



ARMY RESEARCH LABORATORY

AND THE

ARMY RESEARCH OFFICE

BROAD AGENCY ANNOUNCEMENT

FOR

BASIC AND APPLIED SCIENTIFIC RESEARCH



W911NF-07-R-0001-05

FY 2007 - FY 2011

ISSUED BY:

U.S. Army RDECOM Acquisition Center
Research Triangle Park Contracting Division
P. O. BOX 12211
Research Triangle Park, NC 27709-2211



OVERVIEW INFORMATION

Agency Name U.S. Army Research Laboratory

Issuing Acquisition Office: U.S. Army RDECOM Acquisition Center, RTP Contracting Division, P.O. Box 12211, Research Triangle Park, NC 27709-2211

Research Opportunity Title: ARL/ARO Core Broad Agency Announcement for Basic and Applied Scientific Research for Fiscal Years 2007 through 2011

Announcement Type and Date: Initial Announcement - October 2006

Research Opportunity Number: W911NF-07-R-0001-05

Catalog of Federal Domestic Assistance (CFDA) Number and Title: 12.431 – Basic Scientific Research

Eligible Applicants: Proposals may be submitted by degree-granting universities, nonprofit organizations, or industrial concerns. Proposals are encouraged from Historically Black Colleges and Universities and Minority Serving Institutions. Such eligible institutions are identified on the U.S. Department of Education Postsecondary Minority Institutions list. The list is compiled by the Office for Civil Rights, U.S. Department of Education, using enrollment data reported by postsecondary institutions to the National Center for Integrated Statistics and the Office for Civil Rights in the Integrated Postsecondary Education Data System (IPEDS) fall enrollment survey, formerly called the Higher Education General Information Survey (HEGIS). The list is available at <http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst-list.html>. Questions concerning the list must be directed to the U.S. Department of Education at (888)863-6515.

To be eligible for award of a research agreement, a prospective recipient (except other governments, including state and local governments) must meet certain minimum standards pertaining to financial resources, ability to comply with the performance schedule, prior record of performance, integrity, organization, experience, operational controls, technical skills, facilities, and equipment.

Cost Sharing or Matching: cost sharing, matching, or cost participation is not required for eligibility under this BAA.

Research Opportunity Description: The U.S. Army Research Laboratory (ARL) solicits proposals for basic and scientific research in chemistry, electronics, environmental sciences, life sciences, materials science, mathematical and computer sciences, mechanical sciences, physics, computational and information sciences, sensors and electron devices, survivability/lethality analysis, and weapons and materials research.

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INTRODUCTION

This Broad Agency Announcement (BAA) which sets forth research areas of interest to the Army Research Laboratory (ARL) directorates and the Army Research Office (ARO) is issued under the paragraph 6.102(d)(2) of the Federal Acquisition Regulation (FAR), which provides for the competitive selection of basic research proposals. Proposals submitted in response to this BAA and selected for award are considered to be the result of full and open competition and in full compliance with the provision of Public Law 98-369, "The Competition in Contracting Act of 1984" and subsequent amendments.

Research proposals are sought from educational institutions, nonprofit organizations, and commercial organizations for research in chemistry, electronics, environmental sciences, life sciences, materials science, mathematical and computer sciences, mechanical sciences, physics, computational and information sciences, sensors and electron devices, survivability/lethality analysis, and weapons and materials research. Proposals shall be evaluated only if they are for scientific study and experimentation directed toward advancing the state of the art or increasing knowledge and understanding.

ARO has primary responsibility for ARL's extramural basic research programs, with specific research interests as described in Part I.B. The ARL directorates, while having primary responsibility for ARL's in-house research programs, also manage selected extramural basic research programs. The research interests of the directorates are described in Part I.A. Although ARL directorates will consider proposals for comprehensive and interdisciplinary research programs, they can fund only a small number of proposals in a single fiscal year.

Foreign owned, controlled, or influenced firms are advised that security restrictions may apply that could preclude their participation in these efforts. Before preparing a proposal, such firms are requested to contact the ARL Security and Counterintelligence Branch (301) 394-2444 concerning their eligibility. Pursuant to the policy of FAR 35.017 and supplements, selected Federally Funded Research and Development Centers may propose under this BAA.

PART II, Other Programs, addresses specific contributions to Conferences and Symposia and HBCU/MSI support.

The Army has a long history of advocating and supporting research at historically black colleges and universities and minority institutions (HBCU/MSI). We actively seek research proposals from HBCUs and MSIs in full competition with all offerors who may submit proposals under this BAA. Proposals may be submitted at any time. We also encourage the inclusion of HBCUs and/or MSIs as part of a consortium proposal or as subcontractors/ subgrantees to prime recipients.

In order to conserve valuable offeror and Government resources and to facilitate determining whether a proposed research idea meets the guidelines described herein, prospective offerors contemplating submission of a white paper or proposal are strongly encouraged to contact the appropriate technical point of contact (TPOC) before submission. The TPOCs' names, telephone numbers, and e-mail addresses are listed immediately after each research area of interest. If an offeror elects to submit a white paper, it must be prepared in accordance with the instructions contained in PART III Section 3. Upon receipt, a white paper will be evaluated and the offeror shall be advised of the evaluation results. Offerors whose white papers receive a favorable evaluation may be contacted to prepare a complete proposal in accordance with instructions contained in PART III Section 5.

The costs of white papers and/or complete proposals in response to this BAA are not considered an allowable direct charge to any award resulting from this BAA or any other award. It may be an allowable expense to the normal bid and proposal indirect costs specified in FAR 31.205-18.

In accordance with federal statutes, regulations, and Department of Defense and Army policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving financial assistance from the Army.

Offerors submitting proposals are cautioned that only a Contracting or Grants Officer may obligate the Government to any agreement involving expenditure of Government funds. This BAA also applies to research proposals submitted to the RDECOM International Technology Centers.

For ARL Research Areas 1-6, offerors shall discuss the preferred performance period with the technical point of contact (TPOC). For ARO's Research Areas 7-15, it is preferred that proposals are submitted to cover a 3-year period and include a brief summary of work contemplated for each 12-month period so that awards may be negotiated for an entire 3-year program or for individual 1-year increments of the total program.

All administrative inquiries regarding this BAA shall be addressed to voice mailbox number 919-549-4375. Technical questions should be referred to the TPOCs shown following each research area of interest. When an inquiry is made, please clearly state your name, correct spelling, and telephone number.

This BAA is available on the following websites:

<http://www.aro.army.mil/baa>

<http://www.grants.gov>

<http://www.fedbizopps.gov/>.

This BAA is a continuously open announcement valid throughout the period from the date of issuance through 30 September 2011, unless announced otherwise, and supersedes the ARL BAA dated October 2003. Amendments to this BAA will be posted to the FedBizOpps web site and published at the above websites when they occur. Interested parties are encouraged to periodically check these websites for updates and amendments.

JOHN M. MILLER
Director
Army Research Laboratory

PART I: RESEARCH AREAS OF INTERESTS

A. ARMY RESEARCH LABORATORY DIRECTORATES

RESEARCH AREA 1 COMPUTATIONAL AND INFORMATION SCIENCES

1.1. Knowledge Representation through XML. Extensible markup language (XML), a subset of standard generalized markup language (SGML), was approved as a standard by the World Wide Web Consortium (W3C) for developing content-rich markup languages, particular for the internet. As a meta-language, XML has become the de facto technique for knowledge sharing, knowledge representation, and automated analysis. Various XML languages and tools have been developed for e-commerce, B2B (Business-to-Business), telecommunications, wireless connectivity, and many other application domains. XML also forms the basis for the Semantic Web project, the next-generation Web focused on information exchange by creating documents with computational meaning.

The military has a requirement for representations of the battlespace that can be analyzed by both computational systems and subject matter experts to aid the C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance). The digital battlefield has replaced the large-scale deployments that use heavy equipment and antiquated regulations. The massive amounts of information need to be in a flexible format that can be transformed readily to support disparate systems. The Future Combat System (FCS) envisions a seamless merge of information systems and hardware, communicating on the battlespace in real-time with persistent data. The multiple data sources, communication channels, heterogeneous platforms, and information systems in FCS will not only generate cognitive overload to the war-fighter, but will make information fusion difficult without automated assistance.

The army is increasingly moving towards XML technologies for knowledge representation. C-BML (Coalition-Battle Management Language) is an XML schema designed as a singular taxonomy and vocabulary that could be used by all stakeholders in the battlespace. C2IEDM (Command and Control Information Exchange Data Model) is a proposed standard for C2 data, supporting a common operational vocabulary and the exchange of data between C2IS databases. The ARL would like to receive research proposals to explore emerging military XML standards for knowledge representation, supporting information fusion, decision-making, and automated analysis of the battlespace.

Technical Point of Contact: Dr. Reginald L. Hobbs, e-mail: reginald.hobbs@us.army.mil, phone: 301-394-1981.

1.2. Information Science and Technology. The ARL is interested in basic and applied research resulting in technologies that support state-of-the-art capabilities for the war fighter in the analysis, assimilation, and dissemination of real and simulated digitized battle space information. Areas of interest include, but are not limited to:

- a. Intelligent software agents.
- b. Software reuse.
- c. Automated distribution of operational orders.
- d. Information and data fusion/visualization.
- e. Data mining/Social network analysis.
- f. Machine translation of text and speech data.
- g. Mixed small robot/soldier team collaboration and behavior.
- h. Autonomous/robotic platform software integration including manned and unmanned systems.

Technical Point of Contact: Dr. Barbara D. Broome, email: b.d.broome@us.army.mil, phone: 301-394-1956.

1.3. Wireless Information Assurance and Survivable Communications. The ARL is interested in receiving proposals that address the underlying science and technology for survivable and secure communications over wireless networks, information infrastructure protection, and survivable systems engineering. The objectives of the research are to provide secure, survivable, and assured communications over wireless networks, including highly mobile networks. Research interests include, but should not be limited to, advancing the state of the art in the following areas:

- a. Research on automated vulnerability assessment and intrusion detection tools and techniques.
- b. Genetic algorithms used to spawn and control intelligent agents for information assurance.
- c. Information hiding in images and text (steganography and watermarking).
- d. Key distribution and security in a mobile wireless ad hoc network.
- e. Tools and techniques for automating the creation and distribution of interoperable vulnerability knowledge bases.
- f. Tools and techniques for automated analysis and correlation of anomalies, probes, and detections from multiple sites and to support post-incident forensic analysis.

- g. Network management and visualization tools that support real time planning and control of tactical nets as well as tools for intrusion detection and forensic analysis in hybrid networks.

Technical Point of Contact: Mr. Peter P. Budulas, e-mail: peter.budulas@us.army.mil, phone: 301-394-5600.

1.4. Sensor Network Communications. ARL is developing communications devices and technologies for unattended sensors. These unattended devices must work for long periods on limited battery power, use Anti-Jam and Low Probability of Detection waveforms, perform ad-hoc networking for autonomous self-healing routing, and provide network security for authentication, data integrity and privacy. ARL is also interested in leveraging these technologies for use in other energy constrained communications applications. Areas of interest include, but are not limited to:

- a. Ad-hoc network protocols.
- b. Security protocols.
- c. Robust AJ/LPD waveforms.
- d. Energy efficient modems.
- e. Energy efficient RF front-ends and components.
- f. Low power signal processing.
- g. Small broadband antenna.
- h. Forward-error-correction.
- i. Integration of sensor and communications processing
- j. Efficient integration of sensor and communications into Unattended Sensors

Technical Point of Contact: Mr. Ronald G. Tobin, e-mail: ronald.tobin@us.army.mil, phone: 301-394-2184.

1.5. Wireless Mobile Communications. The ARL is interested in receiving proposals that address network science and technology for mobile wireless communications networks, especially the mobile tactical domain, and including sensor networks. The objectives of this research are to enable Army multimedia communications among highly mobile users, sensors, and robotic platforms under adverse channel conditions, with desired quality of service on demand. Research areas of interest include, but are not limited to, advancing the state of the art in the following areas:

- a. Network science, including fundamental limits and tradeoffs, and analysis of protocols.
- b. Bio-inspired paradigms for wireless networks.
- c. Bandwidth and energy constrained mobile transceiver design.
- d. Cross-layer designs, especially with respect to physical layer and media access layer interaction.
- e. Multi-antenna methods, including space-time processing, for mitigating multi-user and intentional interference, while achieving very high capacity.
- f. Techniques for overcoming electronic warfare and jamming threats.
- g. Dynamic spectrum access, and frequency agile systems.
- h. The combination of channel equalization and coding techniques.
- i. Wideband modulation methods such as orthogonal frequency division multiplexing.
- j. Ultra wideband systems, including coexistence issues and system overlays.
- k. Sensor networking systems, including signal processing and communications interactions, distributed detection and estimation, and networking protocols.
- l. Ad hoc mobile networking protocols and procedures.

Technical point of contact: Dr. Brian M. Sadler, email: brian.sadler@us.army.mil,
phone: 301-394-1239.

1.6. Atmospheric Sensing. The ARL is interested in receiving proposals that address the technology and technical barriers for improving the state of the art of critical scientific areas that affect atmospheric modeling and simulation. The objectives of the research are to mitigate the effects of weather and battle-induced atmospheres on combat materiel, personnel, and doctrine; to optimize the performance of friendly forces under realistic battlefield conditions; and to enhance the use of smoke, camouflage, concealment, deception, and multi-spectral and polarimetric technology. Research interests include, but should not be limited to, advancing the state of the art in the following areas:

- a. Research on and models of the propagation of acoustic energy in the atmospheric environment under neutral and battlefield conditions.
- b. Atmospheric effects decision aids for acoustic systems.
- c. Sound detection and ranging techniques.
- d. Computer, artificial intelligence, display, and man-machine interface techniques in weather intelligence concepts.

- e. Unified weather packages of atmospheric effects decision aids for potential use in automated systems of the different battlefield functional mission areas.
- f. Atmospheric effects decision aids consolidating the effects of realistic battlefield conditions and operations, systems, and sub-systems.
- g. Models of polarized electromagnetic propagation through the atmosphere at UV through millimeter-wave lengths under natural and battlefield conditions for mitigating atmospheric effects on Army systems.
- h. Research on and models of atmospheric effects on images and scenes under natural and battle-induced conditions.
- i. Obscuration models for battlefield conditions, including weather, natural and battle-induced smokes, and dust.
- j. Atmospheric effects decision aids for the use of smoke, camouflage, decoys, and multi-spectral and polarimetric technology
- k. Incorporation of the effects of weather, clutter, and battlefield obscurants into intelligence, surveillance, and reconnaissance.
- l. Atmospheric effects decision aids for mitigating the effects of natural and battle-induced atmospheres on intelligence, surveillance, and reconnaissance.
- m. Development of and applications using advanced ultra-compact lidar systems.
- n. Advanced numeric modeling techniques that use state-of-the-art computer technology, such as parallel processing.

Technical Point of Contact: Dr. Alan E. Wetmore, e-mail: alan.wetmore@us.army.mil, phone: 301-394-2499.

1.7. Database Technology. Explore ideas and prototype tools for advanced data management concepts, including schema integration and data warehousing in a standardized data environment, enable transparent access to multiple heterogeneous databases, data mining and knowledge discovery in large distributed databases, automated query formulation strategies using data element thesaurus capabilities, integration of data encyclopedia tools with data and process modeling tools, and automated support for electronic records management and digital signature. Implement and experiment with simultaneously and transparently accessing and manipulating data from different databases, to include support for imaging, multimedia, object-oriented, and traditional applications. Investigate new ideas, and design, implement, and evaluate prototype data management tools that support the Army Information Architecture, Army modernization efforts, and the Army's Future Combat System (FCS).

Technical Point of Contact: Mr. Timothy P. Hanratty, email: timothy.hanratty@us.army.mil, phone: 410-278-3084.

1.8. Software Engineering. In an open systems environment, develop concepts for prototype components of software engineering technologies which reduce software life-cycle costs, increase modularity and interoperability, increase productivity of software design/development and support organizations, and improve the quality, reliability and reusability of delivered components, systems, and products. Explore methodologies and technologies (e.g., object-oriented), which achieve substantial improvement and cost reduction in software development, requirements analysis and definition, software management, complexity, and quality metrics, reuse, re-engineering, maintenance. This includes tools and techniques (e.g., intelligent agents, wrappers) to aid in migrating or interfacing legacy systems to Java-based or other state-of-the-art systems. Topic includes any software engineering technologies, which aid in the Army's efforts to digitize the battlefield and its tactical command and control systems.

Technical Point of Contact: Mr. Timothy P. Hanratty, email: timothy.hanratty@us.army.mil, phone: 410-278-3084.

1.9. Battlefield Environmental Research. The ARL is interested in basic and applied research resulting in technologies that support state-of-the-art capabilities for the war fighter in the measurement, analysis, assimilation, and dissemination of real and simulated digitized battle space weather and atmospheric information. Areas of interest include, but are not limited to:

- a. Microscale atmospheric boundary layer meteorology and numerical simulation, at horizontal resolutions from 100 to less than 10 m that consider real urban and vegetative canopy effects, including methodology and automated technology for application and incorporation of high resolution microscale natural and man-made land surface features.
- b. Technology and algorithms for web enabling of numerical weather prediction models, data assimilation methods, input and output packages, and post processing software, wherein the potential technology and algorithms include, but are not limited to, java spaces, web services algorithms, and other emerging methods leading to the efficient distribution and handling of weather forecasting/nowcasting technology on future Army tactical computer platforms.
- c. Physically accurate weather visualization tools.
- d. Diagnostic tools for determining the realistic spatial variability of atmospheric parameters in limited complex domains.
- e. Methodology and applications for the use of satellite remote sensing of boundary layer environmental conditions with emphasis on smaller scales, that is, meso-gamma scale and microscale.

- f. Innovative new techniques and novel technology exploitation to retrieve data and extract information on boundary layer weather and atmospheric aerosols from traditional and non traditional sensors and sources.
- g. Electromagnetic and acoustic propagation, especially electro-optical EM propagation and infrasonic acoustic propagation.
- h. Atmospheric aerosol properties and behavior, including the natural background, as well as man-made liquid/solid mineral, chemical and biological components.
- i. Environmental decision support technology (tactical decision aids) for transforming weather information into mission planning and battle decision intelligence.
- j. Parameterizations of very small scale atmospheric phenomena found within complex and urban domains for use with diagnostic microscale models of atmospheric flows and other microscale models as appropriate.
- k. Data assimilation methods applicable to small scale numerical weather prediction models such as the Weather Research and Forecasting model as well as very small scale microscale models running with horizontal grid spacing of less than 10 m, and that are capable of running in close to real time.
- l. Data compression methods for large meteorological data bases that can achieve compression ratios significantly greater than current lossless methods and that maintain high accuracies over the entire domain, that is, small maximum absolute error for an entire data set after compression and subsequent decompression.
- m. Innovative technology and methods for detection of severe storms and other atmospheric phenomena such as through detection of impending and occurring lightning.

Technical Point of Contact: Mr. David I. Knapp, email david.knapp3@us.army.mil, phone: 505-678-4574.

1.10. Scalable Computational Sciences. Research and development proposals are required in the areas of multi-disciplinary computational approaches on high performance computers to address challenges in simulating practical Army applications. Specific areas of interest include: (i) innovative and scalable methodologies (including finite element methods, particle methods, etc.) for computational mechanics Computational Fluid Dynamics (CFD), Computational Structural Mechanics (CSM), Computational Electromagnetics and Acoustics (CEA), and Computational Chemistry and Materials (CCM), etc.); (ii) innovative space and time discretization numerical algorithms including scalable equation solvers for a wide class of nonlinear computational mechanics problems; (iii) computational methods for interdisciplinary applications (example: structure-medium interaction, Eulerian-Lagrangian, etc.); (iv) multi-scale computational approaches (example: Macro-meso-micro approaches, molecular dynamics-continuum mechanics coupled approaches, etc.); (v) computational methods to address

innovative structures for Army applications (designing, manufacturing, testing, verification and validation); and (vi) data mining for scientific applications.

Technical Point of Contact: Dr. Raju Namburu, e-mail: raju.namburu@us.army.mil, phone: 410-278-9761.

1.11. Knowledge Fusion Research. ARL is interested in proposals for developing in-depth knowledge and understanding of fundamental science and technology elements required for knowledge fusion, especially for the battlefield and homeland defense domains. A primary objective is to investigate different facets of integration and fusion phenomena with the goal of fusing together data from a wide variety of heterogeneous sources in a way that distills the combined information and adds intelligence to create knowledge. The data involved comes from databases (relational, object, legacy, spatial, temporal, and others), from knowledge bases, from semantic nets that include the coming semantic Web, as well as from sensor data. Knowledge fusion involves fusing the data, applying and integrating various knowledge producing transforms (e.g. threat indices) and inferences (e.g. logical, nonmonotonic, hypothetical) as part of a comprehensive, domain-specific system that provides focused and quickly identifiable knowledge to the human user.

Technical point of contact: Dr. Dana L. Ulery, email: dana.ulery@us.army.mil, phone: 410-278-8609.

1.12. Battlefield Knowledge Management and Discovery. ARL is interested in proposals that address knowledge management and information fusion to develop the situational understanding required for planning and acting within the adversary's decision cycle, including the development of computational models that address the complexity of this class of battlespace problems. There is a need to develop knowledge-intensive systems that require not only the elicitation of human expertise but encoding it in computational formalisms required to implement the reasoning processes. Automated support for discovering knowledge such as interesting patterns in data is required. ARL's interest includes knowledge of heterogeneous data and multimedia types, data mining, text mining, knowledge agents, knowledge brokers, knowledge visualization systems, federated data warehouses, and knowledge standards for application in the wireless environment of the battlefield.

Technical Point of Contact: Mr. Timothy P. Hanratty, email: timothy.hanratty@us.army.mil, phone: 410-278-3084.

1.13. Software Technologies Targeting Interoperability for Systems of Systems. Background: Emerging DoD systems represent a revolutionary leap ahead in the concept of "system of systems" and interdependent operations. Interoperability and the management of complexity is the chief challenge to harness technologies to meet the future needs of the Army for information infrastructure. For example, the Army's Future Combat System (FCS) will be a joint, networked architecture made up of 18 individual systems plus the network and Soldier. It will be an ensemble of manned and unmanned combat systems, designed to provide a multi-functional, multi-mission reconfigurable system of systems maximizing interoperability, strategic transportability and commonality of mission roles including direct and indirect fire, air

defense, reconnaissance, troop transport, counter mobility, and Command and Control (C2) on the move. Full second generation digital systems will provide the nexus for combined arms operations, fully embedded training, and system operation. In order to realize these goals FCS will require 'glue' to bring together the multitude of components within each system as well as assure interoperability amongst the major systems. This 'glue' is the software which ties together all the pieces. However, the software must also accommodate nonfunctional system attributes such as adaptability, flexibility, agility. The predicted number of Lines of Code (LOC) for the FCS applications has been estimated as high as 40 million and may go beyond that. More important than the size of the software base, the complexity of the individual systems and the interface required for joint operations is staggering. The Warfighter Information Network – Tactical (WIN-T) will be the communications backbone. The difficulties of real world networking and communications will provide great challenges in keeping and securing the required information flow. Great complexity surfaces from the merging of system embedded computing and ad hoc networking. The complexity is exacerbated by the fact that FCS will also have to interface and integrate with legacy systems, systems under development and yet-to-be developed applications. Software will be the key component to assure these goals are realized. This realization is both in terms of correct, reliable, and fault tolerant algorithms as well as development tools and processes which assure project schedules are met in terms of time and cost. Both the Air Force and the Navy have similar commitments to network-dependent operations.

Objective: Develop and transition new methodologies, tools, technologies and techniques that improve the quality, dependability and interoperability of software for large, net-centric systems of systems. Key in this effort is to develop and establish principles of interoperability and complexity management as a foundation for developing a service-oriented architecture for these ultra large scale systems. These principles will enable the precise description of components, their construction and their acceptable interactions (e.g., to enforce performance and security requirements), leading to new approaches for building and assembling systems.

Research Concentration Areas: In order to address these challenges, the U.S. Army Research Laboratory (ARL) under the auspices of the OSD Software-Intensive Systems Producibility Initiative (SISPI) is soliciting proposals in the following areas. They are suggestive of topic areas which will enable future DoD systems to move towards net-centric environments. They are not in priority order and are meant to stimulate ideas for prospective proposals. Other novel and creative solutions are strongly encouraged.

Proposals must show and will be expected to deliver prototype but usable software methodologies, prototypes, and/or tools which can be tested and incorporated into DoD R&D programs. "The Software and Systems Test Track <http://www.fbo.gov/spg/USAF/AFMC/AFRLRRS/Reference%2DNumber%2DBAA%2D06%2D13%2DIFKA/listing.html> another component of the OSD SISPI will provide an open framework environment where tools and products may be deployed allowed to interact in real-time, interactive, evolutionary and interdependent means, allowing rigorous testing of new technologies, methodologies and theories in support of the OSD Software-Intensive Systems Producibility Initiative. The Software and Systems Test Track is one place prototype software could be delivered."

- a. Domain-specific modeling languages and semantics.
- b. Model-based design and development/engineering for system of systems architectures and ultra large scale software intensive architectures.
- c. Models which support reflective (self-referential) capability.
- d. Principles and ontology development for organization of components, their design and construction.
- e. Verifiably correct generators and models.
- f. Re-engineering and Integration technologies (methods, tools, metrics, models, etc.) for legacy systems.

Technical Points of Contact: Mr. Jeffrey M. DeHart, email: jeff.dehart@us.army.mil, phone: 301-394-2263 and Mr. Glenn E. Racine, email: glenn.racine@us.army.mil, phone: 301-394-3990.

RESEARCH AREA 2 SENSORS AND ELECTRON DEVICES

2.1. Microsystems Technology. Robotic platforms extend the warfighter's senses and reach and have been used operationally as sensor, communications, and, in some instances, weapons platforms. Especially in complex terrain, like caves and mountains, or an urban environment, these platforms provide operational capabilities to the warfighter that would otherwise be costly, impossible, or deadly to achieve. Future enhancements to warfighting capabilities require a reduction in platform size and the cohesive operation of multiple platforms.

Consider, for example, a small unit searching a building for potential human threats. The platforms are emplaced or launched initially by the unit or a larger robotic platform but their movement is guided by perceived improvements in situational awareness provided by modifying the platform distribution. Thus, determining waypoints, as well as stable controlled movement between waypoints is critical. The ability to hover or perch is also advantageous to operations.

Similar capabilities are also required when searching caves or demolished buildings, but the terrain is more complex to map and to navigate. Paths are irregular and ground surfaces are no longer smooth. Air flow may be gusty. In caves, especially, the lack of ambient lighting and the thermal uniformity of the environment complicate navigation.

Surveillance of a wide area for perimeter or asset defense is an alternative scenario that requires full autonomy from a collection of microsystems. Not only must the collection provide situational awareness, it must also respond in some manner prior to human intervention. Thus, the

requirements on processing to understand and respond appropriately are increased over those of the small unit search.

Enabling the capabilities reflected in the search and surveillance scenarios above requires the solution of fundamental technical issues in several key areas including: aeromechanics and ambulation; electrical power and propulsion; sensing, processing, and communications; navigation and control; mobile, distributed sentience; microdevices and heterogeneous integration of materials; platform packaging; and systems architectures.

Important research issues include:

- a. Platform stability and control in high-disturbance environments.
- b. Vortex-dominated unsteady aerodynamics of flapping wings at low Reynolds numbers.
- c. Bio-inspired, bio-mimetic leg and wing concepts with integrated sensors and actuators.
- d. High-force high-bandwidth large-displacement linear actuators.
- e. Autonomous and semi-autonomous navigation and control over a network.
- f. Group cooperative behavior and planning.
- g. Robust and scalable control architectures.
- h. Integrated sensing to support mobility, communications, and surveillance.
- i. Computational sensing, including compressive imaging.
- j. Efficient sensing and information extraction and utilization.
- k. Constrained information management within a node.
- l. Distributed signal processing, including low complexity techniques for distributed multi-modal sensing and fusion.
- m. Dynamic collaborative processing accounting for sporadic sensing and sensor management.
- n. Communications and networking, including novel communications modalities, dual sensing and communications and implicit communication.
- o. Lightweight robust and possibly asymmetric networking.
- p. Integrated cross-layer communications and network design.
- q. Techniques for network lifetime extension.

- r. Synthesis and development of three-dimensional materials and circuit architectures for sensing, signal processing, and communications.
- s. Smart multifunctional materials.
- t. Robust, low complexity, low power devices for sensing, signal processing and networked communications.
- u. Hybrid power systems.
- v. Power harvesting concepts.
- w. Power & duty cycle management.
- x. Microsystems architectures analysis to understand fundamental limits and perform modeling & simulation.
- y. Design tools capable of balancing and optimizing trade-offs in a microsystem architecture.

Technical Points of Contact: Dr. Joseph Mait, e-mail: joseph.mait@us.army.mil, (301) 394-2462 or Dr. Tom Dolgalski, thomas.doligalski@us.army.mil, (919) 549-4251.

2.2. Sensors, Actuators, and Micro-Mechanics. The Army requires research investigations into electronic materials, devices, and components, and relevant basic physics studies that couple electrical, magnetic, and optical fields with mechanical (elastic) fields. These are needed to ensure that the integration and interfacing of new materials and components into electronic systems will result in the improved system performance required to carry out complex military missions. The Sensors and Electron Devices Directorate (SEDD) is interested in receiving novel proposals that address the technical barriers associated with improving the current state of the art in electronic materials, devices, and components used as sensors, actuators, and micro-mechanical structures. Technical areas of interest include, but are not limited to, the following:

- a. Theoretical and experimental studies of electro-mechanical interactions in solids.
- b. Studies of micro-mechanics that impact electronic/photonic devices.
- c. Investigation of dielectric semiconductors, and ceramic material parameters, including ferroelectric, piezoelectric, and elastic properties.
- d. Nanoelectronic investigation, including the physics of structures that incorporate polarization gradient, strain gradient, and nonlinear interactions.

Technical Points of Contact: Dr. Ronald Polcawich, ronald.g.polcawich@us.army.mil, (301)394-1275 or Dr. Madan Dubey, e-mail: madan.dubey@us.army.mil, (301) 394-1186.

2.3. RF Sensors. Research proposals are desired that will lead to the ability to sense, locate, identify, and engage targets at tactical ranges. These sensors must reliably discriminate between targets and clutter and detect targets in the presence of counter-measures. For example, it is desired to detect a camouflage-netted vehicle partially obscured by foliage or personnel in hiding. Sensors of interest include both passive and active microwave and millimeter wave. Small size and gun or missile launch survivability are required for some applications and low cost is always important. Another area of interest is surveillance (UAV) and fighting platform (rotary wing and ground vehicle) based systems. Methods for fusing the outputs of various sensors and signal propagation modeling are also of interest. Applications include surveillance and target acquisition, target engagement for smart munitions, and navigation and obstacle avoidance.

Technical Points of Contact: Mr. David Wikner, david.wikner@us.army.mil, (301)394-0865. or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.4. Microwave Sensors. ARL is interested in radar models, techniques, concepts, algorithms, and hardware modules that support:

- a. All-weather, wide-area detection, location, and recognition of stationary tactical ground targets that may be behind walls or concealed in foliage and/or employing camouflage, concealment, and deception.
- b. All-weather, wide-area detection, location, and discrimination of surface and near surface buried mines and/or improvised explosive devices.
- c. All-weather, wide area detection, location, and tracking of moving targets (e.g., personnel, tactical vehicles and low flying aircraft) from a ground-based and/or airborne foliage penetrating sensor system.
- d. All-weather, wide-area detection, location, tracking, and recognition of low radar cross-section (RCS) moving ground vehicles (in heavy clutter), low RCS hovering helicopters in defilade, and low RCS fixed-wing aircraft employing nap-of-the-Earth (NOE) flight profiles from an airborne real aperture sensor system.

Proposals are desired in support of ultra-wide frequency band (UWB) synthetic aperture radar (SAR) technology. In particular, research is desired in areas that address the technical obstacles associated with using a UWB SAR for the detection, location, and possibly classification of subsurface targets (ranging from near surface to deeply buried objects). Further, proposals are desired to support low frequency radar models, techniques and enabling component technology. The proposals may address such areas as:

- a. Radar component technology, including wide-bandwidth/ low-frequency antennas, high power transmitters, high-speed signal processors, and analog-to-digital converters.
- b. Radio frequency interference (RFI) extraction/avoidance techniques.

- c. Optimization of algorithm code.
- d. Modeling to support subsurface detection in a variety of environments/soil conditions.
- e. Improved means of estimating/measuring soil parameters, such as dielectric constant and conductivity for field experiments.
- f. Developing techniques to estimate the bulk dielectric constant of and signal loss through wall materials.
- g. High-precision position location systems.
- h. Motion compensation techniques and autofocus routines.
- i. Beam-forming techniques.
- j. Self-aligning and calibrating arrays.
- k. Bistatic system concepts.
- l. Target detection, tracking and classification algorithms.

Technical Point of Contact: Mr. Karl Kappra, e-mail: karl.kappra@us.army.mil, (301) 394-0848.

2.5. Synthetic Aperture Radar (SAR) Imaging and Image Exploitation. Research proposals are encouraged on novel techniques for human-in-the-loop and autonomous generation and exploitation of SAR. Imaging sensors for application during reconnaissance, surveillance, and target acquisition missions from manned and unmanned airborne platforms are of interest. Other areas of interest include algorithms and processing systems for automatic target recognition, personnel detection, terrain delimitation, scene analysis, image compression, image formation, image enhancement, presentation, visualization, and man-machine interface. Of particular interest are new approaches to demonstrate increased robustness against target variability, obscuration, camouflage, sensor geometry variation, and challenging clutter at high data rates for real-time implementation.

Technical Point of Contact: Mr. Jerry Silvius, email: jerry.silvius@us.army.mil, (301)394-0881 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.6. Radio Frequency (RF) Technology for Human Detection, Tracking, and Identification. The Army has an interest in the basic phenomenology of RF detection, tracking, and identification of human targets at MMW frequencies. This includes the generic problem of dismount detection and tracking in urban and rural environments as well as the detection of people in buildings. Additionally, the development of biometric signature characterization techniques for application to dismount detection, tracking, and identification is sought. This area is concerned with both hardware and signal processing solutions. The systems or techniques proposed must have the

high speed necessary to perform in real time, coupling with peripheral processors. Some of the processing characteristics sought are direct and indirect illumination of people for purposes of classifying individuals by gait, respiration rate, heart rate and any other pertinent micro-Doppler signals. The proposed solution must lead to the ability to sense, locate, and identify dismounted targets at tactical ranges from any of a variety of surveillance sensors such as robots, UAVs, or manned fighting platforms.

Technical Points of Contact: Mr. Ken Ranney, email: Kenneth.ranney@us.army.mil, (301)394-0832 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.7. Small Radar (micro-sensor) Systems The Army is interested in lightweight, affordable radar systems that are suitable for and have the ability to sense, locate, and identify targets from any of a variety of surveillance sensor platforms such as robots, UAVs or future micro-sensor platforms. The development of such a system may include phenomenology (signature) measurements in an effort to optimize the hardware and software. The systems or techniques proposed must have the high speed necessary to perform in real time, coupling with peripheral processors.

Technical Points of Contact: Mr. Edward Viveiros, Edward.viveiros@us.army.mil, (301)394-0930 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.8. Field Tunable Radio Frequency (RF) Materials and Devices. The Army requires high performance, broadband frequency agile devices such as tunable filters, phase shifters and true-time delay devices that will help enable affordable single platform multi-mode electronic scanning RF systems for integrated sensors. We are looking for ways to meet Army requirements for frequency agile device performance and affordability through any technically reasonable approach that may include but is not limited to:

- a. Development of higher performance field tunable (permittivity, permeability or their combination) materials.
- b. Improved device designs and structures.

Technical Point of Contact: Dr. Frank Crowne, frank.crowne@us.army.mil, (301)394-5759.

2.10. High Power RF Sources and Amplifiers. The Army requires study and research in the areas of the following high-power vacuum electronics RF sources for electronic warfare (EW), countermeasures, communications, and radar systems; Klystrons, traveling-wave tubes, extended interaction oscillators, extended interaction amplifiers, backward-wave oscillators, microwave power modules, millimeter power modules and crossed field amplifiers. Solutions are sought for the above vacuum electronic RF sources with regard to the following characteristics: compact size and low weight, improved high reliability, low cost, increased life, reproducibility, reparability and simplicity of fabrication, long shelf life, broad bandwidth (or tunability), high power, high efficiency, high gain, high voltage stand-off capability and low noise. Proposed RF source designs must show the potential for meeting one or more of the above requirements.

Solutions are also sought for test and evaluation techniques for the characteristics listed. Innovative simulation/computer techniques for the proposed design approaches are encouraged.

Technical Point of Contact: Mr. Benjamin Huebschman, email: benjamin.huebschman@us.army.mil, (301)394-0242.

2.11. Three-Dimensional Microcircuit Packaging. ARL has a need for heterogeneously integrated electronics including but not limited to new, three-dimensional (3-D) packaging approaches for integrated micro-circuits to reduce size and weight and to improve electrical and thermal performance of ultra-large-scale-integration (ULSI) modules. Size, speed, and processing capability require advanced multichip packaging, using hybrid or monolithic wafer-scale integration (WSI) with 3-D wafer interconnection and assembly. The resulting multichip module must meet military environmental requirements, as well as exhibit high-speed electrical and high-power thermal characteristics. Future modules of this type will be used for ULSI, application-specific integrated circuits (ASIC), and ultra large integrated circuit (ULSIC) chips applied to DoD electronic systems. Proposals are desired that address new, advanced, high-density 3-D packaging and interconnection schemes for use in multi-chip modules, with an emphasis on the use of silicon or other dielectric materials as the substrate/wafer. Potential applications for use in military electronics should be addressed and specific system needs should be included. The 3-D multichip packaging technology developed must be reliable in the military environment. The government will consider proposals that provide for the design, fabrication, and demonstration of proof-of-principle experimental 3-D microcircuit packages.

Technical Point of Contact: Dr. Romeo del Rosario, e-mail: romeo.delrosario@us.army.mil, (301) 394-3562.

2.12. Microwave Device and Analog Signal Processing Research and Development. The Army requires improved microwave devices that are reliable and cost effective, as well as lightweight, reliable signal processing components to handle large volumes of data on a real-time basis. Desired are novel proposals that address the technical barriers associated with improving the state of the art of such devices and components. Technical areas of interest include the following:

- a. Physics-based modeling of microwave devices, components, packages, and radiating structures using semiconductor analysis and computational electromagnetics.
- b. The research and/or novel application of low-cost analog signal processing components based on acoustic wave technology, acoustic charge transport, magnetostatic waves, or high-temperature superconducting materials, either singly or in combination.
- c. Emphasis should be directed toward achieving larger bandwidth, reducing insertion loss and power consumption, or lowering fabrication costs.
- d. Novel linearization techniques.

Technical Point of Contact: Dr. Joe Qiu, email: joe.qiu@us.army.mil, (301)394-2532 or Dr. Frank Crowne, email: frank.crowne@us.army.mil, (301)394-5759.

2.12.a. Broadband Mixed-signal Circuits and Digital Signal Processing Architecture. The Army requires the generation and analysis of broadband complex-modulated vector-waveforms for applications in communication, radar and electronics warfare. The Army is also looking for innovative digital signal processing circuits and architectures to process the large amount of data associated with the increased bandwidth. Technical areas of interest include but are not limited to the following:

- a. High-speed low-power digital-to-analog converters (DACs) and analog-to-digital converters (ADCs).
- b. Circuits and techniques to generate and distribute highly stable and low jitter clock signals for DACs and ADCs. Techniques to synchronize converter clocks with the front-end local oscillators.
- c. Novel broadband high-frequency circuits and techniques for modulation and demodulation of complex waveforms.
- d. High capacity and parallel digital signal processing techniques. These may include both ASIC and FPGA approaches.

Technical Point of Contact: Dr. Joe Qiu, joe.qiu@us.army.mil, (301)394-2532.

2.13. Frequency Control. The Army requires study and research of frequency control device technology since the accuracy and stability of RF sources and clocks are key determinants of the performance of radar, C3I, navigation surveillance, EW, missile guidance, IFF systems and sensors.

- a. High purity quartz and new piezoelectric materials.
- b. Gun Hardened RF oscillators and clocks for smart munitions.
- c. Low-noise vibration resistant RF sources and clocks for FCS systems radar, communications, navigation surveillance, EW, missile guidance, IFF and sensors.
- d. Low-jitter clocks and low phase noise RF sources from HF (1 MHz) to W-band (100GHz).
- e. Resonator theory, modeling and computer aided design of resonators and oscillators. Including 3-d finite element of resonators with improved algorithms to reduce super computer calculation times.
- f. Processing and packaging of high stability resonators and RF sources, including mode suppressant techniques to limit degradation of filters and RF sources, mounted in below cut-off wavelength size modules.
- g. Resonators and oscillator theory leading to optimum performance.
- h. Ultra-low-noise measurement techniques of SAW and bulk resonators, piezoelectric material parameters calculation, modeling and measurement, diagnostic analysis and probing techniques, including fundamental noise studies involving 1/f noise.

