiles; maneuver mechanisms, their associated fluid dynamics, and effects these have on projectiles and navigation algorithms for guidance to the target with the goal of enabling a broad spectrum of future affordable direct and indirect fire precision munitions. In FY14, the goals are to: 1) implement newly derived optimal terminal homing guidance laws and flight control algorithms in simulation codes; and 2) conduct parametric studies across a range of attack angles to quantify resulting control effectiveness to more cost effectively and accurately hit targets.

Soldier Lethality

The objective of this research is the development of advanced lethal mechanisms and improved accuracy of Soldier-based weapons systems using nonstandard approaches to enable significant increases in impact velocities while reducing muzzle pressures, achieving weapon cycling at increased chamber pressures, and maximize bore travel while maintaining weapon compactness. In FY14, the goals are: 1) explore constricted caliber concepts and high pressure gun propulsion to achieve higher energy and range; and 2) develop modeling techniques that couple interior ballistics modeling with structural simulations of deformable projectiles.

Sensors

EO/IR Technologies

The objective of this research is to design materials and concepts for semiconductor device technology for Army sensors. In FY14, the research will develop the growth, characterization and electromagnetic modeling of materials for long wave infrared (LWIR) detectors as well as promote the design of sensor and flexible electronic technologies to support electronic warfare and concealed threat detection. FY14 Goals: 1. Investigate long wave infrared (LWIR) two color IR detectors using combinations of bulk materials and artificially layered structures; 2. Establish detector performance parameters for direct bandgap InAsSb; 3. Model and exploit electromagnetic resonant effects to design and fabricate high quantum efficiency (up to 70%), large format, long wavelength, quantum well infrared photo-detector (R-QWIP) focal plane arrays; 4. Demonstrate a RF photonic time domain correlation channelizing receiver in an ultra-wideband, adaptive Electronics Warfare Signals Intelligence (EW SIGINT) system for use in the Tactical SIGINT Technology (TNT) Program; 5. Research organic devices, materials, and diodes for large area radiation and particle sensors utilizing charge transfer electro-chemical design for flexible electronic applications; and develop flexible electronics printing and processing capability; 6. Develop flexible electronic sensor devices for Army applications, such as large area X-ray radiation sensor and a large area Ultraviolet - Visible photodiode; 7. Grow and characterize gallium nitride materials for extending the spectral range of ultraviolet (UV) detectors to wavelengths of 230-365 nm; 8. Use infrared photo-acoustic spectroscopy to identify explosive materials.

RF Technology

The objective of this research is to develop component technology and signal processing algorithms to support cognitive RF architectures which will allow RF systems to adapt to RF interference. In FY14, the research will design Gallium Nitride (GaN) devices and power amplifiers, wideband antenna elements and arrays, microelectromechanical systems (MEMs) resonators and filters, and advanced signal processing/classification algorithms. In addition, this will support the proof-of-concept design to demonstrate the interoperability of an improvised explosive detection and neutralization for the detection and neutralization of improvised explosive devices on a single platform. FY14 Goals: 1. Wideband, Reconfigurable Transmitter: Design and prototype an integrated power array module with a wideband aperture, high power GaN amplifier, and an integrated waveform synthesizer. Validate and baseline power aperture requirements for operating in non-linear radar and neutralization modes. Extend baseline design for a single antenna element in order to meet array directivity and scanning requirements specifically addressing distributed timing and control between elements; 2. High Sensitivity, Robust Receiver: Design and prototype a highly sensitive harmonic receiver module consisting of a directive aperture, low noise power gain stage and tunable MEMS based filters for reception and processing of target returns. Demonstrate lab base configuration equipment for early base lining of detection algorithms. Investigate integrated receiver processing solutions for adaptive detection scenarios; 3. Algorithm: Investigate algorithms for detection, geo-location, and classification of IEDs. Conduct laboratory experiments to demonstrate detection of target returns in the presence of system generated noise and clutter.

Signal and Image Processing

The objective of this research is to develop techniques that provide actionable information to the Soldier through processing of data from sensors. In FY14, the research will demonstrate the development of algorithms for anomaly detection, scene understanding from image and video data, data fusion, acoustic signal classification, and electric and magnetic field pattern recognition. FY14 Goals: 1. Investigate unsupervised techniques to improve accuracy of automatic detection of human targets in cluttered scenes in static electro-optical/infrared (EO/IR) imagery; 2. Research fusion techniques to identify and improve the accuracy rate of spatiotemporal behaviors of human and vehicle targets in complex scenes from hyperspectral, EO/IR, and LIDAR sensor data; 3. Investigate low frame rate processing techniques to improve aggregate metric for object tracking in wide area motion imagery; 4. Improve acoustic classification of transient threats by applying Markov switching vector autoregressive and support vector machine techniques; 5. Demonstrate real-time detection and classification of electric load targets using phasor processing (no current capability exists).

Emerging Research

The objective of this research is to explore Bio-science, Quantum Science, Nano-Electronics, and Multi-scale Modeling for scientific impact and disruptive technologies. In FY14, the research will demonstrate synthetic biology techniques to improve performance of biological and energetic threat detection sensors operating in extreme environments. In addition, Raman techniques will be explored to control cold atoms and atomic spin for future applications, such as position, navigation, and timing in global positioning system (GPS) denied environments. FY14 Goals: 1. Demonstrate Bose Einstein Condensate (BEC) on chip; 2. Study decoherence mechanisms and optical Raman techniques to coherently control cold atoms and atomic spin; 3.

Measure the optical spectra of energetic and energetic-related materials using ultra fast laser spectroscopy techniques; 4. Use synthetic biology and previous genetic sensing constructs for engineer, sense, and respond module for neutralizing biological contamination; 5. Develop 2nd generation peptide recognition elements using iterative processes involving computational modeling coupled with experimental characterization for materials that perform in extreme environments; 6. Evaluate protein capture agents and synthetic bio-molecules as materials to improve stability and affinity for overall environmental tolerance.

