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BROAD AGENCY ANNOUNCEMENT

FOR

BASIC AND APPLIED SCIENTIFIC RESEARCH

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FY 2007 - FY 2012

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Research Triangle Park Contracting Division
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OVERVIEW INFORMATION

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Eligible Applicants: Proposals may be submitted by degree-granting universities, nonprofit organizations, or industrial concerns. Proposals are encouraged from Historically Black Colleges and Universities (as determined by the Secretary of Education to meet requirements of Title III of the Higher Education Act of 1965, as amended (20 U.S.C. § 1061)) and from Minority Institutions defined as institutions "whose enrollment of a single minority or a combination of minorities…exceeds 50 percent of the total enrollment." [20 U.S.C. § 1067k(3) and 10 U.S.C. § 2323(a)(1)(C)].

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 Office (ARO) solicits proposals for basic and scientific research in mechanical sciences, environmental sciences, mathematical and computer sciences, electronics, computational and information sciences, physics, chemistry, life sciences, and materials science.

TABLE OF CONTENTS 1

INTRODUCTION 2

PART I: RESEARCH AREAS OF INTERESTS 4
RESEARCH AREA 1. Mechanical Sciences 4
RESEARCH AREA 2. Environmental Sciences 15
RESEARCH AREA 3. Mathematical Sciences 22
RESEARCH AREA 4. Network Science 30
RESEARCH AREA 5. Computing Science 35
RESEARCH AREA 6. Electronics 40
RESEARCH AREA 7. Physics 46
RESEARCH AREA 8. Chemistry 52
RESEARCH AREA 9. Life Sciences 54
RESEARCH AREA 10. Materials Science 57
RESEARCH AREA 11. ARO Special Programs 60
Short Term Innovative Research (STIR) Program 61
Young Investigator Program (YIP) 62
Presidential Early Career Award for Scientists and Engineers (PECASE) 63
Research Instrumentation (RI) Program 63
DOD Programs (DURIP, DEPSCoR and HBCU/MI Infrastructure Program) 64

PART II: OTHER PROGRAMS 65
Conference and Symposia Grants
Historically Black Colleges and Universities (HBCU) /Minority Institutions (MI) Infrastructure 67

PART III: PROPOSAL PREPARATION AND SUBMISSION 68
Section 1 - General Information 68
Section 2 - The Application Process 71
Section 3 - White Paper Preparation 71
Section 4 - White Paper Submission 73
Section 5 - Preparation of Complete Research Proposals 73
Section 6 - Submission of Complete Research Proposals 82
Section 7 - Grants.Gov Registration 83
Section 8 - Information To Be Requested From Successful Offerors 85
Section 9 - Required Certifications and Contract Terms and Conditions 85
PART IV. PROPOSAL EVALUATION 94

INTRODUCTION:

This Broad Agency Announcement (BAA) which sets forth research areas of interest to 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 basic and scientific research in mechanical sciences, environmental sciences, mathematical and computer sciences, electronics, computational and information sciences, physics, chemistry, life sciences, and materials science. 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.

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/MI support.

The Army has a long history of advocating and supporting research at historically black colleges and universities and minority institutions (HBCU/MI). We actively seek research proposals from HBCUs and MIs 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 MIs 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). 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.

The ARO prefers proposals submitted to cover a 3-year period and which 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 inquires 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 31 March 2012, unless announced otherwise, and supersedes the ARO 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.

DAVID SKATRUD
Director
Army Research Office

RESEARCH AREA 1
MECHANICAL SCIENCES

1.0 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.

1.1. 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.

1.1.1. *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 predication

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.

1.1.2 *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.

1.1.3 *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.

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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.

1.2. 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.

1.2.1. *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.

1.2.2. *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.

1.2.3 *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
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1.3. 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.

1.3.1. 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 nano-tubes, 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.

1.3.2. 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.

Technical Point of Contact: COL Reed F. Young, email: reed.young@us.army.mil, (919) 549-4255.

1.4. 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.

1.4.1. *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.

1.4.2. *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 2
ENVIRONMENTAL SCIENCES

2.0. 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.

2.1. 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:

2.1.1. *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.* 10^2-10^3m). 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.

2.1.2. *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.

2.1.3. *Terrestrial System Modeling and Model Integration*. One 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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2.2. 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

2.2.1. *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

2.2.2. *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.