- i. Thin film piezoelectric resonators and micro-resonators (MMIC compatible) for resonators filters and RF sources.
- j. Hardware and software development of low power, high-stability clocks.
- k. Design of miniature low loss (<2dB) piezoelectric resonators for compact size, narrow bandwidth bandpass filters (.01%-5%).

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2.14. Wide Band Gap Electronic Devices. The ARL is interested in high power, high frequency devices especially for multifunction applications such as radar and communications. We are studying the materials technology for growing GaN/AlGaIn device structures with reduced defect concentrations and processing them into devices to try to better understand how defects affect the device properties through both material analysis and device modeling. We are also interested in learning how material defects affect device reliability. The materials technology includes optimizing the growth conditions in our MOCVD reactor, and developing the appropriate technologies such as implant activation, contacting, and etching.

We are also interested in high power, high temperature devices and the materials structures such as those made from the wide band gap (WBG) semiconductors, SiC and GaN. Currently, we are characterizing SiC wafers and the device structures grown on them, and attempting to relate the defect structure with the device properties and the reliability of the devices, such as JBS diodes, fabricated from these structures. We are also examining the ion induced defect structures with points of premature failure as represented by the formation of microplasmas. This is made possible by our unique focused ion beam (FIB) transmission electron microscope (TEM) capabilities. The TEM is also being used to examine the oxide – SiC interface in an attempt to understand how to improve the channel mobility in SiC MOSFETs. This work includes both materials analysis and device modeling.

Technical Point of Contact: Dr. Kenneth A. Jones, e-mail: ken.a.jones@us.army.mil, (301) 394-2005.

2.15. RF Wide Band Gap Semiconductors/Devices. The ARL is interested in understanding the modeling requirements for heterojunction devices, such as HBT's and pHEMTs. The modeling issues involve high-field transport and space charge effects to predict intermodulation products and noise issues (in particular 1/f noise). The research is both theoretical and experimental, leading to the understanding of device parameter limitations. The tasks involve microwave CAD, microelectronics fabrication and microwave instrumentation and measurements. We are also interested in high temperature/high power electronic devices in GaN, SiC or other wide band gap materials. Devices support RF/power applications for Army systems operating in extreme environments.

Technical Point of Contact: Mr. Edward Viveiros, email: edward.viveiros@us.army.mil, (301)394-0930 or Dr. Pankaj Shah, email: pankaj.shah@us.army.mil (301)394-2809.

2.16. RF Devices and Integrated Circuit Technology. The ARL is interested in research on innovative electronic materials, devices, monolithic circuits, and integration techniques for digital, mixed signal, and RF-to-sub-millimeterwave applications. Work should involve devices and ICs built upon new Si-based, III–V, III-nitride, and II-VI materials, novel device structures, innovative circuit topology and multi-level integration technology.

Technical Point of Contact: Dr. Alfred Hung, email: h.alfred.hung@us.army.mil, (301)394-2997 or Mr. John Penn, email: john.penn4@us.army.mil, (301)394-1039.

2.17. Emerging Technologies for Semiconductor Investigations. Army electronics systems for the twenty-first century will require a four-order-of-magnitude increase in real-time signal processing capability. These requirements translate to a better understanding of advanced material structures and miniaturization of devices with feature size to the sub-micron region of 0.1 micron and below. Innovative research is sought in the general areas of advanced electronic materials, processing and fabrication science, material processing technologies for semiconductor devices and integrated systems that are critical to Army applications. The major focus in this request includes high speed, non-contact characterization technologies that can be used to aid the understanding, development and fabrication of advanced materials and technologies for microelectronics packaging; fabrication and processing of semiconductors, interconnects and device structures, and the characterization and control of trace impurities, defects and interfaces in semiconductors and masks. Principal emphasis is on surface or interface control during processing of these materials, characterization of their near-surface transport behavior and surface properties, and modeling or theoretical predictions of their properties.

Objective / Approach: This research topic goes beyond the simple desirability of efficient devices and circuits. It is aimed at bridging the gap between research and implementation of new technologies that can be used to support the fabrication of these efficient devices. With the advancement of computers and communication protocols, research results can be better used if the requested effort is broadened to include the integration of these technologies into the overall manufacturing processes. For example, a new surface characterization tool can be used to validate the quality of the advanced material being processed. Its usefulness can be increased by many folds if it can provide real time feed back control to the previous and/or subsequent process equipment (such as thin film deposition process, wafer polishing machines or thermal cycling). Since the ultimate objective is implementation, preventive maintenance concerns for this new technology and its complimentary equipment should be addressed as well.

Conclusion: The work, although basic in nature, is focused on researching technologies to advance the fabrication of new materials, process and electronics that promise to significantly improve the performance, increase the reliability, or reduce the cost of future Army systems. With the need for shorter research-to-implementation cycles, program emphasis has increasingly shifted away from ‘islands of technology’ research to a more balanced approach with interests that cross a broad spectrum of integration requirements. The ultimate goal is higher speed and lower power consumption.

Technical Point of Contact: Mr. Robert Reams, email: robert.reams@us.army.mil (301)394-2800.

2.18. Nanoelectronics and Nanosensors for Army Applications. The Army requires research investigations into the behavior of nanoelectronic and nanosensor devices for application in advanced information processing, ultra-high frequency operation (> 100 GHz), and chemical/biological sensing. The SEDD is interested in receiving novel proposals that address the technical barriers associated with improving the current state of the art. Technical areas of interest include, but are not limited to, the following:

- a. Theoretical and experimental studies of nanodevices.
- b. Novel concepts for electronic and sensor devices, including design, fabrication and testing approaches.
- c. System application considerations including issues of integration, control and management to address high level concerns of interpretation of results and decision making.
- d. Multifunctional 3-D structures and devices.
- e. Nano carbon and other ambipolar class of electronics and devices.

Technical Points of Contact: Dr. Alma Wickenden, e-mail: alma.wickenden@us.army.mil, (301) 394-0094 and Dr. Madan Dubey, email: madan.dubey@us.army.mil, (301)394-1186.

2.19. RF Electronics. Research proposals are requested for electronic sensor devices, modules, and technology for signal generation, amplification, transmission, reception, control and processing. Perform research and development on electronic/optical and quasi-optical devices that will enable future Army C4I systems. Specific areas of interest include:

- a. High frequency devices and modules to enhance situational analysis and increase the communication functionality of Army land forces.
- b. Low power, high accuracy frequency control devices for navigation and communication systems.
- c. Novel RF acoustics and microwave/millimeter wave electron beam devices to enable smart artillery rounds, improved IFF, improved acquisition of slow moving targets and portable chemical sensors.

Technical Point of Contact: Mr. Ed Viveiros, email: edward.viveiros@us.army.mil, (301)394-0930 or Mr. John Penn, email: john.penn4@us.army.mil, (301)394-0423.

2.20. Micro-Devices and Micro-electromechanical Systems (MEMS). Topics of interest include research in material growth, processing, fabrication, and analysis of advanced electronic, sensor and actuator devices. Proposals are requested on scientific and applications studies as well as

modeling, simulation and integration of these devices into circuits and arrays for low cost miniature battlefield sensor and communication systems. Device applications include ground/foilage penetrating and all-weather radar, electronic intelligence, navigation and countermeasures, prognostics and diagnostics, nanoenergetic-MEMS, light weight power sources, and high temperature operation. Specific areas of interest include:

- a. Micro-electromechanical Systems (MEMS) including novel fabrication processes, integration strategies, and 3-dimensional fabrication and assembly.
- b. Advancement of device fabrication technology for MEMS devices with Army applications, i.e., acoustic, pressure sensing, fusing, inertial guidance, and others.
- c. Microrobotics - modeling, design, integration and applications.
- d. Nanoelectromechanical/MEMS, Bio-MEMS and Microfluidics.
- e. Micro and nano power generation.
- f. RF MEMS including switches, phase shifters, resonator and filters, tunable microwave components, and integrated package and assembly strategies.
- g. Nanoenergetics – material processing, self-assembly, printing, integration on a chip, packaging for actuator applications, i.e., thrusters, safety and arming, switches, pumps.
- h. Bio-inspired sensors- active or passive, materials with bio-mimetic applications.

Technical Points of Contact: Dr. Ronald Polcawich, email: Ronald.g.polcawich@us.army.mil (301)394-1275 and Mr. Eugene Zakar, email: eugene.zakar@us.army.mil, (301)394-1628.

2.21. Antenna Front End and Receiver Technology for Multi-Function Radio Frequency Architectures The Army has an interest in researching affordable shared aperture, single system architectures which could implement radar, radiometric, combat ID, command and control, target acquisition, communications, signals intelligence (SIGINT), satellite on the move (SOTM), and communications on the move (COTM) functions – depending on platform requirements. Supporting technologies include, but are not limited to, electronically scanned antennas, multi-beam antennas, multi-band/broadband antennas, and wafer level antennas. Specific areas of interest are broadband antenna elements, low loss phase shifters, low loss delay lines, true time delay architectures, low loss splitters and combiners, planar technologies, issues associated with polarization switching, instantaneous bandwidth, low-loss high performance switches, simultaneous multiple beam formation, wide-bandwidth RF components and modules (LNA's, PA's, Mixers), and high performance design tools. Other supporting technology includes digital receiver technology, high performance A/D converters, high performance filters, programmable synthesizers and signal processing architectures.

Technical Point of Contact: Dr. Steven Weiss, e-mail: steven.weiss@us.army.mil,

(301) 394-1987 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.22. Conformal Antennas. The Army has an interest in integrated antennas and antenna arrays that are platform conformal. Such platforms are broadly defined and can be as diverse as the side of a vehicle, the wing of a UAV or the backpack of a soldier. The antennas should exploit novel techniques (e.g., metamaterials, artificial ground planes, electrically small antennas on a chip, etc.) to achieve comparable performance with traditional antenna architectures such as whip, dish, and slots. An important metric is comparable performance to legacy antennas while reducing cost and increasing affordability.

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(301) 394-1987.

2.23. RF Signatures. ARL has the Army's only high-resolution microwave and MMW radar signature and analysis facility and is interested in proposals for novel ISAR image processing techniques that significantly improve traditional FFT based processing. In traditional processing a step-frequency waveform is used. Range resolution is increased with the number of steps i.e. bandwidth and Doppler resolution or cross-range resolution is increases with number of pulses integrated. We are interested in techniques that will result in high resolutions with fewer pulses. Also of interest are techniques for suppressing noise and clutter in ISAR images of very low radar cross section targets.

Technical Point of Contact: Mr. Bob Bender, email: robert.l.bender@us.army.mil, (410)278-4319 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.24. RF Radiometry. The Army has an interest in RF radiometry for imaging during conditions of fog, dust, smoke, and clouds. The technology can be applied to the detection of military vehicles, air- and ground- vehicle obstacle avoidance, low-visibility aircraft landing, and navigation. Specific research areas of interest include millimeter- and sub-millimeter-wave phenomenology, polarimetry, and synthetic aperture imaging, enabling device technologies, calibration techniques, super resolution techniques, RF optics and scanning designs, motion compensation for sparse arrays, signal processing, and target and clutter models. RF radiometry solutions for concealed weapons detection are also of interest.

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(301) 394-0865 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.25. Next Generation Digital Imaging. The SEDD is actively engaged in research leading to next generation digital imaging systems. Although several critical technologies, including image collection optics, solid state detectors, digital post-detection processing, and image display, impact critically the performance of digital imaging systems, traditional approaches to specifying these components for such systems do not pay sufficient attention to the interplay between them and the subsequent impact that has on overall system performance. In contrast, our integrated approach optimizes the design of the component technologies in parallel. Such an approach provides improved performance while also addressing size, weight, cost and power issues. Recent developments in detector technology, computational capabilities, and the manufacture of

optical surfaces facilitate an integrated imaging design approach. We are interested in proposals that address two or more of the following topics: image reconstruction, aspheric optical design, information theoretic imaging metrics and numerical optimization techniques.

Technical Point of Contact: Dr. Joseph Mait, e-mail: joseph.mait@us.army.mil, (301) 394-2462.

2.26. Prognostics and Diagnostics. Research efforts are sought in the area of prediction of remaining useful life of critical devices, components, and sub-systems on a multitude of Army platforms. This area is particularly concerned with the implementation of prognostics algorithms in a tag/reader format with small form factor and minimal power consumption and is wirelessly networked & interrogable and extensible to existing platform diagnostics and readily available sensors. The systems or techniques proposed must have the processing efficiency necessary to expedite operational and logistical decision making without severely impacting physical and logistical footprint. Compatibility with an open common architecture such as CLOE or PS-MRS is preferred.

Technical Point of Contact: Mr. Kwok Tom, email: kwok.tom@us.army.mil, (301)394-2612.

2.27. Prognostics and Diagnostics health monitoring system. The Army has an interest in the area of Prognostics and Diagnostics health monitoring system as applied to current and future weapons platform. With this embedded health monitoring unit, the commander and logistician will be able to increase readiness and enhanced awareness of material condition. A cost savings can be obtained in shifting the paradigm from a time-based to a condition-based maintenance. Using environmental along with specific application sensors, signal processing will be necessary to predict the remaining operational life expectancy and the operational status. Understanding of the Physics of Failure and reliability engineering are crucial in the development of predictive algorithms. Areas of significant interest are the prognostics prediction algorithms, methodology in the development of prognostics routines, efficiency technique/processing of sensor data to reduce data storage requirements and methods of sensor fusion.

Technical Points of Contact: Mr. Kwok Tom, e-mail: kwok.tom@us.army.mil, (301) 394-0865 or Mr. Eric Adler, e-mail: eric.d.adler@us.army.mil, (301) 394-0933.

2.28. Image Processing(IP).

This topic addresses research interests in algorithm development for image reconstruction, enhancement, detection, recognition, tracking, identification of objects-of-interest and spatiotemporal perception. The data class of interest includes EO-IR-multi/hyperspectral imagery and video. These different types of imagery vary in resolution, wavelength, and sensor type that can be exploited individually or collectively. Robotics and persistent surveillance for ARMY Surveillance and Reconnaissance (ISR) are important applications of interest.

Specific topics include:

a. Model based Automatic Target Recognition (ATR). Algorithms incorporate external knowledge related to the targets, scene, and sensor to perform one or more ATR functions such as detection, recognition, tracking, and identification.

b. Knowledge-based scene understanding and spatiotemporal perception. These algorithms accomplish recognition through inferences from symbolic representations of the scene and environmental characteristics, as well as knowledge of their inter-relationships. Results of prior investigations have shown that poor scene feature classification was the most significant limiting factor for use of these techniques. Studies to extend scene classification algorithms by exploiting additional sources of information should be considered.

c. Multisensor IP algorithms. The passive nature of TV or FLIR ATR is frequently preferred in a battlefield scenario. However, the increased information content and the potential performance boost of combining passive and active sensors makes multisensor fusion approaches worth investigating. Proposals for the development of algorithms providing fusion of FLIR imagery with one or more sensors, such as ladar, TV, or millimeter wave (MMW), will be considered if they represent a performance enhancement over current methods.

d. Hyperspectral IP algorithms. Information content is increased with use of hyperspectral imagery. Special problems arise because of the large amounts of information. Novel methods by which to exploit the increased information content without sacrificing speed of computation are possible topics of research in this area.

e. Robotic or networked sensor IP algorithms. Robotic and networked imagers may be somewhat different, but this research area emphasizes the use of algorithms that can give early indication of targets in the scene. The imagers typically are smaller and are of lower resolution than imagers considered for FLIR ATR or hyperspectral ATR. Information from different vantages may also be used for these types of sensors. Networked sensors may be of visible cameras, acoustic sensors, magnetic sensors, or any of a wide variety of sensors that can detect targets. Innovative use of these types of sensors to produce scene understanding and perception will be considered.

f. Image Synthesis and reconstruction. Algorithms for generating images from sensor array data such as antenna arrays, microphones, hyperspectral sensor systems etc. and from partial or incomplete information. Areas include 3D reconstruction, tomographic reconstruction, super-resolution and sparse-sampled processing, high dynamic range synthesis, image graphics, image rendering and display.

Technical Point of Contact: Dr. Raghuv eer Rao, e-mail: raghuveer.rao@us.army.mil, (301) 394-0860

2.29. Unattended Ground Sensor (UGS) Technology. Technology concepts, sensors, algorithms, and hardware modules that support:

- a. Wide-area detection, localization, classification and identification of people, ground vehicles, aircraft, and ammunition fire (e.g., gunshots, mortar, artillery, etc).
- b. Autonomous determination of accurate position, orientation, localization and field deployment of UGS.

- c. Smart mine sensor field surveillance.
- d. Communication, networking and distributed fusion of information among various UGS nodes to provide robust ISR information.
- e. Remote control of UGS. Of particular interest are low-cost, low-powered, and small-sized hardware modules that implement the functions listed above.

These UGS should be capable of low-altitude air deployment. Issues relevant to variations in dispersion area, terrain, etc are critical.

Technical Point of Contact: Mr. Tom Walker, e-mail: tw.walker@us.army.mil

(301) 394-0756.

2.30. Disposable Sensor Technology. Research proposals are desired that can lead to a complete sensor system consisting of several disposable sensor nodes that can communicate with a remote display. Each disposable sensor node should include one (or more) transducer(s), a signal processor, and a communication device, all in a single package. Disposable sensor nodes should be extremely small, lightweight, and consume extremely low amounts of power. The projected unit cost for individual nodes should be less than \$10 each, based on production quantities in the millions.

The primary performance goal is the detection of personnel and/or human activities, especially in confined areas; e.g., buildings, caves, bunkers, tunnels, sewers, etc. False-alarm rates must be kept low, even in a dynamic battlefield environment. In general, overall network performance is more important than performance metrics for individual nodes: “the network is the sensor”. Other desirable performance goals include detection and/or classification of other targets and/or threats, including gunshots, mortar, artillery, and rocket launches and/or explosions; power line activity; telephone activity; chemical and/or biological threats; unattended air vehicles, micro-air vehicles, and other robotic or autonomous vehicles; etc. Low-bandwidth information, including context-oriented location information, should be exfiltrated via the sensor network to the end user in near-real time. Sensor modalities are not specified in this topic, but could include acoustic, seismic, magnetic, electric field, non-imaging passive infrared, passive RF, chemical/biological, and/or any other transducer(s) that could be used to detect any targets or threats of military significance. Sensors should be chosen and/or configurable for a wide variety of Intelligence, Surveillance, and Reconnaissance (ISR) missions, including self-protection for individual soldiers, surveillance by small groups of soldiers, perimeter security, and border monitoring.

Node-level computations are needed to reduce relatively high-bandwidth raw sensor data to immediately usable information that can be transmitted over extremely low-bandwidth *ad hoc* sensor networks. The sensor output should be as concise as possible, but include a node ID, timestamp, target type, and confidence level. Development of sensor fusion algorithms, including multi-modal algorithms that are independent of particular transducers, can be considered under this topic.

The communications source may be acoustic/ultrasonic, RF, or IR, or it may resonate or reflect "on command" from an external receiver. One-way communication may be used to exfiltrate data to end-users and/or more capable sensors, gateways, etc. The network should be able to infer node location information from some combination of the ISR sensors, the network topology, and/or programming during emplacement. The node reports should include contextual location information; localization should not depend on GPS. The problem of exfiltrating data from confined areas, e.g., through robust multi-hop networking, should be addressed.

Sensors should be deployable by hand, via UAVs, helicopters, and/or cargo rounds (artillery); however high-G packaging techniques are not a focus of this topic. Similarly, proposals submitted under this topic should NOT focus on sensor information assurance, network-level information fusion, novel low-cost sensor technologies, low-power microprocessors, communications and networking theory, novel display technologies, haptic interfaces, low-cost packaging for high-volume production, and/or power and energy technology (i.e., batteries). These are important issues, and components using technology from all of these areas could be part of a proposed sensor system; however, funding to advance these technologies will generally not be funded under this topic.

Technical Point of Contact: Mr. Jeff Houser, e-mail: jeff.houser@us.army.mil, 301-394-0797.

2.31. Acoustic Technology. Proposals are requested for technology in acoustic sensors and signal processing. Specific areas of interest include (i) advanced acoustic sensors and sensor array designs for UGS and on mobile ground platforms including small robot vehicles and on aerial platforms such as aerostats and UAV's; and (ii) advanced signal processing techniques/algorithms for multi-target beam forming, target tracking, target classification and identification, reduction of wind noise reduction, reduction of platform noise reduction, etc. Required detection capabilities include continuous sources (vehicles, aircraft, etc.) and impulsive sources (gun fire, artillery impacts, etc.). Other areas of interest include long-range hearing, biomimetic acoustics, auditory enhancement of individual soldiers, acoustic signature data collection techniques and equipment, acoustic propagation modeling, novel data analysis techniques, and systems to employ acoustic sensors in new innovative ways, and multi-modal sensor fusion with acoustics and other non-imaging and/or imaging sensors. .

Technical Points of Contact: Mr. Mike Scanlon, e-mail: michael.scanlon@us.army.mil, (301) 394-3081 or Dr. Tien Pham, e-mail: tien.pham1@us.army.mil, (301) 394-4282.

2.32. Sniper and Artillery Location Technology. Proposals are requested for research in sensor technology for detecting, tracking and locating the source of hostile small arms, artillery, rocket, and mortar fire. Potential sensors include acoustic, seismic, radar, infrared, and ultra violet. Sensors proposed for this application should be capable of locating the source of enemy fire, and may include other data such as the distance of the miss, the type and number of rounds fired, etc. Source bearing accuracy of better than +/- 10 degrees is desirable.

For small arms, location of the firing source at ranges of 300 m and beyond is desirable. For

mortar/artillery/rocket fire, location of likely firing positions despite intervening terrain or non-benign environmental conditions is of particular interest. The capability to locate the source of mortar firings at ranges greater than 2 km and artillery/ rocket firings at ranges greater than 10 km is desirable. Operation of sensors on individual soldiers, fixed sites, and moving vehicles are all of interest. Research into areas either directly addressing the sniper/mortar/artillery/rocket problem or supporting technologies will be considered.

Technical Points of Contact: Mr. Mike Scanlon, e-mail: michael.scanlon@us.army.mil (301) 394-3081 or Mr. Steve Tenney, e-mail: steve.tenney@us.army.mil, (301) 394-3080.

2.33. Electric Field Sensor Technology. Research proposals are desired that are related to small, rugged, low-power electric field sensors that can be deployed on a battlefield using artillery-based delivery systems, or scattered from air or ground vehicles, or emplaced by individual soldiers. These sensors should be passive or semi-active (i.e., with no local field-generating element), and may operate at low frequencies in the quasi-static zone (or "near field"), where the electric and magnetic fields are not coupled. These sensors should be characterized by exceptionally low power, size, weight, and cost, and/or by exceptionally high sensitivity and low noise (i.e., with performance limited by the background environment).

They should operate in an unattended mode, and should be able to detect, classify, identify, localize, and/or track tactically-significant targets, including ground vehicles (tanks and other tracked vehicles, and wheeled vehicles), air vehicles (fixed-wing, rotary-wing, UAV/MAVs, etc.), and/or other targets and events at tactically-useful distances. These other targets include, but are not limited to, armed individual soldiers, underground facilities, power and telephone lines, RF transmitters; other events including gunshots, mortar and artillery launches, and explosions.

These sensors may be used individually or as part of a wide-area sensor array for surveillance, target acquisition, and/or engagement. While individual sensors may or may not have exceptional individual performance, their low size, power, weight, and cost should permit them to be used on the battlefield in ways not previously contemplated. Moreover, arrays and/or networks of such sensors are expected to provide new sensing capabilities and levels of performance simply not available today.

Unattended surveillance sensors may be stationary or mounted on robotic platforms; these sensors will be integrated with local signal processing and communications capabilities, and should operate unattended for weeks or months after deployment. The sensor output should be quantitative: e.g., analog voltage level(s) or digital word(s); it should contain target information, and possibly a confidence level, suitable for low-bandwidth transmission and/or inter-sensor fusion.

Proposals related to the subject technology are also desired, to the extent that they are applicable to standalone sensors that can be used in proximity fuses, small-unit training and simulation devices, etc. In this case, sensors may operate for a much shorter period of time (typically seconds to hours), so extremely low-power operation is less important, and the final sensor output may be qualitative (yes/no).

Proposals will be accepted in five areas:

- a. Research on novel electric field sensor concepts leading to quantification of detection distance(s), classification, identification, localization, and/or tracking of various classes of targets.
- b. Research directed at environmental and/or platform noise reduction, and/or reduction of sensor front-end noise (particularly $1/f$ noise).
- c. Research related to filtering and/or signal processing techniques, which are expected to improve the detectability of targets in a battlefield environment.
- d. Computer-based modeling of targets and sensors that can provide a capability to perform trade-off analyses of sensor concepts during prototype design.
- e. Research of prototype design(s) of individual electric field sensors suitable for detecting tactically significant targets in battlefield environment.

There are several related topics in this BAA that are intended to complement each other. Proposals that focus on magnetic sensing should be submitted against the "Magnetic Sensor Technology" topic. Proposals that focus on low-cost sensor systems should be submitted against the "Disposable Sensor Technology" topic.

Technical Point of Contact: Mr. David M. Hull, e-mail david.hull@us.army.mil, 301-394-3140.

2.34. Passive Magnetic Sensor Technology. Research proposals are sought for work that can lead to small, rugged, low cost, low power, highly sensitive passive magnetic sensors for use as part of unattended ground sensor systems. The sensors can be deployed using artillery, scattered from the air or ground vehicles, or hand emplaced. Since it is desired that they will operate unattended for weeks or months at a time, they must consume very little power. To provide surveillance over an area of a few square kilometers, many low cost sensors will have to be employed. The sensors may detect ferromagnetic material on vehicles or carried by armed personnel or the low frequency signals generated by vehicles or underground facilities. For most applications, the sensor output should have a digital output that can be used in a tracking/classification algorithm. Magnetic sensors used in some application such as in proximity fuses, small-unit training and simulation devices, etc. may consume more power. Other BAAs cover communications between sensors and to hubs.

Besides using stationary sensors, the sensors also may be employed on robotic platforms, UAVs, and UGVs. In these applications the requirement of low cost is less severe, but there is a need for coping with noise generated by rotational vibrations. Total field magnetic sensors may provide a solution to this problem. Proposals are sought for:

- a. Low cost, energy efficient, high sensitivity vector and total field sensors.
- b. Methods for reducing geomagnetic noise.

- c. New efficient algorithms for identifying and tracking targets.
- d. Methods for reducing the cost and power consumption of magnetic sensors.

Technical Point of Contact: Dr. Alan S. Edelstein, e-mail: alan.edelstein@us.army.mil, 301-394-2162.

2.35. Development of Multi-Spectral Signature Management*. There is an interest for proposals that encompass multi-spectral signature management. This material, both structural and non-structural, shall exhibit absorptive, reflective, and/or transmissive characteristics (both wide and narrow band) as a function of wavelength frequency. The problems of inexpensive application and durability in the Army environment are of interest.

Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507.

*For additional security information: Mr. Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863.

2.36. Temperature Control and Heat Transfer (Low Observable)*. Proposals are requested that examine innovative methods to control the radiant power from vehicles and aircraft by modification of radiometric properties and/or heat transfer control of internal combustion engines and heat-producing machinery. The electromagnetic (EM) region of interest is 16 to 2.0 microns.

Technical Point of Contact: Dr. Keith A. Snail, email: keith.snail@us.army.mil, (301)394-5507

*For additional security information: Mr Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863.

2.37. Visual Signature Management *. Proposals are requested that examine methods to reduce the visual and near infrared (NIR) signature of ground and air vehicles using either active or passive methods or a combination.

Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507.

*For additional security information: Mr Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863.

2.38. Signature Management Codes, Predictions and Modeling *. There is an interest in proposals for modeling the effectiveness of signature-reduction applications and proposed applications in the visible, infrared, and radar portions of the EM spectrum and in the acoustic regime for various Army systems, including ground vehicles, aircraft, tactical units, etc.

Technical Point of Contact: Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507.

*For additional security information: Mr. Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863.

2.39. Integration of Signature Management Technologies *. There is an interest in proposals that examine the effectiveness of incorporating signature management technology into current and planned Army systems. Interest is in air missile, ground and soldier systems.

Technical Point of Contact: Mr. John MacLeod, e-mail: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507.

*For additional security information: Mr Crede Bailey, e-mail: Mr. Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863

2.40. Signature Management Measurements *. Proposals are requested for engineering measurement techniques and systems that would be effective for the development and evaluation testing of signature-reduction technology. Measurements are needed in the visual, infrared, and RF portions of the EM spectrum, as detailed in techniques.

Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507..

* Mr Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863..

2.41. Management of Acoustic Signatures *. Proposals are requested that examine acoustic damping, both carrier wave and modulations of generated acoustic spectra. Applications are for ground vehicles, engine generators, and aircraft.

Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507.

*For additional security information: Mr. Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863.

2.42. Countering Reduced Signature Systems and Vehicles *. Proposals are requested that examine technologies to counter reduced- signature military systems, aircraft and ground vehicles. All areas of the EM spectrum are of interest.

Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507..

*For additional security information: Mr. Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863

2.43. Software Implementation (Low Observable) *. Proposals are requested that examine existing and proposed software programs involving technology and/or security interfaces with low-observable work. Interest lies in upgrading existing programs as required by higher headquarters and developing new low-observable programs as the technology demands.

Technical Point of Contact: Dr. Keith Snail, e-mail: keith.snail@us.army.mil, (301)394-5507..

*For additional security information: Mr. Tim Brown, e-mail: timothy.brown39@us.army.mil, (301)394-3863.

2.44. Electrochemical Power Production and Energy Storage. The areas of technology of interest to ARL are:

- a. Active and Reserve Primary Batteries for Munitions Applications: Research of battery chemistries and battery designs capable of supplying power densities from 20 to 400 Watts/liter after 10 or more years of storage. Storage and use are required over the full military temperature range.
- b. Primary Lithium Batteries: Research of battery chemistries for cells and stacks of cells for man-portable applications, using environmentally-friendly materials and capable of providing better service than the Army's present general-purpose Li/SO₂ and Li/MnO₂. Emphasis is on modification of commercially-based chemistries to permit soft-packaging and all-weather storage and use. This may include Li/air formulations.
- c. Rechargeable Li (Li Ion) Batteries: Research of chemistries for cells and stacks of cells using liquid or polymeric electrolytes and capable of providing specific energies greater than 120 Wh/kg, steady specific power greater than 50 W/kg, continuous and greater than 1kW/kg pulse, over the full military temperature range. Development of manufacturing technology for such batteries.
- d. Fuel Cells: Research of improved Fuel Cells for use with methanol-fuel, hydrogen generators and fuel reformers for use with hydrogen-fueled systems. Development of hydrocarbon fuel reformers and reformer components, including desulfurizers and sulfur tolerant reformer catalysts to provide hydrogen for fuel cells. Development of medium and high temperature fuel cells and components for the direct utilization of hydrocarbon fuels or of impure hydrogen.
- e. Fast-Rise Pulse Power Capacitors: Research of film capacitor technology including the development of high energy dielectric films, impregnants, metallization and manufacturing technology for capacitors that can provide energy densities > 1.5 J/cc. And rise-times in the microsecond range.
- f. High Temperature Capacitors for Power Electronics: Research and development of high temperature polymeric dielectrics including process development for high temperature thin film manufacturing. The capacitors made of such thin film dielectric should be operable at temperatures over 90 degrees C, preferably over 150 degrees C, with low dissipation at frequencies up to 100 kHz and without derating. The current rating and capacitance rating should be as high as the state-of-the-art capacitors for power electronics.

Technical Point of Contact: Dr. Cynthia Lundgren, e-mail: cynthia.lundgren@us.army.mil, (301) 394-2541.

2.45. Power Conditioning The Army is searching for innovative technologies and techniques for reducing the size, weight, cost, and logistics footprint of power conditioning systems across the full range of Army applications. High efficiency and high temperature operation (for reduced cooling) are also critical requirements. Some specific areas of interest include:

- a. Novel power converters.
- b. Novel materials and designs for high-temperature power conditioning capacitors and inductors.
- c. High performance components such as switches and capacitors.
- d. PFNs for electric guns, directed energy, electromagnetic armor and other high power loads.

Technical Point of Contact: Mr. Skip Scozzie, e-mail: charles.scozzie@us.army.mil, (301) 394-5211 or Mr. Bruce Geil, email bruce.geil@us.army.mil, (301)394-3190.

2.46. Wide Band-Gap Power Devices. The SEDD is seeking proposals for research of wide band gap devices in the following areas:

- a. Device design and fabrication of monolithic and hybrid voltage-controlled SiC or GaN high-temperature high-field power devices.
- b. Circuit design and fabrication of highly-efficient Si-based and SiC- or GaN-based high-temperature power electronics for power conversion and motor-control applications.
- c. Circuit simulation to allow topology and device trade off studies for the design of high-temperature power conversion circuits for specific Army Future Combat Systems applications.
- d. High-temperature high-field insulator materials for use as gate dielectric and field passivation layers for application to SiC and/or GaN power devices.
- e. High-temperature packaging and thermal management systems for wide bandgap power electronics ($T_j = 225$ to 400 C).

Technical Point of Contact: Mr. Skip Scozzie, e-mail: charles.scozzie@us.army.mil, (301) 394-5211.

2.47. Micro-Electromechanical Systems (MEMS) Development for Power Generation Components. The Army is searching for innovative MEMS technologies and techniques to reduce the size, weight, cost, and logistics footprint of small (10-500 W) power generation systems across the full range of Army soldier and UAV applications. Technologies to improve small engine and fuel cell performance are also areas of interest. Some specific areas of interest

include:

- a. MEMS base fuel delivery technologies
- b. MEMS based methods to reclaim energy from waste heat and gas flows.
- c. Advanced MEMS based cooling technologies for power electronics and small power generators.
- d. Technologies to support MEMS rotary systems including bearings, motors and similar components
- e. System simulation to improve current MEMS state of the art in thermal, rotary, and fluid delivery designs.

Technical Point of Contact: Mr. Bruce Geil, e-mail: bruce.geil@us.army.mil, (301) 394-3190.

2.48. Directed Energy. ARL is the designated leader for the Army's directed-energy weapon (DEW) technology base program. This includes high-power microwave (HPM), non-nuclear electromagnetic pulse (EMP) (NNEMP), e-beam/x-ray, and high-power acoustics and air pressure waves. ARL has a continuing interest in a broad spectrum of research in these areas, including:

- a. A better understanding of the susceptibility of developmental and fielded systems to attack by an RF DEW threat.
- b. Improved methods and technologies for hardening systems against that threat.
- c. The development of new components (sources, pulsers, and antennas) for possible future application in an RF weapon system:

(1) Generation of microwave power/energy--Novel pulsers/sources are needed that have programmable pulse characteristics so that rise time, pulse width, repetition rate and frequency bandwidth can be changed electronically, along with frequency-sweeping capability over octave bandwidths. Design considerations of low-cost compactness and high efficiency are of particular interest. Switch technologies that convert dc to RF directly with picosecond rise time capability are of interest. Radio frequency oscillators/amplifiers that use picosecond electronics to obtain programmable RF outputs are desired, along with picosecond RF exiters to drive amplifiers. Portable kilowatt and megawatt RF/microwave amplifiers with octave bandwidths are sought. Frequencies of interest are from 0.3 to 10 GHz, with microsecond pulse durations and high duty cycles. Efficiencies should exceed 30 percent and gain should exceed 30 dB. Novel technologies that are suitable to extend high-power pulse amplifiers to 40 GHz or higher are also sought. Bandwidths should be multi-gigahertz and gains should exceed 20 dB. Emphasis will be placed on efficiency, compactness, and portability.

(2) High-power (gigawatt-power) levels--Antennas are needed that can efficiently radiate ultra broadband and narrowband RF energy. Compact antennas are of interest that are small compared to the low-frequency wavelength and can be shaped in conformal configuration. Mode converters that can operate up to gigawatt levels are needed. Compact modulators capable of

driving up to gigawatt sources at several kilohertz pulse repetition rate with impedances of 10 to 200 ohms and pulse lengths up to a few microseconds are also of interest. Research that increases our understanding of HPM antennas, mode converters, and modulators is sought.

(3) The effects of RF and microwave power/energy--Material susceptibility are the primary area of concern. Included are composite materials, electro-optical systems, computers, communications, displays, receivers, sensors, monolithic microwave integrated circuits (MMIC), very high speed integrated circuits (VHSIC), and other sophisticated electronic systems, subsystems, and devices. Upset and damage to electronic devices and their failure mechanisms, caused by RF transients, are of interest. RF coupling and failure mechanisms that are affected by such parameters as frequency, pulse width and shape, repetition rate, amplitude, and polarization are also of interest. Novel schemes are solicited for techniques that can be used for protection against the RF and HPM threats. Advanced methods and techniques are needed for housing composite materials. Methods for the theoretical understanding and prediction of RF effects from transients with a wide range of pulse characteristics are of great interest.

(4) Hardening to RF energy--Army system survivability is enhanced using hardening techniques that are readily verifiable, reliable, and maintainable in the RF environment. ARL needs improved interactive models that yield statistical parameters of the source/system environment for complex scenarios. Models are sought that are suitable for understanding the mechanisms of device susceptibility and leading to improved devices. Detailed models have been developed that use excessive computer resources. New approximate techniques need to be developed to readily accommodate complex scenarios. Models are needed for composite materials, including both resistive and inductive effects. Innovative techniques for hardening front- and back-door entry ports of systems are sought. Hardening includes techniques to limit the throughput of the path or to raise the susceptibility threshold of devices subject to burnout or upset from RF energy. Hardening devices are of interest that:

- a. Can handle large average and peak powers.
- b. Can limit or switch unwanted HPMs in protecting the system or subsystem.
- c. Have frequency and amplitude selectivity. Vacuum microelectronics, semiconductor, and magnetic technologies are all of interest.

(5) RF microwave diagnostics--Novel, non-perturbing RF/microwave diagnostics are sought. Such devices should be able to measure RF/microwave power for microsecond durations and have rise times in the 0.1- to 10-ns range. The diagnostics should be mountable inside enclosures near complex structures. High-frequency probes that can operate above 2 GHz are also of interest. Quality measuring techniques are needed for seams, joints, and contracts for composite materials. The Army has a great interest in testing military systems in a microwave environment. Research topics related to the Army's system testing effort include instrumentation and measurements, anechoic chamber design and characterization, microwave source development, novel testing techniques to allow a military system to be quickly evaluated in a microwave environment, experimentation to determine microwave effects, modulations of microwave signals, and high-power sources.

(6) Battlefield effectiveness of RF-DEW--The Army, as well as DoD in general, is involved in the impact of RF effects on the battlefield. Novel approaches are sought to develop techniques/models that can describe the effects of system degradation on battlefield systems and how the systems may impact the outcome of the battlefield-appropriate measures of effectiveness must be defined for various types of weapons and sensors that could be affected by RF energy.

(7) Photovoltaic (PV) Power Sources - Both novel and conventional photovoltaic and thermophotovoltaic materials, the integration of PV materials with batteries and chargers and design battery charging circuits for tactical recharge will be conducted under this task.

(8) Nuclear Batteries - Radio isotope targets for X-ray irradiation, to measure burn-up and triggering of isomeric materials using both insitu and post irradiation gamma spectrum comparisons, as well as beta spectrometry, are necessary for the development of nuclear batteries of various physics.

(9) Small Engine Power Sources - Testing in the small engine (i.e., Stirling and other cycles) evaluation laboratory, including the measurement of temperature, pressure, emissions (chemical and acoustic), power output, and efficiency will support efforts to develop a small power source to supplement or, in some cases, replace batteries. Experiments will include for the evaluation of standard and novel fuels (e.g. JP-8, methanol) in engines and other power producing devices.

(10) Transportable Nuclear Reactor - A small and safe transportable nuclear reactor would have logistic advantages. The question of the feasibility of a mini-reactor in tactical and/or strategic situations, using war games as analysis tools, is required. The minimum critical volume based on large thermal fission cross-sections, the possibility of small fast neutron fission cross sections so as not to utilize bomb material, attempts to minimize weight and size of converter to electric power, the possibility of minimizing the heat signature, estimating the logistical advantage of a transportable micro reactor, including the cost and time of development, obtaining the cost trade off for different fissile fuels and outlining an approach with trade-offs will be necessary to determine the practicality of such a system. The design of critical components and subsystems, the development of the experimental system, computer model demonstrations for military users, and final development of scaled up field demonstration systems are crucial steps.

Technical Point of Contact: Mr. Eric Adler, email: eric.d.adler@us.army.mil (301)394-0933 or Mr. Mark Berry, email: mark.d.berry@us.army.mil, (301)394-1228

2.49. Photonic Devices and Modules. Research is encouraged pertaining to active and passive devices as well as fiber based technology for sensing, communication including microwave, data and telecommunication and optical signal processing, Active device research includes the development of bulk and integrated sources, modulators, detectors and waveguides, and the development of technologies for their integration into processor architectures. Laser-based Terahertz systems are also sought. Active interface devices include semiconductor light emitting diodes (LED), lasers, vertical cavity surface emitting laser (VCSEL), photo detectors, solar cells,

modulators, amplifiers and waveguides, with operation in the UV to IR spectral region, as well as integrated drivers and receivers. Also of interests are novel RF-Photonic devices, components, modules, and subsystems. Integrated array research should include on-chip processing, layout, mounting, and device cooling for one- and two dimensional arrays as well as the driver and receiver circuitry. Parameters of interest include number of elements, readout speed, noise levels, and dynamic range.