Power and Energy (P&E)

P&E Generation, Management and Science

The objective of this research is to explore and develop storing, collecting, converting, and distributing energy. In FY14, the research will develop semiconductor/electrochemical material and device technology such as metamaterial, plasmonics, bandgap materials for energy storage, and conversion and harvesting. In addition, architectures for efficient power management and conditioning of future tactical energy networks will be explored. FY14 Goals: 1. Energy materials: Develop palladium and structured metallic catalysts for fuel processing. Explore using plasmonics and metamaterials for improved energy storage and conversion materials and devices; 2. Energy conversion and harvesting: Investigate novel structures and bandgap materials for direct energy conversion (for Photovoltaic (PV), Thermophotovoltaic (TPV), thermoelectric (TE)) devices. Explore integrated structures and designs for energy harvesting and conversion (3D microscale converter); 3. Energy networks: Investigate architectures for integrating intelligent power management and advanced power conditioning and distribution for future tactical energy networks. Develop dual intercalation, magnesium and/or sodium chemistries for inexpensive energy storage for energy networks.

Laser Technology

The objective of this research is to investigate, characterize, and develop materials for protection against lasers, UV LEDs/diodes, and high energy lasers. In FY14, the research will focus on the design and feasibility of a fiber laser, based on rare earth doped, double clad fibers, which will significantly improve thermal management that will lead to the achievement of advanced power scalability. In addition, material technology will be investigated to broaden the spectrum of laser protection, and extend the spectral range of UV lasers and light emitting diodes. FY14 Goals: 1. Demonstrate the feasibility of (Continuous Wave) CW, single aperture Raman fiber laser and all-crystal fiber lasers scalable to 10's kW; 2. Demonstrate a table top demo of single aperture, widely tunable mid-wave infrared (MWIR) laser for infrared countermeasure (IRCM); 3. Demonstrate a scale chirped diode laser seed technique to obtain multi kW power output from 1060 nm fiber amplifier; 4. Develop and fully characterize a new or derivative molecule, with a blue shifted absorption peak and a flatter absorption tail, with increased ground-state absorption in the red region, compared to our current platinum optical limiter molecule to better match the operating spectrum of the Tank, Automotive Research, Development and Engineering Center (TARDEC) Vision Protection Program demonstrator; 5. Integrate a photo-conducting semiconductor switch with a potassium tantalite niobate (KTN) inorganic crystal EO shutter, developed in FY13, and measure switching speed, with a goal of ~1ns; 6. Grow and characterize gallium nitride materials for extending the spectral range of UV lasers and light-emitting diode

(LEDs) to wavelengths of 230-365 nm; 7. Design and develop miniaturized components for high-resolution active imaging systems for higher range and angular resolution.

Networks

Network Science

The objective of this basic and applied research is to focus on self-configuring, self-healing, self-defending converged network technologies that enable secure, scalable, energy-efficient, and survivable networks. Such networks must continually adapt to cognitive needs of Soldiers, delivering decision-relevant information of high quality and trust, from widely distributed and dynamic sources, in environments that are austere, adversarial, mobile and disruptive. In FY14, the goals include (1) exploration and development of performance limits of unconventional communications networks in disadvantaged environments; (2) models of dynamic quality and trust in multi-genre networks, including formation of opinion in communicating groups, experimental validation of trust model, and algorithms for optimization of delivered information's quality; (3) advanced experimental methods for multi-genre networks, especially live-virtual-constructive representation of the tactical network; (4) methods for secure and cognitively-appropriate information exchange; (5) methods for detection and prevention of cyber attacks in bandwidth-constrained environments; (6) techniques of dynamic cyber defense with proactive identification of adversary's malware features and infrastructure; (7) models, algorithms, and protocols for cyber-security metrics, especially risk and resiliency of networks.

Information Sciences

The objective of this basic and applied research program is to research and develop supporting technologies to enable the timely fusion of information from all relevant sources for the Soldier at the edge, resulting in improved tactical decision-making. In FY14, the goals are to generate techniques to: (1) provide situational awareness to the Soldier in environments replete with information through intelligent information fusion algorithms; (2) provide information exploitation tools through the development of software and intelligent systems that can process locally or globally sensed information; (3) support the user in forecasting events through social network analysis tools; (4) integrate effective end-user interfaces; and (5) advance the maturation and understanding of emerging capabilities in document/image processing and interpretation. This research will enable the development of adaptive frameworks for real-time translation, algorithms to control and adapt behaviors of autonomous assets, software components for moving payloads through a hybrid Tactical/Cellular wireless networks, and automated social network generation tools with metrics for quality assessment to prioritize decision options.

Advanced Computing and Computational Sciences

The objective of this basic and applied research program is to conduct research and develop a technology-based program that advances the state-of-the-art in computational sciences by exploiting emerging research computing architectures, massively parallel computers, and tactical high-performance computing (HPC) platforms. In FY14, the goals of this program are to develop: (1) basic computational sciences scalable algorithms to advance computational materials by design; (2) interdisciplinary physics based computational methodologies for blast-

structure applications; (3) interdisciplinary scalable algorithms for large-scale DoD network simulations/emulation and big experimental data analytics; (4) advanced software integration techniques and scientific visualization tools; (5) advances in computer science to support systematic evaluation of future and notional warfare combat systems. One result of achieving these goals will be to expedite the acquisition process by encouraging maximum effective use of modeling and simulation with Army HPC assets in order to enhance the operational readiness of our land forces. This capability can then be easily leveraged by RDECOM RDEC's, Test and Evaluation commands, and Program Executive Office/Program Manager (PEO/PM) communities to enhance their development capabilities and products.

Battlefield Environment

The objective of this basic and applied research program is to conduct research in atmospheric science and develop technologies to provide actionable environmental intelligence at Army-scale in complex terrain and highly-localized areas that are crucial to the success of current and future operations. In FY14, the goals are to: (1) characterize the atmospheric boundary layer through theoretical investigations of aerosols as well as increase our understanding of the effects of the atmosphere on acoustics and electro-optic propagation through theoretical models and validation techniques; (2) mitigate atmospheric effects through the continued maturation of adaptive optics; (3) advance the research of atmospheric analyses and very-short-range predictions (Nowcasts) over mission-execution battle-space domains in complex terrain areas, and within urban environments, in order to develop weather forecast models operating at the Soldier scale, including the development of model accuracy assessment methodologies; (4) conduct research to advance the understanding of atmospheric dynamics down to the microscale, and the resulting effects on Army systems and operations in order to provide enhanced weather impacts decision support tools.