2.2.3 *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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2.3 Habitation Science. Habitation Science is basic research that will allow the Army to project power around the globe in a mode that supports operational needs in a sustainable manner. Program interests include rapid start-up of biological processes; membrane processes for water purification; advanced barriers and structures; real-time informatics and analysis; energy recovery and conversion; and resource reuse and transformation. Rapid start-up of biological processes can be defined as sustainable biological systems that incorporate a variety of organisms (bacteria, algae, plants etc) to regenerate air, water and food so as to support forward base camp self-sufficiency. Forward osmosis (FO), membrane distillation (MD) processes, and membrane development hold potential interest. Also, of interest would be advanced system multi-functional design with conceptualization of systems possessing redundancy, integration, and poly-functional materials viewed in the context of systems inhabited by soldiers. Basic research into unit operations that hold the potential to continuously accommodate troops of variable population sizes and perform equally in urban and remote locations under a wide range of climates is of interest. The need exists for basic research that examines systems that maximize recovery of usable energy via physical-chemical and biological processes. Such operations need to simultaneously minimize system mass, volume and power while controlling the amount, composition and release of reaction by-products.

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RESEARCH AREA 3
MATHEMATICAL SCIENCE

3.0. 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.

3.1. 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 bioinformatics and 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 understanding 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 specially interest are high risk attempts to use techniques in fields not traditionally brought to bear on biological problems, as well as innovative efforts at handling large amounts of complex data.

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3.2. 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:

3.2.1. *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.

3.2.2. *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.

3.2.3. *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.

3.2.4. *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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3.3. 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.

3.3.1. 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.

3.3.2. 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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3.4. 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.

3.4.1. *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.

3.4.2. *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 exact 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 order 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 4
NETWORK SCIENCE

4.0. 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.

4.1. 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.

4.1.1. *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.

4.1.2. *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.

4.1.3. *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.

4.1.4. *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.

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4.2. 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.

4.2.1. *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.

4.2.2. *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.

4.2.3. *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.

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4.3. 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.

4.3.1. *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.

4.3.2. *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.

4.3.3. *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.

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4.4 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.

4.4.1. *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

4.4.2. *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.

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RESEARCH AREA 5
COMPUTING SCIENCE

5.0. 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.

5.1. 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.

5.1.1. *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.

5.1.2. *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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5.2. 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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5.3. 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.

5.3.1. *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.

5.3.2. *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.

5.3.3. *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.

5.3.4. *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.

5.3.5. *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 6
ELECTRONICS

6.0 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.

6.1 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 ultra-low-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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6.2 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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6.3 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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6.4 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, gravitometers, 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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6.5 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 counter-terrorism. 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 duel use potential and the potential for significantly impacting the high-frequency electronics of the future.

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6.6 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 7
PHYSICS

7.0. 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 white paper to further the discussion.

7.1. 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.

7.1.1. *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.

7.1.2. *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 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.

7.1.3. *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.

7.1.4. *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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7.2. 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.

7.2.1. *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, superlatives, 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.

7.2.2. *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.

7.2.3. *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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7.3. 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.

7.3.1. *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 programs.

7.3.2. *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.

7.3.3. *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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7.4 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.

7.4.1. *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 a 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.

7.4.2. *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.

7.4.3. *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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7.5. 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.

7.5.1. *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/cm^2. 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.

7.5.2 *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.

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

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RESEARCH AREA 8
CHEMISTRY

8.0. 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 white papers describing a specific research objective, scientific approach, and anticipated scientific impact.

8.1. 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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8.2. 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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8.3. 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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8.4. 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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8.5. 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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8.6. 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 9
LIFE SCIENCES

9.0. 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 four 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 biotechnology, 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. Potential offerors are strongly encouraged to contact the appropriate TPOC for preliminary discussions on their ideas before any submissions. The TPOC may invite the offeror to submit a white paper.