Technical Point of Contact: Dr. Lawrence Stout, email: lawrence.stout@us.army.mil (301)394-4616.

2.50. Novel Optical Processing Algorithms and Techniques. Proposals relating to ideas for new processing systems and configurations are welcome. Methods for modulating light beams with signals of appropriate nature are of interest here. Also of interest are methods for realizing certain processing algorithms (e.g., multi-spectral image processing) and methods for detection using elaborate photosensitive devices (e.g., charge-coupled devices and CMOS detectors). Also of interest are algorithms and architectures for high speed data and telecommunications and networking as well as new concept and architectures to generate, transmit and processing RF-microwave signals in optical domain to improve the current RF systems including antennas and Radars. Important factors are speed, reasonable laser power requirements, insensitivity to lens aberration, small size, noise and environmental immunity, and other aspects of high performance. Both pre- and post-processing electronics are among the system components subject to possible improvement, with interfaces and coprocessors.

Technical Point of Contact: Dr. Lawrence Stout, email: lawrence.stout@us.army.mil, (301)394-4616.

2.51. EO/IR Sensors. Research proposals are desired that will lead to the ability to sense, locate, identify, and engage targets at tactical ranges. These sensors must reliably discriminate between targets and clutter and detect targets in the presence of counter-measures. For example, it is desired to detect a camouflage-netted vehicle partially obscured by foliage. Electro-optical and infrared sensors, both passive and active, and covering the spectrum from the ultraviolet to the far infrared, are of interest. Small size and gun or missile launch survivability are required for some applications and low cost is always important. Another area of interest is surveillance (UAV) and fighting platform (rotary wing and ground vehicle) based systems. Critical components of sensors, such as high-power eye-safe laser sources for laser radar, are of interest. Methods for fusing the outputs of various sensors and signal propagation modeling are also of interest. Applications include surveillance and target acquisition, target engagement for smart munitions, and navigation and obstacle avoidance.

Technical Point of Contact: Mr. Barry Stann, e-mail: barry.stann@us.army.mil, (301) 394-3141 or Dr. Keith Aliberti, email: keith.aliberti@us.army.mil, (301)394-2320.

2.52. Infrared Detectors & Power Sources. The SEDD's research and development goal is to advance the technology for producing technologies for smart, multi-spectral, active and passive, focal plane arrays (FPAs) in ultra-violet to sub-millimeter wave spectral regions, with particular emphasis on the infrared region. Effort is also made to develop new concepts for photovoltaic

and thermoelectric for power generation. Specific examples of areas of interest are:

- a. Materials research, thin film growth, nano/bio-materials and device processing for fabricating single and multi-spectral detectors/arrays for active and/or passive sensors covering the major infrared bands. New materials development for power sources etc.
- b. Epitaxial growth processes of materials on compliant and non-compliant substrates (e.g. HgCdTe, GaAs, InGaAs, etc.) for detectors, solar cells, thermoelectric and other optoelectronic applications.
- c. Novel Uncooled FPA technology.
- d. Computer simulation and modeling of single and multi-color detectors and systems.
- e. Biologically inspired techniques for IR detectors and power source devices.
- f. Development of advanced readout circuits including neuromorphic and bio-inspired circuit designs.

Technical Point of Contact: Dr. Priyalal Wijewarnasuriya, email: priyalal.wijewarnasuriya@us.army.mil, (301)394-0963.

2.53. Development of novel III/V materials and devices. We are interested in understanding the properties of, and developing synthesis methods for arbitrary combinations of III/V elements. The work can be experimental or theoretical and is aimed at finding compounds that may provide improved device performance in electro-optical or high-speed electronic applications. Our interests include, for example, dilute nitrides for mid- and long-wavelength infrared detection, antimonides and interface properties of mixed group V compound structures, and the less commonly used group III and V elements, such as thallium and bismuth. We are also interested in related materials processes needed to make working devices from these materials, such as passivation techniques for low bandgap materials.

Technical Point of Contact: Dr. Stefan Svensson, e-mail: svensson@us.army.mil, (301) 394-0605.

2.54. Deleted

2.55. Novel and Highly Scalable Diode-Pumped Solid State Lasers

- a. Novel Solid State Lasers and Laser Materials: The Army is interested in research on innovative gain media, for example laser-quality ceramics; broad-gain media for frequency agile lasers in UV, NIR and Mid-IR; efficient solid-state materials for stimulated Brillouin scattering, e.g., low threshold, high reflectivity, low sound propagation speed; specialty fibers and fiber lasers suitable for high average powers and power scaling; and laser materials for diode-pumped eyesafe lasers.
- b. Techniques for Power Scaling of Diode-Pumped Solid State Lasers: The Army also has

interest in innovative highly efficient pump-coupling techniques; innovative pump diode and active medium cooling techniques; passive and active laser beam/aperture combining methods; laser wavelength shifting techniques for achieving high average powers with optimum eyesafety; active and passive wavefront distortion compensating/OPD reducing techniques.

Technical Points of Contact: Dr. Larry Merkle, larry.d.merkle@us.army.mil, (301) 394-0941 or Dr. Mark Dubinskiy, e-mail: mark.dubinskiy@us.army.mil (301) 394-1821.

2.56. Hyperspectral/Multispectral/Polarization Imaging. ARL is engaged in the research and development in the design and development of high performance compact, field-portable hyperspectral and multispectral imaging systems from the vacuum ultraviolet (UV) to the long wave infrared (LWIR) using tunable filter technologies including acousto-optic tunable filter (AOTF), Fabry-Perot etalon, diffractive optics, Michelson interferometer, liquid crystal, and other promising approaches. There is considerable interest in designing miniature sensors using micro electromechanical systems (MEMS) approach. Development of high performance hyperspectral/multispectral/polarization imager technology is critical to the Army's needs in chemical and biological agent detection as well as for target detection including buried mine detection. The range of applications includes spectroscopic remote sensing of biological and chemical agents, detection of explosives, detection of chem/bio agents on surfaces, pollution monitoring, detection of plumes, condition-based management, and polarization imaging for detection of targets and backgrounds, etc. One area of interest is development of novel collinear and noncollinear AOTFs operating from the UV to LWIR including growth of a variety of nonlinear birefringent materials with high acousto-optic figure-of-merit useful for designing broadband AOTF cells. It is desirable to include polarizing elements in such systems to obtain spectropolarimetric images for better target and chem/bio detection. System designs for compact automated hyperspectral/polarization imagers from UV to long IR incorporating suitable detectors, optics, image collection and processing software incorporating automated target detection algorithms and on chip preprocessing capabilities including biological inspired algorithms, electronically tunable polarimetric elements, suitable high sensitivity focal plane arrays, compact cooling systems, and schemes to improve the noise equivalent spectral radiance (NESR) of such imagers are of critical interest. Research in automatic processing algorithms for spectroscopic and spectropolarimetric imaging data including data storage techniques and data compression is encouraged for detection of biological and chemical agents, and target and backgrounds. Parameters of interest include efficient spectral dispersing elements; design of AOTF cells and transducers including designs to facilitate operation over two or more octaves in frequency; MEMS-based tunable etalons including materials, processing, fabrication, and packaging; diffractive optic elements including cooled lenslet arrays; design and fabrication of electronically tunable compact polarizing elements; higher sensitivity focal plane arrays with high dynamic range, fast efficient readout circuits, etc.; and compact packaging of such imagers for field portability and UAV and UGV operations.

Technical Point of Contact: Dr. Neelam Gupta, e-mail: neelam.gupta@us.army.mil, (301) 394-2451.

2.57. Luminescent Materials and Devices for Displays. The ARL requires research investigations into luminescent materials, devices, and components, and relevant basic physics studies that couple luminescence, electrical, optical and mechanical properties of these materials and devices. Research and study are needed to ensure that the displays available for the current and new systems will provide improved performance that is required to carry out complex military missions. The SEDD is interested in receiving novel proposals that address the technical barriers associated with improving the current state of the art in luminescent materials, devices, and components used as the basis for the display technology in Army systems. Technical areas of interest include, but are not limited to, the following:

- a. Theoretical and experimental studies of luminescence including electroluminescence, (organic and inorganic) cathodoluminescence, and photoluminescence.
- b. Investigations on the materials, devices, and tools that will lead to the development of displays on flexible substrates.
- c. Studies of micro-mechanics that impact display devices.
- d. Investigation of light modulation materials and devices.

Technical Points of Contact: Dr. David Morton, e-mail: david.morton1@us.army.mil, (301) 394-1916 or Dr. Eric Forsythe, e-mail: eric.forsythe@us.army.mil, (301) 394-0606.

2.58. Flexible opto-electronic materials and devices. The ARL requires research investigations into novel materials and devices for opto-electronic applications that includes, thin film transistors, diodes, electronic components for flexible electronic applications. In addition, materials and device research is sought for photovoltaic and other energy harvesting electronic applications. The research in materials and devices shall include relevant basic physics studies that couple electrical, optical and mechanical properties of these materials and devices. Research and study are needed to ensure that the opto-electronic devices for the current and new systems will provide improved performance that is required to carry out complex military missions. The SEDD is interested in receiving novel proposals that address the technical barriers associated with improving the current state of the art in flexible opto-electronic materials, devices, and components used as the basis for Army systems. Technical areas of interest include, but are not limited to, the following:

- a. Theoretical and experimental studies of electronic properties including; carrier transport, carrier mobility, carrier injection, electronic performance and stability. The device shall be based on organic materials, inorganic materials and/or organic/inorganic hybrid materials.
- b. Investigations on the materials, devices, and tools that will lead to the development of thin film transistors, diodes, electronic components (capacitors, resistors) required to enable electronic architectures on flexible substrates. The device shall be based on organic materials, inorganic materials and/or organic/inorganic hybrid materials.
- c. Investigations on the materials, devices, and tools that will lead to the development of photovoltaic devices solar cells, and related energy harvesting devices on rigid and flexible

substrates. The device shall be based on organic materials, inorganic materials and/or organic/inorganic hybrid materials.

d. Studies of micro-mechanics that impact the opto-electronic devices.

Technical Point of Contact: Dr. Eric Forsythe, e-mail: eric.forsythe@us.army.mil, (301) 394-0606.

2.59. Nonlinear Optics. The ARL requires research investigations and proposals in nonlinear optical (NLO) materials, components and devices that can reduce their optical transmission across the visible and NIR (400-900nm) wavelength range passively when subjected to an incident laser beam within that wavelength range. Reductions of optical transmission on the order of 1000X or greater is desired. The speed at which such materials, components, or devices switch from transmissive to non-transmissive states needs to be on the order of <1ns. Materials and devices must be highly transmissive in the initial state. Concepts need to be able to be incorporated into low F/# optical viewing systems, yet must not greatly impact the normal performance of those systems. Technical areas of interest include, but are not limited to, the following:

- a. Development of optical materials with large nonlinearities and a broad wavelength and/or pulsewidth response. This can include molecular modeling, material synthesis, and characterization of nonlinear parameters as well as nonlinear transmission studies.
- b. Modeling efforts to relate nonlinear material properties to their ability to effectively reduce transmission. Modeling effort should include details on how the nonlinear materials affect the propagation of incoming laser beams.
- c. Development of optical viewing systems and components that incorporate the materials and devices above.

Proposals utilizing solutions other than NLO materials that suggest novel methods of reducing transmission will also be considered.

Technical Point of Contact: Mr. Andy Mott, e-mail: Andrew.mott@us.army.mil, (301) 394-0942.

2.60. Biologically Inspired and Biologically Derived Sensor, Power, Device and Materials Research. Natural evolutionary processes that organize functionality of biological systems could be considered to be the pinnacle of engineering science. This capability combined with our initial steps to understand how nature uses evolution to create structures and functionality through the advent of modern biotechnology has ushered in an unprecedented ability to manipulate biological components and organisms. These developments could provide researchers a new paradigm for development of revolutionary photonics, electronics, organic-electronic hybrid devices and sensors. In an effort to capitalize on these advances, targeted investigations will be conducted in the following areas:

- a. Biosensors to either sense biology or sense with biology.

- b. Biomimetic sensors.
- c. Photonic and electronic devices which replicate/mimic or harness biology to function;
- d. Biologically derived or inspired power generation and storage.
- e. Bioelectronics that are built from biological structures or assembled/enabled by biological structures. Inclusive in these efforts will be the development of new characterization methodologies (spectroscopy and metrology) geared specifically to investigations of organic and hybrid inorganic–organic material properties.

Technical Point of Contact: Dr. Paul M. Pellegrino, e-mail: paul.m.pellegrino@us.army.mil, (301) 394-2030.

2.61. Advanced Concepts for Hazardous Material Sensing Applications. The ARL is exploring new enabling detection technologies for hazardous material sensing applications. The ultimate goal of our research efforts is to develop sensors (both point and standoff) of hazardous substances for field use. The areas of potential application include, but are not limited to, food/water safety and defense, toxic industrial chemical (TIC) and toxic industrial material (TIM) sensing, improvised explosive devices (IED) detection, unexploded ordinance (UXO) and chemical and biological defense. Desirable features of sensor systems include: high specificity in analyte identification, small in size for field portability, low power requirements, low cost, and stability for long periods of time under various environmental conditions. The several key sensor research thrust areas are transduction technique, biological or chemical recognition, and direct spectroscopic methodologies. Our current research interests include development of both point and remote sensing for hazardous materials using synthetic molecular recognition elements, and optical and electrochemical transduction technologies. The desired sensor technologies are not limited to these methods, but may use mechanical or other novel detection methods. Recognition technologies include, but are not limited to, molecular imprinting, ssDNA hybridization, dsDNA hybridization, aptamers, peptides and phage or cell surface display technologies. Optical technologies include, but are not limited to, new optical sources and detectors for sensors, fiber optics, interferometry, non-linear optics, photonics devices, Raman techniques, and fluorescence. Electrochemical technologies include, but are not limited to, AC voltametry, AC impedance and cyclic voltametry techniques.

Technical Point of Contact: Dr. Paul M. Pellegrino, e-mail: paul.m.pellegrino@us.army.mil, (301) 394-2030.

2.62. Technology Demonstrations and Assessments for Special Operations and Low Intensity Conflict (SOLIC). ARL is interested in proposals that focus on demonstrating (prototype level) or assessing (unique facilities) across any of the technical areas described in the Army Research Laboratory Directorates portion of this BAA for SOLIC applications. Demonstrations and

assessments should be at least at the brass board prototype level. The focus is to demonstrate the transition of technology for the application of advanced systems and equipment to the U.S. Army, United States Special Operations Command, and other unique missions related to transformation of the U.S. military and the Global War on Terrorism in the following mission areas:

- a. Direct Action Support: Development and demonstration of advanced technology supporting small team and transformational combat units (interim brigade, objective force, and future combat systems) combat operations. This includes close quarters combat and fire support (laser target designation, etc.)
- b. Intelligence, Surveillance and Reconnaissance Support: Development and demonstration of technology supporting enhanced situational awareness and real-time intelligence for small team and transformational combat units (interim brigade, objective force, future combat systems) and their tactical support elements at forward operating bases and joint special operations task force locations.
- c. Special Reconnaissance Support: Development and demonstration of technology supporting dismounted, long term reconnaissance into non-permissive areas.
- d. Psychological Operations: Development and demonstration of equipment providing production and dissemination and assessment of Psyop media. This includes leaflets, RF broadcasts, and text messaging and other formats.
- e. Expeditionary Warfare/Unconventional Warfare: Development and demonstration of technology and systems supporting rapid deployment operations. This involves the rapid build-up of lethal and sustainable forces in remote areas.
- f. Military Operations in Urban Terrain: Development and demonstration of technology and systems supporting a range of military operations in urban terrain. This includes enhanced situational awareness and use of unmanned systems.
- g. Network Centric Warfare: Development of technology and systems for engaging enemy network systems, and protecting friendly networks.
- h. Knowledge Superiority: Development, application and demonstration of hardware and software to provide and apply knowledge superiority to U.S. Army and Special Operations Forces objectives.
- i. Counter-drug Operations: Development and demonstration of technology and systems supporting counter-drug operations. This includes equipment that is able to detect and identify the presence of drugs in any form, or in any container.

Technical Point of Contact: Mr. Steve Murrill, email: steve.murrill@us.army.mil, (301)394-5210.

2.63. Technology Demonstrations and Assessments for Department of Defense Biometrics.

The use of biometrics as an enabling technology has grown recently due to its success in various military applications. Biometrics has an important role as an enabling technology in Department of Defense (DoD) mission areas such as intelligence (e.g., tagging, tracking, locating), access control (both physical and logical), and forensics (e.g., latent matching). In addition, biometrics can be leveraged to support various other missions within DoD to include Identity Management.

As biometrics matures within DoD, the requirements and needs of the user are becoming increasingly complex and require specific solutions that have not yet been developed. It is DoD's intent to advance the state-of-the-art in a targeted approach to provide users with new and enhanced biometrics capabilities. The U.S. Army Research Laboratory (ARL), on behalf of the DoD Biometrics Task Force, solicits proposals focused on the development and demonstration of functional models and the assessment of biometric functionality across the two (2) Focus Areas indicated below that can lead to a demonstration in a relevant environment, at the brass board level, within 18 months. Demonstrations and assessments will be performed in coordination with the DoD Biometrics Task Force. Results are to include technical performance measurements and analysis from actual testbeds and laboratory environments that indicate the effectiveness of the technology to advance the state-of-the-art in current biometrics capabilities across and/or within the following two (2) Focus Areas.

a. **Single Sensor Capturing Multiple Modalities:** The ability to collect biometric data is a critical step in the overall biometric process. Traditional biometric collection systems are able to collect a single biometric (e.g., fingerprint). In some cases, a single device can use multiple sensors to collect multiple modalities (e.g., finger, face, and iris). However, using multiple sensors to capture multiple modalities demands extra time and resources. The ability to capture multiple modalities with the same sensor, whether contact or contactless, would be a valuable asset for our Warfighters and users within DoD. Below are examples of possible multi-modal fusion sensor challenges that could be addressed:

- Hand Capture – Could collect palm, hand geometry, fingerprint, and/or vascular biometrics with a single sensor
- Face Capture – Could collect face, ear, and/or iris biometrics with a single sensor

b. **Multi-Modal Matching Capability:** Several biometric systems rely on the use of a single biometric modality (e.g., fingerprint) for the verification and/or identification of individuals to produce highly accurate results. However, with the advent of stand-off biometric collection and less than optimal samples due to the tactical environment, relying on only a single modality has the potential to limit the matching accuracy. Future biometric technologies must be able to combine multiple modalities (e.g., fingerprint, iris, face, voice, DNA, palm, vascular, ear) of varying quality and origin, and other non-biometric data, without sacrificing speed, to allow for improved matching and more robust identity analysis. Below are examples of possible multi-modal matching algorithm challenges that could be addressed:

- Algorithms that can adapt their matching capability to the types of biometric modalities available and their respective quality

- Algorithms that can execute on many processor architectures, from smaller/embedded devices to larger enterprise systems

Technical Point of Contact: Dr. Keith Aliberti, keith.aliberti@us.army.mil, (301)-394-2320

2.64 Vehicle Integrated Antenna Technologies. ARL is soliciting innovative research proposals in the area of vehicle integrated antenna technologies. The proposed research should investigate novel approaches that enable advances of in-situ antenna designs for application to covert RF systems on military vehicles. Such advances are required to allow transmitting and receiving antennas on vehicle platforms to be concealed or completely covert. All technologies ranging from camouflaged to embedded antennas are solicited. Both high and medium gain wideband antennas are required with polarization diversity from circular to dual polarization being highly desirable. Primary design considerations shall be to reduce the visual signature of ultra wideband antennas that exhibit similar EM performance to current state of the art solutions. Antenna concepts for three frequency bands of interest are sought: 100MHz to 1 GHz, 1 GHz to 3 GHz, and greater than 3 GHz with emphasis on circular polarization approaches. Overlapping frequency bands are also of interest. Proposals ranging from multiple covert antennas to multifunction RF systems with simultaneous transmit and receive functions are solicited for application to complex detection and geolocation systems.

a. Applications of such integrated antennas for covert operations fall into two general classes: 1) sensitive receiver systems and 2) high power radar transmitters. The host platform for these antennas can be a full size tactical vehicles requiring broad beamwidth (>40°) or omnidirectional or small robotic vehicles (Talon or unmanned aerial vehicle requiring directional antennas with reduced size.

b. The Vehicle Integrated Antenna Technologies program will establish the feasibility and demonstrate new and innovative antenna designs that have the potential to enhance the way that the Department of Defense (DoD) installs antennas on vehicle platforms. The scope of this BAA is limited to demonstrating the innovative designs proposed, providing sufficient antenna details to allow antenna simulation verification, and describing the opportunity that exploitation of the approach could provide the DoD. Antenna performance must be compared to commercially available equivalents to demonstrate advantages of the proposed design. The as-installed antenna on the host vehicle must have similar performance while providing reduced visual signature compared to COTS alternatives. Efforts that successfully demonstrate feasibility of the antenna design may lead to future, longer term efforts that fully investigate and develop the technology necessary to exploit integrated antennas for ground vehicle applications.

c. Examples of research topics that are of interest include the following:

- 1) *Use of Artificial Magnetic Conductors to Reduce Ground Plane Effects for Wideband Antennas* – provide usable bandwidth over an octave or more for antennas fully integrated into ground vehicles.
- 2) *Platform RF Systems* – Innovative antenna concepts that replace vehicle structural elements such as a bumper that serves as an antenna. Novel applications of camouflaged

antennas such as antenna elements embedded in glass or composite structures will also be considered. Antenna systems that can be integrated into the platform structure during the manufacturing process are of interest.

- 3) *Platform Feed Systems* – Innovative feed systems that improve performance (multi-function / reduced co-site / improved gain and pattern) and reduce the impact on platform integration. Feed systems that allow a single RF cable to feed multiple antennas and feed systems that can be integrated into the platform structure during the manufacturing process are of interest.
- 4) *Integrated Platform-Enhanced Aperture Design* – Aperture design research to improve performance by incorporating the platform as part of the aperture design to obtain omnidirectional pattern coverage.
- 5) *Metamaterial Aperture Design* - Volumetric characterization of antennas with metamaterial apertures integrated into the vehicle structure is of interest. In addition, further research into the application of metamaterials in antenna design, to include embedding them in armor, is also of interest.
- 6) *Leaky Wave Antennas* - Research into Leaky Wave antennas that can be fully integrated into the vehicle structure and scanned electronically are of interest. The approaches should consider the ability for vehicles to radiate in all directions and at different frequencies (VHF is of interest).
- 7) *Wideband, Multi or single element, Multi-function Platform Antenna/RF Distribution Systems*: Development of RF distribution and antenna technologies that reduce visibility are of interest.

d. Proposals that describe integrated antenna technologies that could substantially reduce the visual impact of RF systems on ground vehicles but do not directly fit into one of the topics listed above can be submitted under this BAA.

Technical Point of Contact: Dr. Steven Weiss: steven.weiss@us.army.mil, Telephone: 301- 394-1987.

2.65 Sensor Data and Information Fusion: The Army is interested in fundamental theory of sensor processing and their models to provide the basis for data and information fusion to enhance the probability of detection & classification with minimal false alarms and to achieve a high level confidence in the detection & classification. Research in robust target detection and classification algorithms based on multiple phenomenologies is sought. The Army is interested in data and information fusion algorithms that are robust and well grounded in phenomenology which can be implemented at the node and network levels. There is also interest in techniques and methodologies for determining the quality of information before and after fusion along with the notion of value of information for Intelligence, Surveillance and Reconnaissance (ISR) applications. The Army is seeking scalable fusion architectures that can be used at node level and network level for situational awareness to fuse disparate, multi-modal multi sensor data/information. Fusion methodologies for hard and soft data fusion and algorithms for efficient data dissemination over the network are also sought. The Army is seeking research into sensing methodologies for information gathering rather than data gathering and inferring the adversarial intent.

Technical POC: Dr. Lance Kaplan, email: lance.m.kaplan@us.army.mil, (301) 394-0807

RESEARCH AREA 3 SURVIVABILITY/LETHALITY ANALYSIS

3.1. Radio Frequency Directed Energy (RFDE)/ High Power Microwave (HPM)/Electromagnetic Effects/ Electromagnetic coupling phenomena. ARL SLAD mission is to provide survivability, lethality and vulnerability (SLV) analysis and evaluation support over the entire life cycle of major Army systems; and help acquire systems that will survive and be lethal in all environments against the full spectrum of battlefield threats. This is done by conducting survivability, lethality, and vulnerability (SLV) investigations, experiments, simulations, and analyses. SLAD develops tools, techniques, & methodologies to improve the SLV analyses.

ARL SLAD has a continuing interest in a broad spectrum of research in these areas, including: Electromagnetic Coupling Phenomenology. There is ongoing interest in EM coupling to analog and digital systems, subsystems, components, boards, ICs, and components. Of interest are susceptibility levels and dependent parameters. Understanding coupling phenomena provides insight into the system effects and is useful for analyst projections. Additionally, a methodology (that can be validated in a laboratory or open air environment) is needed to analyze and understand the performance of communication/electronic/ADP equipment when deployed/operating in battlefield electromagnetic environments (EME). EME sources in the battlefield include radars dedicated to various warning functions (acquisition, track, etc.) covering broad frequency bands, communication transmitters, and accouterments of EM generating equipment used in the BM/C4I functions during a battle. Some of the sources encountered in the battlefield come under the realm of high power microwave (HPM) and the coupling phenomenon associated with the pulsed environment needs to be understood.

Ideally a HPM predictive tool would be developed and used for ADP equipment survivability assessments. The RF coupling study can be approached by placing the equipment under test (EUT) and the ancillary equipment in an anechoic chamber:

- a. To understand the low level RF coupling phenomenon associated with narrow-pulsed and/or transient EM environment.
- b. To characterize its performance when exposed to out-of-band environment in the 100 MHz to 18 GHz range.
- c. To diagnose/instrument digital EUT systems; e.g., computers, network devices, receivers, for RF effects. These measurements are conducted in an anechoic chamber to insure clutter free environment and facilitate cause and affect relationships observed due to RF environment.

The results from out-of-band radiated susceptibility measurements would be invaluable in characterizing EUT susceptibility profiles. This profile would define EUT system sensitive

frequencies and the corresponding incident power density levels required to induce an electronic effect. The radiated susceptibility profile would provide information to protect friendly forces' equipment as well as provide insight on exploiting hostile forces equipment. This exploitation could result in interrupt/delay, corruption or denial of information/data.

System response against narrow-pulsed or EM transient pulsed environments would allow an analyst to project the performance behavior of the system in a tactical environment. If performed thoroughly, this effort may provide an insight into predictive tools for the system performance in presence of HPM/DEW environment.

Such a methodology also provides a more deliberate and an efficient effort in carrying out IW attacks via RF weapon by bounding the critical parameters effective in inducting performance degradation and/or system malfunction. Furthermore, this methodology would provide invaluable information in the design and acquisition process of fielding weapon systems. The radiated susceptibility data would then be used as the basis for defining/focusing technical parameters for HPM field tests as well as RF hardening recommendations to improve system survivability.

Technical Point of Contact: Mr. Daniel Williams, e-mail: daniel.williams4@us.army.mil, (505) 678-4694.

3.2. RF Digital Models/Simulations. Developing theoretically based digital models and simulation tools for the analysis of RF electronic countermeasures (ECM) against radar/sensor functions. These tools would be mathematically defined in order to verify functionality. The tools would identify/quantify the information gained or lost by the radar's receiving/signal processing function and guidance function of the radar/sensor system. New techniques for modeling and simulation of radar functions and their interaction with the external environment, specifically ECM, are also being sought.

Technical Point of Contact: Mr. Jose Gonzalez, e-mail: Jose.marcos.Gonzalez@us.army.mil, (505) 678-5309.

RESEARCH AREA 4 WEAPONS AND MATERIALS RESEARCH

4.1. Composite Materials. Proposals are requested involving fundamental and applied research of materials issues of polymer-, metal-, and ceramic-matrix composites and their hybrids and at extending theory and experimental methodology where current theory and techniques are not adequate for modeling, analyzing, or characterizing the synthesis, processing, microstructure, and properties of such advanced materials and material systems. The broad areas of interest include such issues as dissimilar material bonding and adhesion, interpenetrating networks, TS-TP adherend interfaces, multilayer composites, and hybrid fiber systems; synthesis and thermo chemical and mechanical analysis of constituent material forms; surface analysis techniques; energetic and chemical interphase/interface development/properties; cure behavior and modeling; transport and degradation properties including thermal, oxidation, electrical, and chemical; effects of additives and fiber treatments on formation and properties of the fiber-matrix and hybrid system interphase/interface; failure modeling and analysis; special

thermoplastic composite issues including intimate and healing mechanisms and modeling; interactions of composite and hybrid systems with electromagnetic and radiative fields; modeling/analysis of void formation and effects of voids and other defects on strength, modulus, microcracking, etc.; composite-specific testing and analysis technique development and utilization including mechanical and electromagnetic property tests, fiber and matrix property tests, environmental exposure tests, etc.; statistical analysis of composite properties; assessment and analysis of industry-reported composite material property data; fundamental concerns and mechanisms for novel curing including electron beam, dielectric, microwave, etc.; physical property analysis; hygrothermal effects testing and analysis; thermal and oxidative stability; impact and delamination resistance; viscoelastic effects; analysis of process-induced properties; micro- and macromechanical analysis of fracture, buckling, delamination, etc.; mechanics of laminated forms; numerical analysis; material durability and performance; and fundamental research in new material developments including fiber forms and surface modifications, low-density core materials, low-viscosity thermosetting resins, and processable phenolic resins, etc. Special emphasis should be placed on composite materials supporting personal and vehicular armor; on low-observable and lightweight, multi-functional materials for aircraft, flight body, ground vehicle, and soldier systems; on materials for munitions, ordance, cannons, armaments, and their sub-components, and on the characterization of polymer/hybrid materials surfaces and interphase phenomena, adhesive bonding, durability/life extension, and smart/intelligent material systems. Reporting of scientific results and conclusions may be incorporated into scientific meetings and publications including general literature (conference proceedings, journals, etc.), technical reports, and standardization documents .

Technical Point of Contact: Ms. Shelby Killian, e-mail: Shelby.killian1@us.army.mil, (410) 306-2747.

4.2. Advanced Materials and Materials Processing. The WMRD is seeking proposals for high quality research and development in advanced materials and materials processing approaches that are critical to Army applications. The Army needs are being driven by the need for lighter weight, lower cost, environmentally friendly, and more reliable materials for the Army. Reduced weight is a goal for all weapon systems and logistics support items including ground and air vehicles, missiles, munitions, etc. Major future weapon systems include the Future Combat System and the Ground Soldier System. There is an interest in materials and manufacturing processes that will reduce the cost of the weapon systems, or increase capability at no additional cost. Army weapon systems are being extended beyond original design life. Accordingly there is an interest for materials and processes that will help lower the operating and support costs of weapon systems. Environmentally friendly materials and processes can reduce disposal and cleanup costs. Processing technologies of interest include those that will be applicable during high rate production and also for rapid prototyping. The objective of rapid prototyping is to reduce lead-time and where possible to make cost independent of order size. Proposals may impact materials currently in use within existing systems or look forward to future systems, subsystems, or support items. Some examples of areas of interest include (i) materials such as bulk and composite amorphous materials, nanomaterials, advanced metal matrix composites, polymer materials, etc. Some goals are to discover, synthesize and process bulk and amorphous metallic alloys for potential applications such as kinetic energy applications; novel processing for refractory metal and alloy warhead liners for shaped charge and explosively formed projectile

applications; other example uses include structural, armor, coatings, multifunctional, etc. applications, (ii) processing methods include joining, bonding, laser processing, shaping, etc. Example objectives include joining difficult to weld materials, dissimilar metals; rapid prototyping, direct metal deposition techniques, processing to enhance surface properties, etc.

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4.3. Electromagnetic (EM) Gun System Technology. The Army requires significant advances in the state-of-the-art electromagnetic technology for application to future weapon systems. Research interests include conducting formal studies, technical assessments and critical evaluations; providing essential research; and addressing the critical scientific, engineering and technical issues associated with the development of electric armaments. Specific research interests include, but should not be limited to the following areas:

- a. Railgun Research into
 - (1) methods, materials, and claddings to control rail wear and erosion at start-up, mid-velocity/gouging regime, and high speed/transition regime;
 - (2) characterization and control of railgun acoustic, optical, infrared, and electromagnetic firing signature;
 - (3) robust, low mass and volume railguns;
 - (4) functional, mass, and volume efficient railgun breeches;
 - (5) advanced techniques to measure railgun electromechanical and dynamic characteristics during and after the firing event; and
 - (6) upgrades to existing electromagnetic launch facilities.
- b. Pulsed Power Research into:
 - (1) high strength materials and fabrication techniques for rotating machine containment structures;
 - (2) high conductivity, high strength, low density conductor materials;
 - (3) sources of pulsed power for railgun operations; and
 - (4) effective and efficient electromagnetic shielding for pulsed power sources.
- c. Electromagnetic Projectile Research into

- (1) techniques to control and suppress armature transition from metal-on-metal contact to arcing contact;
- (2) low parasitic mass armatures;
- (3) hypervelocity aerodynamics and aerothermodynamics of projectiles launched from electromagnetic guns;
- (4) microelectronic techniques to control the trajectory of hypervelocity projectiles;
- (5) accuracy of electromagnetic launch;
- (6) analysis of the trajectory of hypervelocity projectiles to include controlled and uncontrolled flight at all altitudes; and
- (7) target defeat mechanisms that take advantage of electromagnetic launch capabilities.

d. System Research into:

- (1) thermal management of all components of a vehicle mounted electromagnetic gun system;
- (2) efficiency of all components of an electromagnetic gun system;
- (3) vulnerability of electromagnetic gun systems;
- (4) simulation of the dynamics and battlefield performance of platforms equipped with electromagnetic gun systems;
- (5) integration of electromagnetic gun systems on future vehicles;

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4.4. Warhead Technology. Proposals are sought for research and development of topics related to advanced warhead technologies. Of specific interest are multi-functional warheads and scalable warheads for application in all classes of weapon systems and for use in all environments. Areas of interest include experimental, computational, analytical investigations in controlled fragmentation, blast, shaped charges, explosively formed penetrators, energetic materials that can be used in a multi-purpose fashion, and lethal mechanism integration.

Technical Point of Contact: Mr. Tim Farrand, email: farrand@us.army.mil, (410) 278-6065.

4.5. Weapons Effectiveness. The WMRD and other Directorates in ARL conduct an extensive applied research program in support of improving weapons effectiveness. This topic encompasses a diverse spectrum of weapons and systems, including small, medium, and large

caliber gun-launched systems; rocket and missiles; hybrid gun-missile concepts; direct-fire and indirect fire weapons (LOS, NLOS, BLOS); smart munitions, munitions guidance, navigation, and control (GN&C), and high g-hardened gun-launch technologies; energetic materials development; interior, transitional, and exterior ballistics; ballistic wear and erosion, defensive weapons and systems such as active protection and extended area protection; non-lethal weapons technologies; robotic platforms, unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV), including hardware, command and control algorithm development, behavior modeling and simulation, and operations in semi-autonomous, near-autonomous, and fully autonomous modes. Proposals may address improving weapons effectiveness of existing systems or new concepts, as well as tactical use of weapons, such as under conventional battlefield conditions, in military operations in urban terrain, or in non-military homeland defense applications for Federal or local law enforcement agencies. Proposed research can be in modeling and simulation, experimental in nature, or both.

Technical Point of Contact: Dr. Jeffrey Morris, e-mail: jeffrey.morris3@us.army.mil, (410) 306-0760.

4.6. Counter-Improvised Explosive Devices (IED) Technologies. The WMRD and other Directorates in ARL conduct an extensive applied research program in support of the development of materiel that support a diverse spectrum of technologies to defeat improvised explosive devices. Research interests include numerical modeling, experimental research, and technologies that can address the understanding and the defeat of a diverse spectrum of improvised explosive devices.

Technical Point Contact: Mr. David Lyon, e-mail: david.h.lyon@us.army.mil, (410) 306-0980.

4.7. Novel Insensitive Energetic Materials. The WMRD is seeking proposals for high quality research and development in novel energetic materials technology. There is interest in low cost, higher performance, and insensitive novel energetic materials technologies to enable energy release tailoring, performance, and acceptable vulnerability characteristics for a wide range of future gun, missile, and warhead munitions. Novel energetic materials formulations and associated technologies support insensitive munitions requirements that will enable munitions to reliably fulfill their performance, readiness and operational requirements on demand, but minimize the probability of inadvertent initiation and severity of subsequent collateral damage to weapon platforms, logistic systems and personnel when subjected to unplanned stimuli. Proposals may impact munitions currently in use within fielded systems or future munitions, subsystems, or support items. Some examples of areas of interest and emphasis include: novel propellant and explosive formulations, new crystals/molecules, nano-technology material, advanced binders and energetic polymers, desensitization technologies, metastable compounds, reactive materials, energetic structural materials, activated metal powders, hydrides, novel energy releasing processes and mechanisms, ignition and initiation, wear and erosion, modeling and simulation, advanced diagnostics and testing methods, and detection methodologies. Proposals are also sought that address novel energetic materials and formulations in conjunction with munitions system design and packaging. Some examples of areas of interest and emphasis include: liner materials, passive/active venting, coatings, thermal protection materials, and barrier/ballistics material.

Technical Points of Contact: Dr. Brad E. Forch, e-mail: brad.forch@us.army.mil, (410) 306-0929; Dr. Patrick Baker, e-mail: patrick.john.baker@us.army.mil, (410) 278-0204.

4.8. Human Incapacitation – Penetration of Soft Tissue. The WMRD and other Directorates in ARL conduct an extensive applied research program in human incapacitation and wound ballistics. There is interest in low cost, high performance materials and materiel for use in barrier and body armor applications. Proposals for modeling and simulation and/or experimental validation are sought that address ballistic interaction with metal, glass, composite, or other barrier materials, vehicle armor, individual body armor, and penetration of soft tissue. Proposals may impact lethality and/or survivability aspects of small caliber and medium/large caliber fragment-producing munitions currently in use within fielded systems or future munitions, subsystems, or support items, as well as the defeat of these threats by the individual warfighter.

Technical Point of Contact: Dr. James Newill, e-mail: jim.newill@us.army.mil, (410) 306-0967.

4.9 Fundamental Basis for Survivable Systems Subjected to Multi-physics, Multi-phase Asymmetric Threats. For traditional force on force battlefields, the protection requirements for armored vehicles, soldiers, and other Army assets were based primarily on conventional war concepts and threats. However, asymmetric battle have shown that the protection is required on all types of military and civilian structures and encompass a wide variety of both conventional and unconventional threats, such as kinetic energy projectiles, IEDs (roadside, buried, vehicle-born, and suicide Improvised Explosive Devices) grenades, missiles, and mines. In addition, the battlefield in which these assets operate includes complex urban terrains and the United States homeland. Proposals are requested to conduct a broad, interdisciplinary basic research program to develop advanced science and engineering based methodologies that afford advanced understanding of crew and vehicle survivability under unpredictable explosive-device induced blasts. To date the fundamental underlying mechanisms that challenge the survivability of critical Army/civilian structures and systems with respect to the unconventional explosive threats is not well understood. This highly multidisciplinary research area includes complex interactions between terrains, explosives, and extremely hard to extremely soft material systems. Modeling unconventional blast-effects on structures requires a two-step process:

- a. The first step is modeling of the blast itself resulting in a multi-phase flow, which requires improved physical understanding of detonation processes as well as their packaging and the environmental conditions. Modeling and characterization of the dynamic behavior of a wide range of explosive packaging methods including combinations of soils, pavement overlays, metal, and other encapsulations result in extreme spatial and temporal pressure gradients and fragment distributions. Fine scale temporal and spatial resolutions are needed to achieve a threshold level of predictive capability. It is essential to accurately model the explosion/combustion reaction chemistry to deal with the issues surrounding reacting multi-phase flow from metallized blast explosives (using aluminum, higher density metal fuels, and/or thermites, etc). Turbulent mixing, combustion, and reaction chemistry (both during the detonation and fireball formation) need to be addressed. The capability to independently represent both

the fluid and solid components so they can be coupled to and applied to the structure in a realistic manner is essential.

- b. The second step of the two-step process is to model the effects of explosive systems on military and civilian structures. This requires parallel, explicit, Lagrangian codes with a library of continuum and structural elements, robust parallel contact algorithms capable of dealing with explosively driven deformations, and adaptive techniques to capture the physics of localization and subsequent failure. The design optimization of explosive systems and their effects involves problems that are geometrically and materially nonlinear. Fracture and fragmentation of large military and civilian systems involves a variety of spatial and temporal scales from nanometers to meters and microseconds to seconds. Two important effects of explosive systems and other kinetic energy penetrators on Army systems is the generation, and dispersion of stress waves through complex material configurations and the formation of highly lethal behind armor debris.
- c. The final area of need is to develop tailored materials (novel metal laminates/ advanced metallic-composite) for enhanced survival from explosive systems. Finite Element tools need to be utilized to develop design guidelines that provide yield strength, ductility, modulus, etc. parameters necessary for fabrication. As materials are developed, test and evaluation methods need to develop methods for imbedded/organic diagnostics to monitor dynamic material properties as samples are evaluated in order to verify and improve material models.