Mobility and Logistics

Platform Mechanics

The objective of this research is to explore innovative technologies and capabilities that will expand our understanding of the materials genome. This knowledge will benefit future aircraft structures by allowing them to withstand more severe military operational demands without incurring structural fatigue problems over the platform design life. In FY14, the goals are to: (1) identify two detectable and measurable damage precursors in metallic or composite materials, (2) identify the mechanical energy release rate of microscopic damage due to shear banding, matrix cracking, and fiber matrix debonding, (3) correlate the mechanical energy release rate response to acoustic emission signal/amplitudes (dB) within an 80% accuracy, (4) utilize a 3-D printing/additive manufacturing technique to produce three scaled-aircraft simple structural components incorporating a “Fatigue-Free Structures” concept, and (5) provide frequency based modeling and experimental validation for single base axial and rotational excitation. The focus on Aeromechanics will encompass: (6) experimental studies and a modeling and simulation development to improve flow control.

Vehicle Propulsion

The objective of this research is the advancement of innovative technologies that will enhance engines, drives and power transmissions, primary power combustion and fuels, and non-primary power based on combustion processes. In FY14, the goals are to: (1) develop techniques, processes, and tools to understand and improve the fuel injection spray and combustion characteristics of JP-8 and other alternative fuels under various temperatures and pressure conditions, (2) develop computational and experimental capabilities for modeling and simulating the spray and combustion process for JP-8 and alternative fuels, (3) conduct experiments and develop algorithms to achieve improved drive-train component performance, (4) create a conceptual framework for the engine materials state, (5) and perform experiments and analytical studies for a more a precise characterization of advanced turbine air cooling, Variable Speed Power Turbine performance, and the thermo acoustics of turbine engines.

Autonomous Systems

The objective of this research is to achieve increased levels of autonomy, robust mobility, and Soldier-assisting task performance capabilities over a broad range of platforms. This includes unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV), and micro-systems. In FY14, ARL will focus research on intelligent control, creating high-level capabilities that will enable semantic level reasoning and an emerging ability to divine intent from actions and context. ARL will explore novel modes of mobility, such as legged mobility and the manipulation of the environment which considers both mechanics and control. ARL will also explore the fundamental physical processes that impact micro-scale air vehicle flight, including the questions of aerodynamics, fluid-structure interaction, actuation, and control that are unique to this scale of vehicle. The FY14 goals are to: (1) develop an initial algorithm to successfully detect enemy contact in a simulated squad-level route reconnaissance mission. The algorithm will employ visual observations, mission knowledge, and positional information for the Soldiers and demonstrate its capability in one or more virtual scenarios. (2) Create a predictive performance capability for dynamic modes of unique mobility. Future unmanned systems may focus initially on jumping and rolling motion, and a validated model of predictive performance should be in the 90% accuracy range for ascertaining if an object will continue to roll when tipped over. (3) Demonstrate a bench top structural model employing active wing geometric adaptation. This is a precursor step to wind tunnel performance testing for micro-systems. The goal is to achieve a 20% change in wing aspect ratio through the use of dielectric elastic membrane actuators. (4) Provide technology integration and support resulting in successful experimentation and meeting project needs > 90% of the time. (5) Develop software for more robust and higher speed navigation of Packbots, communications maintenance, generation of mission specifications from natural language, multi-robot teaming with Soldier formations, semantic labeling of objects and activities, and recognition of previously visited locations.

Reliability

The objective of this research is vehicular reliability and focuses on the elements of total system, propulsion, and structural reliability. At the system level, the FY14 goals include: (1) Create an initial algorithm and procedure for estimating technology costs from multiple perspectives and various lifecycle points. (2) Develop a modeling and simulation (M&S) tool to assess and predict performance, reliability and the impact of various technologies on future capabilities. Within propulsion, tribology, surface, and interface science will be explored to improve

component reliability; M&S tools will be enhanced to better predict the reliability of engine and drive train components by integrating experimental data and analysis; and discoveries in high temperature materials and configurations will be made to improve engine and turbine performance. Structural research: innovative prognostics and diagnostics, and structural health monitoring technologies and capabilities will be improved to support the future implementation of Army Condition-Based Maintenance initiatives. The FY14 goals are as follows: (1) Verify the Recursive Probabilistic Method Integration (RPI)-based risk predictive code based upon five actual or test-simulated aircraft structural scenarios; (2) Formulate the original theory of distributed compressed sensing in the context of structural health monitoring incorporating structural mechanics and a compressed sensing algorithm; (3) Explore and establish technologies capable of conducting electrical impedance spectroscopy on carbon fiber composites as a means to predict remaining useful life. Also, establish a damage ratio index curve for electrical impedance spectroscopy; and predict the remaining life within 10% at 50% life.

Survivability and Lethality Analysis

Ballistic Vulnerability/Lethality

The objective of the analysis efforts is to fully understand the effects of weapons against materiel and personnel. Ballistic and blast experiments will be conducted to supply appropriate data and continue development of software tools to perform ballistic vulnerability/lethality (V/L) analyses. New analysis capabilities and improved processing times will enhance core V/L models, Modular Unix-Based Vulnerability Estimation Suite (MUVES), Ballistic Research Laboratory Computer Aided Design (BRLCAD), and Operational Requirements-Based Casualty Assessment (ORCA). Analysis of the lethality of U.S. weapons against foreign material and structures will be conducted. Investigations of the feasibility of novel techniques, such as acoustic fire suppression, to reduce the vulnerability of U.S. systems will also be preformed. Experimental and modeling techniques will be developed to allow assessment of injury potential from behind-armor blunt-trauma, including the development and application of under-body methodologies to generate estimates of vehicle response and occupant injury for up to six live-fire tests of ground systems. These activities will enable SLAD to recommend design improvements that will enhance the survivability of high-priority Army systems, drive design decisions by PMs, and inform formal evaluations.