Technical Point of Contact: Dr. Reed Skaggs, email: rskaggs@arl.army.mil, (410) 278-9329.

4.10. High Rate Deformation and Failure of Materials. Proposals are requested to investigate the high rate behavior of materials undergoing deformation beyond the elastic limit to include fracture and failure. Materials of interest include polymers, high density metals, ceramics, materials used for constructing urban structures, and materials capable of energetic response to mechanical stimuli. The broad area of interest covers experimental, computational, and theoretical investigations with an emphasis towards the development of a computational predictive capability of high rate deformation and failure of materials subjected to ballistic impact conditions. Advanced constitutive characterization and modeling, equation of state, dynamic fracture (both experimental and computational), material decohesion, and thermomechanical coupling are included in this wide area of interest. Also included are experimental and computational issues associated with the bridging of length scales ranging from microstructural to macroscopic. Reporting of scientific results and conclusions may be incorporated into scientific meetings and publications including general literature (conference proceedings, journals, etc.), technical reports, and standardization documents.

Technical Point of Contact: Dr. Todd W. Bjerke, e-mail: bjjerke@arl.army.mil, (410) 306-0800.

RESEARCH AREA 5 HUMAN RESEARCH AND ENGINEERING

5.1 The Human Research and Engineering Directorate (HRED) plans, manages, and conducts a comprehensive, multi-disciplinary program of scientific research directed toward defining human performance in perceptual, cognitive, and psychomotor domains. HRED research provides the scientific foundations for militarily relevant databases on human performance and associations among enhancers, distracters, and stressors, which affect that performance. Those data and associations are then embedded in modeling and simulation tools, which in turn serve to guide optimal design of human-system interaction in battlefield environments.

Discussion of potential proposal ideas with the HRED POC are expected prior to white paper or proposal preparation.

Point of Contact: Dr. Tomasz Letowski, email: tom.letowski@us.army.mil, 410-278-5968, or Mr. John Lockett, e-mail: john.lockett@us.army.mil, 410-278-5875.

5.2 HRED has research interests in modeling effects on cognitive and team performance of different time-scales and other factors operating in a multi-echelon battle-management environment; defining and modeling effects of humans in automation, such as (a) effect of the automated system's interruption of ongoing human-in-the-loop tasks, (b) characterizing the nature and extent of an automated or semi-automated system's tolerance for neglect of human input; modeling interactions among cognitive, perceptual, and psychomotor performance of unmanned aerial and ground vehicles.

Discussion of potential proposal ideas with the HRED POC are expected prior to white paper or proposal preparation.

Points of Contact: Dr. Keryl Cosenzo, email: keryl.cosenzo@us.army.mil, or 410-278-5885 or Dr. Donald Headley, email: don.headley@us.army.mil, 410-278-5919.

RESEARCH AREA 6 VEHICLE TECHNOLOGY

6.0. The Vehicle Technology Directorate (VTD) develops the technologies needed to: extend the life of current combat vehicles; provide components for future systems; and shorten the design and development cycle by enabling flexible, affordable manufacture of the next generation platforms. VTD is focusing its research towards development of lighter, faster and more fuel-efficient air and ground vehicles, improved mobility for unmanned systems, and development of new enabling mechanics technologies for microsystems. Research is directed at all aspects of vehicle loads and dynamics, structural dynamics, engine and power generation, and power transfer and systems. Vehicle loads and dynamics research is directed at impact dynamics, structural dynamics, and aeroelasticity. Vehicle structural dynamics research is directed at structures, fatigue and fracture and non-destructive evaluation. Vehicle engine and power

generation research is directed at internal combustion and gas turbine concepts and emphasizes light weight, fuel efficiency, power density, maintainability and reliability. Vehicle power transfer and power systems research is directed at drive trains, gearing, shafting, vibration monitoring, seals and transmission concepts, as well as life prediction methodologies. Unmanned mobility research is directed at robotic autonomous mobility, small heavy fuel engines, and large disturbance locomotion systems. Microsystems research is directed at developing a fundamental understanding of high-separation low-Reynolds number aeromechanics, multifunctional and biologically inspired structures, and distributed energy conversion for micro-propulsion. VTD topics shall be included in this BAA as funding is programmed.

Technical Point of Contact: LTC Tony Moffatt, email: james.a.moffatt@us.army.mil, 757-864-6795.

B. ARMY RESEARCH OFFICE (ARO)

RESEARCH AREA 7 MECHANICAL SCIENCES

7.0 Research supported in the mechanical sciences portion of the Mechanical Sciences Division of the Army Research Office is concerned with a broad spectrum of fundamental investigations in the disciplines of fluid dynamics, solid mechanics, structures and dynamics, and propulsion and energetics. Though many creative and imaginative studies concentrate on a particular sub-discipline, increasingly, new contributions arise from interdisciplinary approaches such as the coupling between aerodynamics and structures, combustion and fluid dynamics, or solid mechanics and structures as in the structural reliability areas. Additionally, several common themes run through much of these four sub-disciplines, for example, active controls and computational mechanics. Research in such areas is addressed within the context of the application rather than as a separate subject of study. Fluid dynamics research is primarily concerned with investigations in the areas of rotorcraft wakes, unsteady aerodynamics of dynamic stall and unsteady separation, and fundamental studies of micro adaptive flow control. Solid mechanics include a wide array of research areas such as high strain rate phenomena, penetration mechanics, heterogeneous material behavior, and reliability of structures. The structures and dynamics area is focused on investigations in vehicle structural dynamics and simulation and air vehicle dynamics including rotor aeromechanics. Research in the propulsion and energetics area is concentrated on processes characteristic of reciprocating (diesel) and gas turbine engines and the combustion dynamics of propellants used for gun and missile propulsion. The following narratives describe the details of the scope and emphasis in each of these sub-disciplinary areas.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a white paper. Some TPOC's have provided specific instructions for timing of submittals, see below.

7.1. Fluid Dynamics. Research in fluid dynamics supports the development of improved or new technology for advanced helicopters, small gas turbine engines, improved airdrop (parachute) systems, maneuverable high-speed missiles and high performance gun-launched projectiles, and miniature unmanned air vehicles. While basic research studies that address the fundamental flow physics underlying these devices are solicited, innovative research in the specific topical thrust areas listed below is especially encouraged.

7.1.1. *Vortex-Dominated Flows*. In contrast to fixed-wing aircraft, rotorcrafts always operate under the influence of their own wakes. The prediction of rotor performance, vibratory loads, and blade-vortex interaction noise depends strongly on the accurate prediction of the rotor wake, and the prediction methodology of this wake remains one of the major challenges in fluid mechanics. Current computational fluid dynamics (CFD) approaches are computationally intensive, especially for Eulerian methodologies where the vorticity diffuses numerically through the grid points and makes prediction inaccurate. The process by which vorticity is shed by the blade and rolls up to form vortex filaments is not now adequately simulated for rotorcraft load distributions. In fact, under certain flight conditions, multiple vortices are observed to form due to negative lift over the blade tip. The application of non-intrusive optical diagnostic techniques should yield new phenomenological understanding for the study of multiple vortices, wake structures, and wake development. New numerical algorithms or different techniques to increase accuracy and reduce the computational requirements are required.

7.1.2 *Unsteady Aerodynamics*. A high level of unsteady flow, which cannot be adequately predicted by steady or quasi-steady approaches, can characterize the flow field around many modern Army weapons systems. One classical example of very high Army relevance occurs on the retreating blade of a helicopter rotor, where the high angles of attack experienced by the retreating blade of the helicopter rotor leads to boundary-layer separation followed by load and pitching-moment overshoots. Mild separation causes increased vibration and reduces performance, while severe dynamic stall leads to unacceptably large vibratory loads and limits forward flight speeds, load, and maneuver capabilities. The physics of this flow phenomenon are known to depend on the Mach and Reynolds numbers of the flow, and hence future research in this area needs to be performed under realistic flight conditions. Improved theoretical and numerical simulation is needed for understanding the unsteady separation process and evaluating concepts for separation control. The simulations must be capable of accounting for transition of the boundary layer (and under some circumstances, the transition in the separating free shear layer). Detailed experimental measurements of velocity and pressure are needed in the separating region for the fundamental understanding the separation process, the development of new turbulence models valid during the stall process, and the validation of numerical simulations: here, the current focus is on quantitative flow field measurements rather than merely quantitative measurements on the airfoil surface. These measurements will probably require the use of new non-intrusive optical methods. Combined experimental and numerical efforts towards control of unsteady separation using passive and active flow control (including the emerging field of Micro-adaptive Flow Control) are also sought.

A second example of the importance of unsteady aerodynamics occurs on maneuvering missiles and projectiles. As future emphasis in flight vehicle control and "smart" systems pervades munitions design, advances in aerodynamic phenomena, such as dynamic high alpha separation,

vortex shedding, control surface/vortex interaction, divert thruster/vehicle interaction, roll control stability, and propulsion system integration will be required. New composite material vehicles will have stringent thermodynamic limits and enhanced nonlinear aero elastic response to maneuver forces. Smart structures and MEMS technology will redefine control strategies, control surface shape and control surface dynamics, consequently driving fluid dynamics into new areas of research. All of these developments require the prediction and experimental verification of complex nonlinear transient flow fields. This will require improved CFD for turbulent flow separation prediction, large eddy simulation, vehicle vortex interactions, and accurate computations of gross flow field response to MEMS boundary layer flow perturbations. Parallel developments in experimental techniques will be required to measure these complex flow fields to help verify and guide the predictive technology.

7.1.3 Micro Adaptive Flow Control. Micro Adaptive Flow Control (MAFC) technologies enable control of large-scale aerodynamic flows using small-scale actuators. MAFC technologies combine adaptive control strategies with advanced actuator concepts like micro-scale synthetic jets, microelectromechanical systems (MEMS)-based microactuators, pulsed-blowing, plasma actuators, and combustion actuators. These techniques are used to cause the delay, or prevention, of fluid flow separation; to induce flow separation in previously unseparated flow; to alter supersonic flow shock structure; or to otherwise alter the large-scale flowfield and provide overall system benefit. Army systems for which MAFC is currently being investigated include on-blade controls, dynamic stall control on helicopter rotor blades, separation control for drag and buffet reduction on helicopters, surge and stall control within Army gas turbines, and dispersion reduction and terminal guidance of subsonic, transonic and supersonic Army projectiles.

While recent successful demonstrations of the efficacy of MAFC technology have taken place, much of this research has tended to be somewhat Edisonian in nature. Basic research needs to enhance and focus the adoption of this technology include developing fundamental understanding of the method by which MAFC actuation alters the overall flowfield; the development of robust and efficient MAFC actuators featuring greater control authority and higher bandwidth; the development of computational analysis methodologies capable of accurately and efficiently predicting the effect of unsteady MAFC actuation on the entire flowfield; and the integration of all these technologies into Army systems.

Technical Point of Contact: Dr. Frederick Ferguson
email: Frederick.ferguson1@us.army.mil, (919) 549-4322

For quick reply through receptionist: reply to EmailARO with the technical point of contact's name in the subject line and your correspondence in the body of the message.

7.2. Solid Mechanics The light, lethal, survivable, continental United States (CONUS)based modern Army with quick power projection capabilities around the globe has abiding interest in building the most effective fixed and mobile assets with advanced materials and systems. Weapons, platforms, ammunition, and ground structures are designed with severe weight and volume restrictions, and are frequently limited by material strength and failure. Innovative use of material combinations for specific applications necessitates understanding the behavior of

materials and structures under complex and severe constraints. Solid mechanics research plays a crucial role in the prediction of strength, damage initiation and progression, and failure of Army material systems under extreme loading conditions, such as blast and impact. A major research aim in solid mechanics is to reduce development cost by minimizing the need for expensive testing, and to optimize performance. The program seeks approaches based on the underlying physics of solids that form the foundation of optimization tools to enhance performance, while minimizing weight and volume and for the design of actual systems. The program focuses on the material and system response to *blast, shock, impact, and penetration, and the mechanics of heterogeneous systems* including *computational modeling based Solid Mechanics Research*. Thrust areas related to the development of better protective systems against blast and impact loading, are directly related to the challenges facing the current and future Army. Under these conditions, the Army faces research problems with the unique constraints of very high strain rates, large deformations, high pressures, and rapid changes in temperature. Hence, a fundamental understanding of the behaviors of a variety of complex materials and systems including engineered materials and soft human tissue is needed. Research approaches should consider topological effects (both micro- and macro-scale), specific material geometry, layering, and interface properties on the response to blast and impact loading. In addition, it may also address non-traditional concepts including nanotechnology, biologically inspired hierarchical structures, active protection, and the functional degradation of electronic components. Interrelated analytical, experimental, and computational formulations are needed to address these difficult multi-physics problems. Predictive models, validated by well-characterized experiments, are needed to identify dominant mechanisms at relevant scales.

To establish the suitability of proposed research topics, researchers are encouraged to contact the Program manager by electronic mail and submit a preliminary proposal (not to exceed five pages). For the Solid Mechanics Program, preliminary proposals should be submitted no later than 15 October of each fiscal year. These preliminary proposals will undergo technical evaluation in terms of scientific merit and Army relevance. Preliminary proposals, which are judged to be a high priority by the committee, will be invited to submit a complete proposal.

7.2.1. Blast, Shock, Impact, and Penetration. This research topic addresses the need to understand the response of Army assets to impact and explosive detonation. It integrates approaches based on finite deformation, high pressure and high strain-rate, damage, and failure mechanics. Research should be conducted through a combination of physically-based experiments, analysis, and computations. No single material will fulfill all of the Army's functional requirements. Therefore, combinations of materials such as polymer-, metal-, and ceramic-matrix composites, ceramics, metals, active materials, and functionally graded materials will be needed to achieve the desired thermo-mechanical response. The complexity of Army systems comprised of these materials is compounded by their highly anisotropic and heterogeneous nature, and the severe gradients and complex stress states resulting from blast and impact loading environments. Paramount to this effort is a better understanding of the mechanics of interfaces and impact mechanisms, such as high velocity behaviors that might occur at the penetrator/target interface or within developing cracks at macroscopic and microscopic scales. An important aspect of this research area is the deformation and fracture of materials under high strain rates (up to 10^7 s^{-1}), large strains (up to 500%), high temperatures (up

to the melting point), and high pressures (up to 5 GPa). Innovative research on processes in materials and structures that absorb energy, deflect penetrators, and/or laterally disperse momentum is strongly encouraged.

Blast and impact into brittle materials presents special challenges due to cracking and comminuted of material ahead of the penetrator, high-speed granular flow of comminuted material, and the mixing of eroded penetrator material and comminuted target material. Ceramics and geological materials exhibit extreme sensitivity to defects and loading histories, which may result in highly rate dependent failure strengths and the propagation of failure waves. Metals are susceptible to inelastic deformations leading to ductile failure under low to medium loading rates, but transition to more brittle behavior under higher loading rates. In addition, heat generation, and thermal softening occur in metals further complicating the behavior of these materials under extreme loads and loading rates. Blast and impact of composite systems presents still another set of challenges that result from their complex microstructure, material boundaries, and the number of different and coupled failure modes that may occur. Since personnel protection is a key objective for Army platforms, an understanding of the response of biological tissue to blast and impact is essential.

All of this requires greatly improved understanding, effective modeling, and efficient computational schemes. Because blast and impact events often involve erosion and sliding of both the projectile and the target, explicit modeling of these processes with friction-based theories and computational techniques are essential. Computational methods for treating discontinuities in a three dimensional context are required. These methods must concentrate not only on the techniques required to track a moving boundary, but also on the relevant physics and mechanics associated with those surfaces. Examples might include boundaries between dissimilar materials, shock fronts, elastic/plastic boundaries, phase boundaries, shear bands and cracks, as well as penetrator/target interfaces. Constitutive models should be three-dimensional and should allow for system nonlinearities.

In blast and impact environments, complex interactions between the shock and release waves usually initiate damage mechanisms in the target; accurate modeling of the target behavior will require controlled, high fidelity experiments. Therefore, innovative experimental techniques that incorporate high-speed data acquisition and imaging are necessary to capture the deformation processes and relative motion between surfaces. Accurate experimental techniques are required to delineate the nature, timing, and evolution of damage and failure in heterogeneous materials. An important aspect of this area of research is the development of novel experimental techniques that can be used to generate data for the wide ranges and combinations of strain rates, strains, temperatures, and pressures of interest.

7.2.2. Mechanics of Heterogeneous Systems. The mechanics of heterogeneous structures involves the development of integrated analytical, computational, and experimental approaches to investigate the response of hybrid structures that may include combinations of high strength and lightweight engineered composites, ceramics, and functionally graded materials. Heterogeneity at all scales should be considered, from nanomaterials to systems created through combinations of different materials at larger scales. Experimental and computational techniques are needed to optimize material microstructure as well as the topology of systems to provide the desired

structural response for specific boundary and loading conditions. Physically based structural design guidelines for energy absorbing structural systems comprised of tailored combinations of materials and heterogeneities at different length and time scales are sought. There are continuing technology barriers that need to be overcome if reliable Army structures such as helicopters, ground vehicles, bridges, and weapons systems are to be designed, manufactured, and maintained over a long period of time. Of special interest to the Army is the thermo-mechanical response at strain rates encountered in high-speed impact or explosive loading. Probabilistic as well as deterministic approaches are encouraged. Phenomena of interest are wave propagation, scattering, dispersion, damage evolution, and failure.

At appropriate length and time scales, the quantitative prediction and measurement of parameters related to dominant heterogeneities and mechanisms are needed for specific material systems in order to relate nano and micro effects to the macro scale. Deterministic and statistical scaling methodologies for toughness, strength, and geometrical effects that account for the multitude and variability of heterogeneities such as interfaces, interphases, particulate dispersion, fiber volume fraction and distribution, constituent shape, and their combined effects on failure are needed. Innovative methods and models to control material properties and damage by graded interfaces, coatings, and mechanical impedance mismatches are required. Constitutive relations for multi-scale mechanisms should include failure and damage criteria, which are mechanism-based and experimentally verifiable. The determination of universal scaling laws that can be used to bridge physical scales would greatly enhance our understanding and prediction of phenomena such as inelastic deformations, localization, distributed damage and failure, and fragmentation.

7.2.3 Computational Modeling Based Solid Mechanics Research. Over the past decades, the finite element methods that were developed in the mechanics community have had a tremendous impact on engineering practice and Army designs. Although these methods have been highly effective for linear and some nonlinear analyses, substantial breakthroughs are needed for failure modeling and representations of blast and impact live fire tests. Commercially developed algorithms that rely on the deletion of elements to model the nucleation and propagation of cracks are inadequate. These algorithms are highly sensitive to the size and mesh arrangement and distribution. Furthermore, no convergence theories or even empirical evidence of convergence has been obtained so far for these methods. New theories are needed that can overcome the limitations of traditional continuum fracture models that are based on crack tip singularities. New principles need to be devised for the construction of failure surfaces and cohesion strength. New methodologies are needed to account for energy dissipation due to crack progression, large-scale yielding, and interfacial separation. It has become important to be able to develop material properties in terms of subscale models because with the rapid advent of new material systems, testing is becoming prohibitively time consuming and expensive. New theoretical approaches are needed to develop hierarchical methods for failure that account for the inherent statistical aspects of failure. Methodologies that explore fracture processes at the microscale and relate them to the meso and macroscopic levels should be investigated. Computational models for the creation of free surfaces that are mesh independent and that incorporate evolving time-dependent boundary conditions and physically based failure initiation criteria need to be developed. These computational models should capture the complex interactions of failure processes and defects in three dimensions. To achieve the requisite accuracy in three-dimensional problems, effective adaptive methods that can treat crack

propagation, shear band formation and other failure modes are needed. The capability to model fragmentation, contact, and penetration is also of strong interest.

Technical Point of Contact: Dr. Bruce LaMattina
email: Bruce.LaMattina@us.army.mil, (919) 549-4379

7.3. Actuation, Dynamics, and Mechanisms. Significant challenges facing Army laboratory engineers and scientists include the influence of inertial, thermal, electrical, magnetic, impact, damping, and aerodynamic forces on the dynamic response of materiel systems (e.g., ground vehicles, rotorcraft, missiles, and projectiles) as well as improving the inherent feature set of the components (i.e., mechanisms and sensing) that comprise them. Such challenges are of fundamental importance to the design and construction of affordable, reliable, durable, and maintainable Army equipment, notably robotic systems, with acceptable levels of performance, personnel safety, and comfort. Consequently, ARO is supporting basic research in these areas, with emphasis on the stability and control of interconnected dynamic systems, and novel actuation and sensing mechanisms. Submittal of fundamental research proposals on the general topics described above is encouraged, keeping in view the paramount importance of advancing fundamental understanding through conduct of novel, innovative, revolutionary, and/or high-risk research. More specific details of the program's predominant thrust areas are described in the following paragraphs.

To establish the suitability of proposed research topics, direct contact by telephone or electronic mail with the TPOC and submittal of informal preliminary proposals (not to exceed five pages) are strongly encouraged. For the Actuation, Dynamics, and Mechanisms Program, preliminary proposals should be submitted not later than 15 October of each fiscal year. These preliminary proposals will undergo technical evaluation in terms of scientific merit and Army relevance. Offerors whose preliminary proposals are assigned a high priority rating by the TPOC will be invited to submit to ARO a complete, formal proposal in early March of each year.

7.3.1. *Stability and Control of Interconnected Dynamic Systems*. This topic consists of five supporting and inter-related research thrusts including: high degree-of-freedom dynamical systems, discrete and continuous systems, complex topologies, non-linear flexural dynamics, and embedded state sensing. Advances in these areas are required to understand and improve the inherent capability of the organic structural components used in military systems and to enhance/enable subsequent applied research in energy harvesting, vibration and noise suppression, prognostics and diagnostics, and structural health monitoring.

The science of structures and dynamics has been afforded significant interest in the research community for many years. Tremendous gains have been realized in a wide variety of applications including air vehicle dynamics, smart structures, and vibration analysis. However, more recent advances in computational modeling, high-power computing, and finite element analysis has provided opportunity to explore aspects of dynamic systems heretofore unobtainable due to their complexity. This research centers more on the features of enabling technologies (e.g., complex topologies). Research areas include embedded sensors and actuators, formulation of suitable constitutive relations, improved structural damping concepts, modeling and optimal design of smart composite structures, finite element formulations and control algorithms. New

active damping techniques, based, for example, on combinations of viscoelastic, carbon nanotubes, and active materials, combined with shunted electric circuits and non-linear adaptive control strategies, have emerged as candidates for improving structural performance and reliability. Topics of interest include the role of viscoelastic materials, nano-technology, constitutive equations, elastomeric dampers, magneto-rheological fluid dampers, modeling and design, non-linear control techniques, and techniques for including damping effects in mathematical and computational models.

The assurance of structural reliability of military air and land vehicles and weapon systems will greatly enhance confidence in their safety, reduce the probability of mission failures, and diminish the costs of operation and maintenance. An important element in achieving reliable systems is a strong capability of inspecting and assessing the physical condition of critical structural components. Significantly improved techniques for inspection, analysis, and interpretation are urgently needed to facilitate the assessment of the health of a structure and to promote the design, fabrication, and reliable operation of future and current military systems. Inability to detect damage in heterogeneous structures that may comprise combinations of composites, ceramics, and metals is a limiting factor to their use in practice. The application of active materials to the development of novel sensing techniques, such as MEMS, and the ability to interpret sensor signals effectively and accurately in nearly real time are fundamental for improving the reliability of physical systems. Miniaturized sensory devices could be incorporated into heterogeneous structures to signal the presence, location, and extent of local and global failure modes, such as fiber breakage, fiber pull-out, delamination, and large matrix structural cracking. With advances in micro-sensors (including MEMS devices), piezoelectric actuator technology, system identification, information technology, adaptive control theory for sensor nets and wireless telemetry, condition-based operation of military systems will lead to enormous gains.

7.3.2. Novel Actuation and Sensing Mechanisms. This topic consists of five research thrusts including: distributed, multi-scale, multi-physics, multifunctional, reconfigurable, auto-configurable, morphing, adaptive and/or stochastic mechanisms and actuation; high bandwidth/stroke mechanisms; direct chemical-to-mechanical conversion (i.e., artificial muscles); controlled/opportunistic energy recovery and transfer; and micro active flow control. Fundamental research is needed to understand the interrelations between forms and functions, shapes and behaviors, structures and dynamics, the principles and constraints that govern the interactions between multiple functions, the integration issues that build a coherent functional system based on homogeneous and/or heterogeneous components that have multiple functions, and the adaptive capability allow such systems to dynamically select and switch its functions based on the tasks and environments in hand. Three fundamental challenges are at the core of this exciting new field: What are these structures made up of? How do they control the dynamics of any given structure if it is dynamically chosen? How do such smart structures adapt and change their configurations based on the tasks and environment? Advances in these areas will lead to numerous benefits including enhanced locomotion and mobility, reduced size/weight/power; increased power density, increased mission functionality and sustainability, and improved articulator manipulation, grasp, sensing, and haptics.

Numerous large, complex mechanical systems used by the Army consist of interconnected multi-body structures, e.g., heavy machinery, wheeled/tracked military land vehicles, machine tools, rotorcraft, weapon systems, etc. These complicated systems often consist of numerous combinations of rigid and flexible elements. New and innovative approaches are needed for the efficient analysis, design, and control of large materiel items that consist of interconnected flexible bodies. Recent advances in computer and graphics hardware and software capabilities are stimulating recent advances in motion based simulators with computer generated imagery that interfaces materiel dynamic models and their physical environments. Innovative approaches for modeling the deformation of materiel system components based on the finite element method and experimental identification techniques are needed to develop more detailed models. Examples of potential research areas are automatic formulation of the constrained equations of motion, symbolic equation processing, generation of computational methods and associated computer codes, algorithm optimization for computer architectures, model reduction and error quantification techniques, fluid payload dynamics, suspension systems and control, weapons positioning control, optimization techniques, and non-linear control algorithms.

The Army has need for increased power density and improved mechanical efficiency in propulsion drive systems. Future operational demands dictate increased power capabilities while maintaining existing, or even reduced, space and weight requirements for such systems. To meet these needs, advanced configurations, components, and analysis tools are required. These will follow from a better understanding of the mechanics involved with fatigue, stress, strength, life, and damage progression is required. Advanced modeling techniques for gear stress and life analysis are needed. Better understanding in the fatigue failure mechanism as applied to gear tooth bending and contact fatigue is required to enable the advanced modeling.

The promulgation of electronic devices both soldier- and vehicle-borne has increased energy requirements well beyond that accommodated by classic energy-storage capabilities especially in light of the related logistic burdens (e.g., storage and transport). Controlled/opportunistic energy recovery and transfer shows tremendous promise to offset those requirements. To date, research has centered on linear methodologies consisting of cantilever systems and piezoelectric/piezomagnetic materials. However, current techniques have proven lacking because energy output is optimized only at a single resonance frequency vice across the range of ambient motion available. Nonlinear and multimode motion-based energy harvesting techniques show significant promise with order-of-magnitude increases. Fundamental technical barriers to advancement in this area include analytical and numerical techniques for optimal performance given mechanical, material, and electrical tradeoffs; characterization of mechanical and electrical nonlinear behaviors and their coupling as applied to harvesting techniques; simultaneous use of multiple transduction techniques; and broadening harvesting frequencies to match ambient energy profiles.

Smart or adaptive structures consist of incorporated sensing, actuation, signal processing, and control capabilities that can spontaneously respond in real, or nearly real, time to external stimuli to compensate for undesirable effects and enhance desirable ones. They offer opportunities to realize structural vibration suppression or isolation, unsteady load control, reduction of noise, desirable shape change, load alleviation, aeromechanical stability augmentation, beam shaping and steering in antennas, and structural damage detection. Mathematical modeling as related to

sensor and actuator phenomenology and application will play a major role in the development of multi-functional concepts and approaches. Challenges that include constitutive relations, hysteretic and cyclic loading effects, robust controller issues, fabrication techniques, power delivery systems, etc. must be confronted and overcome.

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7.4. Propulsion and Energetics. Propulsion and energetics research supports the Army's need for higher performance propulsion systems. These systems must also provide reduced logistics burden (lower fuel/propellant usage) and longer life than today's systems. Fundamental to this area are the extraction of stored, chemical energy and the conversion of that energy into useful work, for vehicle and projectile propulsion. In view of the high temperature and pressure environments encountered in these combustion systems, it is important to advance current understanding of fundamental processes as well as to advance the ability to make accurate, detailed measurements for the understanding of the dominant physical processes and the validation of predictive models. Thus, research in this area is characterized by a focus on high pressure, high temperature combustion processes and on the peculiarities of combustion behavior in systems of Army interest.

7.4.1. Engines. Research on combustion in engines is focused on intermittent, reacting flows encountered in diesel combustion chambers and on continuous combustion characteristics of small, gas turbine combustors. Optimizing engine performance, through understanding and control of in-cylinder combustion dynamics, while retaining high power density, is a major objective. This focus leads to a strong emphasis on fuel injection processes, jet break-up, atomization and spray dynamics, ignition and subsequent heterogeneous flame propagation. Research on heterogeneous flames requires supporting study into kinetic and fluid dynamic models, turbulent flame structure, soot formation and destruction, flame extinction, surface reactions, multiphase heat transfer, and other factors which are critical to an understanding of engine performance and efficiency. An additional consideration is the high pressure/temperature environment, encountered in advanced engines, which influences liquid behavior and combustion processes at near-critical and super-critical conditions. Of particular interest are investigations of fundamental characteristics related to highly stressed engines such as elevated temperature combustion, accelerated mixing, and transient heat transfer. Engine performance degradation under low temperature conditions, due to reduced fuel volatility, high oil viscosity, poor atomization and vaporization, etc., is a major concern. Fundamental research is needed in many areas, including low temperature physical and chemical rate processes, instantaneous friction and wear mechanisms, and combustion instability effects at low temperatures. With advances in sensing, modeling and control architectures, it is becoming possible to further optimize the performance of combustion systems. Providing the foundations for such active control is also a major goal of the program.

7.4.2. Propellant Combustion Processes. Research on propellant combustion processes is focused on understanding the dynamics of the planned and inadvertent ignition and subsequent combustion of energetic materials used for propulsion in gun and missile systems and in ordinance. The program is also addressing the characterization of advanced energetic materials, e.g. those based on nano-scale structures and/or ingredients. Basic research is needed in several

areas, including, plasma- and laser-induced ignition; thermal pyrolysis of basic ingredients and solid propellants; flame spreading over unburned surfaces (particularly in narrow channels); surface reaction zone structure of burning propellants; chemical kinetics (including possible ion kinetics in the presence of plasmas) and burning mechanisms; propellant flame structures; characterization of physical and chemical properties of propellants and their pyrolysis products; and coupling effects among the ignition, combustion, and mechanical deformation/fracture processes with or without the presence of a plasma. The use of advanced combustion diagnostic techniques for reaction front measurements, flame structure characterization and determination of reaction mechanisms is highly encouraged. This includes characterization of radiative and convective stimuli delivered by plasma injection sources as well as the thermal, kinetic, and mechanical responses of the propellant. Complementary model development and numerical solution of these same ignition and combustion processes are also essential. There is also need to understand the unplanned or accidental ignition of energetic materials due to stimuli such as electrostatic discharge, impact, friction, etc. This requires, for example, research on the processes of energy absorption and energy partitioning in the materials, the effect of mechanical damage on the ignition events, and other topics relating to the safety of energetic materials.

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RESEARCH AREA 8 ENVIRONMENTAL SCIENCES

8.0. The Environmental Sciences Division of the Army Research Office supports fundamental research in the Atmospheric and Terrestrial Sciences, i.e. research in the physical sciences of planet Earth in support of Army requirements. The need for research in the environmental sciences stems from the impact that the environment has upon virtually all aspects of Army activities. As military technology become ever more complex and sophisticated, both systems and operations are increasingly influenced by the natural environment and variability in environmental conditions. Despite continuing Army efforts to develop an all-weather/all-terrain capability, environmental conditions still constrain Army operations. Thus, the potential impact and leverage of environmental factors must be clearly understood in order to increase existing system capabilities and performance, take advantage of environmental weakness within adversary systems, and optimize the design of new systems. The ability of the Army to function properly and efficiently in all these environments requires equipment and tactics designed with full knowledge of the potential effects of the environment. Intelligent planning for the battlefield must take advantage of the environment. An in-depth understanding of individual environments on micro- to macro-scales and capabilities to predict environmental effects and behavior for places and times differing from the “here and now” are required. Advanced simulators for training and mission rehearsal require realistic behavior of atmospheric processes and terrain. Domains of specific interest range from the shallow subsurface, the land surface and the earth-air interface, to the lower atmosphere and cover surficial environments which vary from the polar regions to the tropics under all weather conditions, both favorable and adverse.

The Army is also committed to be a national leader in environmental and natural resource stewardship for the present and future generations as an integral part of its mission.

Responsibilities in this arena include the restoration of sites contaminated through prior Army activities, as well as achieving a state of environmentally sustainable operations on all military installations, particularly those utilized for training and testing. Cost-effective land use and restoration requires in-depth knowledge and understanding of the physical principles and processes operating in the terrestrial and atmospheric domains across a variety of scales which range from the microscopic to megascopic.

The natural environment is, by nature, a multifaceted and dynamic system so that there is an increasing need for multidisciplinary approaches to address the complex research issues that presently characterize the atmospheric and terrestrial sciences. Because of limited resources, not all subjects that fall within the broad interest areas defined below can be included in the current ARO Environmental Sciences research program at any point in time. Emphasis areas are reviewed periodically and funding concentrated in specific areas on a 3-5 year time frame. The submission of white papers is strongly encouraged. For Terrestrial Sciences funding consideration, white papers should be submitted in November of each fiscal year. Offerors whose white papers are evaluated and are found to have significant technical relevance and merit will be requested to submit a complete proposal during the April-May time frame of each fiscal year.

Potential offerors are encouraged to contact the appropriate TPOC for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a white paper.

8.1. Terrestrial Sciences. In general, the Terrestrial Sciences program is concerned with the impact of the Earth's surficial environment on Army activities. Program interests cover a broad spectrum, ranging from terrain characterization and analysis, mobility considerations under combat conditions and military engineering, to the management and stewardship of its installations as regards the impact of Army activities on the natural environment. Primary emphasis is directed toward understanding the behavior of the land surface and the near-surface environment, understanding the natural processes operating upon and within these domains, and modeling these environments for predictive and simulation purposes. Special emphasis is given to the need to better understand, model/simulate, and predict those environments/conditions that are most extreme, dynamic, or restrictive to systems performance or military operations. The three areas of current interest to the Terrestrial Sciences program are:

8.1.1. Terrain Properties and Characterization. Terrain affects all aspects of Army operations. The effective understanding and use of terrain is critical to military success on the battlefield. It is in effect a force multiplier, affecting mission planning, system performance, unit mobility and effectiveness, and training readiness. At present, the Army cannot rapidly and efficiently perform the terrain analysis that is required before personnel, vehicles, and weapons are deployed. A 'rapid mapping' capability to remotely sense and interpret the features of and upon the earth's surface and an automated capability/methodology for handling and analysis of large aggregates of remotely sensed data are critical for the 21st Century Army. Terrain information may be considered elevation data, soil and environmental characteristics, natural terrestrial features and man-made structures, and urban environments. A capability to remotely sense and interpret the features of and upon the earth's surface, together with an automated capability/methodology for handling and analysis of large aggregates of remotely sensed data,

are critical for the for the improved terrain characterization capability required for most of the technology areas important to the *Army Objective Force*. Research related to terrain characterization is directed toward fostering the development of advanced geoscience-based capabilities for the rapid post-acquisition generation, analysis, and utilization of terrain data acquired through remote sensing technology. Characterizing terrain features and conditions from sparse data plus the accurate detection of short-term dynamic surface conditions and terrain feature change are high priority research issues. A problem of particular importance is the accurate remote sensing measurement of soil moisture at the scales of Army operations (*e.g.* 10^2 - 10^3 m). Knowledge of the properties and phenomenology of the surface and near-subsurface is critical to support military operations on land, ranging from operational mobility, the detection of landmines and unexploded ordinance, natural material penetration/excavation, military engineering activities, to training and testing land sustainability. Effective military action requires a rapid and accurate assessment of the influence of soil and rock properties. Strength and deformation properties of geomaterials are highly variable due to the intrinsic heterogeneity of bedrock geology and soil formation processes and moisture content over variable spatial scales, rock mass competency, and groundwater pressure over small spatial scales. A thorough understanding of the behavior of geomaterials under different environmental and dynamic loading conditions is a critical need for mobility prediction and as input for projectile penetration prediction to destroy hardened and deeply buried targets. Also of concern is the issue that soil and rock properties and behavior measured in the field are typically much different than observed in the laboratory. This dilemma has profound consequences for predicting geomaterial behavior. Specific research is need to provide new approaches to (or techniques for) the non-intrusive geophysical characterization of subsurface materials and their spatial distribution; the prediction of location, frequency, and scale of subsurface heterogeneity; the detection and discrimination of buried objects (particularly landmines, unexploded ordinance, hazardous wastes, and contaminant plumes), tunnels and underground structures; and high-resolution field data sets for non-intrusive measurement validation. The ability to discriminate subsurface features and objects in the presence of surface roughness, natural geologic heterogeneity, and anthropogenic clutter requires advanced signal processing and analysis techniques.

8.1.2. Terrestrial Processes and Landscape Dynamics. Environmental factors can directly affect the Army's strategy, mobility, field operations, and logistics. With the expected increased sensitivity of the future Army to these factors, the importance of this information will become even more critical. Therefore, the focus of this research area is the development of an improved understanding of surficial processes within the terrestrial environment that can affect Army operations. The dynamics of natural processes and systems operate over a wide range of scales and are only poorly understood at the time and space scales required by the Army; hence much of what is needed is a fundamental understanding of the appropriate ways to couple processes of highly differing scales and types. A continuous dynamic interaction takes place between solid earth materials and the most abundant fluids, water and air. A variety of dynamic environmental parameters and conditions affect the performance of geophysical sensors. Fluvial processes are dominant in shaping the continental surface through both erosion and deposition. In more arid regions, eolian processes can give rise to both erosional and depositional landforms. Military problems arising from these interactions include localized flooding in battle areas, deterioration of trafficability, and obscuration from blowing dust and sand. The nearshore zone is a complex boundary region where air, land, and sea interact over a wide range of space and time scales. It

is also a region in which incident energy is often dissipated or transformed to motions at other scales. The result is a highly non-linear, coupled, dynamic system. Surface waves, coastal circulations, and sediment transport all have important impacts on Army operations within this region; however, information on these processes is essentially nonexistent for most areas around the globe. At 0°C, water changes from the liquid to solid phase, resulting in the formation of snow, ice, and frozen ground. Such conditions dramatically alter the battlefield environment and affect the performance of systems and materiel. Icing is a particular issue for aircraft, rotorcraft, optical sensors, and antennas. An improved understanding of the fundamental character and dynamic nature of the surface environment and its evolution through time, as well as the consequences of military interaction with this environment, is essential for the continued development, improvement, and sustainability of Army training and testing activities. In particular, there is a need for the development of first-principle physical/chemical process models and computer-based techniques for monitoring, modeling, and simulating the natural environment, as well as improved technologies and methodologies for environmental characterization and prediction. Special emphasis is given to the need to better understand, model/simulate, and predict those environments/conditions that are most dynamic or restrictive to systems performance or military operations. The development of an improved understanding, physical representation, and quantification of terrestrial processes affecting Army operations are of particular interest to this research area. Improved measurements and theoretical treatments are needed to treat the complex, often nonlinear dynamics governing these processes, which are a result of both physical and biologic processes and the interaction of these processes with terrain evolution. Such processes operate over a wide range of discontinuous time and space scales, which make them extremely difficult to characterize, quantify, and model. Explicit consideration of these processes and their interactions will lead to critically needed improvements in the ability to predict environmental effects on Army operations. Important in this context is research that seeks to the response of landscape to modification by Army use and the fundamental nature of subsurface flow and mass transport and then numerically model these complex processes. Critical to developing an engineering-scale understanding of the properties and behavior of surface environments is a fundamental knowledge about the natural processes that operate on surficial materials at a variety of scales. Field observation, laboratory experiments, and computational modeling must be integrated to solve well-formulated problems. Predictive geotechnical models, based upon well-characterized constitutive relationships, are required to identify controlling processes and parameters across a spectrum of scales. Extreme environments (hot, cold, dry, and wet, or combinations thereof) pose unique challenges to future Army systems and personnel because deserts, tropics, and cold regions are extremely hostile environments that dramatically affect human and materiel performance, thus inducing a negative effect on the performance of military systems and operations. Extreme environments also are important because they can exhibit unusual recovery rates following disturbance. Within the US, approximately 70% of DOD lands occur in highly sensitive arid and semi-arid environments. The character of terrain in arid environments can determine how military operations are conducted on these lands and military activities can directly impact the terrain in a manner that causes both short-term and long-term stresses on the surficial environment and ecosystem. The repeated use of such lands for military purposes, particularly training and testing activities, increases the risk of soil disturbance, damage to vegetative cover, degradation of water quality, and the disruption of animal populations and archeological sites. These impacts can be particularly adverse over the long term as battlefield readiness and sustainable training

requirements place significant demands on the delicate terrains that characterize arid and semi-arid environments.

8.1.3. Terrestrial System Modeling and Model Integration. One of the objectives of research to characterize the natural environment and understand terrestrial processes is to better prepare the soldier for combat through the development of the next generation of battlefield decision aids. An important application of this research is to develop or enhance integrated system models and simulators. A vision of terrestrial system models for the Army includes products that enhance mission success through improved decision-making. The future battlefield will generate massive amounts of data that describe this space. Synthetic models will be essential to supporting leaders in the real-time analysis of battlespace terrain data and in selecting the best courses of action for a particular terrain or environmental situation. The Army maintains various modeling and simulation systems, such as the and the SYNThERM cold climate energy balance model, NATO Reference Mobility Model, the Engineer Obstacle Planning System, the Surface Water Modeling System, the Groundwater Modeling System, the Watershed Modeling System, the Army Training and Testing Area Carrying Capacity Model, and the Integrated Dynamic Landscape Analysis and Modeling System to name but a few. These current systems allow for the computation of a variety of outputs, including mobility analyses, watershed response, groundwater flow and transport, military reservation land use response, and prediction of winter specific engineering effects. The Army is continually developing new features for existing numerical models and, in some instances, new environmental model systems, such as the emerging Land Management System. Research products, to be fully useful, must be integrated into modeling systems. This is often a non-trivial undertaking. The integration of the output from existing models offers many challenges related to different computational domains, resolution, and time scales. The ability to integrate advances in fundamental theory and process understanding is necessary to fully exploit these advances. The Army also faces a host of management and logistical issues, ranging from traditional training and testing to installation range management and coastal logistics, which require the coupling of models and analysis tools of highly contrasting scale for more effective decision making and long-term planning. Not atypically, differing processes exist at often radically different, but interrelated time and space scales. A fundamental understanding is needed of the appropriate ways to consider heterogeneous and dynamic terrain properties, couple natural processes of highly differing spatial scales, and the most efficient methods to model interrelated physical and ecological phenomena.

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8.2. Atmospheric Sciences. The Army has the responsibility to provide fundamental knowledge of the atmospheric boundary layer over land to all US armed services. Intelligence preparation of the battlefield depends on a full knowledge of atmospheric conditions and their effects on operations, weapon systems, and the soldier. It requires an ability to estimate atmospheric details at specific locations and at present and future time to maximize strategic weather advantages. Knowledge of the atmosphere and its effects on soldiers and sensor systems are essential for command and control as well as visualization of the battlefield at all echelons. The Army lead responsibility for chemical and biological defense requires detailed knowledge of the

threat once it is induced into the air. In garrison, Army training and preparedness depend on accurate representation of atmospheric test conditions and on physically correct portrayal of atmospheric processes and effects in simulations.

The research program is broadly based to address the wide spectrum of conditions and influences of the atmospheric boundary layer on Army operations and systems. It is divided into three general research areas of the boundary layer problems: atmospheric effects on sensors and systems, characterization of the atmosphere at high resolution, and management of atmospheric information

8.2.1. Atmospheric Effects on Sensors and Systems. The Army depends heavily on propagation of electromagnetic and acoustic signals through the atmosphere for detection, ranging and operation of smart munitions as well as reconnaissance and information dominance of the battlefield. Atmospheric turbulence can severely impact the performance of optical and infrared sensors as well as acoustic detection systems by affecting the propagation, imaging, and coherence of the received signals from active or passive systems. Furthermore the effects of surface and natural environmental conditions on propagation of images and signals must be considered because of the near-ground operation of many Army systems.

8.2.2. Characterization of the Atmosphere at High Resolution. Research efforts concentrate on increasing Army knowledge of physical processes in the atmospheric boundary layer at the engagement scale of the battlefield. This scale, characterized by horizontal distances to 20 km at resolutions at 10's of meters and times of seconds to hours, is the most inhomogeneous and changeable portion of the atmosphere.

The principal research concern is the diurnal evolution of the turbulent and stable atmospheric boundary layer. Research topics span a full spectrum of atmospheric boundary layer dynamical conditions including, but not limited to: parameterization and scaling of boundary layer processes for micro scale and mesoscale predictive models; surface conditions from simple to heterogeneous terrain elevation and slope, vegetation, and moisture; surface energy budgets; scale interactions; temperature and moisture fluctuations, especially as they affect the atmosphere as a medium for propagation of acoustic and electromagnetic signals; and natural or induced obstructions to visibility. A principal focus of the boundary layer dynamics is their application to prediction of the mean and fluctuating concentrations of chemical and biological agents in realistic terrains on appropriate scales.

Comprehensive measurements of wind velocity, temperature, moisture, surface energy exchanges and fluxes at resolutions showing their scales of variability in the atmospheric boundary layer are essential for advancing understanding of boundary layer processes affecting Army operations and systems. The variables should be measured in space and time to clearly define the evolution of three-dimensional physical processes within a volume of interest. Such measurement programs should highlight both the instrumentation development and the interpretation of the physical processes from the sensed data.

These topics are considered from perspectives of theory, field experiments, and analyses of the faithfulness and validity of models and simulations of these processes. The research results are

expected to contribute to improved models of boundary layer processes for visualization and field use through strong interactions with appropriate Army laboratory scientists.

8.2.3. Management of Atmospheric Information. Providing useful atmospheric effects information to the soldier and decision maker is the focal point of the Army's atmospheric sciences effort. The information needs of each user may be very different. Furthermore, the information must be in a form that is readily understood in light of the user's needs. At the same time, the path from data to information must have a fundamental scientific basis. The science issues behind the information management include an ability to obtain data from multiple sources, friendly or adverse, quantitative and qualitative; fusing the data into a comprehensive representation of the present and future atmospheric state; understanding of the uncertainties of the data and their effects on the application; and communicating the complex four dimensional atmospheric in the language and application of the user. To accomplish the goals of information management, improved computational methods are needed to assimilate and integrate the data, assess the atmospheric present and future state, and disseminate the user's needed information in a timely and effective manner.

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RESEARCH AREA 9 MATHEMATICAL SCIENCES

9.0. Mathematical language, theory, and methods pervade research, development, testing, and evaluation encountered by the Army and the academic disciplines in science, engineering, technology. Furthermore, increased demands are being placed on the mathematical sciences because of its role in building a foundation for emerging sciences and technologies in the information, network, life, decision, and social sciences. Although these problems are often naturally stated in terms of their disciplinary context, their solutions are often dependent on new mathematical results and theories. For example, promising approaches to computer vision for automatic target recognition (ATR) require research in a wide range of mathematics including constructive geometry, numerical methods for stochastic differential equations, Bayesian statistics, probabilistic algorithms, and distributed parallel computation. In the area of modeling and simulation of large-scale systems (systems of systems approach), improvements in model fidelity and capacity depend on the mathematics of optimization, stochastic methods, large scale scientific computing and real time computing for embedded systems. Similarly, advances in robotic and sensor systems depend on mathematics of dynamics, control, communication, logic, cooperation, and complexity. In order to respond to these increasing demands on the mathematical sciences, the ARO supports and advances fundamental research and knowledge that focuses on the needs of the Army. To accomplish this objective, the Division supports extramural basic research in the five areas that follow. The research supported by the Division does not cover all the topics in these areas, only those areas that are of strategic importance for the Army. The sub disciplinary boundaries within the Division and the disciplinary boundaries in the ARO are not rigidly drawn and there is strong interest in and appreciation for multidisciplinary research in which the mathematical sciences play a major role. Potential offerors are encouraged to contact the appropriate TPOC for preliminary discussions on their

ideas. The TPOC may invite the offeror to submit a whitepaper.

9.1 Biomathematics. Biomathematics is an exciting and important new area of activity for ARO. The introduction of biomathematics as a separate area of basic research recognizes the importance and specialized nature of quantitative methods in the biological sciences. Biology involves a large number of entities that interact with each other and their environment in complex ways and at multiple scales. This complexity makes biomathematics a highly interdisciplinary field that requires unique and highly specialized mathematical competencies to quantify structure in these relationships. Mathematical techniques currently utilized in the field range from computational biology techniques for analyzing small-scale “-omics” data to multi-compartmental modeling in physiology, epidemiology and neurobiology, to agent-based and network models involved in understanding ecosystem dynamics and human social dynamics. Beyond contributing to the understanding of biological systems, research in control techniques is also valuable for its potential application in militarily important areas such as microbial biowarfare and disease spread.

The ultimate goal of the biomathematics program focuses on using existing mathematics and creating new mathematical techniques to uncover fundamental relationships in biology, spanning different biological systems as well as multiple spatial and temporal scales. Of special interest are high risk attempts to use techniques in areas of mathematics not traditionally brought to bear on biological problems, as well as innovative efforts at handling large amounts of complex data.

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9.2 Modeling of Complex Systems. The Modeling of Complex Systems Program is a program of fundamental mathematics-oriented research the objectives of which are to develop quantitative models of complex phenomena of interest to the Army, especially those for which current models are not based on first/basic principles, and to develop new metrics, preferably those based on first/basic principles, for these models. The complex phenomena of interest to the Modeling of Complex Systems Program are mainly physical phenomena, human-generated phenomena (information, wireless networks, geometric modeling) and human cognitive and behavioral phenomena. Complete and consistent mathematical analytical frameworks for the modeling effort are the preferred context for the research, but research that does not take place in such frameworks can be considered if the phenomena are so complex that such frameworks are not feasible. Metrics are part of the mathematical framework and are of great interest. Traditional metrics, when they exist, often do not measure the characteristics in which observers in general and the Army in particular are interested. For many complex phenomena, new metrics need to be developed at the same time as new models. Just as is the case for the modeling effort, these metrics should preferably be in a complete mathematical analytical framework. The research in modeling of and metrics for complex phenomena supported by the Modeling of Complex Systems Program is mainly mathematical analysis (not computational mathematics).

The complex systems of interest to the Modeling of Complex Systems Program include those in the following four areas:

9.2.1. *Network-Based Information Fusion.* Information superiority is recognized as a key to success in military conflict, peacekeeping and humanitarian operations. Network-based sensing by organized or self-organizing networks of large numbers of geographically dispersed physics-based sensors of various modalities (optical, IR, acoustic, electromagnetic, etc.), information-based sources and human-based sources is an area of prime interest. Targets of interest are physical, informational, cognitive and social targets. Extraction and fusion of “soft information,” that is, information from human sources, such as text/voice and databases has been extensively investigated, but not in the context of fusion with “hard information” from physics-based sensors. Full understanding in operational situations is provided by information from all sensors, where “sensor” now has a wider definition of “any source, physics-based or human-based, that provides relevant information.” The information produced by the sensors has to be transmitted and fused in a fashion that provides reliable summary information with low error rates while using the minimum amount of network resources. Basic research in network-based fusion of hard information from physics-based sensors with soft information as well as in network-based fusion of hard information and soft information separately is needed.

9.2.2. *Geometric and Topological Modeling.* Representation of complex, irregular geometric objects and of complicated, often high-dimensional abstract phenomena and functions is fundamental for Army, DoD and civilian needs in modeling of urban and natural terrain, geophysical features, biological objects (including humans and their clothing), effectiveness of military training and many other objects and functions. Real-time representation and visualization of 3D terrain (not just as a height field but with multivalent height functions and non-genus-0 topology) directly from real-time or stored point-cloud data cannot be achieved with current techniques. A key to achieving this goal is data compression at ratios and with accuracy that strongly exceed what is currently available. A multitude of variants of piecewise planar surfaces (including those on triangulated irregular networks or “TINs” and triangular mesh surfaces or “TMSs”), splines, multiquadrics, kriging, wavelets, neural nets and many other techniques developed in the past perform well on many types of data. However, none of these procedures are able to provide, without human intervention, representation of irregular objects and functions with the accuracy and compression that is needed. New approximation theory that does not require the assumptions (primarily smoothness) of classical approximation theory and that provides structure for the many new non-smooth approximation techniques currently under investigation is required. Research on the metrics in which approximation should take place is needed. Approximation theory for information flow and other abstract phenomena in large wireless communication and sensor networks is of interest. The approximation theory developed under support of this program is expected to provide building blocks for computational geometry, pattern recognition, automatic target recognition, visualization systems, information processing and network information flow.

9.2.3. *Human Cognitive and Behavioral Modeling.* Quantitative, analytical models of cognition and behavior are required for training, simulation (computer generated forces) and mission planning. One of the most challenging areas of cognitive and behavioral research has been the creation of these models. Models that do exist are often time consuming to build, require large amounts of data as input and have limited accuracy. Research focused on mathematically justified, practically useful, computationally tractable and data-tractable models is needed. (“Data-tractable” means “does not require more data or more detailed data than is realistically

likely to be available.”). Research on the metrics in which the accuracy of the models should be measured is needed.

9.2.4. *Additional Areas of Opportunity.* Analytical research that provides new ways to model and measure complex physical, informational, cognitive and social systems of Army/DoD interest can be considered for inclusion in the Program.

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9.3. Numerical Analysis. Numerical computation has become an essential part of both scientific inquiry and of engineering design. It is now possible to simulate potential designs and analyze failures after they have occurred. Such simulations often require considerable effort to set up, considerable computer time and memory on large scale parallel systems and considerable effort to distill useful information from the massive data sets which result. In addition, it is not often possible to quantify how well the models simulate the real problem or how accurate the simulation is. This problem is especially acute for simulations of failure processes. Data has become ubiquitous but mathematically sound methods for incorporating the data into accurate simulations are lacking. Finally, simulations are often not timely. The most recent example of this is the Corps of Engineers’ inability to predict with enough reliability that the levees in New Orleans would fail before they did. The emphasis in the Computational Mathematics program is on mathematical research directed towards overcoming these and related shortcomings.

9.3.1. For problems that are not time-limited, research areas of interest include but are not limited to the following:

- a. *Advances in Numerical Analysis.* New methodologies are required for solving currently intractable Army problems. Advances which reduce computer time, are amenable to implementation on advanced computer architectures, are robust and have high order accuracy are of interest. Rigorous analysis is needed to determine structure, predict performance and drive adaptivity.
- b. *Multi-scale methods.* More and more, problems of interest to the Army are characterized by the fact that behavior at microscopic scales has a large influence on performance of systems. To solve these problems, algorithms are needed to deal with different mathematical models at different scales, interacting subsystems, and coupling between models and scales. The emphasis is on mathematical methods which have universal application rather than methods applicable only to specific problem areas.
- c. *Verification and Validation.* Models used for simulation may not be accurate due to uncertainties in the models themselves or uncertainties in parameters or interactions among components. Likewise, analytical and computational methods are needed to quantify errors generated by the translation of a model to a computer algorithm, the choice of parameters in the algorithm and the execution of the algorithm. Systematic methods are needed to

evaluate and quantify these and other sources of uncertainty. The emphasis is on determining the accuracy of the entire simulation, not just on a particular computer code.

- d. **Data Driven Simulations.** Advances in sensors and signal processing have greatly increased the amount of data available to scientists and engineers. The type of information which can be distilled from this data is different from and complements that generated by numerical simulation. If these two modes of investigation could be combined, it might be possible to obtain information unavailable to either mode acting alone. Uncertainties and incompatibilities between data and simulation make such combinations difficult. There is considerable interest in mathematical methods for combining data with simulation.
- e. **Supporting Technologies.** As numerical computations become larger and more complex, the non-numerical issues become more important. Computers have heterogeneous architectures, multiple processors, and complex memory hierarchies. Data is distributed among multiple computers connected to each other over networks with different bandwidths. Without mathematical tools that map algorithms to architectures with minimal input from programmers and users, computation on such systems is difficult and time consuming. In addition, large scale computations produce huge data sets. Tools are needed to extract useful information from such data sets and to present results in ways that are easily understood.

9.3.2. Army systems often operate under unpredictable and adverse conditions. In the face of uncertainty, it would be very useful if results could be simulated fast enough to drive decision making, exercise control, and help avoid disaster. Such simulations need to be created, run, and interpreted in better than real time. While this may not be possible at this time, we seek research directed towards making this goal achievable. Such research should include but is not limited to the following:

- a. **Reduced Order Models.** At this time, it is not possible to carry out full scale simulations in real time. In order to investigate the behavior of systems under a variety of possible scenarios, many runs need to be made. The only economical way to do this is through reduced order models. Possible methods to create these models include adaptive simplification, methods based on singular value decompositions, and reduced order numerics. All such approaches should be investigated. To be useful, all such models should be equipped with reliable estimates of accuracy.
- b. **Problem Solving Environments.** If decision making is to be driven by simulation, it is necessary to set up simulations very quickly and obtain results in an understandable format. Matlab is one current tool for such a problem solving environment. Are there other approaches?
- c. **Embedded Simulation.** As the size of powerful computers decreases, it should be possible to use simulation to drive control systems. What are the advantages and disadvantages of such an idea? How accurate do such simulations need to be?

- d. **Decision Making.** One valid criticism of numerical simulation is that it takes so long to set them up, run them, and post-process the results that they cannot be used to guide decision making. The computational mathematics program is interested in any mathematical ideas that can help address this problem.

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9.4. Probability and Statistics. Many Army research and development programs are directed toward system design, development, testing, and evaluation which depend on the understanding of stochastic dynamical systems, stochastic processes, and statistical data. The Probability and Statistics program supports research in stochastic analysis, applied probability, and statistical methods in response to the Army's need for real-time decision making under uncertainty and for the test and evaluation of systems in development. Special emphasis is placed on methods for analyzing data obtained from phenomena modeled by such processes. The two major areas of research are described below.

9.4.1. Stochastic Analysis and Applied Probability. Many Army research and development programs are directed toward modeling, analysis, and control of stochastic dynamical systems. Such problems generate a need for research in stochastic processes, random fields, and/or stochastic differential equations in finite or infinite dimensions. The thrust research areas in stochastic analysis and applied probability include but are not limited to the following:

- a. **Stochastic Delay and Partial Differential Equations.** Research on analytical and numerical methods for solving stochastic delay and partial differential equations and their related nonlinear filtering and control problems is one of the program objectives. These equations play important role in modeling many physical and biological processes in continuum and under noisy environment. These equations are often driven by standard Brownian motion, semi-martingale (e.g. Levy processes), and/or fractional Brownian motion. To effectively describe the state processes of these equations, it is necessary that infinite dimensional Banach or Hilbert spaces be employed. The Hamilton-Jacobi-Bellman theory via dynamical programming principle and/or necessary optimality conditions in terms of maximum principles have yet to be developed for optimal control of these infinite dimensional equations. Particularly challenging problems include the optimal control of these equations under partial and/or noisy observation with applications to informational, physical, and/or biological phenomena.
- b. **Complex and Multi-scale Networks.** Stochastic modeling, analysis, and control of complex multi-scale networks that address issues in (1) command and control of joint/combined networked forces; (2) impact of network structure on organizational behavior; and (3) relationship of network structure to scalability and reliability, and (4) reliability and survivability are among the research priorities in the Probability and Statistics Program. Mathematical studies of biological networks and/or biologically inspired networks, such as molecular motors, protein dynamics, metabolic and gene expression networks are important elements in building Army's future combat systems. The Army also has a vital interest in resource management and optimization in very large networks, especially

communication networks with stochastic components. Stochastic analysis and control of high-speed wired or wireless network traffic that exhibits properties of long range dependence and self-similarity are important. With limited availability of bandwidths in large scale wireless communication networks, research on dynamic spectrum allocation problems is urgent for military and commercial applications. Mathematics of operations research such as scheduling, supply chain management, and manufacturing are also among the topics which will be considered under the program.

- c. Spatial-Temporal Event Pattern Recognition. Developments of theoretical foundation and efficient algorithms for spatial-temporal event pattern recognition in nonlinear and noisy environments are considered keys to winning the war against terrorism.
- d. Quantum Stochastics and Quantum Control. With technological advances now allowing the possibility of continuous monitoring and rapid manipulations of system at quantum level, there is an increasing awareness of the applications and importance of quantum filtering and quantum control in engineering of quantum states, quantum error correction, quantum information, and quantum computation. These applications are extremely important in future military operations. Quantum mechanical systems exhibit an inherently probabilistic nature upon measurement. To further understand the back action effects of measurements on quantum states and control of the system based on these measurements, mathematical development of non-commutative quantum stochastic calculus, quantum filtering and quantum control theory is necessary. Proposed mathematical research of this nature that has potential applications in quantum information and quantum computation is hereby solicited.
- e. Stochastic Pursuit-Evasion Differential Games with Multi-players. Studies on multi-player stochastic pursuit-evasion differential games, hunter-prey relationships, and swarming behavior, shall be helpful in efficient operations of autonomous agents, such as UAVs and ground vehicles, in large and small scale military operations. The formulation and characterization of the value function for multi-players pursuit-evasion games with asymmetric information and/or noisy and incomplete observations require further research attention. In particular, the scenarios in which the evaders have insider or anticipated information are particularly applicable to urban warfare.
- f. Stochastic Control of Systems Driven by Fractional Processes. Stochastic systems driven by fractional processes such as fractional Brownian motion and fractional Levy processes have wide range applications in many areas of science and engineering. However, optimal control problems described by these systems remained unsolved. Research on the characterization and computation of the value functions and optimal control strategies for these problems are therefore solicited.
- g. Other Areas that Require Stochastic Analytical Tools. Mathematics of operations research such as scheduling, supply chain management, and manufacturing are also among the topics which will be considered under the program. Other research areas of importance to the Army in stochastic analysis and applied probability include (i) stochastic fluid

dynamics and turbulence; (ii) interacting particle systems and their applications to material science and nano-technology; and (iii) stochastic modeling and analysis of polymers.

9.4.2. *Statistical Methods.* The following research areas are of interest to the Army and are important in providing solutions to Army problems.

- a. *Analysis of Very Large or Very Small Datasets.* The state-of-the-art in statistical methods is well adapted to elicit information from medium-size data sets collected under reasonable conditions from moderately well understood statistical distributions. However, Army analysts frequently have very large or very small data sets sampled from nonstandard, poorly understood distributions. The two situations lead to very different statistical problems. The information available in large multidimensional data sets is frequently obscured, which suggests the application of data mining methods. Large data sets may occur in a stream, that is, they may be produced quickly and continually, so that new data compression methods are required to extract and update the relevant information for the decision-maker. The quality of the data is often varied because environmental factors are not under the control of the individuals and systems that collect the data. The advantages associated with quantity then are superseded by the need for improved data quality. On the other hand, in many testing situations, only small amounts of data are available due to cost, time, and safety constraints. The problems to be studied are sometimes vaguely formulated and appropriate models are not developed before acquiring the data. Close collaboration with scientists who work in the field of applications is required to develop new methodologies for addressing the problem of extracting information from meager samples. To extract more information from less data, improved methods for combining information from disparate tests may be needed.
- b. *Reliability and Survivability.* This research area is dedicated to the study of the performance and cost of engineered systems. Many of the models and methods developed will have immediate application to problems that face the military. For example, reliability and life length methodologies are needed for analyzing mechanical and electrical systems, especially those with extremely low failure rates. To support future network-centric operations, the Army needs novel and efficient statistical tools for improving network reliability and survivability, and for analyzing data collected from sensor networks.
- c. *Data, Text, and Image Mining.* Analysis of data stream in real time as well as cluster analysis and their applications to data, text, and image mining are important tools for anomaly detections in the global war against terrorism. New and unifying methodologies are needed in order to provide efficient search for patterns or meaning from the analysis of usually huge data sets that consist of multivariate measurements. Developments of mathematical theory for data, text, and image mining techniques are also highly desirable.
- d. *Statistical Learning.* Theoretical developments and computational approaches to statistical learning that are applicable to problems such as classification, regression, recognition, and prediction are crucial in making good and timely military decisions under uncertainty at all levels. Supervised and unsupervised learning methods (including learning decision and regression trees, rules, connectionist and probabilistic networks), visualization of patterns

in data, automated knowledge acquisition, learning in integrated architectures, multi-strategy learning, and multi-agent learning are among the foci of statistical research in this program.

- e. **Data Stream.** The Army has pressing research needs in the area of streaming data. Especially, sampling theory methodology or the consideration of data epochs with meta-analysis relating findings across epochs may reduce the need to retain the entire stream of information. Since the information sought may be contained in a very small fraction of the data, useful methods for data reduction may depend on effective modeling of the data stream and the relationship of the relevant information to the overall stream.
- f. **Bayesian and Non-parametric Statistics.** Future emphasis in statistics on "predictive" models vice explanatory models is important. Military operations call for predictive models based on a growing base of sensor-fueled data stores. Increased computational capability is also leading statistics in a new direction, away from using "classical" results which are really approximations to avoid computational issues. This suggests a need for increased emphasis on research in areas such as robust statistics, non-parametric statistics, non-linear models etc. In addition to a greater volume of data, data are increasingly messy, for example, spot reports are very free-form. More work leveraging computational capability in developing novel approaches for making sense of messy data is of interest.

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RESEARCH AREA 10 ELECTRONICS

10.0 Electronics. Electronic components are recognized as key force multipliers in today's Army and will remain so for the foreseeable future. To maintain our technological advantage, the U.S. Army Research Office's Electronics Division seeks to support scientific and engineering endeavors in research areas that possess the potential to define new electronic capabilities or to enhance future electronic performance. The Electronic research sub-areas are Solid State Devices, Optoelectronics, Quantum Electro-Magnetic Devices, Sensors and Detectors, Electromagnetics and RF Circuit Integration, Power Electronics, and Terahertz Science and Technology. We invite proposals for research to advance our understanding of electronic devices, materials, and processes with a strong prospect for use in future Army technology. Potential offerors are encouraged to contact the appropriate TPOC for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a white paper.

10.1 Solid State Devices. This research area emphasizes efforts to establish a new and comprehensive base of knowledge for the electronic, photonic, acoustic and magnetic properties of solid-state materials, structures and devices. Functions such as very intelligent surveillance and target acquisition; command, control, and communications; electronic warfare; and reconnaissance, must be accomplished with the high data rates and real-time capability that

are essential for these applications. To support the U.S. Army vision of Objective Force and Future Combat System of Systems (FCSS), these systems will need to operate at much higher speeds and frequencies, have greatly increased functionality, and have much higher levels of integration than present day technology provides. Therefore, fundamental research in the area of Solid State Devices is the corner stone and an essential requirement in the development of these future systems for military defense.

To establish the needed science base for future Army battle-space capabilities, innovative research is sought in the general areas of; novel electronic materials for advanced devices, nanoscale processing and fabrication science, nano/molecular electronic science and technology, nanoscale physical modeling and advanced simulation, ultrafast electronics, advanced device concepts, mixed technologies (electronic, photonic, acoustic & magnetic), heterogenous devices and technologies, micromachined devices and ultralow-power technologies. Therefore, the program currently emphasizes fundamental research in, (1) Nanoscale Growth and Processing Science, (2) Nanoscale (Semiconductor) Electronics, (3) Molecular Electronics and (4) Advanced Device Concepts, with a focus towards identifying and overcoming existing scientific barriers. Important science and technological barriers include, but are not limited to, the discovery and implementation of new and revolutionary growth techniques for engineering materials and for mixing and matching diverse material systems; the development of novel processing, fabrication and self-assembly techniques for realizing effective integration of diverse materials and devices into ultra-dense and complex solid-state electronic systems; the establishment of a theoretical base of knowledge into conventional and non-traditional (molecular) nanoscale electronics for bridging the gap between today's microelectronics to the future where molecular devices will be integrated with nanoscale semiconductor devices and components; the development and implementation of accurate physical models and robust simulation tools for identifying novel ultra-small device concepts and complexly-coupled nanosystems and accurately predicting their behavior; the development of a comprehensive science base that will provide fundamental insights into quantum-confined structures with time dynamic, nonequilibrium, dissipative electronic processes that are imbedded in practical circuits with realistic interconnects; and the development of new and effective integration techniques for realizing complex heterogeneous devices (i.e., devices utilizing different materials and operating on different physical principals) and mixed technology systems.

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10.2 Optoelectronics. Research in this subarea includes novel semiconductor structures, processing techniques, and integrated optical components. The generation, guidance and control of optical/infrared signals in both semiconductor and dielectric materials are of interest. The Army has semiconductor laser research opportunities based on low dimensional semiconductor structures (quantum dots, wells, wires, etc.) operating in the eye-safe (>1.55), 3-5, 8-12, and 18-24 microns regions for various applications, such as ladar, IR countermeasures, and free space/integrated data links. Research is necessary in semiconductor materials growth and device processing to improve the efficiency and reliability of the output of devices at these wavelengths.

High performance devices and components will be optimized for applications including high

data-rate optical networks. Interfacing of optoelectronic devices with electronic processors will be investigated for full utilization of available bandwidth. Electro-optic components will be studied for use in guided wave data links for interconnections and optoelectronic integration, all requirements for high speed full situational awareness. Optical interconnect components are needed in guided-wave data links for computer interconnection and in free-space links for optical switching and processing. For optical processing of images, research leading to two-dimensional (2-D) arrays of surface-emitting lasers is necessary. Research addressing efficient, novel optical components for high speed switching, such as optical Micro-Electro-Mechanical Systems (MEMS) is needed. Emitters and architectures for novel display and processing of battlefield imagery are important.

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10.3 Sensors and Detectors. The ultimate goal of Army sensors is 100% situational awareness to include day/night, all weather, non-line-of-sight and through natural and man-made obstructions for sensing of vehicles, personnel, weapons, chemical and biological threats, projectiles, explosives, landmines, IEDs, and motion. Sensing technologies of interest to this research sub-area currently include acoustic; seismic; passive electromagnetic; magnetic, hyperspectral, and infrared. Other innovative sensors that meet an Army need are also welcome. Novel ways to characterize nano-structures and semiconductor devices used for sensing are also of interest. Note that chemical, biological, and radar sensors are generally funded through other sub-areas as is image processing.

Novel infrared detectors and multispectral structures are of particular interest. Efforts are sought that raise the operating temperature and reduce the cost of “cooled,” high performance, infrared detectors, as well as, efforts that increase performance of “uncooled” infrared detectors. Research opportunities include components based on quantum confined devices and semiconductor materials operating in the infrared 1-24 microns regions. Also of interest is the ultra-violet spectral region. In both regions, studies involving growth, defects, interfaces, substrates, doping, and other electronic characteristics will be considered.

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10.4 Electromagnetics and RF Circuit Integration. Army Transformation is driving the need for basic research supporting mobile, multifunctional, reliable, and high-performance communications and sensor systems. In Electromagnetics and RF Circuit Integration, this research falls into the following general technical areas: computational electromagnetics, antennas, RF component development, RF circuit integration, and landmine/UXO/IED detection.

Problems of interest in computational electromagnetics can be divided into two regimes: device, circuit, package, and antenna modeling at short length scales, and radio wave

propagation modeling at large length scales.

Advanced models and simulations tools must be developed to accurately predict device, circuit, package, antenna, and system performance. Of special interest are physically-based models that enable the simulation of integrated circuits and modules as the levels of integration increase and as the circuits become denser and more complex. The coupling of radiation into and out of complex structures is a problem of special interest. New analysis concepts, techniques, and methodologies are needed with improvements in algorithm speed and efficiency including model order reduction, design for inherently low computational dispersion, and hardware acceleration. The human interface for these tools should simplify the problem setup, data presentation and analysis process, possibly including knowledge-based tools enabling the integration of multiple computational engines.

Propagation effects have a major impact on communications and radar systems. Research is sought leading to innovative and efficient techniques for near-real-time propagation modeling, capable of point-to-point calculations over paths that include urban, rural, and foliated environments with natural and man-made structures including tunnels, validated with appropriate experimental data, with effective interactivity and information delivery to the user.

Innovative approaches are needed to increase the performance and decrease the size and signature of tactical antennas operating from the HF to W frequency bands. Novel and new materials, configurations, and fabrication techniques for multifrequency, multiband operation are of interest. This will require fast frequency switching circuits and techniques for tunable antennas that minimize nonlinear effects over a wide band of frequencies. Radically innovative approaches are needed to increase the performance and reduce the cost of electronically steerable apertures (ESA), including the antenna elements and ancillary components. Ultimately, completely new approaches are sought for a new class of antenna elements that are efficient, point sensors and radiators of the vector electromagnetic fields with little or no mutual coupling for highly oversampled antenna arrays giving improved direction finding capabilities and radiation pattern control.

The electronic systems of the future will operate in an increasingly dynamic and complex spectral environment. This drives the need for innovative concepts that will produce devices and components with extremely high dynamic range, extremely wide instantaneous bandwidth, extremely high linearity, and multi-channel phase tracking. These requirements apply to active devices such as power amplifiers and low-noise amplifiers, as well as to passive components such as filters, mixers, couplers, etc. Because these devices and components will be used in mobile systems and because energy storage technology has not kept pace with developments in electronic technologies, the active components must also be energy efficient with low instantaneous peak power requirements and the passive components must have low losses. Optimal partitioning between digital and analog technology combined with new circuit topologies will be critical.

Integration technologies provide millimeter-wave/microwave circuits at small size, lightweight, low cost, and high reliability. Novel techniques for integrating circuits are of special interest at higher frequencies in order to overcome loss, coupling, and spurious radiation problems. Hybrid

techniques that combine high performance from component optimization with low fabrication cost due to compatibility with high volume production processes are needed. Fabrication and integration techniques including dense 3-D and heterogeneous integration must be developed that give the system designer access to transmission lines with constant impedance over wide frequency range, inter-layer high-frequency and optical interconnect, hermetic self-packaging, and ease of assembly and handling. Thermal/mechanical effects must be analyzed and minimized. Innovative approaches such as micromachining will provide significant advantages for circuit integration and the production and integration of passive components, including integrated antennas.

Innovative electromagnetic and hybrid approaches are needed for the detection of landmines, unexploded ordnance, and improvised explosive devices. Radar, acoustic electromagnetic induction, gravimeters, nuclear and infrared techniques have been applied in traditional approaches. Innovations on the traditional approaches and hybrid combinations with potential improvements in usability and probability of detection with significant reduction in false alarm rate are of interest to this program.

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10.5 Terahertz Science & Technology. This research area emphasizes efforts to establish a new scientific foundation for understanding and utilizing terahertz (THz) frequency sensing as a new tool for the detection, identification and characterization of chemical and biological (CB) agents on the battlefield. This research area also includes a parallel thrust to identify and develop advanced device concepts that are suitable for realizing THz-frequency sensors and sensor systems that are militarily useful (i.e., compact, robust, cost effect, etc.) in realistic battlefield scenarios.

To establish the needed science and technology base for future Army battle-space capabilities, innovative research is sought in the general areas of THz frequency sensing science and advanced device concepts that facilitate robust functionality at frequencies within the submillimeter-wave or THz frequency regimes (i.e., the part of the electromagnetic spectrum between approximately 1 mm (300 GHz) and 100 μm (3 THz). To improve device performance, the Army is interested in new device and circuit concepts, including quantum transport devices such as resonant tunneling structures, and quantum-transition devices in which photon emission can occur through intersubband transitions between quasi-bound states. It also includes traditional devices with revolutionary circuit and packaging techniques to improve performance. The components of particular interest are electrically-driven room-temperature sources, cw or pulsed, operating between ~ 0.3 and 3 THz. Innovative and novel methodologies should be explored until an effective approach is discovered or developed. Here, the development of efficient sources and integrated semiconductor-based components and systems is a priority.

In addition, a key application of interest for terahertz and ultrafast electronics is battlefield remote sensing of biological agents. Another second class of application is point detection of biological/chemical agents and explosives, such as RDX and TNT that also interact with THz radiation via low-frequency vibrations and rotational modes. Rapid, unambiguous identification

of chemical agents, precursors, and degradation products is required in many areas of the DoD including treaty verification and counterterrorism. The ultra-high resolution offered by THz spectroscopy may provide this rapid identification even when the substance is in a complex mixture. A final, and possibly even more far-reaching application of THz electronics, is in the development of concepts for extending ultra-wideband sensing and communications. Indeed, the fusion of an advanced THz-frequency sensing capability with conventional sensor-network communications and high-speed data processing has the potential for significantly enhancing the network-centric capability of the Army's Future Combat System of Systems (FCSS) concept. Here, THz electronics will collectively impact spectroscopic sensing, radiometric imaging and data transmission/processing. Furthermore, commercial local-area-wireless networks can already be envisioned at frequencies as high as 400 GHz, therefore, THz electronics has a strong dual use potential and the potential for significantly impacting the high-frequency electronics of the future.

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10.6 Power Electronics The goal of Power Electronics is to reduce the logistics burden on the warfighter through research and development into new and better ways to manage and create power for Army electronic components and systems. The research area includes the design of low peak power, highly efficient circuits and protocols for communications, radar transmitters, unattended ground sensors, and soldier electronics. It also involves high power management systems for all electric vehicles, directed energy systems, and high energy lasers. It involves novel power generation and distribution concepts including biomimetics, distributed generation, and nuclear batteries. It also includes renewable power strategies such as photovoltaics and energy harvesting, but does not include chemical battery or fuel cell technology.

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RESEARCH AREA 11 COMPUTING SCIENCE

11.0. The Army has learned from its experiences in the Gulf War, Afghanistan, and Iraq that it requires a force that can be deployed rapidly to any area in the world. Delays incurred while deploying a heavy force with 70-ton tanks are no longer acceptable, nor is the logistics tail needed to support it. Hence, the Army has begun transformation to a lighter more mobile force that meets the challenges of nonlinear warfare against a wide range of potential enemies, from highly trained and organized forces to regional threats and terrorists. This new Future Force will be realized with smaller, lightly armored mobile units that are equipped with more precise, lethal weapons. Since vehicles will have less physical protection, one key to providing their survivability is to increase the real-time information available so that timely decisions and actions can be made. This means availability of in situ, on-the-move information will be critical to the success of mobile force operations. New sensor, communication, and weapon systems based on unmanned cooperative robotic systems and tele-operated aerial and ground vehicles must be developed. Also, in spite the increased complexity of future battlefield information systems, dependence on them will only increase; therefore, they must be extremely reliable and secure. For this reason, Computing Science is a key technology underpinning the Future Force.

In order to respond to these increasing demands on computing sciences, the Army Research Office (ARO) supports and advances fundamental research and knowledge that focuses on the needs of the Army. To accomplish this objective, the Computing Science Division supports extramural basic research in the areas that follow. The research supported by the Division does not cover all the topics in these areas, only those areas that are of strategic importance for the Army. The sub-disciplinary boundaries within the Division and the disciplinary boundaries in the ARO are not rigidly drawn and there is strong interest in and appreciation for multidisciplinary research in which computing sciences play a major role.

11.1. Computational Architectures and Visualization. The Computational Architectures and Visualization program is concerned with modeling, analysis, and design of both hardware and software architectures with special emphasis on the effect the technological shift to heterogeneous, multi-core processors will have on these architectures. The program also supports innovative research in all aspects of visualization running the gamut from computational geometry and computer graphics to large-scale computer simulations and virtual environments.

As the title suggests, the main thrusts of this program are computational architectures and visualization. Each thrust has specific areas of interest which can be found in the following paragraphs. However, an overarching theme for the program is the efficient managing and processing of massive data sets. This is due to the fact that the Army's ability to generate data of all types from the battlefield to the laboratory far outpaces the Army's ability to efficiently manage, process, and visualize such massive amounts of information. The computational architecture thrust attempts to address this issue by sponsoring innovative architectural designs of both hardware and software components and their interfaces. The visualization thrust addresses the issue by providing support for innovative algorithms to render massive data sets and/or massive geometric models and to perform large scale simulations such as battlefield simulations, training simulations, and scientific simulations.

11.1.1. *Computational Architectures.* The goal of this thrust is to support the investigation of new effective architectures, computational methods and software tools for future computing systems. As computer hardware continues to improve and change, architectural modeling and design concepts (or paradigms) as well as software must adjust to take advantage of these improvements. These new computational systems must be scalable (usable on large-scale complex problems and able to handle massive amounts of data) and accurate (precise enough to predict and detect phenomena of interest). Other important issues to be considered for these advanced architectures, especially with the shift of computer manufacturers to multi-core processors, are programmability, language and compiler support, real-time scheduling, resource-allocation and the development of a flexible software environment.

11.1.2. *Visualization.* The visualization thrust of this program is concerned with all aspects of visualization and computer simulation of interest to the Army and is not limited to any one type of data or computer model. Specific research areas of interest are, but not limited to, discrete mathematics, computational geometry, robust geometric computing, graph theory, geometric and solid modeling, interactive graphics, 3D visualization tools, and synthetic environments. Special emphasis is placed on making very large simulations and the visualization of massive data sets faster, more computationally efficient, and more interactive for the user.

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11.2. Information Processing & Fusion. Research is aimed at the development of theories, algorithms, and tools concerning data processing, information extraction, and information integration to support the development of real-time situational awareness and advanced targeting capabilities for military operations. Emphasis is placed on mathematical methodologies and algorithms for image processing, image understanding, video-based target recognition and tracking, and data/information fusion.