Electronic Warfare

The electronic warfare (EW) objectives are focused on developing tools and methodologies to analyze the performance of systems in EW environments. Efforts include development of state of the art hardware, including Digital RF Modules (DRFM) and software methodologies and tools capable of application across a broad range of laboratories, hardware-in-the-loop simulations, controlled environments (anechoic chambers and reverberation chambers for example), and open air test ranges. These tools will then be utilized to analyze the performance of Army sensors, electronics, and communications and network systems in complex electromagnetic/electronic warfare (EW) environments. Derived performance data will be utilized to conduct assessments of systems capabilities and limitations while operating in a contested EW environment. For FY14, emphasis will be on the conduct of performance assessments of Air and Missile Defense and communication systems in an advanced DRFM based Electronic Attack (EA) environment.

Information Assurance and Computer Network Defense

The objective of this effort is to analyze the security of Army-specific systems, including off-the-shelf software and network technologies to identify specific vulnerabilities and recommend mitigations. This effort will involve analyzing hardware, software, and telecommunications protocols to identify vulnerabilities prior to test events. If vulnerabilities are found, tools, procedures, or threat exploitation methods will be developed. In addition, studies and analyses will be conducted to address threat technology; model real-world threat attacks; develop tools to portray threats, perform experiments, and test threat computer network operations against technologies and developmental or fielded systems. These methodologies and tools will be used during NIE 14.1 and 14.2 to analyze system vulnerabilities and provide specific findings to PMs and the Army Evaluation Center (AEC).

Systems of Systems

The objectives are to develop and apply methodologies and tools to model the performance of systems of systems at the engineering level to support the full range of force operating capabilities. This capability is crucial to assessment of technology and system tradeoffs to illuminate and evaluate survivability aspects of competing capability packages in a System of Systems (SoS) context. The realization of this capability is a modeling and simulation tool called the System of Systems Survivability Simulation (S4), which fills a critical and fundamental gap in the means to evaluate metrics (e.g., mission effectiveness, survivability, lethality and network operations) while developing reusable scenarios from the Company to Brigade level within restrictive budget limits. For FY14, one key technical objective is to deploy a tool enabling an analyst to run a version of S4 tailored for a Counter-IED route clearing missions. This version of S4 will enable the analyst to change performance parameters, run multiple simulations, and evaluate the results using user-selectable measures and metrics.

Warrior Injury Assessment Manikin (WIAMan)

The objective of the Warrior Injury Assessment Manikin (WIAMan) Project is to develop a new and scientifically valid capability for predicting injuries to mounted Soldiers that result from the vertical accelerative loads caused by under-body blast (UBB). The current capability is based on tools that were built for assessing injuries for frontal collisions of automobiles, and they are inadequate for the military environment and UBB. The project will create new fundamental understanding on the response and tolerance of the human body, specifically mounted Soldiers, in the UBB loading environment. This knowledge, and the requirements of the Title 10 Live Fire Test and Evaluation Program, will be used to develop concepts for an improved anthropomorphic test device (ATD) and the associated instrumentation that are needed to make valid measurements and assessments of the risk of musculo-skeletal injury to Soldiers. Prototypes of the improved ATD and instrumentation will be fabricated and refined to meet requirements for use in Title 10 Live Fire Test and Evaluation (LFTE). Injury prediction capabilities will be developed and validated. A technical data package will be produced for use in procurement and accreditation of the WIAMan capability products.

FY14 goals include: 1) Conduct biomechanics research to establish biofidelity response corridors for under-body blast loading environment for the lower-leg, pelvis, lumbar spine, head-neck, and whole body; 2) Initiate biomechanics research to establish human injury tolerance with initial emphasis on the lower extremities, 3) Complete the initial design of the WIAMan

anthropomorphic test device, instrumentation, and data acquisition system; and integrate them. Conduct Finite Element Analysis of the design to assess it's biofidelity; 4) Conduct blast-driven experiments for human response and vulnerability to vertical accelerative loading; 5) Spin-out knowledge from WIAMan research to the Research, Development, Test, and Evaluation (RDT&E) and materiel acquisition community to enhance protection technology research and human injury assessment in developmental and live fire testing.

Human Dimension

Soldier Sensory Performance

The goal of this research area is to understand the attentional and cognitive requirements of interpreting unaided and aided visual, auditory, and tactile signals in complex, dynamic militarily relevant environments. Research will be conducted on uni-modal and multi-modal sensory performance in three areas: fundamental sensory capabilities of the Soldier; methods, devices, and technologies for aiding perception; and advanced approaches for augmenting perception. Using the same principles that enable optimal perception for our Soldiers, research will reverse the perspective to develop approaches to deny perceptual information to the observer/enemy. Models of human visual, auditory, and tactile perceptual capabilities that drive detection, recognition and spatial orientation will be developed. As the work progresses from highly controlled laboratory conditions to a rich field environment, high fidelity measures of performance will necessarily be developed. Ultimately, this research will provide a foundation for principled guidance to the materiel development community.

Translational Neuroscience

In this research area, the goal is to enable system designs that are consistent with brain function, taking into account its limitations and exploiting its potentials to maximize Soldier performance. Research is focused on the capability to sense, extract, and integrate information about brain activity in dynamic, complex environments with multi-aspect measurements of human behavior. This approach creates a unique research niche that addresses both basic and applied research questions that differ from those asked by the vast majority of neuroscientists who focus on how the brain works. This neuroscience research effort has three focus areas: (1) the underlying sensor and computational technologies for context-based neuro-imaging in everyday environments, (2) improved understanding of individual differences using brain structure/function imaging and modeling, and (3) development of proof-of-principle neurotechnology exemplars with potential to have broad military and civilian impact. The Cognition and Neuroergonomics Collaborative Technology Alliance is an integral aspect of the overall program.