With the pervasive availability of unmanned systems in future military operations, advanced sensing will be of critical importance to the future force. This program emphasizes mathematical methodologies underlying automated sensing capabilities and robust target tracking through innovative approaches such as bio-inspired methods and optimized sensing asset allocation. Research efforts will support the creation of innovative algorithms for robust video-based tracking under challenging urban environments. Also supported is research on area monitoring using a network of cameras and other sensing modalities, potential applications including detection of improvised explosive devices (IEDs) and persistent surveillance. Research on brain-computer interfaces has the potential to provide a revolutionary capability for human-machine interactions. Work in this area actively supports advanced research in both minimally invasive and non-invasive imaging modalities for brain-computer interfaces.

The increased capability of electronic systems and proliferation of sensors are generating rapidly increasing quantities of data and information to the point that system operators and commanders are becoming saturated with information. Innovative methods for effective indexing and retrieval of multimodal data (e.g. imager and video data) are sought. An area of increasing

importance is data and information fusion, especially from disparate sensors and contextual information. Sponsored research activities address several basic issues of data fusion, including information content characterization of sensor data and performance modeling. Of particular interest is research on collaborative target inference and target tracking by fusing data from disparate sensors as well as contextual information. Performance of target tracking can be improved through integrated approaches that consider target recognition, data association, and motion estimation.

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11.3 Information and Software Assurance. From the Army perspective, Information Assurance must address the delivery of authentic, accurate, secure, reliable, timely information, regardless of threat conditions, over the distributed and heterogeneous computing and communication system. The computing system may range from a hand-held mobile unit to a centralized high performance information process system. Heterogeneous communication system consists of both tactical (mobile, wireless) and fixed (wired) communications infrastructures.

11.3.1. *Supporting Army Mission Characteristics*. The objective of this research is to enable dynamic management of communities of interest (COI) by the battlefield commander. The commander needs the ability to alert the membership in a specific COI based on issues ranging from classification of the data to specifics of the battlefield situation. Individual war fighters may simultaneously be members of multiple COIs depending upon battle space specifics. Research is needed in the areas of protocols and techniques, which support reconfigurable, survivable and self-healing, efficient, and computing and communication environments that would allow for the dynamic creation of COI as well as to assure delivery of trustworthy data within reconfigurable and network centric environments. Reconfigurable, survivable, and self-healing systems allow a combat unit to dynamically establish and maintain its command and communication capability under diversified and extreme battlefield situations. New computing and communication protocols and techniques need to be developed so that critical information delivery and critical infrastructure functions can be assured, while maximizing the longevity of such systems under the resource constraints.

The Army requires a fully mobile, fully communicating, agile, and situationally aware force that operates in a highly dynamic, network-centric environment. This force consists of a heterogeneous mixture of individual Soldiers, ground vehicles, airborne platforms, unmanned aerial vehicles, robotics, and unattended sensor networks that operate in a complex wireless environment. To support net-centric warfare, new research is needed to 1) develop novel techniques for intrusion or anomaly detection and vulnerability assessment of mobile wireless networks that is automated, efficient, scalable, adaptive, and secure; and 2) develop security services and wireless security infrastructures for highly mobile tactical and unattended sensor networks that are distributed, scalable, and extremely resource efficient.

11.3.2. *Innovative Approaches to Attack Prevention, Detection, and Response*. Prevention works best when it is designed into the system architecture instead of being added on later, and so the development of system-security architectures and protocols that mitigate or reduce vulnerabilities is of critical importance. Research is needed to address the development and

implementation of the security policies that these systems will need to support, as well as automated system configuration updates to allow a system to be flexible enough to meet a change in security policy or threat situation.

Formal representations coupled with cognitive learning-based approaches for zero-second identification and characterization are of utmost importance, potentially providing means of responding to unknown attacks based on automatically generated attack response processes, as opposed to employing the current signature-based state of the art. Research is needed on cognitive-based analytical techniques of attack response planning, wherein automatic processes are able to conjecture and determine response solutions to attacks, while providing confidence levels in the likelihood of correct attack categorization, and self-assessment of response impact to a host system's capabilities. Research on detection and mitigation of sophisticated cyber threats, enhancement of the security interoperability of new security technologies, and determination of hostile intent are sought in the following areas: 1) reasoning mechanisms supporting the identification, representation, and understanding of system, network, and application vulnerabilities by which security objectives are compromised, their origin, properties, and manifestation in software and hardware, and remediation; 2) development of techniques for detecting and depicting vulnerabilities using models, taxonomies, patterns, and representational tools (graphs, trees, etc.), including their structure and interrelationship of active and passive components; 3) diagnosis and analysis of attack mechanisms by which threats target our systems, networks, and information infrastructure, including study of preconditions and dependencies; 4) investigation and development of architectural strategies and solutions to counter potential security threats, using advanced methodologies and novel technologies; and 5) exploration, identification, and validation of metrics, measurement techniques, and probabilistic techniques by which the effectiveness of specific security solutions and compositions of security solutions may be characterized and differentiated.

Intrusion protection includes both host-based defenses that harden a host against attack and network-based defenses that identify and respond to problems identified in the network itself. New technologies will need to be developed that take into account the needs and special properties of emerging types of platforms such as wireless mobile devices. Innovative approaches to system protection are sought which will incorporate the development of anomaly based detection, correlation, and fusion methods, adaptive response mechanisms, and automatic generation of responses.

11.3.3. Development of Next Generation Resilient Computing and Communication Systems. A primary goal of this Information Assurance thrust is to define, develop, and evaluate systems and network architecture structures that would survive sophisticated attacks and intrusions. Another important goal of this research thrust is to define, develop, and evaluate systems and network architectures that scale to large configurations and yet retain the ability to self-heal and recover from unexpected events with measurable confidence. The objectives of this thrust are to 1) gain advanced understanding and knowledge of survivability principles for complex system design and development; 2) develop next generation communication and computing systems that are resilient against attacks of different levels of severity and are capable of recovering and self-healing from any potential compromises; and 3) develop benchmark and testing metrics to evaluate system integrity and survivability.

11.3.4. *Embedded System Security.* Embedded systems are used heavily in critical defense applications. Malicious or accidental failures in embedded systems can have dire consequences. The integrity of embedded infrastructures, such as configuration and code, is of utmost importance. Another distinguishing feature of embedded systems is autonomous operation, which poses new challenges in the context of system integrity. Since embedded systems are reactive (interact with their environment), unexpected environment events can cause failures in embedded systems. Environment events can also be generated by a malicious adversary, whose goal is to have the embedded system fail. Novel techniques are needed to verify the integrity of embedded infrastructure (which may include device, software code, and configuration). These techniques should be geared towards discovering behavior of embedded systems under environment events and discovering "weak spots" or vulnerabilities in embedded infrastructures. Advanced techniques based on static, dynamic, or hybrid (a combination of static and dynamic) analysis of an embedded system are sought to identify exploitable vulnerabilities in embedded infrastructure (an exploitable vulnerability can be used by an adversary to drive the embedded system to an unsafe state) and to verify the integrity of embedded infrastructure.

Embedded systems often have to operate autonomously in a changing environment. Therefore, infrastructure of an embedded system has to be updated to adapt its behavior to the change in environment or change in the overall mission. Infrastructure updates manifest themselves as software updates or changes in the deployment configuration. Unauthorized or unverified updates to the infrastructure of an embedded system can compromise its integrity. New techniques are needed that allow updates to the infrastructure of an embedded system without violating its integrity. In addition techniques that prevent tampering with embedded infrastructures are also needed since field deployed embedded devices such as unmanned sensor nodes are prone to capture.

11.3.5. *High Confidence, Robust, and Resilient Software.* Today's software has unique characteristics of being large, complex, and decentralized. In addition, the current generation of software often operates in a heterogeneous environment, involving both infrastructure servers and mobile devices. To achieve the goal of information superiority in network-centric operations for the DoD, software for tactical systems must be highly reliable, adaptable, and flexible to changing environments, as well as resilient against potential attacks and intrusions. Research is needed in the area of high confidence, robust, and resilient software design, development, and verification, especially for mobile code and software supporting tactical mobile systems. The next generation software must provide full fault tolerance; can defend effectively against exploits and attacks; and be capable of healing and recovering from faults and potential compromises in order to sustain mission critical services. To achieve that goal, reliable and effective mechanisms to monitor and verify software execution status are also sought.

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RESEARCH AREA 12 PHYSICS

12.0. The objective of the Physics Program of the Army Research Office is to develop forefront concepts and approaches, particularly exploiting atomic-scale and quantum phenomena, which

will in the long-term have revolutionary consequences for Army capabilities, while in the mid-term providing for Army needs. In support of this goal, the interests of the Physics Division are primarily in the following areas: Condensed Matter Physics; Statistical Mechanics and Nonlinear Dynamics; Quantum Information Science; Atomic and Molecular Physics; and Optical Physics and Image Science. There is little direct interest in Relativity and Gravitation, Cosmology, Elementary Particles and Fields, Nuclear Physics, Astronomy, or Astrophysics, since they generally have little impact on the areas of Army needs. Nevertheless, the possible relevance of topics within these other physics disciplines is not absolutely discounted, and discussions of potential exceptions are welcome.

The disciplinary boundaries of the ARO are not sharply drawn as shown by the joint support of a number of efforts by the Physics Division and other ARO Divisions. In addition, it is not necessary that a potential investigator be associated with a Physics Department to receive support from the Physics Division.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a pre-proposal or white paper to further the discussion.

12.1. Condensed Matter Physics. Condensed Matter Physics (CMP) is a foundational science enabling fundamental Army technologies in areas such as information processing, communications, sensors, optical components, electronics, optoelectronics, night vision, seekers, countermeasures, and many others. Technologies such as these would not exist today, at least not as we know them, without visionary research in the field of CMP. The ARO CMP workpackage strives to continue this level of impact by looking beyond the current understanding of natural and designed condensed matter, to lay a foundation for revolutionary technology development for next generation and future generations of warfighters. Areas of future impact include novel computational components and architectures, novel electronic and optoelectronic devices and ones with higher efficiencies and significantly lower weight, and secure communications and sensing technologies.

12.1.1. Nanometer-scale physics. The CMP program is interested in the investigation of physical phenomena operative in nanometer-sized materials. The objective is twofold: to investigate and control nanoscale phenomena in well-defined nanometer-sized environments, and to elucidate how these phenomena are modified and may be exploited when such nanostructures are assembled into novel composite materials or device structures. Related interests include collective and cooperative nanoscale phenomena, understanding the evolution of atomic to nanoscale to bulk behavior, and phenomena at surfaces and interfaces.

12.1.2. Physics of infrared devices. Prolific engineering efforts to develop infrared devices have pushed the limits of performance, and have underscored the need to understand the physical processes involved in these device structures. Processes of interest are the coupling of the carrier transport to the electromagnetic field modes within the device structure, nonlinearities, and collective effects. Expanding design space beyond band structure engineering, which controls the carrier transport, to include photonic or plasmonic engineering, which can control the electromagnetic field, is also of interest. Both theoretical studies and experimental investigations

that link carrier transport, device structure, and materials growth and processing conditions are required.

12.1.3. Strong correlations and novel quantum phases of matter. Discovering, understanding, and experimentally demonstrating novel phases of matter in strongly correlated systems will lay a foundation for new technology paradigms for applications ranging from information processing to sensing. Interest includes strong correlations of electrons as well as of other particles or excitations. Material systems of interest range from complex oxides, to two dimensional electron gas systems, to synthetic assemblies simulating both real materials and lattice models. The program seeks to foster novel ideas targeting the discovery of new quantum phases of matter, and how excitations within these phases can be probed and controlled.

12.1.4. Unique instrumentation development. Advanced studies of CMP phenomena will often require unique experimental techniques that are not readily available. The construction and demonstration of new methods for probing *and controlling* unique phenomena, especially in the studies of novel quantum phases of matter, is of particular interest. Further, structures and assemblies exhibiting unique CMP phenomena may require unique synthesis techniques, which might range from biological assembly to optical lattices. Establishing such techniques for the fabrication or simulation of condensed-matter systems are of interest when they provide access to novel quantum phenomena which are not otherwise readily obtainable.

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12.2. Statistical Mechanics and Nonlinear Phenomena. This program is very closely related both to other programs in physics, particularly condensed-matter physics, and to ARO's programs in mathematics, chemistry, life sciences, materials science, and engineering sciences. The program thus encompasses a broad base. Unlike the rest of the Physics program, it also encompasses both classical and quantum mechanical systems. Overlapping condensed-matter physics, of interest are many-body theoretic approaches that address the correlation problem, e.g., in extended molecular and condensed matter systems to provide the means to predict reaction kinetics, nonequilibrium dynamics, and application to the "alloy problem." There is interest in quantum optics research to explore the role of coherent states, squeezed states, and other non-classical states with unique statistical signatures, which may provide new tools for improved information processing and means to control information. However, statistical physics goes beyond thermodynamics, into non-equilibrium structures and their metastability, into information theoretic formulations, and into decision algorithms to connect the underlying physics to real world applications via proper modeling, instrumentation and data analysis.

12.2.1. Statistical Physics. This area extends beyond the topical areas of conventional condensed-matter physics. It includes research in liquid crystals (for displays, information processing, etc.), clusters, quantum-well structures, superlattices, and metastable structures such as quasi crystals and alloys. It explores fundamental interactions such as electron-phonon coupling, spin-phonon coupling, and polaritons. In addition, it studies the role of elementary interactions such as spin-waves in ferrites and plasmons in multi-quantum wells for coherent THz radiation generation. Another area of interest is the study of "cooperative behavior" which appears in many different forms in condensed-matter physics, optics, and elsewhere, and is the

basis of phase transitions, swarming behavior, and scale-free networks among other things. The program encompasses research in both classical and quantum domains, from macroscopic (phenomenological/mean field) to microscopic levels of description of the mechanisms involved. In addition to analytical techniques, it includes the development of new computational methodologies. For example, it includes the use of the principle of maximum entropy, functional integral methods in many-body physics, and extensions of the density functional method. Extensions beyond the usual physics domain are also of interest. Examples include studies of networks, disease propagation, markets, and complexity.

12.2.2. Nonlinear Dynamics. Nonlinearities can be useful for Army applications in optics, in magnetism in the form of magnetostatic solitonic waves for millimeter wave signal processing, in semiconductor multi-quantum-well plasmas for generating coherent THz radiation, and in general when an interaction potential significantly deviates from a harmonic form. Defects, both unintentional and intentional, can play major roles. Many of the elementary excitations of condensed-matter physics could be investigated in light of information processing to increase S/N, density of information and speed of processing.

12.2.3. Nonequilibrium Dynamics. Many aspects of the field of nonequilibrium statistical physics have significant unresolved scientific issues. These issues are not just of academic interest; they impact engineering sciences, from growth of new materials to implementations in neural nets, and also have potential implications for what is dubbed "smart" or "intelligent" systems that have adaptive learning capabilities. The physics to be studied should be coupled with actual material mechanisms. As an example, in magnetism, this may translate into the study of the coupling of spins to phonons, to provide a realistic relaxation mechanism and the associated resonant line widths.

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12.3. Quantum Information Science. Quantum mechanics provides the opportunity to perform highly non-classical operations that can result in exponential speed-ups in computation or ultra-secure transmittal of information. This work package seeks to understand, control, and exploit such non-classical phenomena for revolutionary advances in computation and secure communication. There are three major areas of interest within this work package.

12.3.1. Fundamental Studies. Experimental investigations of a fundamental nature of quantum phenomena potentially useful for computation and secure communication are of interest. Examples include coherence properties, decoherence mechanisms, decoherence mitigation, entanglement, nondestructive measurement, complex quantum state manipulation, and quantum feedback. An important objective is to ascertain the limits of our ability to create, control, and utilize quantum information in multiple quantum entities in the presence of noise. Of particular interest is the demonstration of the ability to manipulate quantum coherent states on time scales much faster than the decoherence time, and in a manner that translates to scalability in a quantum information processing system. Theoretical analyses of non-classical phenomena may also be of

interest if the work is strongly coupled to a specific experimental investigation, such as proof-of-concept demonstrations in atomic, molecular, and optical systems as described in the Atomic, Molecular, and Optical Physics program.

12.3.2. Quantum Computation. Quantum computing will entail the assembly and manipulation of hundreds of quantum bits. The objective is the experimental demonstration of quantum logic performed on several quantum bits operating simultaneously, which would represent a significant advance toward that ultimate goal of tremendous speed up of computations. Demonstrations of quantum feedback and error correction for multiple quantum bit systems are also of interest. In addition to the algorithm for factoring, there is particular interest in developing quantum computation algorithms that efficiently solve classically hard problems, and are useful for applications involving resource optimization, imaging, and the simulation of complex physical systems. Input/output interfaces for quantum computation to efficiently handle large amounts of classical data are of interest.

12.3.3. Quantum Communication. The ability to transmit information through quantum entanglement distributed between spatially separated quantum entities has opened the possibility for an ultra-secure means of communication. Beyond quantum cryptography, the objective is to demonstrate quantum communication of information based on distributed entanglements such as in quantum teleportation. Of particular interest would be the demonstration of long-range quantum entanglements, entanglement transfer among different quantum systems, and long-term quantum memory.

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12.4. Atomic and Molecular Physics. Research in atomic and molecular physics will create fundamentally new capabilities for the Army, as well as providing the scientific underpinnings to enhance existing technologies. Topics of interest include quantum degenerate atomic gasses, both Bose and Fermi, their excitations and properties, including mixed species, mixed state, and molecular; matter-wave optics and matter-wave lasers; nonlinear atomic and molecular processes; quantum control; novel forms and effects of coherence; and emerging areas. Cooling schemes for molecules are of importance for extending the range of systems that may be exploited. Applications range from ultra-sensitive detectors including improved inertial sensors and navigation aides; to sensor protection; to novel sources. In addition, areas of application include novel materials processing, e.g., by obtaining increasingly complex molecules, clusters, or patterned structures, perhaps from something like matter-wave holography, or through quantum control.

12.4.1. Matter-wave Optics. Matter waves offer new or enhanced capabilities in a number of areas. For example, cooling, trapping and coherent control of atoms and molecules may provide ultra-sensitive sensors, including gyroscopes for inertial navigation, or ultra-high resolution lithography. In addition to the sensitivity advantage of matter waves, they also have additional degrees of freedom such as mass and associated “external” quantum states (together with a richer internal state structure) that might provide handles for new sensing capabilities. The use of coherent matter waves and Bose condensates (e.g., as in a “matter-wave laser”) requires basic

research to better understand issues such as coherence and decoherence, trapping and out-coupling techniques, and “matter-wave optics” to collimate, diffract, split, combine, interfere and otherwise manipulate matter waves. Laser cooling and trapping of atoms and molecules also may provide proof of principle demonstrations of key components of quantum computing.

12.4.2. Molecular Physics. The molecular physics program is distinguished from programs in chemistry and in materials science. One distinguishing feature is its focus not on synthesis, but on the underlying *mechanisms*, such as electronic transport, magnetic response, coherence properties (or their use in molecule formation/selection), and/or linear and nonlinear optical properties. The systems of interest are well-defined molecules, generally small or of high symmetry, and their functionalized variants. The objective is to broaden the scope of atomic physics questions into the molecular regime. Cooling, trapping, and Bose condensing molecules fall into this scope. Coherent atomic-molecular superposition states, a novel form of matter, are another example. The ability to use Feshbach resonances and otherwise tune interactions is also relevant here, both as a mechanism for ultracold molecule production and as a way to cross over from weak coupling to strong coupling limits in superfluidity. Quantum fluids in an optical lattice provide yet more novelty, and offer a forum for investigating open questions in condensed-matter physics.

12.4.3. Fundamental Atomic and Molecular Physics. The Division also has a general interest in exploring fundamental atomic and molecular physics topics that may have an impact on technologies of interest to the Army. For example electromagnetically induced transparency allows propagation of light through a medium that is normally strongly absorbing, and it also provides unique access to nonlinear effects that could lead to very efficient frequency multiplication and tunable sources of electromagnetic radiation. General issues of quantum coherence, quantum interference, and quantum control and their numerous potential applications are also of interest.

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12.5. Optical Physics and Imaging Science. The Army of the 21st century will rely more on sensing, imaging processing, and autonomous target tracking and recognition than ever before. The objective of this work package is to investigate fundamental physical phenomena that will lead to revolutionary advances in these areas. The Physics Division emphasizes fundamental science that uses photons and their properties (e.g. coherence, wavelength, polarization) in ways that will significantly improve information processing capabilities for the Army in the coming decades. Much like the breakthroughs in integrated electronics that brought revolutionary changes to computing and signal processing, a key objective is to integrate elemental optical components into “integrated optics” or “photonics” for smart, adaptive, reconfigurable sensing and image processing. Another objective is to improve the imaging capabilities of the Army by extending beyond the visible and infrared regions to consider advantages of the THz and ultraviolet regions. The Division has an interest in the identification and resolution of basic research issues that would demonstrate the utility of these approaches.

12.5.1. Optical physics. The physics of optical materials with ultra-large nonlinearities is sought. Such materials can be exploited for their well-known Kerr effects, electro-optic effects, parametric conversion, harmonic generation capability, and optical phase conjugation, among others. The goal is to develop a new class of materials that have much greater nonlinearities than existing materials, while maintaining otherwise good optical characteristics. Another topic of interest is coherence. The degree of coherence can affect such things as imaging and information content. In addition, we are looking for new frontiers in optical physics. Solitons, optical vortices, left-handed materials, and light filaments are examples of past and present interest. Any optical phenomena that can improve Army capability are sought.

Another area of interest is high-energy, ultrashort pulsed lasers, which have now achieved intensities of 10^{22} W/cm². The applications of these pulses include high-harmonic generation, nanolithography, 3-D internal design, micromachining, particle beam acceleration and control, and light filaments. In the near future even higher intensities are expected. Theoretical and experimental research is needed to describe and understand how matter behaves under these conditions -- from single particle motion to the effects in materials -- and how to generate these pulses and use them effectively.

12.5.2 Unconventional Optics and Imaging. The Division has an interest in extending the capabilities of optical components and systems. Examples of such approaches include hybrid optical/digital systems to minimize classical optics aberrations, and adaptive optics to mitigate atmospheric distortions. Also of potential interest are new approaches to imaging through turbid and scattering media. Several other image-enhancement technologies, such as hyperspectral imaging and infrared polarimetric imaging, having been receiving attention recently. The Division has an interest in the identification and resolution of basic research issues that would demonstrate the utility of these approaches. Also of interest are other approaches that would increase the resolution or contrast of scenes, or otherwise improve the information quality of images.

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12.5.3 Any area in fundamental physics that may be exploited to achieve the goals described above is welcome.

RESEARCH AREA 13 CHEMISTRY

13.0. Chemistry is central to the Army. Explosives, propellants, fuel cells, and batteries convert chemical energy into mechanical and electrical energy. Macromolecules provide materials for equipment. Detection, identification, and destruction of such chemicals, and the design and construction of protective barriers protect the soldier against chemical agents. More effective

methods are needed to destroy toxic military wastes for the restoration of military real estate and the safe demilitarization of surplus munitions. We invite proposals for research to advance our understanding of chemical materials and processes with a strong prospect for use in future Army technology. We encourage you to communicate with the appropriate ARO Technical Point of Contact for preliminary discussions of your ideas. We encourage several page preproposals describing a specific research objective, scientific approach, and anticipated scientific impact.

13.1. Experimental Physical Chemistry. We support research on fast reactions of energetic species. We are especially interested in the investigation of chemical reactions using time-resolved techniques to observe transient species and infer reaction pathways and other experiments and calculations that enable modeling of the time dependent processes of ignition and combustion. New probes for condensed (especially solid) phase reactions are of great interest. Novel experiments to provide information about rates of slow reactions (leading to material damage) are encouraged. We seek to exploit the new science of quantum molecular control to solve Army problems. Research on controlled transformation of toxic materials to relatively benign products in chemical reactors is also of interest.

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13.2. Electrochemistry and Advanced Energy Conversion. The Army relies on power sources to support many different weapons systems, communications, and other devices. Power sources under development are primarily batteries and fuel cells, although other high-performance power sources are of interest. This program supports fundamental chemical studies of materials and processes that limit the performance of current or enable future power sources. Topics include ionic conduction in electrolytes, electrocatalysis, fuel processing, interfacial electron transfer, transport through coatings, surface films and polymer electrolytes, and activation of carbon-hydrogen and carbon-carbon bonds. Novel electrochemical synthesis, investigations into the effect of microenvironment on chemical reactivity, and quantitative models of electrochemical systems are also encouraged.

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13.3. Organic Chemistry and Organized Media. This program supports basic research in the detection and decontamination of toxic materials and soldier protection. Fundamental research aimed at eliminating toxic materials and protecting the soldier from toxic materials is needed. New, more efficient, and environmentally benign organic reactions, both catalytic and stoichiometric, are needed. Of particular interest are nitration and oxidative and nucleophilic displacements at phosphorus and sulfur for the destruction of toxic organic compounds. Selected mechanistic studies that promise new insights to the pathways of the above reactions are encouraged, as are new synthetic pathways with reduced production of waste by-products.

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13.4. Polymer Chemistry: The focus of this program is high-risk, high-impact fundamental research with Army relevance. Of particular interest are studies of macromolecular architecture and functionality in order to understand how the molecular level affects bulk properties and material performance. This includes research on new monomers, branching and composition effects, supramolecular assembly, and macromolecular hierarchy. Additionally, of joint interest with the Mechanical Behavior of Materials Program in the ARO Materials Science Division, are research efforts seeking to generate statistically valid bulk mechanical behavior data with small polymer samples.

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13.5. Surfaces and Catalysis. This program supports fundamental research on the decomposition and interaction of molecules on well-characterized surfaces and catalysts. The fundamental characterization of reactions of organic functional groups on surfaces and catalysts is of great interest. The development of new methods to investigate the interactions of organo-phosphorus, -sulfur, and -nitrogen molecules on surfaces is also of interest. Development of reactive multifunctional materials including coatings and fabrics are included in this program. Research areas of interests include nanoparticle reactivity, the reaction mechanisms of hazardous materials with plasmas, and the fate of toxic materials on surfaces in the environment. A particular area of interest is in the interface between nanostructures and biomolecules including biocolloids to generate advanced materials.

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13.6. Theoretical Chemistry. Predictive computational methods for chemical processes (e.g., combustion) and properties and molecular architectures (e.g., crystal structures, mechanical moduli) are of great interest to support Army requirements for insensitive munitions, for propellants and explosives with greater energy density, and for multifunctional materials. Novel approaches to increase the accuracy of models of intermolecular forces are of great interest. We seek improvement of the efficiency of calculations by focusing on those elements of the models involved that provide the most information; especially methods that go beyond linear sensitivity analysis.

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RESEARCH AREA 14 LIFE SCIENCES

14.0. Extramural research in the Life Sciences is supported by the Army Research Office. For those proposals related to purely medical topics, the investigator is invited to contact the U.S. Army Medical Research and Materiel Command. The ARO Life Sciences Division research

program is currently focused on five sub area work packages. The titles, scopes and points of contact for these work packages, each of which address general aspects of basic research in life sciences, as well as the specific thrusts described, are listed below. A small number of symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas related to ongoing programs in Army laboratories.

14.1. Biochemistry

This program focuses on fundamental studies in biochemistry, structural biology, cell biology, and biophysics that will facilitate the development of novel systems and processes to enhance soldier protection and performance. Research areas include protein and nucleic acid structure-function relationships, enzymology, molecular recognition, signal transduction, cell-cell communication, macromolecular structure, and synthetic biology. This program also supports basic research in protein engineering for novel or enhanced enzymatic function, sensing capabilities of biomolecules and cells, biomimetic and bio-inspired systems, biomolecular power and energy generation, structural studies of molecular and macromolecular organization for novel materials or surfaces, and relevant systems biology studies involving the modeling and testing of complex biological networks at both the genetic and multiscale levels. There is also significant interest in novel methods for biomolecule production, purification, and structure determination.

Technical Point of Contact: Dr. Stephanie McElhinny, e-mail: stephanie.mcelhinny@us.army.mil, (919) 549-4240

14.2 Molecular Genetics and Genomics. This program emphasizes basic research in molecular genetics and genomics that will enable optimization of Soldier cognitive and physical performance, Soldier protection, and Army logistics. This includes human performance and protection under both normal conditions, and when these things are affected by a variety of stressors that are likely to be encountered in battlefield situations, such as dehydration, heat, cold, sleep deprivation, fatigue, caloric insufficiency, microbial factors, and psychological stress. Genetic and genomic research areas include identification and characterization of gene function; gene regulation; genetic interactions; gene pathways; gene expression patterns; mitochondrial regulation and biogenesis; and nuclear and mitochondrial DNA replication; mutagenesis; oxidative stress; and DNA repair. Also included are molecular responses to pathogens, pathogen identification, and pathogen inactivation, as well as host-pathogen interactions, and host components of infection and resistance to infection. This program is also interested in the biotechnology of microarrays, including both genomic- and proteomic-based platforms, for real time detection of pathogens or physiological states that would reduce or interfere with human performance. This program also supports development of new biomaterials and bioproduction methods, and other advances in biotechnology methods and applications.

Technical Point of Contact: Dr. Micheline Strand, e-mail: Micheline.strand@us.army.mil, (919) 549-4343.

14.3. Microbiology and Biodegradation.

Fundamental studies in microbial physiology, genetics, ecology and evolution. Included are studies to elucidate antimicrobial resistance mechanisms, microbial community interactions including biofilm formation, communications & population dynamics, studies of organisms that are not culturable, studies of organisms at the single cell level and studies of organisms that have adapted to extreme environments. Areas of special concern to the Army include methods to enhance stabilization of materiel and to prevent microbial growth. Also included is the development and exploitation of microbial systems for unique biotechnological applications and bioengineering processes. This might include approaches such as metabolic engineering or protein evolution and use individual microbial species or consortia of microorganisms, emphasizing the control, stability, and mechanisms of the basic cellular processes involved. Biochemical and physiological mechanisms, underlying the biodegradative processes in normal, extreme, and engineered environments and fundamental studies on organisms in these environments, the properties of materials that make them susceptible or resistant to biological attack, basic concepts for anti-fungals, and studies of microbiological mechanisms with potential for contributing to the remediation of sites contaminated with toxic wastes will also be considered.

Technical Point of Contact: Dr. Wallace Buchholz, e-mail: wallace.buchholz@us.army.mil, (919) 549-4230.

14.4 Neurophysiology and Cognitive Neuroscience.

Research in the perception and cognition subfields of neurophysiology and the cognitive neurosciences, covering several or all areas of electrophysiology, psychophysiology, sensory and perceptual physiology, computational neurobiology, psychophysics, neuropsychology, and integrative neurobiology is of interest. Specific examples can include physiological, neuropsychological and/or cortical/cognitive mechanisms underlying successful completion of complex task behaviors applicable to non-laboratory environments under non-ideal conditions, to include both amelioration of induced losses as well as enhancement in defined perceptual, cognitive and/or motor abilities. Investigations can span the gamut from multi-unit recordings through evoked potentials and neuro-imaging technologies to humoral and psychological correlates of both central and peripheral nervous system function. Non-medically oriented research in both human volunteers and animal models designed to elucidate the fundamental physiology underlying cognition and possible non-invasive methods of monitoring cognitive states and processes during normal activity is appropriate. Perceptual and/or psychophysiological implications of mind-machine interfaces ranging from optimizing auditory, visual and/or somatosensory display and control systems based on physiological or psychological states through modeling of individual cognitive dynamics and decision making is appropriate to this research area.

Technical Point of Contact: Dr. Elmar T. Schmeisser e-mail elmar.schmeisser@us.army.mil, (919) 549-4318.

14.5. Social and Behavioral Science

This program supports scientific research that focuses on the basic theoretical foundations of human behavior at various levels (individual actors to whole societies) and across various temporal and spatial scales. This includes, but is not limited to, research on the evolution and dynamics of social systems and organizations, human adaptation and response to both natural and human induced perturbations (e.g., global climate change, mass migration, war), interactions between human and natural systems, the role of culture and cognition in accounting for variations in human behavior, human decision-making under risk and uncertainty, the search for organizing principles in social networks, and the emergent and latent properties of dynamic social systems and networks. Such research can apply a wide range of approaches including computational modeling, mathematical modeling, agent-based simulations, econometric modeling and statistical modeling, to name a few. The program also recognizes the fact that the building and validation of models in the social sciences is often limited by the availability of adequate and appropriate sources of primary data. Thus, research that includes the collection of primary data for the development and testing of models is encouraged. Finally, the program also supports the development of methodologies (e.g., data collection, statistical methods, research designs) that have the potential to help advance our understanding of human behavior.

Technical Point of Contact: Dr. Jeff Johnson e-mail jeffrey.c.johnson4@us.army.mil, (919) 549-4209.

RESEARCH AREA 15 MATERIALS SCIENCE

15.0. The objective of research supported by the Materials Science Division of the Army Research Office is to discover the fundamental relationships that link chemical composition, microstructure, and processing history with the resultant material properties and behavior. The work, although basic in nature, is focused on developing new materials, material processes, and properties that promise to significantly improve the performance, increase the reliability, or reduce the cost of future Army systems. With the need for lighter weight and higher performance systems in the future, program emphasis has increasingly shifted away from metals research to a more balanced program with interests that cross a broad spectrum of materials, including polymers, ceramics and semiconductor materials. Fundamental research that lays the foundation for the design and manufacture of multicomponent systems such as composites, hierarchical materials and "smart materials" is of particular interest.

Other important areas of interest include new approaches for materials processing, new composite formulations, and surface treatments that minimize environmental impacts; and novel composite concepts, including multifunctional and hierarchical materials. Finally, there is general interest in identifying basic research in the area of manufacturing science, which will address fundamental issues related to the reliability and cost (including environmental) associated with the production and long-term operation of Army systems. The following areas

of research are not intended to reflect all of the activities of the Materials Science Division; there is always interest in new ideas and cross-disciplinary concepts in materials science that may have future applications for the Army.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a white paper.

15.1. Materials Design. The objective of the materials design program is to tailor material properties for application-driven property requirements. The research should investigate property interrelationships in materials growth, processing or characterization with the approach eventually leading to stronger coupling of experimental research with theory or modeling (including phenomenological modeling). The goal is to predict and control material behavior during processing and operation, to predict property changes over time (based on science rather than statistics), to optimize performance and reliability, and to reduce cost and time to development. It would also be advantageous to develop strategies to define constraints imposed by the experiment and theory and to establish and populate open databases for processing-microstructure-properties-performance etc. These could be continually updated to enable design, simulation, modeling and theory to evolve and ultimately for property tradeoff in support of performance optimization to occur. In addition, this should also facilitate communication among researchers and engineers at the materials, subsystem, and system level. One area of emphasis will be surface and interface engineering in support of materials integration. There is particular interest in identifying new ways of combining similar and dissimilar materials which provide multifunctional capabilities, recognizing that functionality is often derived from properties very close to the interface. Processing models that build a solid theoretical underpinning will be a key to control/optimization of surface and interface properties. Surface and interface research in areas such as organic/semiconductor, bio/semiconductor, or bio/organic/semiconductor interfaces; dielectrics/semiconductor interfaces; transparent conductive thin films; dissimilar material and nano electrical contacts; and bonded or alternative substrates can be envisioned. Another area of emphasis will be development of in-situ and ex-situ analytical methods for analysis over the appropriate dimensions, that is, methods with appropriate spatial resolution or appropriate sensitivity. The goal is to understand and control material and growth parameters that affect a desired or undesired property within a particular property range. Other areas of interest are investigations of high temperature materials and their relevant degradation modes; development of adaptive materials capable of response to internal or external stimuli; study of self-repair or self-healing effects; growth and characterization of embedded nano-sized constituents designed for material and performance health monitoring; and investigations of novel methods leading to large-scale, large-quantity processing of nanomaterials. It is intended that in addition to promoting convergence, combination and integration of similar and dissimilar materials the program also promotes convergence of and cross-disciplinary concepts for materials design.

Technical Point of Contact: Dr. John Prater,
email: John.T.Prater@us.army.mil, (919) 549-4259

15.2 Mechanical Behavior of Materials: The Mechanical Behavior of Materials program seeks to establish the fundamental relationships between the structure of materials and their mechanical properties as influenced by composition, processing, environment, and loading conditions. The program emphasizes research to develop innovative new materials with unprecedented mechanical, and other complementary, properties. Critical to these efforts is the need for new materials science theory that will enable robust predictive computational tools for the analysis and design of materials subjected to a wide range of specific loading conditions, particularly theory which departs from standard computer algorithms and is not dependent upon tremendous computational facilities. The primary research thrust areas of this program include: a) high strain-rate phenomena (e.g., experimental and computational analysis of the physical mechanisms which govern deformation in advanced materials, lightweight damage tolerant materials); b) property-focused processing (e.g., materials science theory to predict the range of properties attainable with advanced processing methods, novel approaches for enhancing specific toughness); and c) tailored functionality (e.g., innovative materials containing unique and specifically designed chemical and biological functionalities and activities while maintaining, or preferably enhancing, requisite mechanical properties). Additionally, of joint interest with the Polymer Chemistry program in Chemical Sciences are research efforts seeking to generate statistically valid bulk mechanical behavior data with small polymer samples. In all cases, three to four page white papers describing a specific research objective, scientific approach, and anticipated scientific impact are encouraged to initiate a discussion of potential research directions.

Technical Point of Contact: Dr. David Stepp
email: David.M.Stepp@us.army.mil, (919) 549-4329

15.3. Synthesis and Processing of Materials. The program on Synthesis and Processing of materials focuses on the use of innovative approaches for processing high performance structural materials reliably and at lower costs. Emphasis is placed on the design and fabrication of new materials with specific microstructure, constitution, and properties. Research interests include experimental and theoretical modeling studies to understand the influence of fundamental parameters on phase formation, micro structural evolution, and the resulting properties, in order to predict and control materials structures at all scales ranging from atomic dimensions to macroscopic levels. Trends in this subfield include non-equilibrium materials processing (e.g., rapid solidification); powder synthesis and consolidation; novel processing of ceramics, polymers, metals and composites; welding and joining including composite materials; elastomers; fibers and fabrics; and utilization of micro structural, compositional, or other unique signatures which may provide non-destructive in situ feedback process control to enhance product reproducibility and quality. Supercritical fluid, shock-induced chemical processing and other innovative approaches for processing materials are also of interest.

Technical Point of Contact: Dr. David Stepp
email: David.M.Stepp@us.army.mil, (919) 549-4329

15.4. Physical Properties of Materials. The Physical Properties of Materials program seeks to understand the fundamental mechanisms responsible for various physical properties of materials. Whitepapers/proposals in the area of innovative processing and electronic, magnetic and optical characterization techniques to understand the mechanisms and enhance the physical properties of materials are of particular interest. Emphasis on multifunctionality of materials is strongly encouraged. The primary research thrusts of this program include: 1) defect engineering of advanced materials and interfaces (e.g., both bulk and thin-film form of materials including ferroelectrics, piezoelectrics, semiconductors, and high temperature superconductors); 2) thermal management materials (e.g., new materials in thin film or bulk form including carbon based materials, alloys, composites, and novel thermal property characterization methods); and 3) novel 2D free-standing materials (e.g., fundamental studies on physical properties of novel 2D and composites of 2D/3D oxides and nitrides, 2D materials processing and characterization methods to determine unique unprecedented properties).

Technical Point of Contact: Dr. Pani Varanasi
email: Pani.Varanasi@us.army.mil, (919) 549-4325

RESEARCH AREA 16 NETWORK SCIENCE

16.0. Work over the past ten years by researchers in various fields including Statistical Mechanics, Anthropology, Structural Biology, Distributed Systems, Theoretical Computer Science, Robotics and Control theory has shown that there is a lot of commonality in the structure of networks around us – be it communication among a school of fish, pack of wolves, a group of jihadis, or an *ad-hoc* wireless network. The goal of the Network Science Division is to make use of this commonality, in a synergistic way, to address issues of importance to the Army. Networks of sensors, communication and computation nodes, and robots are pervasive throughout the Army and especially in Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems. The Network Science Division identifies and addresses the Army's critical basic research problems in C4ISR where progress has been inhibited by a lack of novel concepts or fundamental knowledge. Research in this program has application to a wide variety of developmental efforts and contributes to the solution of technology-related problems throughout the Army's Future Force operational goals.

The ARO supports and advances fundamental research and knowledge that focuses on the needs of the Army's effort to be net-centric. To accomplish this objective, the Division supports extramural basic research in the four areas of Communication and Human Networks, Intelligent Networks, Multi-Agent Network Control and Decision Sciences. The boundary between these programs is fluid and, thus, a research topic might fall in more than one area. However, a common theme of all these extramural research programs is their relevance to the Army.

Potential offerors are encouraged to contact the appropriate TPOC for preliminary discussions on their ideas. The TPOC may, then, invite the offeror to submit a whitepaper.

16.1. Communication and Human Networks. This program is concerned primarily with establishing the fundamental understanding necessary to support the Army's future mobile, wireless tactical battlefield communications needs. These systems must support broad-based and highly mobile communications and must perform in environments of impressive diversity, from dense foliage to dense urban obstructions, and unintentional and intentional jamming. Future Army tactical communication systems for the digital battlefield will consist of many different types of networks and must be capable of communicating on the move. These systems will be highly mobile creating highly dynamic network topologies (mobile ad-hoc networks) and routing multimedia (voice, data and video) data. Also of interest is interaction between communications and human networks.

16.1.1. *Wireless Network Theory*. Research is required in the broad area of wireless network science including fundamental limits, performance characterization, novel architectures, and high fidelity simulation. Metrics, fundamental limits, and performance need to be characterized for multi-hop wireless networks with mobility, node loss, and bursty traffic. New simulation techniques are necessary to allow for very large simulations without losing the fidelity at the physical layer that is necessary for realistic results.

16.1.2. *Mobile Ad Hoc and Sensor Networks*. Research is required in the area of mobile ad hoc networks, including cross layer design, robust, survivable and cooperative networking, and physical layer design. Low energy consumption is of primary concern for sensor networks. In order to meet energy, throughput, and QoS requirements, cross layer design is necessary from the physical to the admission control and transport protocols. Robust and survivable network solutions are needed to recover from network disconnects, failures, and malfunctioning nodes in order to minimize disruption to communications and services. LPI/LPD/AJ and physical layer authentication are key design considerations.

16.1.3. *Network Integration*. The integrated network may be highly heterogeneous, including disadvantaged nodes with severe energy and bandwidth constraints, as well as mobile access points such as in unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), and satellites. There is a need for managing the heterogeneity of networks, nodes and protocols, for resolving interoperability issues when a common platform does not exist, as well as creating network architectures that maximize performance. Research is needed in spectrum management and reuse, including wideband sensing and networking protocols, and implementing spectrum policy.

16.1.4. *Human Networks*. Topology, dynamics, and information flow within human networks is of interest as well as interaction of communications and human networks. In particular, this program will leverage mathematical techniques invented in the context of communication networks, such as network information theory, graph theory, and Markov chains, to analyze human networks. Interaction between human and communications networks need to be analyzed, such as the interaction of QoS communications goals with the requirements of the human network in a tactical scenario.

Technical Point of Contact: Dr. Robert Ulman
e-mail: Robert.Ulman@us.army.mil, (919) 549-4330

16.2. Decision & Neuro-Sciences. The objective of the Decision and Neuro Sciences program is to develop theoretical foundations, models, and algorithms to support timely, robust, near-optimal decision making in highly complex, dynamic systems, operating in uncertain, resource-constrained environments with incomplete information against a competent thinking adversary. Although, based on operations research methodologies such as modeling, simulation and numerical optimization, this program is expected to include multi-disciplinary emphasis to accommodate complex, multi-dimensional decision frameworks in today's asymmetric warfare. Examples of research that could contribute towards this unifying goal are:

- a. Modeling and simulation of contemporary environments (addressing adversarial strategies, classic terrain features, demographically-informed population information, as well as dynamic temporal information) with the objective of decision support
- b. Fundamental graph theory and network analysis in support of modeling social networks and other complex systems behaviors and processes
- c. Numerical optimization and modeling to include capabilities for stochastic behaviors; novel approaches which address more general conditions and distributions
- d. Bayesian and other evidential reasoning and fusion approaches to model wide ranging, perhaps real-time, and incomplete information.
- e. Sequential dynamic decision making approaches
- f. New algorithms with provable or demonstrable improved performance bounds.
- g. Game theoretical and simulation approaches applied to asymmetric warfare situations
- h. Empirical studies into physiological, psychological and cognitive modeling of decision making

This new program, just initiated in FY09, advances work in developing improved and robust models and algorithms taking into account multiple complex factors, including highly stochastic and dynamic behaviors.

16.2.1. *Stochastic Optimization*. Research into numerical methods to improve current optimization algorithms should address more general conditions: non-linearity, generalized differentials, stochastic properties (constraints and objective function), mixed integer constraints, as well as highly complex and dynamic properties. Both mathematically convergent and heuristic methods are to be considered. Specific efforts to improve and extend network and graph theory-based methods which take into account social and cultural properties are important.

16.2.2. *Improved Inference Models*. Research into numerical methods to improve inference models to address fusion of complex information across multiple levels of uncertainty and probability distribution properties should be addressed. Effort in developing improved mathematically-based inference models which fuse highly dynamic, uncertain, incomplete information will be considered. Study of human and other biological systems decision dynamics in experimental settings is an important focus to identify decision processes and to possibly inspire new numerical approaches.

16.2.3. *Modeling and Simulation of Complex Networks.* Development of fundamental modeling and simulation of complex networks which do not adhere to simplifying assumptions related to linear, ergodic and equilibrium behaviors – conditions present in contemporary environments. Studies and developments which uncover adaptive and self-organizing behaviors to explain and improve operational decision making are important.

Technical Point of Contact: Dr. Janet Spoonamore
e-mail: Janet.Spoonamore@us.army.mil, (919) 549-4284

16.3. Intelligent Networks. The overall objective of the Intelligent Networks program is to augment human decision makers (both commanders and soldiers) with enhanced-embedded battlefield intelligence that will provide them with the necessary situational awareness, reconnaissance, and decision making tools to decisively defeat any future adversarial threats. The challenge is to find methods that facilitate the development of intelligent and autonomous systems that perceive their environment by means of sensing and through context, and use that information to generate intelligent, goal-directed, desired behaviors. This area of research poses unique challenges for the Army as it involves developing an autonomous capability for mixed teams of air and ground vehicles that act to complement a soldier's capabilities.

The focus is on developing a formalized mathematical, algorithmic, and practical understanding of perception, control and learning to facilitate the development of intelligent and autonomous systems. The Intelligence Networks program aims to be the glue that supports fundamental work in "intelligence," which is utilized in several other programs in Computing Science and Network Science divisions.

16.3.1. *Integrated Intelligence.* Topics of interest are sub-components for vision, knowledge representation, reasoning, and planning that can be integrated in a synergistic fashion to yield a sum that is more than its parts.

16.3.2. *Robust Reasoning Under Uncertainty.* The ability to adapt or compensate, in reasoning, for the uncertainty inherent in real systems related to modeling error, sensing errors and noise, system failures, and changing dynamic environments, are important.

16.3.3. *Socio-Cultural Computing.* Research on the mathematical tools to model and reason about societies and cultures is needed that brings together tools from Game Theory, Social Sciences and Knowledge Representation.

Technical Point of Contact: Dr. Purush Iyer
e-mail: purush.iyer@us.army.mil, (919) 549-4204

16.4 Multi-Agent Network Control. The Multi-Agent Network Control Research Program is concerned with developing the theory and tools, through appropriate application and creation of the relevant mathematics, to the modeling, analysis, design, and control of complex real-time physical and information-based systems, including distributed and embedded, networked

autonomous and semi-autonomous, non-linear, smart structures, and decentralized systems. The program invests in fundamental systems and control theory and relevant mathematical foundations for areas of control science with two major thrusts: Intelligent Control and Multi-Agent Systems.

16.4.1. *Intelligent Control*. The advancements in ubiquitous computation, communications, sensing, biological systems, cognitive sciences, etc., provide a new horizon for control paradigm advancements. Topics of interest in this thrust include multivariate, adaptive, nonlinear, optimal, stochastic, embedded, and hybrid control, learning systems, swarming behaviors, non-conventional game theory, and intelligent decision-making. Control theoretic framework, accurate, efficient, demonstrable computational procedures, analytical solutions of intelligent control of time-sensitive applications in severe environments, using noisy sensors are of special interest

16.4.2. *Multi-Agent Systems* The anticipated dynamics of the future battle space will require a greatly increased level of automation to enable the necessary mobility, sensor coverage, information flow, and responsiveness to support the military goals of information superiority, dominant maneuver, and precision engagement. Intelligent collaborative networks of software and physical agents will allow the Army to satisfy this increased tempo within the constraints of reduced manpower and casualties. Topics of interest in this thrust include integrated agent-based decision and control architectures, dynamic resource management, and fault-tolerant operation, especially under network delay, bandwidth communication and computational constraints. This thrust is also interested in establishing mathematical foundations related to distributed system theory; metrics for system complexity, information content, flow, structure, swarming phenomena, design of emergent behavior for heterogeneous multi-agent systems, and information processing and data fusion for decision-making, distributed multi-agent theory with applications to heterogeneous teams of robotic, UAVs, biological entities, and/or software.

Technical Point of Contact: Dr. Randy Zachery
e-mail: randy.zachery@us.army.mil, (919) 549-4368

RESEARCH AREA 17 ARO SPECIAL PROGRAMS

17.1. SHORT TERM INNOVATIVE RESEARCH (STIR) PROGRAM. The objectives of the STIR program are to provide rapid, short- term investigations to assess the merit of innovative concepts in basic research. Proposed research may be for the continuation of or the natural outgrowth of experimental or theoretical explorations.

17.1.1. *Eligibility*. Research proposals are sought from educational institutions, nonprofit

organizations, and commercial organizations. Prospective offerors of a STIR proposal are encouraged to contact the appropriate TPOC identified in PART I Research Areas 7-15 **only** of this BAA to ascertain the extent of interest in the specific research project.

17.1.2. Research Sought. Proposals in the amount of \$50,000 or less are sought for research in the areas identified in PART I, Research Areas 7-15 of this BAA.

17.1.3. Proposal Preparation.

17.1.3.1. Organizations or institutions should submit proposals that are no more than twenty (20) pages in length, inclusive of the budget, transmittal letter, and attachments. Any proposal in excess of 20 pages will not be considered. No brochures or explanatory material should be submitted with the proposal. A one-page signed budget must accompany the proposal.

17.1.3.2. Proposed research efforts must be "stand alone" and not predicated on the use of any facilities other than those under the direct control of the offeror. Research must be completed within nine (9) months of award of the agreement. **Extensions of the nine-month performance period will not be granted.**

17.1.3.3. Proposals shall be submitted with a Proposal Cover Page (Form 51). Limited rights data should be identified as an attachment to the proposal. Otherwise, we will assume that the proposal does not contain limited rights data.

17.1.3.4. No capital equipment may be purchased. Travel costs must not exceed \$500. Report preparation costs must not exceed \$100. The assessment of indirect costs or fee is unallowable.

17.1.3.5. The principal investigator(s) should disclose and explain the relevancy of the proposal to the research interests identified in PART I, Research Areas 7-15 of this BAA.

17.1.3.6. A brief, final technical report must be submitted to the ARO within thirty (30) days of completion of the grant or contract. Please note that your award document will reference Form 18, "Reporting Instructions," as found at <http://www.aro.army.mil/index.htm>. You shall use these reporting instructions for format instructions only; the due date for receipt of a final technical report is thirty (30) days from completion of the award.

17.1.3.7. Submit electronic proposals to baa@arl.army.mil.

17.2. YOUNG INVESTIGATOR PROGRAM (YIP). The objective of the YIP is to attract to Army research outstanding young university faculty members, to support their research, and to encourage their teaching and research careers. Young investigators meeting eligibility requirements may submit a YIP proposal. Outstanding YIP projects may be considered for a Presidential Early Career Award for Scientists and Engineers (PECASE). PECASE awards are the highest honor bestowed by the Army on outstanding scientists and engineers beginning their independent careers.

17.2.1. Eligibility. This program is open to resident aliens and U.S. citizens holding tenure-track

positions at U.S. universities and colleges who have held their graduate degrees (Ph.D. or equivalent) for fewer than five years at the time of application. Faculty at an institution of higher education which does not designate any faculty appointments as "tenure track" are eligible if that is so indicated in the proposal and the supporting letter from the university states that the faculty member submitting the proposal will be considered for a permanent appointment.

17.2.2. Research Sought. Proposals are invited for research in areas described in PART I, Research Areas 7-15 **only** of this BAA. Proposals may be submitted at any time. As is the case for the regular research programs, **we strongly encourage informal discussions with the cognizant ARO technical program manager before submission of a formal proposal.** An award in each topic area is not guaranteed. YIP awards not to exceed \$50,000 per year for three years will be made based on research proposals and supporting material. These funds may be used to defray those reasonable costs normally allocable to the research effort (e.g., direct salaries, indirect costs, graduate student support, equipment, supplies, etc.).

17.2.3. Proposal Preparation.

17.2.3.1. An individual applying for a YIP award must submit a research proposal and a supporting letter, each through university officials. Any resulting agreement will be made to the institution, not to the investigator. The research proposal should follow the format set forth in PART III of this BAA. The institutionally approved proposal and letter should be sent to the address found in Part III with the attention line as ATTN: DR. Larry Russell, AMSRD-ARL-RO.

17.2.3.2. The supporting letter must be from the applicant's Department Chairperson, Dean, or other official who speaks for the university regarding support for and commitment to the applicant. Strong university support for the applicant is essential. This support can include the applicant's 9-month academic salary, release time from administrative responsibilities, the purchase of equipment, support for the applicant's graduate students, waiver of indirect costs, departmental cost sharing, start-up funding, and so on. It must be clear that the university views the applicant as a truly outstanding, potential leading faculty member and is making a long-term commitment to the application and the research.

17.2.4. Evaluation Factors. The evaluation factors to be used in determining which proposals are selected for funding are described in PART IV of this BAA. In addition, proposals submitted for YIP funding will be evaluated based on a long-term commitment by the university to the applicant and the research. YIP proposals will be selected for award on a competitive basis after a peer or scientific review.

17.2.5. Presidential Early Career Award for Scientists and Engineers (PECASE).

17.2.5.1. An applicant may not directly apply for a PECASE award. Instead, once a year ARO technical program managers will nominate PECASE candidates from among all ARO YIP proposals and white papers (if any) received. The technical program manager will make the PECASE nomination based on strong endorsement of the YIP proposal by the external scientific reviewers and on the great potential shown by the investigator to contribute to science and to the

mission of the Army.

17.2.5.2. Following nomination of a PECASE candidate, a supplemental PECASE proposal will be required in which the candidate will indicate how PECASE funding would augment the YIP project. PECASE awards are not to exceed \$200,000 per year for five years. Supporting information including letters of recommendation, detailed scientific biographical information, and a summary of past research accomplishments will be required in the PECASE proposal.

17.2.5.3. Complete PECASE proposal packages will be evaluated by external scientific reviewers. The proposals which demonstrate the greatest potential to contribute to science and to the mission of the Army will be rank ordered by an Army PECASE Evaluation Committee. The PECASE packages are evaluated based on (1) Publications, (2) Presentations, (3) Scientific Leadership, (4) Mission Relevant Research, (5) Community Outreach, (6) Department Commitment & Recommendation Letters and (7) Scientific Quality of Research.

17.2.5.4 Continued Support. Support under the YIP is limited to three years and PECASE support is limited to five years. Upon completion of the YIP or PECASE project, young investigators may apply and be considered for continued support in the areas identified in PART I, Research Areas 7-15 of this BAA. Decisions about continued funding outside the context of the YIP or PECASE will be made following a peer or scientific review and a review of ARO's research priorities and the creativity and productivity demonstrated during the previous research program.

17.3. RESEARCH INSTRUMENTATION (RI) PROGRAM. Research instrumentation is designed to improve the capabilities of U.S. universities to conduct research and educate scientists and engineers in areas important to national defense. Of the funds available to acquire research described in PART I of this BAA, funds may be provided to purchase instrumentation in support of this research or in the development of new research capabilities.

17.3.1. Eligibility and Areas of Interest. To be eligible for an instrumentation award, an offeror must have at the time of submission, a current grant or contract with the ARO, and the instrumentation requested must be in support of research presently being carried out. It is highly recommended that potential offerors contact the appropriate ARO TPOC manager for advice and assistance before preparation of an instrumentation proposal.

17.3.2. Content of Request for Instrumentation. The request for instrumentation shall include:

17.3.2.1. A concise abstract (approximately 300 words) that describes the instrumentation requested and the research to be supported by that instrumentation.

17.3.2.2. A budget that addresses equipment to be purchased, cost per item, and total cost. Indicate the proposed source of the equipment and the name and telephone number of a contact at that source. The budget should indicate the amount of funds to be contributed by other sources toward the purchase of the instrumentation.

17.3.2.3. A description of how the proposed instrumentation will: (i) establish new research

capabilities, (ii) contribute to research currently proposed to DOD, or (iii) enhance the quality of research currently being funded by ARO.

17.3.2.4. A description of how the proposed instrumentation will interface with or upgrade other research facilities and instrumentation now available.

17.3.2.5. A description of the amounts and sources of ongoing or proposed support for the research to be supported by the instrumentation.

17.4. DOD PROGRAMS.

17.4.1. Each year the Army Research Office, along with the Office of Naval Research (ONR) and the Air Force Office of Scientific Research (AFOSR), participates in two programs sponsored by the Office of the Deputy Under Secretary of Defense for Science and Technology. These two programs, titled the Defense University Research Instrumentation Program (DURIP) and the Defense Experimental Program to Stimulate Competitive Research (DEPSCoR), are conducted under separate BAAs that are posted yearly on the ARO web site. For the purpose of these two programs, the areas of interest for submitting proposals are limited to Research Areas 7-15 as identified in PART I.B of this BAA. Offerors are reminded that these two BAAs have definitive closing dates for receipt of proposals (see each specific BAA for details). In addition, offerors must review the specific BAAs for eligibility considerations.

Technical Point of Contact: Dr. Kurt Preston e-mail Kurt.Preston@us.army.mil (919) 549-4234.

17.4.2. HBCU/MSI Research and Educational Program. In addition to the ARO basic research program, there are other special funding opportunities available to HBCUs/MSIs through ARO. Research and educational programs and activities for HBCUs/MSIs are established in accordance with Section 252 of the National Defense Authorization Act for Fiscal Year 2010 (enacted in 10 U.S.C. 2362) and the Department of Defense Appropriations Act, 2010. The program is executed under policy and guidance of the Office of the Director of Defense Research and Engineering (ODDR&E (Research Directorate/Basic Science Office)).

The program aims to (a) enhance programs and capabilities in scientific and engineering disciplines critical to the national security functions of the DoD, (b) encourage greater participation in DoD programs and activities, (c) increase the number of graduates, including underrepresented minorities, in the fields of science, technology, engineering and/or mathematics (STEM), and (d) encourage research and educational collaboration with other institutions of higher education directed toward advancing the state of the art or increasing knowledge and understanding.

In addition, ARO may periodically release special DoD solicitations that target specific groups such as Tribal Colleges and Universities (TCUs). The DoD solicitations may offer one or more of the following components: research; instrumentation enhancement (for research and/or educational purposes); scholarships; fellowships; collaborative research; and centers of excellence.

Eligibility. Eligible institutions are identified on the U.S. Department of Education Postsecondary Minority Institutions list. The list is compiled by the Office for Civil Rights, U.S. Department of Education, using enrollment data reported by postsecondary institutions to the National Center for Integrated Statistics and the Office for Civil Rights in the Integrated Postsecondary Education Data System (IPEDS) fall enrollment survey, formerly called the Higher Education General Information Survey (HEGIS). The list is available at <http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst-list.html>. Questions concerning the list must be directed to the U.S. Department of Education at (888)863-6515.

An institution whose name does not appear on the list but who has received documents from the Department of Education certifying their minority status must submit a copy of such certification with their proposal(s).

Solicitations are available on the ARO website under “Funding Opportunities” as well as the Grants.gov website. These solicitations will have a definite closing date for proposal submission, and offerors are advised to review the solicitations for eligibility considerations.

Technical Point of Contacts:

ARL-Adelphi: Dr. Vallen L. Emery, Jr.

e-mail: vallen.emery@us.army.mil, (301)394-3585

ARL-ARO: Ms. Peggy Lacewell

e-mail: peggy.lacewell@us.army.mil, (919)549-4339

PART II - OTHER PROGRAMS CONFERENCE AND SYMPOSIA GRANTS

1. Introduction. The Army supports conferences and symposia in special areas of science that bring experts together to discuss recent research or educational findings or to expose other researchers or advanced graduate students to new research and educational techniques. The Army encourages the convening in the United States of major international conferences, symposia, and assemblies of international alliances.

2. Eligibility. Scientific, technical, or professional organizations which qualify for tax exemption under the provision of 26 U.S.C. Sec. 501 (C) (3) and otherwise qualify under the criteria in this BAA may receive conference and symposia grants. Notwithstanding the above, the Department of Defense (DOD) has imposed certain restrictions on the Army's co-sponsorship of scientific and technical conferences and symposia. Specifically, DOD Regulation 5500.7-R and DOD Instruction 5410.20 prohibits co-sponsorship of conferences and symposia with certain non-federal entities unless one of several narrow exceptions apply. A DOD Component Command or Organization is a co-sponsor of an event when they are one of the organizations that develops the substantive aspects of the event and/or provides substantial logistical support

for the event. For questions regarding your organization's eligibility for a conference or symposia grant, please contact the ARO Legal Office at (919) 549-4292 or e-mail: ed.beauchamp@us.army.mil , or the ARL-Adelphi Legal Office at (301) 394-1696 or e-mail: patrick.emery@us.army.mil.

3. Conference Support. Conference support proposals should be submitted a minimum of six (6) months prior to the date of the conference.

4. Technical Proposal Preparation. The technical portion of a proposal for support of a conference or symposium should include:

- a. A one page or less summary indicating the objectives of the project.
- b. The topics to be covered.
- c. The location and probable date(s) and why the conference is considered appropriate at the time specified.
- d. An explanation of how the conference will relate to the research interests of the Army and how it will contribute to the enhancement and improvement of scientific, engineering, and/or educational activities as outlined in PART I B of the BAA.
- e. The name of chairperson(s)/principal investigator(s) and his/her biographical information.
- f. A list of proposed participants and the methods of announcement or invitation.
- g. A summary of how the results of the meeting will be disseminated.
- h. A signed cover page.

5. Cost Proposal Preparation. The cost portion of the proposal should show:

- a. Total project conference costs by major cost elements.
- b. Anticipated sources of conference income and amount from each.
- c. Anticipated use of funds requested.
- d. A signed budget.

6. Participant Support. Funds provided cannot be used for payment to any federal government employee for support, subsistence, or services in connection with the proposed conference or symposium.

HISTORICALLY BLACK COLLEGES AND UNIVERSITIES AND MINORITY SERVING INSTITUTIONS (HBCU/MSIs)

The Army has a long history of advocating and supporting research at HBCU/MSIs. Through this solicitation the Army Research Laboratory (ARL) and the Army Research Office (ARO) actively seek proposals from the HBCU/MSI community in full and open competition with all offerors. Proposals may relate to any research topic described herein. Prospective offerors are encouraged to contact the technical point of contact (TPOC) whose name, telephone number, and email address is listed with the respective research topics. In addition to single investigator research proposals, collaborative research proposals are also encouraged. Collaborations may be between HBCU/MSIs and other institutions of higher education (not limited to HBCU/MSIs) and/or industry partners.

The ARL is interested in awarding cooperative agreements, grants, and contracts to HBCU/MSIs that will advance research and development in science, math, and engineering with potential application in support of the Army war fighter. Areas of interest include but are not limited to the following:

- Support of education and research partnership agreements;
- Professional development for faculty to participate in ARL research and development activities and to develop methods for integrating these activities into their curricula;
- Participation in Summer Faculty/Sabbatical Leave research programs and Intergovernmental Personnel Act (IPA) appointments at ARL laboratories;
- Support for graduate student research on HBCU/MSI campuses or at ARL laboratories (i.e., MS or Ph.D. degree programs relevant to the ARL mission);
- Opportunities for supporting research conducted by newly hired tenure track faculty at HBCU/MSIs;
- Support of M.S. and Ph.D. candidates while completing theses and dissertations on ARL-approved topics;
- Opportunities for HBCU/MSIs to conduct research symposia, workshops, and other related technical assistance programs that provide "hands on" training and information to HBCU/MSIs;
- Awards for Centers of Excellence at HBCU/MSIs (i.e., research and education centers relevant to Army transformation);
- Summer internship opportunities for undergraduate and graduate students at ARL laboratories;
- Instrumentation and equipment upgrade of science laboratories;

- Faculty special training.

Program interests cover a broad spectrum including funding to augment projects resulting in technologies that support state of the art capabilities for the war fighter. The Army is also committed to support outreach programs that increase the available pool of science, mathematics, and engineering students to act as research assistants and pursue graduate degrees in those areas. Novel proposals that address innovative techniques for increasing the number of minority students attending college with math and science literacy are also of interest. These may include, for example, summer science programs, Saturday science academies, online and distance science education, science partnerships with local secondary schools, and other types of outreach that may increase the pool of science, mathematics, and engineering students.

Point of Contact for the ARL initiatives above is Dr. Vallen E. Emery, Jr., (301) 394-3585, Vallen.emery@us.army.mil

The Army Research Office encourages basic research proposals from HBCU/MSIs in response to Research Areas 7-16 of this announcement in full and open competition with all offerors. Included are special emphasis programs such as Short-Term Innovative Research (STIR) and the Young Investigator Program (YIP), described in detail elsewhere in this announcement.

Additional funding opportunities are available through ARO under the DoD Research and Educational Program for Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MSI). The program is under policy and guidance of the Office of the Director of Defense Research and Engineering (ODDR&E (Research Directorate/Basic Science Office)). The program aims to (a) enhance programs and capabilities in scientific and engineering disciplines critical to the national security functions of the DoD, (b) encourage greater participation in DoD programs and activities, (c) increase the number of graduates, including underrepresented minorities, in the fields of science, technology, engineering and/or mathematics (STEM), and (d) encourage research and educational collaboration with other institutions of higher education directed toward advancing the state of the art or increasing knowledge and understanding. Solicitations are issued annually and are available on the ARO web site and through Grants.gov. Additionally, there may be an annual solicitation for Tribal Colleges and Universities (TCUs) which is reserved for this respective group. The DoD solicitations may include one or more of the following components: research; instrumentation enhancement (for research and/or educational purposes); scholarships; fellowships; collaborative research; and centers of excellence.

Point of Contact for the ARO HBCU/MSI and DoD HBCU/MSI programs is Ms. Peggy Lacewell; e-mail: peggy.lacewell@us.army.mil, (919)549-4339.

2. Eligibility: Eligible institutions are identified on the U.S. Department of Education Postsecondary Minority Institutions list. The list is compiled by the Office for Civil Rights, U.S. Department of Education, using enrollment data reported by postsecondary institutions to the National Center for Integrated Statistics and the Office for Civil Rights in the Integrated Postsecondary Education Data System (IPEDS) fall enrollment survey, formerly called the Higher Education General Information Survey (HEGIS). The list is available at

<http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst-list.html>. Questions concerning the list must be directed to the U.S. Department of Education at (888)863-6515.

PART III - PROPOSAL PREPARATION AND SUBMISSION

SECTION 1 - General Information:

Preliminary Inquires: The ARL and ARO receive several hundred research proposals annually. Because of financial constraints, we are able to provide support for only a limited number of the proposals received. We realize that the preparation of a research proposal often represents a substantial investment of time and effort by the offeror. Therefore, in an attempt to minimize this burden, we strongly encourage organizations and individuals interested in submitting research proposals to make preliminary inquiries as to the general need for the type of research effort contemplated, before expending extensive effort in preparing a detailed research proposal or submitting proprietary information. The TPOCs for each area of interest are identified as part of the description of that area and shall be contacted as appropriate and /or submit whitepapers.

Classified Submissions: Classified proposals are not expected. However, in an unusual circumstance where an offeror believes a proposal has the potential to be classified, the ARO Security Office shall be contacted on (919) 549-4356 prior to the proposal's submission. If the proposal is for topic areas 2.35 through 2.43, the Security Point of Contact, Mr. Tim Brown shall be contacted on (301)394-3863 prior to the proposal's submission. Classified submissions shall not be submitted electronically.

Use of Color in Proposals: All proposals received shall be stored as electronic images. Electronic color images require a significantly larger amount of storage space than black-and-white images. As a result, offerors' use of color in proposals should be **minimal** and used **only when absolutely necessary** for details. Do not use color if it is not necessary.

Post Employment Conflict of Interest: There are certain post employment restrictions on former federal officers and employees, including special government employees (Section 207 of Title 18, U.S.C.). If a prospective offeror believes a conflict of interest may exist, the situation should be discussed with ARL legal personnel (ARO: Mr. Ed Beauchamp ed.beauchamp@us.army.mil or ARL: Mr. Pat Emery at patrick.emery@us.army.mil) prior to expending time and effort in preparing a proposal.

Statement of Disclosure Preference: Please complete Form 52 or 52A stating your preference for release of information contained in your proposal. Copies of these forms are available at <http://www.arl.army.mil/main/main/default.cfm?Action=29&Page=218#baaforms>.

Equipment: Normally, title to equipment or other tangible property purchased with contract funds vests with nonprofit institutions of higher education or with nonprofit research organizations if vesting will facilitate scientific research performed for the Government. Commercial organizations are expected to possess the necessary plant and equipment to conduct

the proposed research. Deviations shall be made on a case-by-case basis.

Types of Awards: The ARL and ARO have the authority to award a variety of instruments. The ARL/ARO reserves the right to use the type of instrument most appropriate for the effort proposed. Offerors should familiarize themselves with these instrument types and the applicable regulations before submitting a proposal. Following are brief descriptions of the possible award instruments.

1. Procurement Contract. A legal instrument which, consistent with 31 U.S.C. 6303, reflects a relationship between the Federal Government and a State, a local government, or other recipient when the principal purpose of the instrument is to acquire property or services for the direct benefit or use of the Federal Government.
2. Grant - A legal instrument that, consistent with 31 U.S.C. 6304, is used to enter into a relationship:
 - a. The principal purpose of which is to transfer a thing of value to the recipient to carry out a public purpose of support or stimulation authorized by a law or the United States, rather than to acquire property or services for the DOD's direct benefit or use.
 - b. In which substantial involvement is not expected between the DOD and the recipient when carrying out the activity contemplated by the grant.
 - c. No fee or profit is allowed.
3. Cooperative Agreement - A legal instrument which, consistent with 31 U.S.C. 6305, is used to enter into the same kind of relationship as a grant (see definition "grant"), except that substantial involvement is expected between the DOD and the recipient when carrying out the activity contemplated by the cooperative agreement. The term does not include "cooperative research and development agreements" (CRADA) as defined in 15 U.S.C. 3710a. No fee or profit is allowed.

Regulations governing Grants and cooperative agreements include:

- a. OMB Circular A-21, "Cost Principles for Educational Institutions"
- b. OMB Circular A-87, "Cost Principles for State, Local and Indian Tribal Governments"
- c. OMB Circular A-102, "Grants and Cooperative Agreements with State and Local Governments"
- d. OMB Circular A-110, "Uniform Administrative Requirements for Grants and Agreements with Institutions of Higher Education, Hospitals, and Other Non-Profit Organizations"
- e. OMB Circular A-122, "Cost Principles for Non-Profit Organizations"

- f. OMB Circular A-133, "Audits of States, Local Governments, and Non-Profit Organizations"
- g. DOD Grant and Agreement Regulations (DODGARs), DOD 3210.6-R

Copies of OMB regulations may be obtained from:

Executive Office of the President Telephone: (202) 395-7332
Publications Service FAX Requests: (202) 395-9068
New Executive Office Building <http://www.whitehouse.gov/OMB/grants>
725 17th Street, N.W., Room 2200
Washington, DC 20503

An electronic copy of the DODGARs may be found at
<http://www.dtic.mil/whs/directives/corres/html/32106r.htm>

4. Other Transaction for Research. A legal instrument, consistent with 10 U.S.C. 2371, which may be used when the use of a contract, grant, or cooperative agreement is not feasible or appropriate for basic, applied, and advanced research projects. The research covered under an other transaction shall not be duplicative of research being conducted under an existing DOD program. To the maximum extent practicable, other transactions shall provide for a 50/50 cost share between the government and the offeror. An offeror's cost share may take the form of cash, independent research and development (IR&D), foregone intellectual property rights, equipment, or access to unique facilities, as well as others. Due to the extent of cost share, and the fact that an other transaction does not qualify as a "funding agreement" as defined at 37 CFR 401.2(a), the intellectual property provisions of an other transaction can be negotiated to provide expanded protection to an offeror's intellectual property. No fee or profit is allowed on other transactions.

5. Other Transaction for Prototype. A legal instrument, consistent with 10 U.S.C. 2371 (as supplemented by Section 845 of Public Law 104-201 and Section 804 of Public Law 104-201), which may be used when the use of a contract, grant, or cooperative agreement is not feasible or appropriate for prototype projects directly relevant to weapons or weapon systems proposed to be acquired or developed by the DOD. The effort covered under an other transaction for prototype shall not be duplicative of effort being conducted under an existing DOD program. No fee or profit is allowed on other transactions for prototypes.

NOTE: In accordance with DOD Directive 3210.6, the DODGARs may include rules that apply to other nonprocurement instruments, when specifically required in order to implement a statute, Executive Order, or Government wide rule that applies to other nonprocurement instruments, as well as to grants and cooperative agreements.

Unsuccessful Proposal Disposition Unless noted in an offeror's proposal to the contrary, unsuccessful proposals will be retained for six (6) months from declination and then properly destroyed.

SECTION 2 – The Application Process

The application process is in three stages as follows:

Stage 1. Verify the accuracy of your Dun & Bradstreet (D&B) registration at the D&B website <http://fedgov.dnb.com/webform> before registering with the Central Contractor Registration (CCR) at <http://www.ccr.gov>. Prospective offerors must be registered in CCR prior to award. The CCR obtains Legal Business Name, Doing Business Name (DBA), Physical Address, and Postal Code/ Zip+4 data fields from D&B: If corrections are required, registrants will not be able to enter/modify these fields in CCR; they will be pre-populated using D&B Data Universal Numbering System (DUNS) record data. When D&B confirms the correction has been made, the registrant must then re-visit [ccr.gov](http://www.ccr.gov) and 'accept' D&B's changes. Only at this point will the D&B data be accepted into the CCR record. Allow two (2) business days for D&B to send the modified data to CCR.

Stage 2 - Prospective proposers are requested to submit white papers prior to the submission of a complete, more detailed proposal. The purpose of white papers is to minimize the labor and cost associated with the production of detailed proposals that have very little chance of being selected for funding. Based on assessment of the white papers, feedback will be provided to the proposers to encourage or discourage them to or from submitting full proposals. White papers should present the effort in sufficient detail to allow evaluation of the concept's technical merit and its potential contributions of the effort to the Army mission. Due to Government budget uncertainties, no specific dollars have been reserved for awards under this BAA.

Stage 3 - Interested offerors are required to submit full proposals. All proposals submitted under the terms and conditions cited in this BAA will be reviewed regardless of the feedback on, or lack of, a white paper.

All white papers and proposals should be submitted electronically in a Portable Document Format (.PDF) either via Grants.gov or email. Requests for waiver of electronic submission may be submitted via e-mail to aror.baa@us.army.mil or regular mail:

Army Research Office
ATTN: AMSRD-ARL-RO-SS-SI (Proposal Processing)
P.O. Box 12211
RTP, NC 27709-2211

All required forms may be downloaded from the ARO web site at www.aro.army.mil under "For the Researcher" (Forms, ARO BAA Forms).

SECTION 3: White Paper Preparation

1. White papers should state the potential advantage to the Army, present the offeror's technical approach, and identify physical products and data to be delivered to the Government and/or any equipment, information and support required from the Government, as well as the cost and proposed duration of the effort. Offerors should identify residual equipment or capabilities that,

after demonstration, will remain property of the Government.

2. White papers are limited to five (5) pages plus the cover page and a one page addendum as discussed below. Evaluators will be advised that they are only required to review the white paper cover page and up to six pages including the addendum.
3. Combine all files and forms into a single PDF before submitting.

TECHNICAL INFORMATION:

1. A brief technical discussion of the effort's objective, approach, and level of effort shall be submitted. Also include the nature and extent of the anticipated results and, if known, the manner in which the work will contribute to the accomplishment of Army's mission and how this would be demonstrated.
2. The type of support, if any, that the offeror requests of the Government, such as facilities, equipment, demonstration sites, test ranges, software, personnel or materials, shall be identified as government furnished equipment (GFE), government furnished information (GFI), government furnished property (GFP), or government furnished data (GFD). Offerors shall indicate any Government coordination that may be required for obtaining equipment or facilities necessary to perform any simulations or exercises that would demonstrate the proposed capability.
3. As an addendum to the white paper, include biographical sketches (one page) of the key personnel who will perform the research, highlighting their qualifications and experience.
4. The cost portion of the white paper shall contain a brief cost estimate revealing all the component parts of the proposal, including research hours, burden, material costs, travel, etc.

RESTRICTIVE MARKINGS ON WHITE PAPERS:

1. Any proprietary data that the offeror intends to be used only by the Government for evaluation purchases must be identified. The offeror must also identify any technical data contained in the white paper that is to be treated by the Government as limited rights data. In the absence of such identification, the Government will assume to have unlimited rights to all technical data in the white paper. Records or data bearing a restrictive legend may be included in the white paper. It is the intent of the Army to treat all white papers as privileged information before the award and to disclose their contents only for the purpose of evaluation.
2. The offerors are cautioned, however, that portions of the white papers may be subject to release under terms of the Freedom of Information Act, 5 U.S.C. 552, as amended.

EVALUATION AND DISPOSITION OF WHITE PAPERS:

1. Evaluation Process: Offerors are advised that invitations for complete proposals will be made based on the initial white paper submission and the availability of funding. As stated above, the white paper will be evaluated for the concept's technical merit and potential contributions of the effort to the Army mission. Offerors whose white papers are evaluated as having significant technical merit may be invited to submit a complete detailed proposal. Care must be exercised to ensure that classified, sensitive, critical technologies are not included. If such information is required, appropriate restrictive markings and procedures should be applied.

2. Disposition Process: After completion of the evaluation, the offeror will be notified in writing of the results.

SECTION 4: White Paper Submission

White Papers must be submitted electronically using one of the two following formats:

EMAIL SUBMISSION (for Grants, Contracts, or Other Agreements)

1. White papers submitted via email must be in the following format but do not require any special forms:

- Single PDF formatted file as an email attachment
- Page Size: 8 ½ x 11 inches
- Margins – 1 inch
- Spacing – single
- Font – Times New Roman, 12 point

2. White papers should be emailed directly to the Technical Point of Contact. Include the BAA number W911NF-07-R-0001-05 in the email subject line.

GRANTS.GOV SUBMISSION (Not to be used for Contracts)

1. Prospective grantees must complete several steps in order to participate in the Grants.Gov application process. Starting early is extremely important as it may take several weeks to complete the processes necessary to submit an application through the Grants.Gov Apply portal. See Section 7 for additional information on electronic proposal submission through Grants.Gov.

2. Apply through the Grants.Gov APPLY portal, <http://www.grants.gov/Apply>. A Grant Application Package is available for download through the Grants.Gov Apply portal under CFDA Number 12.431/Funding Opportunity Number W911NF-07-R-0001-05. The following documents are mandatory: (1) Application for Federal Assistance (Research and Related) WHITE PAPER ONLY SF 424 (R&R) and (2) Attachments form. The PDF Form may be saved to a working directory on a computer and opened and filled in using the latest compatible Adobe Reader software application found at this Grants.Gov hot-link: http://www07.grants.gov/help/download_software.jsp#adobe811.

3. The SF 424 (R&R) must be fully completed. White Papers must be clearly identified as such with the word “WHITEPAPER” preceding the subject in Block 11, “Descriptive Title of

Applicant's Project," and reference the research topic area being addressed by identifying the specific paragraph from Part 1. The SF 424 does not need to be signed when submitted via Grants.gov. All documents must be combined into a single PDF formatted file titled "W911NF-07-R-0001-05, WHITEPAPER" and uploaded into the mandatory Attachments form.

SECTION 5: Preparation of Complete Research Proposals

COVER PAGE ARO FORM 51 (Contracts) or SF 424 (R&R) (Grants and Agreements):

1. See PART III of this BAA for the required Cover Page. Proposals will not be processed without either: (1) a signed Cover Page, ARO Form 51 (for contracts), or (2) an SF 424 R & R Form (for grants and agreements).
2. Should the project be carried out at a branch campus or other component of the submitting organization, that branch campus or component should be identified in the space provided.
3. The title of the proposed project should be brief, scientifically representative, intelligible to a scientifically literate reader, and suitable for use in the public press.
4. The proposed duration for which support is requested should be consistent with the nature and complexity of the proposed activity. For Research Areas 1-6 offerors shall discuss the preferred performance period with the TPOC. For Research Areas 7-15, the ARO normally awards research agreements for periods up to three (3) years (1 basic year of performance with two 1-year options). Nevertheless, the federal awarding agency reserves the right to make awards with shorter or longer periods of performance.
5. Specification of a desired starting date for the project is important and helpful however, requested effective dates cannot be guaranteed. Should unusual situations, such as long lead-time on awards, create problems regarding the proposed effective date, the investigator should consult the proposing organization's business office.
6. Should any of the special aspects apply to a proposal, the appropriate box (es) should be checked.
7. Pursuant to 31 U.S.C. 7701, as amended by the Debt Collection Improvement Act of 1996 [section 31001(I)(1), Public Law 104-134], federal agencies shall obtain each awardees' Taxpayer Identification Number (TIN). This number may be the Employer Identification Number for a business or non-profit entity or the Social Security Number for an individual. The TIN is being obtained for purposes of collecting and reporting on any delinquent amounts that may arise out of an awardees' relationship with the Government.
8. Offerors shall provide their organization's Data Universal Numbering System (DUNS) number. The DUNS number is a nine-digit number assigned by Dun and Bradstreet Information Services.

9. If known, offerors shall provide their assigned Commercial and Government Entity (CAGE) Code. The CAGE Code is a 5-character code assigned and maintained by the Defense Logistics Service Center (DLSC) to identify a commercial plant or establishment.