Social/Cognitive Network Science

This aspect of the ARL Network Science research area addresses decision-making in networked environments and is tightly aligned with the domains of Information and Communication Networks. HRED's efforts focus on two areas: socio-technical network operations and network-enabled cognition with both areas sharing the goal of improving distributed collaboration and decision-making in complex network-enabled operations. The research contributes to the development of theory, measures, models, and understanding of social networks and the

cognitive implications of those networks; and ultimately it will guide the design of team-system interaction and feed future operational systems. Research is conducted via modeling, networked laboratory human-in-the-loop, virtual simulations, and field exercises such as those conducted by the Mission Command Center of Excellence (CoE) and Communications-Electronics Research, Development and Engineering Center (CERDEC). An applied cognitive system engineering approach is used employing cognitive work analysis and the newly developed dynamic social network tools. Key themes include trust in automation, the unique workload and information properties associated with networked environments, measurement of team performance and situation awareness, and methods to drive the information and communication networks with dynamic social network information for real time support of the Soldier/decision-maker. The strategic focus in the area is linked to that of the Network Science Collaborative Technology Alliance and also the International Technology Alliance that call out the need to understand social/cognitive, information, and communication networks in concert.

Human Robot Interaction (HRI)

The goal of the human robotic interaction (HRI) research is to develop human factors technologies and design principles that enhance the Soldier interface with robots, and therefore, manage workload and improve overall Soldier-robot performance. As robotic systems increase in capability and functionality, the operator will require "matching" enhancements to the displays and interfaces to task and control those robotic systems. This includes the investigation of supervisory control, bi-directional communication, levels of robotic autonomy and interface automation, multimodal inputs and scalable interface technologies, and human-robot and robot-robot teaming that invokes the concepts of trust and social/cultural interactions. Concept validation employs modeling, laboratory and field experiments, and simulations, moving from highly controlled to militarily-relevant environments. HRI also includes research to leverage bio- and cognition-inspired designs for robots. Key deliverables are being transitioned to current programs of record as well as to advanced development. This research program is one of the areas of the overall ARL Autonomous Systems Enterprise. Examining capabilities developed at Tank Automotive Research, Development and Engineering Center (TARDEC) is also a core of our multi-year collaboration enabling early human system integration in the maturation of the technology.

Interaction of Physical and Cognitive Soldier Performance

The goal of this research area is to understand the effects of cognitive and physical demands on the Soldier and to improve Soldier-system survivability, sustainment, and efficiency, and optimize performance. Substantial research has been conducted in laboratories to understand the isolated effects of physical and cognitive stress on Soldier performance. This line of research will extend previous research by including interactive effects of physical stress on cognitive performance and vice versa for the dismounted Soldier. Soldiers are persistently overburdened both physically and cognitively, and the interactive effects of physical and cognitive stress on Soldier performance are poorly understood. New metrics of the interaction of physical and cognitive stress are being developed, and high fidelity measures of performance are being transitioned from the laboratory to the field environment.

Soldier Centered Design Tools and Analyses for the Future

The goal of human systems integration (HSI) is to optimize total system performance, minimize total ownership costs, and ensure the system is built to accommodate the characteristics of the user population that will operate, maintain, and support it. The purpose of HRED's HSI research area is to develop human performance analyses techniques and modeling tools to represent system level mental and physical human performance trade-offs at the system-of-systems level as a function of such factors as task requirements, level of automation, interface modality, workload, and type of training. A new dimension to be incorporated is the impact of social and cultural influences on performance, in particular decision-making.

Adaptive Training

Adaptive training research encompasses both the artificially-intelligent agents that adapt to the characteristics, actions, states of the trainee and/or the training environment, and context and the characteristics of the agents when embodied as virtual humans (VHs). The goal of adaptive tutoring research is three-fold. The first goal is to discover; then innovate tools and methods to enable computer-based tutoring systems (CBTS) to adapt instruction based on learner states (cognitive, affective, and competence) to optimize learner gains (performance, retention, accelerated learning, and adaptability). The second goal is to capture empirical results from research embodied in a modular tutoring architecture to enable users to easily author CBTS, automate instructional management, and conduct analysis of CBTS technology (components, methods, and tools) to determine best practices and standards. The third goal is to innovate the foundational building blocks of VHs, to include but not limited to natural language processing, gestures, and photo-realistic graphics, and to understand the social and learning effects of those building blocks.

Synthetic Natural Environments

The goal is to investigate, develop tools, and establish new methods that can be used to create reactive, interactive, and immersive environments with sufficient fidelity and computational efficiency to enhance training effectiveness, and to enable mission planning and experimentation and testing. Physics-based approaches, including complex terrain layer technologies, will be prototyped to improve dynamic effects, interoperability, and reuse; and to support runtime improvements in synthetic natural environments modeling across live, virtual, and constructive simulation domains. Advanced computational and networking approaches will be developed in order to blend Massively Multiplayer Online Games and virtual worlds to create environments sufficiently fast and seamless to provide training and mission rehearsal capability to support a global grid of distributed online users.

Advanced Simulation

The goal of advanced simulation is to develop improved tools and methods to facilitate local and geographically distributed interaction between models and simulations in support of collective training, mission planning, mission rehearsal, research, and experimentation. ARL will conduct research and technology development in the Army System of Systems program focused on analysis, design, testing, and evaluation. ARL will lower the barrier of entry to using powerful, complex simulations and federations of simulations by non-computer scientists. Advanced simulation research is critical in developing tools and methods to allow easy access to and instantiation of the simulated environment. The research will result in low-cost, easy-to-use, and

accessible tools and methods to enable rapid design, integration, and use of models and simulations to support training, testing, experimentation, and acquisition. The payoff is greater accessibility to powerful simulation tools by a broader section of the Army, and lower effort, cost, and time to federate and execute large-scale distributed exercises and experiments.