TABLE OF CONTENTS:

Use the following Format for the PROPOSAL TABLE OF CONTENTS

Forms are available at

<http://www.arl.army.mil/main/main/default.cfm?Action=29&Page=218#baaforms>

<u>SECTION</u>	<u>PAGE NUMBER</u>
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Statement of Disclosure Preference (Form 52 or 52A)	B-1
Project Abstract	C-1
Project Description (Technical Proposal)	D-1 - D- <input type="checkbox"/>
Biographical Sketch	E-1 - E- <input type="checkbox"/>
Bibliography	F-1 - F- <input type="checkbox"/>
Current and Pending Support	G-1 - G- <input type="checkbox"/>
Facilities, Equipment, and Other Resources	H-1 - H- <input type="checkbox"/>
Proposal Budget	I-1 - I- <input type="checkbox"/>
Contract Facilities Capital Cost of Money (DD Form 1861)	J-1
Appendices	K- <input type="checkbox"/>
List Appendix Items: _____	

This format applies to proposals submitted via email and via Grants.gov (for award of grants and agreements). Offerors' proposals should show the location of each section of the proposal, as well as major subdivisions of the project description.

STATEMENT OF DISCLOSURE PREFERENCE (FORM 52 OR 52A): Complete and sign ARO Form 52 (Industrial Contractors) or ARO Form 52A (Educational and Nonprofit Organizations).

PROJECT ABSTRACT:

1. The Project Abstract shall include a concise statement of work and basic approaches to be used in the proposed effort. The abstract should include a statement of objectives, methods to be employed, and the significance of the proposed effort to the advancement of knowledge.
2. The abstract should be no longer than one (1) page and be in a form suitable for release under the Freedom of Information Act, 5 U.S.C. 552, as amended. The abstract should indicate the effort intended for each 12-month period of research, where applicable.

TECHNICAL PROPOSAL (PROJECT DESCRIPTION): The technical portion of the proposal shall contain the following:

1. A complete discussion stating the background and objectives of the proposed work, the approaches to be considered, and the level of effort to be employed. Include also the nature and extent of the anticipated results and, if known, the manner in which the work will contribute to the accomplishment of the Army's mission.
2. A brief description of your organization. If the offeror has extensive government contracting experience and has previously provided the information to the ARL, the information need not be provided again. A statement setting forth this condition should be made.
3. The names of other federal, state, local agencies, or other parties receiving the proposal and/or funding the proposed effort. If none, so state. Concurrent or later submission of the proposal to other organizations will not prejudice its review by the ARL if we are kept informed of the situation.
4. A statement regarding possible impact, if any, of the proposed effort on the environment considering as a minimum its effect upon water, atmosphere, natural resources, human resources, and any other values.
5. The offeror shall provide a statement regarding the use of Class I and Class II ozone-depleting substances. Ozone-depleting substances mean any substance designated as Class I by EPA, including but not limited to chlorofluorocarbons, halons, carbon tetrachloride, and methyl chloroform and any substance designated as Class II by EPA, including but not limited to hydrochlorofluorocarbons. See 40 C.F.R. Part 82 for detailed information. If Class I or II substances are to be utilized, a list shall be provided as part of the offeror's proposal. If none, so state.
6. The type of support, if any, requested (e.g., facilities, equipment, and materials).

BIOGRAPHICAL SKETCHES:

1. This Section shall contain the biographical sketches for senior personnel only.

a. **Co-Principal Investigators:** The individual(s) a research organization designates as having an appropriate level of authority and responsibility for the proper conduct of the research and submission of required reports to the agency. When an organization designates more than one PI, it identifies them as individuals who share the authority and responsibility for leading and directing the research, intellectually and logistically. The sponsoring agency(s) does not infer any distinction in scientific stature among multiple PIs.

b. **Primary Principal Investigator:** The "Primary" PI provides a single or initial point of communication between the sponsoring agency(s) and the awardee organization(s) about scientific matters. If not otherwise designated, the first PI listed will serve as the "Primary" PI. This individual can be changed with notification of the agency. The sponsoring agency(s) does not infer any additional scientific stature to this role among collaborating investigators.

2. The following information is required:

- a. Relevant experience and employment history including a description of any prior Federal employment within one year preceding the date of proposal submission.
- b. List of up to five (5) publications most closely related to the proposed project and up to five (5) other significant publications, including those being printed. Patents, copyrights, or software systems developed may be substituted for publications.
- c. List of persons, other than those cited in the publications list, who have collaborated on a project or a book, article, report or paper within the last four (4) years. Include pending publications and submissions. Otherwise, state "None."
- d. Names of each investigator's own graduate or post graduate advisors and advisees. The information provided in "c" and "d" is used to help identify potential conflicts or bias in the selection of reviewers.

3. For the personnel categories of postdoctoral associates, other professionals, and students (research assistants), the proposal may include information on exceptional qualifications of these individuals that merit consideration in the evaluation of the proposal.

4. The biographical sketches are limited to three (3) pages per investigator and other individuals that merit consideration.

BIBLIOGRAPHY: A bibliography of pertinent literature is required. Citations must be complete (including full name of author(s), title, and location in the literature).

CURRENT AND PENDING SUPPORT:

1. All project support from whatever source must be listed. The list must include all projects requiring a portion of the principal investigator's and other senior personnel's time, even if they receive no salary support from the project(s).
2. The information should include, as a minimum: (i) the project/proposal title and brief description, (ii) the name and location of the organization or agency presently funding the work or requested to fund such work, (iii) the award amount or annual dollar volume of the effort, (iv) the period of performance, and (v) a breakdown of the time required of the principal investigator and/or other senior personnel.

FACILITIES, EQUIPMENT, AND OTHER RESOURCES: The offeror should include in the proposal a listing of facilities, equipment, and other resources already available to perform the research proposed.

BUDGET PROPOSAL (including DD Form 1861): **Note: The DD 1861 form is used for contract proposals only and is usually only associated with commercial “for-profit” entities.**

1. Each proposal must contain a budget for each year of support requested and a cumulative budget for the full term of requested support. The budget form (Form 99) may be reproduced as needed. Locally produced versions may be used, but you may not make substitutions in prescribed budget categories nor alter or rearrange the cost categories as they appear on the form. The proposal may request funds under any of the categories listed so long as the item is considered necessary to perform the proposed work and is not precluded by applicable cost principles. In addition to the forms, the budget proposal should include up to five (5) pages of budget justification for each year.
2. A signed summary budget page must be included. The documentation pages should be titled "Budget Explanation Page" and numbered chronologically starting with the budget form. The need for each item should be explained clearly.
3. All cost data must be current and complete. Costs proposed must conform to the following principles and procedures:

Educational Institutions: OMB Circular A-21

Nonprofit Organizations: OMB Circular A-122*

Commercial Organizations: FAR Part 31, DFARS Part 231, FAR Subsection 15.403-5, and DFARS Subsection 215.403-5.

All offerors (when applicable): DOD Grant and Agreement Regulations (DODGARs), DOD 3210.6-R

**For those nonprofit organizations specifically exempt from the provisions of OMB Circular A-122, FAR Part 31 and DFARS Part 231 shall apply.*

4. The itemized budget(s) must include the following:

a. Direct Labor: Show the current and projected salary amounts in terms of man-hours, man-months, or annual salary to be charged by the principal investigator(s), faculty, research associates, postdoctoral associates, graduate and undergraduate students, secretarial, clerical, and other technical personnel either by personnel or position. State the number of man-hours used to calculate a man-month or man-year. For proposals from universities, research during the academic term is deemed part of regular academic duties, not an extra function for which additional compensation or compensation at a higher rate is warranted. Consequently, academic term salaries shall not be augmented either in rate or in total amount for research performed during the academic term. Rates of compensation for research conducted during non-academic (summer) terms shall not exceed the rate for the academic terms. When part or all of a person's services are to be charged as project costs, it is expected that the person will be relieved of an equal part or all of his or her regular teaching or other obligations. For each person or position, provide the following information:

(1) The basis for the direct labor hours or percentage of effort (e.g., historical hours or estimates).

(2) The basis for the direct labor rates or salaries. Labor costs should be predicted upon current labor rates or salaries. These rates may be adjusted upward for forecast salary or wage cost-of-living increases that will occur during the agreement period. The cost proposal should separately identify the rationale applied to base salary/wage for cost-of-living adjustments and merit increases. Each must be fully explained.

(3) The portion of time to be devoted to the proposed research, divided between academic and non-academic (summer) terms, when applicable.

(4) The total annual salary charged to the research project.

(5) Any details that may affect the salary during the project, such as plans for leave and/or remuneration while on leave.

b. Fringe Benefits and Indirect Costs (Overhead, General and Administrative, and Other): The most recent rates, dates of negotiation, the base(s) and periods to which the rates apply must be disclosed and a statement included identifying whether the proposed rates are provisional or fixed. If the rates have been negotiated by a Government agency, state when and by which agency. **A copy of the negotiation memorandum should be provided.** If negotiated forecast rates do not exist, offerors must provide sufficient detail to enable a determination to be made that the costs included in the forecast rate are allocable according to applicable OMB Circulars or FAR/DFARS provisions. Offerors' disclosure should be sufficient to permit a full understanding of the content of the rate(s) and how it was established. As a minimum, the submission should identify:

(1) All individual cost elements included in the forecast rate(s);

(2) Bases used to prorate indirect expenses to cost pools, if any;

- (3) How the rate(s) was calculated;
- (4) Distribution basis of the developed rate(s);
- (5) Bases on which the overhead rate is calculated, such as "salaries and wages" or "total costs," and
- (6) The period of the offeror's fiscal year.

Note: The 2010 National Defense Authorization Act (NDAA) provided for an Indirect Cost Cap of 35% for all 6.1 funded awards; future appropriations may do the same, and if they do, this will be stipulated in any award document.

- c. Permanent Equipment: If facilities or equipment are required, a justification why this property should be furnished by the Government must be submitted. State the organization's inability or unwillingness to furnish the facilities or equipment. Offerors must provide an itemized list of permanent equipment showing the cost for each item. Permanent equipment is any article or tangible nonexpendable property having a useful life of more than one year and an acquisition cost of \$5,000 or more per unit. The basis for the cost of each item of permanent equipment included in the budget must be disclosed, such as:

- (1) Vendor Quote: Show name of vendor, number of quotes received and justification, if intended award is to other than lowest bidder.
- (2) Historical Cost: Identify vendor, date of purchase, and whether or not cost represents lowest bid. Include reason(s) for not soliciting current quotes.
- (3) Engineering Estimate: Include rationale for quote and reason for not soliciting current quotes. If applicable, the following additional information shall be disclosed in the offeror's cost proposal:
 - (4) Special test equipment to be fabricated by the awardee for specific research purposes and its cost.
 - (5) Standard equipment to be acquired and modified to meet specific requirements, including acquisition and modification costs, listed separately.
 - (6) Existing equipment to be modified to meet specific research requirements, including modification costs. Do not include equipment the organization will purchase with its funds if the equipment will be capitalized for Federal income tax purposes. Proposed permanent equipment purchases during the final year of an award shall be limited and fully justified.

(7) Grants, cooperative agreements, or contracts may convey title to an institution for equipment purchased with project funds. At the discretion of the contracting/grants officer, the agreement may provide for retention of the title by the Government or may impose conditions governing the equipment conveyed to the organization. The Government will not convey title to commercial contractors.

(8) It is the policy of the DOD that all commercial and nonprofit contractors provide the equipment needed to support proposed research. In those rare cases where specific additional equipment is approved for commercial and nonprofit organizations, such approved cost elements shall be "nonfee-bearing." In addition, commercial contractors are precluded from using contract funds to acquire facilities with a unit acquisition cost of \$10,000 or less (see FAR 45.302-.1).

- d. Travel: Forecasts of travel expenditures (domestic and foreign) that identify the destination and the various cost elements (airfare, mileage, per diem rates, etc.) must be submitted. The costs should be in sufficient detail to determine the reasonableness of such costs. Allowance for air travel normally will not exceed the cost of round-trip, economy air accommodations. Specify the type of travel and its relationship to the research project. Requests for domestic travel must not exceed **\$3,000 per year per principal investigator**. Separate, prior approval by the ARL is required for all foreign travel (i.e., travel outside the continental U.S., its possessions and Canada). **Foreign travel requests must not exceed \$1,800 each per year per principal investigator**. Special justification will be required for travel requests in excess of the amounts stated above and for travel by individuals other than the principal investigator(s). Individuals other than the principal investigator(s) are considered postdoctoral associates, research associates, graduate and undergraduate students, secretarial, clerical, and other technical personnel. Additional travel may be requested for travel to Army laboratories and facilities to enhance agreement objectives and to achieve technology transfer.
- e. Participant Support Costs: This budget category refers to costs of transportation, per diem, stipends, and other related costs for participants or trainees (but not employees) in connection with ARL-sponsored conferences, meetings, symposia, training activities, and workshops (see PART II - Special Programs). Generally, indirect costs are not allowed on participant support costs. The number of participants to be supported should be entered in the parentheses on the budget form. These costs should also be justified in the budget justification page(s) attached to the cost proposal.
- f. Materials, Supplies, and Consumables: A general description and total estimated cost of expendable equipment and supplies are required. The basis for developing the cost estimate (vendor quotes, invoice prices, engineering estimate, purchase order history, etc.) must be included. If possible, provide a material list.
- g. Publication, Documentation, and Dissemination: The budget may request funds for the costs of preparing, publishing, or otherwise making available to others the findings and products of the work conducted under an agreement, including costs of reports, reprints, page charges, or other journal costs (except costs for prior or early publication);

necessary illustrations, cleanup, documentation, storage, and indexing of data and databases; and development, documentation, and debugging of software.

- h. Consultant Costs: Offerors normally are expected to utilize the services of their own staff to the maximum extent possible in managing and performing the project's effort. If the need for consultant services is anticipated, the nature of proposed consultant services should be justified and included in the technical proposal narrative. The cost proposal should include the names of consultant(s), primary organizational affiliation, each individual's expertise, daily compensation rate, number of days of expected service, and estimated travel and per diem costs.
- i. Computer Services: The cost of computer services, including computer-based retrieval of scientific, technical, and educational information, may be requested. A justification/explanation based on the established computer service rates at the proposing organization should be included. The budget also may request costs, which must be shown to be reasonable, for leasing automatic data processing equipment. The purchase of computers or associated hardware and software should be requested as items of equipment.
- j. Subawards (subcontracts or subgrants): A precise description of services or materials that are to be awarded by a subaward must be provided. For subawards totaling \$10,000 or more, provide the following specific information:
 - (1) A clear description of the work to be performed.
 - (2) If known, the identification of the proposed subawardee and an explanation of why and how the subawardee was selected or will be selected.
 - (3) The identification of the type of award to be used (cost reimbursement, fixed price, etc.).
 - (4) Whether or not the award will be competitive and, if noncompetitive, rationale to justify the absence of competition.
 - (5) A detailed cost summary.
- k. Other Direct Costs: Itemize and provide the basis for proposed costs for other anticipated direct costs such as communications, transportation, insurance, and rental of equipment other than computer related items. Unusual or expensive items shall be fully explained and justified.
- l. Fixed Fee: The fixed fee, if any, which a commercial organization proposes to assess the research project.
- m. Subcontracting Plan: If the total amount of the proposal exceeds \$500,000 and the offeror is a large business or an institute of higher education (other than HBCU/MI) and the

resultant award is a contract, the offeror shall submit a subcontracting plan. The subcontracting plan shall comply with the policies identified in the FAR and appropriate Department and Service supplemental regulations. Adequacy of the plan will be considered and finalization of an acceptable plan will be a necessary condition for award. The plan as approved by the contracting officer will be incorporated into and made a part of the contract.

CONTRACT FACILITIES CAPITAL COST OF MONEY: If cost of money is proposed, a completed Contract Facilities Capital Cost of Money (FCCM) (DD Form 1861) is required. **Note: This form is used for contract proposals only and is usually only associated with commercial “for-profit” entities.**

APPENDICES: Some situations require that special information and supporting documents be included in the proposal before funding can be approved. Such information and documentation should be included by appendix to the proposal.

SECTION 6: Submission of Complete Research Proposals

Proposals must be submitted through the organizational office having responsibility for Government business relations. All signatures must be that of an official authorized to commit the organization in business and financial affairs.

Proposals must be submitted electronically using one of the two following formats. The content will remain the same whether using email or Grants.gov.

EMAIL SUBMISSION

- a. E-mail directly to aror.baa@us.army.mil. Do not email full proposals to the TPOC. All e-mailed proposals must contain the information outlined in PART III “Table of Contents” including the electronic forms as follows: (1) ARO Form 51, Proposal Cover Page (for contracts) or SF 424 R&R (for grants and agreements); (2) ARO Form 99, Summary Proposal Budget or equivalent, (3) ARO Current and Pending Support (unnumbered form), and (4) ARO Form 52 or ARO Form 52a. These forms may be accessed at <http://www.aro.army.mil/baa> under BAA Forms. The fillable PDF forms may be saved to a working directory on a computer and opened and filled in using the latest compatible Adobe Reader software application found at this Grants.Gov hot-link: http://www07.grants.gov/help/download_software.jsp#adobe811.
- b. All forms requiring signature must be completed, printed, signed, and scanned into a PDF document. All documents must be combined into a single PDF formatted file to be attached to the e-mail.
- c. Proposal documents (excluding required forms) must use the following format:
 - Page Size – 8 ½ x 11 inches
 - Margins – 1 inch
 - Spacing – single
 - Font – Times New Roman, 12 point

GRANTS.GOV SUBMISSION

1. Grants.gov Registration (See Section 7 below) must be accomplished prior to application through this process.

2. Apply through the Grants.Gov APPLY portal, <http://www.grants.gov/Apply>. A Grant Application Package is available for download through the Grants.Gov Apply portal under CFDA Number 12.431/Funding Opportunity Number W911NF-07-R-0001-05. The following documents are mandatory: (1) Application for Federal Assistance (Research and Related) (SF 424 (R&R)), and (2) Attachments form.

(a) The SF 424 (R&R) must be fully completed. Block 11, “Descriptive Title of Applicant’s Project,” must reference the research topic area being addressed in the effort by identifying the specific paragraph from Part 1.

(b) The Attachments form must contain the information outlined in the “Table of Contents “Part III of this BAA including three electronic forms as follows: (1) ARO Form 51, Proposal Cover Page; (2) ARO Form 99, Summary Proposal Budget; and (3) ARO Current and Pending Support (unnumbered form). These forms may be accessed at <http://www.aro.army.mil/forms/forms2.htm>. The fillable PDF forms may be saved to a working directory on a computer and opened and filled in using the latest compatible Adobe Reader software application found at this Grants.Gov hot-link: http://www07.grants.gov/help/download_software.jsp#adobe811.

(c) All documents must be combined into a single PDF formatted file titled “W911NF-07-R-0001-05 Proposal” and uploaded into the mandatory Attachments form.

(d) Once the E-Business POC has authorized privileges to the AOR, the AOR will receive an email notification that they have been given authorization. The AOR may then proceed to submit applications to Grants.Gov. To find the application on Grants.gov, follow the link <http://www.grants.gov/search/basic.do> and enter the BAA number in the “Search by Funding Opportunity Number:” block. For application instructions, go to <http://www.grants.gov/Apply>. The training demonstration at <http://www.grants.gov/CompleteApplication> will assist AORs in the application process. Remember that you must open and complete the Application for Federal Assistance (Research and Related) (SF 424 (R&R)) first, as this form will automatically populate data fields in other forms. If you encounter any problems, contact customer support at 1-800-518-4726 or at support@grants.gov. If you forget your user name or password, follow the instructions provided in the Credential Provider tutorial. Tutorials may be printed by right-clicking on the tutorial and selecting “Print”.

SECTION 7: Grants.Gov Registration

1. Registration. Each organization that desires to submit applications via Grants.Gov must complete a one-time registration. See <http://www.grants.gov/GetStarted>. The following steps are required:

- a. Request a DUNS Number – Follow the instructions at:
<http://www.grants.gov/RequestaDUNS> to obtain a DUNS number. It is highly recommended that you request the number by telephone at 1-866-705-5711. This will take about 10 minutes to complete and there is no charge. NOTE: Once the telephone registration is completed, you must wait 24 hours before attempting to use that DUNS for registration in the Central Contractor Registry (CCR).
- b. Register in the Central Contractor Registry (CCR) – Go to <http://www.grants.gov/CCRRegister> and click on the “Help” button to locate the tutorial. It is recommended that you print the tutorial for reference and follow the instructions in the link above. You are required to designate an Electronic Business Point of Contact (E-Business POC) and a Marketing Partner Identification Number (MPIN) in CCR. It is important to provide the MPIN to the E-Business POC. For assistance with the CCR, contact the Assistance Center at 1-888-227-2423 or at CCR@dliis.dla.mil. You may also access the CCR Handbook at <http://www.ccr.gov/handbook.asp>. **VERY IMPORTANT: Knowing the MPIN and who is designated as your organization’s E-Business POC in the CCR is a significant step in the process. This person will function as the organizational agent to approve personnel who can submit binding proposals on behalf of your organization.**
- c. Authorized Organizational Representatives (AORs) approved by the E-Business POC are the individuals that will be given authority to submit proposals on behalf of your organization. All AORS must download and install the latest compatible version of Adobe software on their computer workstation found at this Grants.Gov hot-link: http://www07.grants.gov/help/download_software.jsp#adobe811. Pure-Edge Viewer Software is no longer supported. This free software will allow AORs to access, complete and submit applications electronically and securely. All submissions will be required in the current compatible version of Adobe software. If you encounter any problems, contact customer support at 1-800-518-4726 or e-mail support@grants.gov.
- d. Register with the Credential Provider – AORs must register with the Credential Provider. AORs must wait a minimum of 3 business days for the CCR to activate the organization’s account before attempting to register with the Credential Provider at <https://apply.grants.gov/OrcRegister> and click on the “Help” button to locate the tutorial. Print the tutorial for reference and follow the instructions in the link above. Record the user ID and the password that you enter because you will need this information to register with Grants.gov as an AOR. AORs must wait approximately 20 minutes after completing the Credential Provider registration before proceeding to the

next step of registering with Grants.Gov. If you encounter any problems, the Credential Provider may be reached at 1-800-386-6820 or via email at pkihelp@orc.com.

- e. Register with Grants.Gov – AORs must register with Grants.Gov, utilizing their User ID and Password obtained from registering with the Credential Provider. Go to <https://apply.grants.gov/GrantsgovRegister> and click on the “Help” button to locate the tutorial for reference and follow the instructions in the link above. After you have completed the Grants.Gov registration process, you will receive a confirmation that indicates whether your registration was successful. After an AOR successfully registers with Grants.Gov, an email will be generated to your organizations E-Business POC to notify them that an individual has registered in Grants.Gov to be an AOR capable of submitting applications in Grants.Gov on behalf of your organization. AORs will not be able to submit electronic applications until they receive authorization from the E-Business POC. Normally, the E-Business POC should process these requests within one Business Day. If you encounter any problems, please contact customer support at 1-800-518-4726 or support@grants.gov.

- f. Designation of Privileges to the AOR – The E-Business POC is the sole authority of the organization with the capability of designating or revoking an individual’s ability to submit grant applications on behalf of their organization through Grants.Gov. Once the E-Business POC receives the email notification from the individual wishing to be recognized as an AOR, the E-Business POC should go to: <https://apply.grants.gov/agency/AorMgrGetID> and click on the “Help” button to locate the tutorial, then log into the system using the DUNS number and Marketing Partner Identification Number (MPIN) designated for their organization when CCR registration was performed. Once in the system the E-Business POC should follow the instructions for designating privileges to the AOR. If the E-Business POC cannot locate the CCR MPIN, contact the CCR Assistance Center at 1-888-227-2423 or at CCR@dliis.dla.mil.

The User Guide is found at:

http://www.grants.gov/GrantsGov_UST_Grantee/!SSL!/WebHelp/userguide.doc.

SECTION 8: - Information To Be Requested From Successful Offerors

Offerors whose proposals are accepted for funding will be contacted before award to provide additional information required for award. The required information is normally limited to clarifying budget explanations, representations, and certifications.

SECTION 9: Required Certifications and Contract Terms and Conditions:

1. CERTIFICATION AT APPENDIX A TO 32 CFR PART 28 REGARDING LOBBYING:

By signing and submitting a proposal that may result in the award of a grant or cooperative agreement exceeding \$100,000, the prospective awardee is certifying, to the best of his or her knowledge and belief, that:

- a. No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
- b. If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, Disclosure Form to Report Lobbying, in accordance with its instructions.
- c. The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

“This disclosure is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this disclosure is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S.Code. Any person who fails to file the required disclosure shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.”

2. CERTIFICATION REGARDING DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS--PRIMARY COVERED TRANSACTIONS:

Appendix A to 32 CFR Part 25

By signing and submitting this proposal, the prospective primary participant is providing the certification set out below. The inability of a person to provide the certification required below will not necessarily result in denial of participation in this covered transaction. The prospective participant shall submit an explanation of why it cannot provide the certification set out below. The certification or explanation will be considered in connection with the department or agency's determination whether to enter into this transaction. However, failure of the prospective primary participant to furnish a certification or an explanation shall disqualify such person from participation in this transaction.

The certification in this clause is a material representation of fact upon which reliance was placed when the department or agency determined to enter into this transaction. If it is later determined that the prospective primary participant knowingly rendered an erroneous certification, in addition to other remedies available to the Federal Government, the department or agency may terminate this transaction for cause or default.

The prospective primary participant shall provide immediate written notice to the department or

agency to which this proposal is submitted if at any time the prospective primary participant learns that its certification was erroneous when submitted or has become erroneous by reason of changed circumstances.

The terms "covered transaction," "debarred," "suspended," "ineligible," "lower tier covered transaction," "participant," "person," "primary covered transaction," "principal," "proposal," and "voluntarily excluded," as used in this clause, have the meanings set out in the Definitions and Coverage sections of the rules implementing Executive Order 12549. You may contact the department or agency to which this proposal is being submitted for assistance in obtaining a copy of those regulations.

The prospective primary participant agrees by submitting this proposal that, should the proposed covered transaction be entered into, it shall not knowingly enter into any lower tier covered transaction with a person who is proposed for debarment under 48 CFR part 9, subpart 9.4, debarred, suspended, declared ineligible, or voluntarily excluded from participation in this covered transaction, unless authorized by the department or agency entering into this transaction.

The prospective primary participant further agrees by submitting this proposal that it will include the clause titled "Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion--Lower Tier Covered Transaction," provided by the department or agency entering into this covered transaction, without modification, in all lower tier covered transactions and in all solicitations for lower tier covered transactions.

A participant in a covered transaction may rely upon a certification of a prospective participant in a lower tier covered transaction that it is not proposed for debarment under 48 CFR part 9, subpart 9.4, debarred, suspended, ineligible, or voluntarily excluded from the covered transaction, unless it knows that the certification is erroneous. A participant may decide the method and frequency by which it determines the eligibility of its principals. Each participant may, but is not required to, check the List of Parties Excluded from Federal Procurement and Nonprocurement Programs.

Nothing contained in the foregoing shall be construed to require establishment of a system or records in order to render in good faith the certification required by this clause. The knowledge and information of a participant is not required to exceed that which is normally possessed by a prudent person in the ordinary course of business dealings.

Except for transactions authorized under paragraph 6 of these instructions, if a participant in a covered transaction knowingly enters into a lower tier covered transaction with a person who is proposed for debarment under 48 CFR part 9, subpart 9.4, suspended, debarred, ineligible, or voluntarily excluded from participation in this transaction, in addition to other remedies available to the Federal Government, the department or agency may terminate this transaction for cause or default.

CERTIFICATION REGARDING DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS--PRIMARY COVERED TRANSACTIONS

The prospective primary participant certifies to the best of its knowledge and belief, that it and

its principals:

- a. Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded by any Federal department or agency;
- b. Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;
- c. Are not presently indicted for or otherwise criminally or civilly charged by a government entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (b) of this certification; and
- d. Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or local) terminated for cause or default.

Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

3. CERTIFICATION REGARDING DRUG-FREE WORKPLACE REQUIREMENTS:
Appendix C to 32 CFR Part 25

By signing and/or submitting this application or grant agreement, the grantee is providing the certification set out below.

The certification set out below is a material representation of fact upon which reliance is placed when the agency awards the grant. If it is later determined that the grantee knowingly rendered a false certification, or otherwise violates the requirements of the Drug-Free Workplace Act, the agency, in addition to any other remedies available to the Federal Government, may take action authorized under the Drug-Free Workplace Act.

For grantees other than individuals, Alternate I applies.

For grantees who are individuals, Alternate II applies.

Workplaces under grants, for grantees other than individuals, need not be identified on the certification. If known, they may be identified in the grant application. If the grantee does not identify the workplaces at the time of application, or upon award, if there is no application, the grantee must keep the identity of the workplace(s) on file in its office and make the information available for Federal inspection. Failure to identify all known workplaces constitutes a violation of the grantee's drug-free workplace requirements.

Workplace identifications must include the actual address of buildings (or parts of buildings) or

other sites where work under the grant takes place. Categorical descriptions may be used (e.g., all vehicles of a mass transit authority or State highway department while in operation, State employees in each local unemployment office, performers in concert halls or radio studios).

If the workplace identified to the agency changes during the performance of the grant, the grantee shall inform the agency of the change(s), if it previously identified the workplaces in question (see paragraph five).

Definitions of terms in the Nonprocurement Suspension and Debarment common rule and Drug-Free Workplace common rule apply to this certification. Grantees' attention is called, in particular, to the following definitions from these rules:

Controlled substance means a controlled substance in schedules I through V of the Controlled Substances Act (21 U.S.C. 812), and as further defined by regulation (21 CFR 1308.11 through 1308.15);

Conviction means a finding of guilt (including a plea of nolo contendere) or imposition of sentence, or both, by any judicial body charged with the responsibility to determine violations of the Federal or State criminal drug statutes;

Criminal drug statute means a Federal or non-Federal criminal statute involving the manufacture, distribution, dispensing, use, or possession of any controlled substance;

Employee means the employee of a grantee directly engaged in the performance of work under a grant, including:

(i) All "direct charge" employees; (ii) all "indirect charge" employees unless their impact or involvement is insignificant to the performance of the grant; and, (iii) temporary personnel and consultants who are directly engaged in the performance of work under the grant and who are on the grantee's payroll. This definition does not include workers not on the payroll of the grantee (e.g., volunteers, even if used to meet a matching requirement; consultants or independent contractors not on the grantee's payroll; or employees of subrecipients or subcontractors in covered workplaces).

CERTIFICATION REGARDING DRUG-FREE WORKPLACE REQUIREMENTS (ALTERNATE I - GRANTEES OTHER THAN INDIVIDUALS)

The grantee certifies that it will or will continue to provide a drug-free workplace by:

- a. Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of

such prohibition;

- b. Establishing an ongoing drug-free awareness program to inform employees about--
 - (1) The dangers of drug abuse in the workplace;
 - (2) The grantee's policy of maintaining a drug-free workplace;
 - (3) Any available drug counseling, rehabilitation, and employee assistance programs;
and
 - (4) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace.
- c. Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);
- d. Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will--
 - (1) Abide by the terms of the statement; and
 - (2) Notify the employer in writing of his or her conviction for a violation of a criminal drug statute occurring in the workplace no later than five calendar days after such conviction;
- e. Notifying the agency in writing, within ten calendar days after receiving notice under paragraph (d)(2) from an employee or otherwise receiving actual notice of such conviction. Employers of convicted employees must provide notice, including position title, to every grants officer or other designee on whose grant activity the convicted employee was working, unless the Federal agency has designated a central point for the receipt of such notices. Notice shall include the identification number(s) of each affected grant;
- f. Taking one of the following actions, within 30 calendar days of receiving notice under paragraph (d)(2), with respect to any employee who is so convicted--
 - (1) Taking appropriate personnel action against such employee, up to and including termination, consistent with the requirements of the Rehabilitation Act of 1973, as amended; or
 - (2) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health, law enforcement, or other appropriate agency;
- g. Making a good faith effort to continue to maintain a drug-free workplace through

implementation of paragraphs (a), (b), (c), (d), (e), and (f).

The grantee may insert in the space provided below the site(s) for the performance of work done in connection with the specific grant:

Place of Performance (street address, city, county, state, zip code)

Check () if there are workplaces on file that are not identified here.

(ALTERNATE II - GRANTEES WHO ARE INDIVIDUALS)

(a) The grantee certifies that, as a condition of the grant, he or she will not engage in the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance in conducting any activity with the grant;

(b) If convicted of a criminal drug offense resulting from a violation occurring during the conduct of any grant activity, he or she will report the conviction, in writing within 10 calendar days of the conviction, to every grants officer or other designee, unless the Federal agency designates a central point for the receipt of such notices. When notice is made to such a central point, it shall include the identification number(s) of each affected grant.

CERTIFICATIONS REQUIRED FOR CONTRACT AWARDS. Certifications and representations shall be completed by successful offerors prior to award. Federal Acquisition Regulation (FAR) Online Representations and Certifications Application (ORCA) is at website <http://orca.bpn.gov>. Defense FAR Supplement and contract specific certification packages will be provided to the contractor for completion prior to award.

PROTECTION OF HUMAN SUBJECTS. All research involving human subjects must be conducted in accordance with 32 CFR 219, 10 USC 980, and DoDD 3216.2, as well as other applicable federal and state regulations. Contractors/grantees must be cognizant of and abide by the additional restrictions and limitations imposed on the DoD regarding research involving human subjects, specifically as regards vulnerable populations (32 CFR 219 modifications to subparts B-D of 45 CFR 46), recruitment of military research subjects (32 CFR 219), and surrogate consent (10 USC 980). The regulations mandate that all DoD activities, components, and agencies protect the rights and welfare of human subjects of study in DoD-supported research, development, test and evaluation, and related activities hereafter referred to as “research”. The requirement to comply with the regulations applies to new starts and to continuing research.

ANIMAL USE. DOD Directive 3216.1, dated April 17, 1995, provides policy and requirements for the use of animals in DOD-funded research. The DoD definition of animal is any live nonhuman vertebrate. All proposals that involve the use of animals must address DoD compliance with Directive 3216.1.

Provisions include rules on animal acquisition, transport, care, handling, and use in 9 CFR parts 1-4, Department of Agriculture rules implementing the Laboratory Animal Welfare Act of 1966 (7 U.S.C. 2131-2156), and guidelines in the National Academy of Sciences (NAS) "Guide for the Care and Use of Laboratory Animals" (1996), including the Public Health Service Policy and Government Principles Regarding the Care and Use of Animals in Appendix D to the Guide.

BIOLOGICAL DEFENSE SAFETY PROGRAM REQUIREMENTS. Successful offerors whose Principal Investigators are conducting research with Bio-safety Levels 3 and 4 material must prepare a Facility Safety Plan in accordance with 32 Code of Federal Regulations (CFR) 626.18. See URL: www.access.gpo.gov/nara/cfr/waisidx_99/32cfr626_99.html for a copy of 32 CFR 626.18, Biological Defense Safety Program.

MILITARY RECRUITING: This is to notify potential offerors that each grant or cooperative agreement awarded under this announcement to an institution of higher education must include the following term and condition:

"As a condition for receipt of funds available to the Department of Defense (DOD) under this award, the recipient agrees that it is not an institution of higher education (as defined in 32 CFR part 216) that has a policy of denying, and that it is not an institution of higher education that effectively prevents, the Secretary of Defense from obtaining for military recruiting purposes: (A) entry to campuses or access to students on campuses or (B) access to directory information pertaining to students. If the recipient is determined, using the procedures in 32 CFR part 216, to be such an institution of higher education during the period of performance of this agreement, and therefore to be in breach of this clause, the Government will cease all payments of DOD funds under this agreement and all other DOD grants and cooperative agreements to the recipient, and it may suspend or terminate such grants and agreements unilaterally for material failure to comply with the terms and conditions of award."

If your institution has been identified under the procedures established by the Secretary of Defense to implement Section 558, then: (1) no funds available to DOD may be provided to your institution through any grant, including any existing grant, (2) as a matter of policy, this restriction also applies to any cooperative agreement, and (3) your institution is not eligible to receive a grant or cooperative agreement in response to this solicitation.

This is to notify potential offerors that each contract awarded under this announcement to an institution of higher education shall include the following clause: Defense Federal Acquisition Regulation Supplement (DFARS) clause 252.209-7005, Military Recruiting on Campus.

Reporting Requirements: Each award agreement shall include the required technical and financial reporting requirements in its terms and conditions.

Subcontracting: Pursuant to Section 8(d) of the Small Business Act [15 U.S.C. 637(d)], it is the policy of the Government to enable small business concerns to be considered fairly as subcontractors under all research agreements awarded to prime contractors and grantees. When appropriate a subcontracting plan complying with the policies identified in the FAR and appropriate Department and Service supplemental regulations will be required. Adequacy of the

plan will be considered and finalization of an acceptable plan will be a necessary condition for award. The plan as approved by the contracting officer will be incorporated into and made a part of the contract.

Army Contractor Manpower Reporting: The Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) operates and maintains a secure Army data collection site where the contractor will report ALL contractor manpower (including subcontractor manpower) required for performance of this contract. The contractor is required to completely fill in all the information in the format using the following web address:

<https://contractormanpower.army.pentagon.mil>. The required information includes: (1) Contracting Office, Contracting Officer, Contracting Officer's Technical Representative; (2) Contract number, including task and delivery order number; (3) Beginning and ending dates covered by reporting period; (4) Contractor name, address, phone number, e-mail address, identity of contractor employee entering data; (5) Estimated direct labor hours (including sub-contractors); (6) Estimated direct labor dollars paid this reporting period (including sub-contractors); (7) Total payments (including sub-contractors); (8) Predominate Federal Service Code (FSC) reflecting services provided by contractor (and separate predominant FSC for each sub-contractor if different); (9) Estimated data collection cost; (10) Organizational title associated with the Unit Identification Code (UIC) for the Army Requiring Activity (the Army Requiring Activity is responsible for providing the contractor with its UIC for the purposes of reporting this information); (11) Locations where contractor and sub-contractors perform the work (specified by zip code in the United States and nearest city, country, when in an overseas location, using standardized nomenclature provided on website); (12) Presence of deployment or contingency contract language; and (13) Number of contractor and sub-contractor employees deployed in theater this reporting period (by country). As part of its submission, the contractor will also provide the estimated total cost (if any) incurred to comply with this reporting requirement. Reporting period will be the period of performance not to exceed 12 months ending 30 September of each government fiscal year and must be reported by 31 October of each calendar year. Contractors may use a direct XML data transfer to the database server or fill in the fields on the website. The XML direct transfer is a format for transferring files from a contractor's systems to the secure web site without the need for separate data entries for each required data element at the web site. The specific formats for the XML direct transfer may be downloaded from the web site.

PART IV - PROPOSAL EVALUATION

1. Proposals submitted in response to this BAA will be evaluated using the factors listed below (in descending order of importance):

- a. The overall scientific and/or technical merits of the proposal.
- b. The potential contributions of the effort to the Army mission and the extent to which the research effort will contribute to balancing the overall ARL//ARO research program.
- c. The offeror's capabilities, related experience, facilities, techniques, or unique combinations of these, which are integral factors for achieving the proposed objectives.
- d. The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or other key personnel who are critical to achievement of the proposed objectives.

1. **Co-Principal Investigators:** The individual(s) a research organization designates as having an appropriate level of authority and responsibility for the proper conduct of the research and submission of required reports to the agency. When an organization designates more than one PI, it identifies them as individuals who share the authority and responsibility for leading and directing the research, intellectually and logistically. The sponsoring agency(s) does not infer any distinction in scientific stature among multiple PIs.

2. **Primary Principal Investigator:** The "Primary" PI provides a single or initial point of communication between the sponsoring agency(s) and the awardee organization(s) about scientific matters. If not otherwise designated, the first PI listed will serve as the "Primary" PI. This individual can be changed with notification of the agency. The sponsoring agency(s) does not infer any additional scientific stature to this role among collaborating investigators.

- e. The offeror's record of past performance.
- f. The reasonableness and realism of proposed costs, any fee, and the availability of funds.

[**NOTE:** If your proposal leads to the award of a contract, proposal evaluation and award performance may be subject to the Office of Federal Procurement Policy's (OFPP) guidance on past performance.]

2. Upon receipt of a proposal, the ARL//ARO staff will perform an initial review of its scientific merit and potential contribution to the Army mission and also determine if funds are expected to be available for the effort. Proposals not considered having sufficient scientific merit or relevance to the Army's needs or those in areas for which funds are not expected to be available may be declined at this point without further review.

3. All proposals are treated as privileged information prior to award and the contents are disclosed only for the purpose of evaluation. Proposals not declined as a result of an initial review will be subject to a peer review by highly qualified scientists. While the offeror may restrict the evaluation to scientists from within the government, to do so may prevent review of the proposal by those most qualified in the field of research covered by the proposal. The offeror must indicate on the appropriate proposal form (Form 52 or 52A) any limitation to be placed on disclosure of information contained in the proposal.

4. Each proposal will be evaluated based on the scientific merit and military relevance of the specific research proposed as it relates to the overall Army program rather than against other proposals for research in the same general area.