Training Application Domains

The goal is to execute research that overcomes challenging problems in the domains of the dismounted Soldier squad; live training and testing; and medical simulation and training. The work in this area leverages and extends fundamental research in adaptive training, synthetic natural environments, and advanced simulation. Dismounted Soldier squad research will improve training environments and human-simulation interaction capabilities to support realistic training in virtual, augmented, and mixed reality simulations. The payoff will be advanced natural locomotion modalities; computer recognition and location tracking; hand and arm signals; sensory perception; directional sound; smell; visual field-of-view; and depth perception to improve immersion and interaction with virtual objects. Live training and testing research will enhance interactions and effects in a variety of mounted and dismounted ground platforms to support training and accurate testing. Technologies will be developed to provide more accurate positioning and tracking of individuals, platforms, and munitions. The payoff is lower effort, cost, and time to author and integrate realistic live training and testing capabilities that replicate the operational environment and optimize learning for programs of record. Medical simulation and training will investigate, develop, and enhance training environments, models, and human-simulation interaction capabilities to support realistic training using live, virtual, and mixed reality simulations. Research is also conducted to evaluate performance of combat life savers, medics, and physicians. The payoff will be advanced synthetic tissue and bodily fluids for tactical combat casualty care and surgical training; objective measures of skill and self-efficacy; olfactory stimuli; modeling of wounds, symptoms, and physiology; and research in three-dimensional visualization to improve immersion and interaction with virtual patients.

3. Personnel Objectives

People are ARL's most valuable resource and ARL must continue to enhance the skills and expertise of its team members to keep pace with today's technological challenges. ARL strives to ensure the Army's scientific and technological advantage is maintained, as well as effectively and efficiently accommodating advances and changes in the Army's business processes and practices. ARL will continue to invest in an outreach program designed to support science, technology, engineering, and mathematics (STEM) education, and promote opportunities in research that attract and develop future world-class scientists and engineers. The goal is a pre-eminent, multidisciplinary, adaptive, and learning team capable of meeting the challenges associated with the continuing evolution of the Soldier's technology requirements.

To meet this objective, ARL will:

- Identify, recruit, develop, and retain the nation's best workforce needed to contribute to and lead Army research.
- Promote positive morale and motivation through acknowledgement and reward of individual and group excellence by ARL team members in all aspects of ARL operations.
- Maximize overall results for ARL by promoting partnerships with industry and academia.

ARL personnel goals in FY14 follow:

- Evaluate current workforce skills and demographic needs and identify any projected skills gaps.
- Identify and utilize recruitment methods that will enhance ARL's ability to effectively recruit a diverse, world-class, forward-looking, and adaptable workforce.
- Maintain or grow the percentage of technical staff holding advanced degrees.
- Achieve 80% of staffing goals based on directorates' Strategic Staffing Plans.
- Provide continuous education, professional development, and training opportunities for all members of the ARL Team, including attendance at in-house programs and participation in national and international workshops and symposiums. Ensure 40% of staff takes some form of mission appropriate career development training.
- Emphasize leadership and executive development; review and identify approaches for development of ARL's leaders' skills and competencies necessary to lead ARL into the future.
- Encourage mentoring; provide the necessary tools to assist the workforce in forging mentoring relationships.
- Promote 2% of science and engineering (S&E) staff holding competitive, restricted Fellow status in one or more major professional organizations.
- Foster employee recognition through participation in ARL and external honorary award programs.
- Pursue authority to implement the adoption of new or improved personnel demo flexibilities.
- Provide research experiences to faculty and students at ARL facilities.
- Partner with leading researchers in industry and academia to ensure that ARL programs produce advanced technologies that support Soldiers in the field today and in the future.
- Coordinate internships for DoD Hopps scholars at Army, Navy, and Air Force laboratories.
- Execute a robust summer student program and publish compendium of ARL Summer Student research.
- Manage the STEM Education & Outreach program, and bring students into the laboratory for interaction with scientists and engineers.

Quantified FY14 hiring goals, by technical area, are listed below:

- Survivability, Lethality & Vulnerability (SLV) Assessment and Analysis: 31
- Material Sciences: 26
- Information Sciences: 14
- Human Dimension: 12
- Ballistics & Aeromechanic Sciences: 10

4. Infrastructure Objectives

A robust technical infrastructure provides the environment necessary for development of technologies critical to Warfighter capabilities required in both the current and future force. The breadth and scope of ARL's technical, mission unique infrastructure is unparalleled. The pace of

scientific and engineering advancement mandates the continuous assessment, upgrading, and acquisition of state of the art internal technical infrastructures. To meet this objective, ARL will:

- Effectively maintain and build ARL's infrastructure to enable appropriate core technical competencies and cutting edge scientific research that maximizes achievement of ARL's goals and its response to the Army's top challenges.
- Increase ability of ARL to appropriately assign funding to infrastructure projects.
- Promote efficient and effective infrastructure project execution.

ARL infrastructure goals in FY14 follow:

- Develop and implement an ARL process for identifying and implementing infrastructure and facility improvements that ensure ARL's facilities and equipment are capable of supporting cutting-edge research in emerging technologies.
- Support RDECOM PLACES team initiatives towards the creation of a separate MILCON line for the RDTE installations to increase authority for Laboratory Revitalization and use of discretionary funding.
- Invest at least 2% of mission funding in new equipment.
- Invest at least 1% of mission funding in infrastructure.
- Complete all infrastructure projects on time and within established budgets.
- Key projects planned for FY14, by technical area, are listed below.

Information Sciences

- Develop the Modeling Network and Information Sciences Collaborative Environment to Facilitate and enhance collaboration through information sharing, decision support tools, cross-laboratory test-bed access, and laboratory-wide research technology projects.
- High Performance Computing Facility: Providing a high performance computing capability and computational enabling technologies to ARL, the Army, and the DoD is a critical part of the CISD mission. As one of 5 DoD High Performance Computing Modernization Program (HPCMP) Centers, the ARL DoD Supercomputing Resource Center (DSRC) supports over 1500 DoD HPC users across numerous DoD Services' RDT&E Programs. ARL has the only DSRC providing classified high performance computing capabilities to DoD RDT&E Programs. To meet the laboratory's computational requirements, CISD completed Phase I of the renovation of Building 120, which now houses three production supercomputer systems totaling over 40,000 processor cores, as well as the unclassified mass storage archive capabilities supporting 2 PB of capacity. Throughout FY14 and continuing through the first quarter of FY15, CISD will complete the second phase of the renovation, expanding the HPC facilities from 5,000 to 20,000 square feet (Q1 FY15), the generator-backed utility power from 4 to 6 MW (Q2 FY14), and the water chiller plant from 600 tons to 1,400 tons (Q1 FY15). New systems procured via the HPCMP's Technology Insertion-14 acquisition will be supported in the Phase II facility and made operational (Q2 FY15).

Materials Sciences

- WMRD's Advanced Polymer Processing Laboratory will provide fundamental experimental capabilities that support scientific discovery and innovation under the ARL's Materials Science Core Technical Competency. This state of the art facility will

provide new capability for handling large quantities of nano-particulates, and the controlled processing of novel fibers, films, and bulk polymer specimens. The project includes renovation of existing lab-space. Equipment in this newly renovated, controlled environment (temperature, humidity and particulate levels) materials processing laboratory include: clean room and high filtration hoods, fiber drawing and spinning systems, solid extrusion and mixing systems, and compression and injection molders.

Ballistics and Aeromechanic Sciences

- Design and initial site work for ARL Vehicle Innovative Power-train Experimental Research (VIPER) facility. Complete first 12 months of estimated 30 month contract providing a unique and flexible system-level facility for experimentation on innovative drive-train and power transmission technologies for Army vehicle propulsion.

Electronic and Information Warfare/Vulnerability Analysis & Assessment

- The Electronic Warfare (EW)/Electronic Attack (EA) Laboratory Capability Enhancement: Technology enhancements in telecommunications have driven the need for high speed, high resolution RF signal capture and deconstruction to support Electronic Warfare (EW) and Electronic Attack (EA) analysis. To address those needs, SLAD plans to purchase radio frequency (RF) signal capture, processing, and analysis capabilities; and integration support upgrades. These upgrades will support two distinct competency areas within ARL SLAD: Electronic Warfare and Computer Network Operations. Specifically, these enhancements will allow for monitoring and analysis of network and sensor performance during large scale experiments and tests, including the Army's largest integrated test activity, held twice annually, the Network Integration Evaluation (NIE).
- Electro-magnetic Vulnerability Assessment Facility (EMVAF) and Electromagnetic Environment (EME) Generator: To support EMVAF customer needs for realistic and repeatable electromagnetic test environment simulations for EW experiments and system integration, SLAD is planning to procure, adapt where appropriate, and utilize commercial off-the-shelf (COTS) equipment and a Joint Improvised Explosive Device Defeat Organization (JIEDDO) developed outdoor EME system for chamber use. The EMVAF/EME will produce multiple simultaneous communications and radar emitters over the freq range of 20 MHz to 1.3 GHz, with potential to expand up to 6 GHz. The EME will allow independent control of frequency, power, and modulation (AM & FM, with a potential to expand to PM, including I & Q) for hundreds of emitters. The electromagnetic environment will dynamically change over time and provide 3 dB uniformity over the large positioner within the chamber. The EME will support playback of recorded emitters for future EME, such as an urban and rural environment of Korea, or other RF environments around the world. This capability may be adapted to support future NIEs.

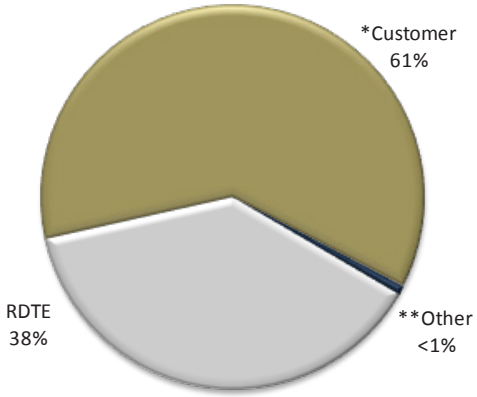
5. FY13-14 Budget - ARMY RESEARCH LABORATORY (ARL)

The chart on the next page reflects ARL's actual funding received and expenses incurred for FY13 and a projection of the same for FY14. ARL's projected total funding for FY14, which includes Operations and Maintenance (OMA), RDTE, Office of the Secretary of Defense (OSD), DARPA, and both Customer Reimbursable and Direct Cite programs, reflects a slight increase in basic research investments from FY13, but all other programs remain relatively consistent with FY13. These increases in the foundational basic research budget are focused on emerging technology areas such as Cyber Defense and Quantum Intelligence. ARL has historically received and executed Congressional funding for Silicon Carbide and Nano-Materials related research projects at the level of $45M annually, and the expectation is that the aforementioned will continue into FY14. ARL continues to manage and execute a technically diverse and robust fiscal program of $1.9B.

Army Research Laboratory

Funding

FY14 Data — $ Millions



* Customer = Reimb, Dir Cite, DARPA, OSD
** Other = OMA

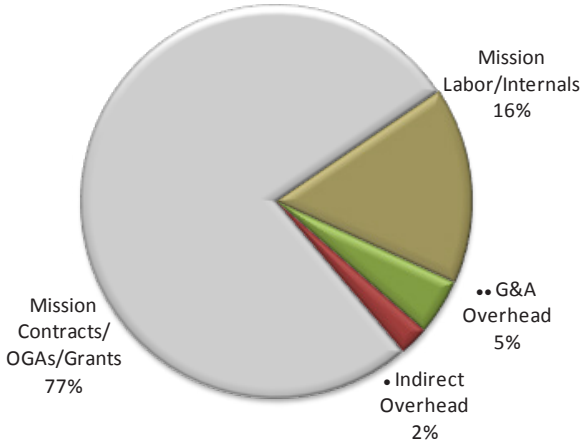
RDTE:	FY13 Actual	FY14 Projected
6.1 Basic Research	294.0	321.1
6.2 Applied Research	284.0	295.9
6.3 Advanced Development	19.8	18.4
6.4 Demonstration and Validation	2.6	0.0
6.6 Technology Analysis	85.7	83.5
6.7 Operational System Dev	11.7	13.8
*** Carry in/Carry Out Adj	4.7	10.0
RDTE Subtotal	**702.5**	**742.7**
Customer Reimbursable	353.4	351.0
Customer Direct Cite	609.0	600.0
OSD	40.2	30.0
DARPA	198.5	198.0
OMA	10.1	14.0
*** Carry in/Carry Out Adj	40.3	10.0
Total Funding	**1954.0**	**1945.7**

FY14 Projected
Top Reimbursable Customers ($M)

DoD	150.5
Other Army	86.4
PEOs/PMs	38.8
AMC	31.3
JIEDDO	24.0
Navy	20.0

Expenses

FY14 Data — $ Millions



	FY13 Actual	FY14 Projected
Mission Labor	253.5	265.5
Mission Other Internals	45.9	50.0
Mission Contracts/OGAs/Grants	1517.0	1493.7
Indirect Overhead	46.0	47.0
G&A Overhead	91.6	89.5
Total Expenses	**1954.0**	**1945.7**

• Indirect Overhead = admin & mgmt by directorate
•• G&A Overhead = ARL corporate admin & mgmt

6. Performance Evaluation

ARL's innovative performance evaluation approach continues to provide effectiveness in measuring ARL's outputs and outcomes in a meaningful manner. This approach has been fully implemented at ARL since 1996, and has been presented in numerous fora to the research community, senior leadership of the Army and the Defense Department, the Office of Science and Technology Policy (OSTP), the Office of Management and Budget (OMB), and the Government Accountability Office (GAO). This system continues to assist in enhancing ARL's leadership role in the research community.

The purpose of the ARL performance evaluation approach is to measure: (1) relevance, (2) productivity, (3) quality, and (4) the research environment. Peer Review, Customer Evaluation (feedback) and Metrics are the three performance measures that are used. Peer review is performed on primary mission areas by a Technical Assessment Board (TAB) from the National Research Council (NRC) of the National Academies of Science and Engineering. The ARO extramural basic research program undergoes peer review by a technical Boards of Visitors (BOV); one for each of ten scientific disciplines: physics, chemistry, life sciences, mechanical, electronic, materials, environmental, mathematics, network science, and computing sciences. Customer evaluation is performed by a formal customer survey process and reviews of metrics, as well as by feedback from the RDECOM Board of Directors (BoD) chaired by the RDECOM Director. Several dozen metrics are collected and used to measure areas such as customer satisfaction, business performance, and overall laboratory health. Table 6.1 shows the application and relationship of performance measures to the areas being measured.

Relevance
Does the work result in something that the customer needs?

Productivity
Is the deliverable a quality product that is reliable and responsive to the customer's requirement?

Quality
Is the technical program at, or beyond, the state of the art? Is it world class?

Research Environment
Is the laboratory environment conducive to performing quality research?

How...	Why...			
	Relevance	Productivity	Quality	Research Environment
Peer review	❍	❄	●	❄
Metrics	❍	❄	❍	●
Customer Eval	●	●	❄	❍

● ***Very Useful***
❄ ***Somewhat Useful***
❍ ***Less Useful***

Table 6.1 Performance Evaluation Approach

In FY14, the implementation of the Peer Review pillar of the construct continues through the ARL Technical Assessment Board (TAB) which is administered by the National Research Council (NRC). The seven member Board has six, ten-to-sixteen member panels that report to it, one for each of ARL's Directorates. The review process consists of an annual set of visits with a formal report published every other year. This two year cycle allows ARL the time to act on the TAB's recommendations from one year's review before the next year's cycle begins. Upon request, the ARL TAB will form panels to review and provide discussion and an assessment on up to three cross-directorate functional special topic areas.

The ARO Board of Visitors (BOV) reviews roughly half of the ARO's 6.1 basic research extramural program each year. In FY14, reviews of chemical sciences, environmental sciences, life sciences, mechanical sciences, and materials science will be conducted.

The polling of the Research, Development and Engineering Centers (RDECs) and our reimbursable customers will be done in FY14 for the Customer Evaluation pillar. An annual stakeholders' meeting reviews ARL customer responsiveness and performance, and ratifies the TPA's with the BoD RDEC members.

The Metrics pillar consists of several dozen measures that are systematically collected during the year. A table listing principal ARL metrics is at the end of this section. Some of the metrics are measurements of outputs and some are measurements either of inputs, which are considered necessary to accomplish the output metrics or, by experience or assessment, thought to increase the likelihood of accomplishing the output metrics. The metrics serve three primary purposes for management: evidence of ARL's progress toward achieving the measurable attributes of a "world-class" research organization; a tool for decision-making for achieving needed improvements; and general information about the health of the laboratory environment.

ARL Metrics	FY14 Goal
% of goals met by Major Lab Programs (less ARO)	80%
% of S&T program in TPAs	40-60%
% TPA objectives/deliverables met	80%
Minimum % of research mission resources reprogrammed to new/reoriented research goals	10%
% of DRI projects transitioning into mission research	20%
% of DSI projects transitioning into mission research	50%
TPA customer survey rating average score (scale 1-5)	4.0
Reimbursable customers survey average score (scale 1-5)	4.5
Total # of S&Es	1300
# and % of S&Es with PhDs	560/40%
# of man-months of visiting S&Es	200
# of Post-Docs	70
# of staff months of ARL internal developmental assignments within home Directorate	240
# of staff months of ARL internal developmental assignments outside of home Directorate	70
# of staff months of developmental assignments outside of ARL	90
# of invention disclosures	45
# of inventions applications	65
# of patents awarded	35
% of mission funding invested in new equipment	2%
% of mission funding invested in infrastructure	1%
% of infrastructure objectives achieved	80%
# and $ value of SBIR Actions (Phase I, II, IIE)	105/$43.0M
# of CRADA Agreements	75
# of TSA Agreements	20
# of DEA/ Information Exchange Annexes (IEA) International Agreements	19
# of PA/MOU International Agreements	5
# of TTCP International Panels	17
# of NATO International Panels	7
# of ESEP	3
# of refereed papers	310
# of Technical Reports	575
# of technical reports per S&E annually	0.5

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