9.1. Bioengineering. Fundamental studies to define structure-function relationships and biochemical interactions for enzymes, receptors and other macromolecules exhibiting mechanisms and properties uniquely relevant to synthetic and degradative pathways of interest to the military, including establishment of the foundations for manipulation and exploitation of biocatalysis, ribosomal and non-ribosomal biosynthesis to enhance permissiveness toward elaboration of useful biomolecular structures and cellular systems designed with "metabolic engineering" in mind. Also, research to provide insight from nature on novel theoretical principles and mechanisms in sensory and motor function, as well as on materials with extraordinary properties, from biological sources. Includes not only initial molecular events, signal transduction pathways and integrated information processing for the powerful sensing capabilities exhibited in the biological world, but also self-assembly processes, hierarchical structure formation, and functional characterization of biomolecular materials such as those with potential "biomimetic" utility for nanometer scale fabrication or for energy and information transfer, among other possibilities.

Technical Point of Contact: Dr. Robert Kokoska
email: Robert.kokoska@us.army.mil, (919) 549-4342

9.2 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 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 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

9.3. Microbiology and Biodegradation. 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. Included are research investigations in analytical microbiology (including microbial signatures), and in general microbial mechanisms with relevance to Army problems. Addressed here also is research into microbial communities and how to study organisms that cannot be grown in the lab, as well as research into methods to enhance the stabilization of military materiel, which would include methods to prevent microbial growth. Also included is the development of microbial systems for unique biotechnological applications and bioengineering processes with individual microbial species or consortia of microorganisms, emphasizing the control, stability, and mechanisms of the basic cellular processes involved.

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

9.4 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, neuro-psychological 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 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 psycho physiological 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

RESEARCH AREA 10
MATERIALS SCIENCE

10.0. 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.

10.1. 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

10.2 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

10.3. 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

10.4. 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 11
ARO SPECIAL PROGRAMS

11.0 Proposal Submission Requirements.

All ARO Special Program proposals should be submitted via www.grants.gov.

The following grants.gov forms are required for submission:

1. SF 424 (R&R), form entitled Application for Federal Assistance.
2. Research & Related Senior/Key Person Profile form
Note: (This form is used for up to 8 CO-PIs, if more use Expanded Form.)
3. Research and Related Other Project Information form
4. Research and Related Budget form-Sections A thru K, Budget Period 1 and subsequent periods, if required form(s) and Research & Related Budget –Cumulative Budget form.
5. R&R Subaward Budget Attachment(s) form. (If required) Use this form when sub awardees are contemplated for project. This form, if required, should be attached on form named "Attachments Form" as "Attachment 6".
6. Attachments Form. On this form, you will attach the various files that make up your grant application. Please refer to this BAA for more information about each needed file.
7. SF-LLL form. Note: (This form used only if Lobbying Activities Certification is required.)
8. Please identify which ARO Special Program your submission should be directed to: i.e.; Short Term Innovative Research (STIR), Young Investigator Program (YIP), Presidential Early Career Award for Scientists and Engineers (PECASE) or Research Instrumentation (RI). Annotate on Form SF424 (R&R), block entitled "Applicant Identifier" to the right of block "2" the name of the special program, i.e., Division to which the submission is to be considered. Name of Program Manager is to be placed to the right of block #3 which is entitled as "State Application Identifier". **This is required to expedite processing.**
9. Educational Information: The years the PI/CO-PI's degree(s) were conferred and the scientific discipline of degree(s). Attach this information at item # 11, Other Attachments, on the form named Research & Related Senior/Key Person Profile. Label the attachment as "Educational Information".

The following ARO form is **required** for submission:

Note: ARO Form 52A-Statement of Disclosure Preference: Please complete ARO Form 52A stating your preference for release of information contained in your proposal. A copy of this form is available at http://www.aro.army.mil/forms/forms2.htm. This form must be signed by Principal Investigator and Sponsored Programs Office/Administrative Representative. This form should be attached on form named "Attachments Form" as "Attachment 7".

11.1. 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.

11.1.1. *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.

11.1.2. *Research Sought*. Proposals in the amount of $50,000 or less are sought for research in the areas identified in PART I of this BAA.

11.1.3. *Proposal Preparation*. Submit proposals via www.grants.gov.

11.1.3.1. 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 "Research and Related Budget form-Sections A thru K, Budget Period 1" must accompany the proposal. For purposes of the STIR submission only, Grants.Gov multiple budget pages, sections "A-K" are considered "1 page" against the twenty page limitation.

11.1.3.2. 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.**

11.1.3.3. Proposals shall be submitted with form entitled Application for Federal Assistance, SF 424 (R&R). 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.

11.1.3.4. 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.

11.1.3.5. The principal investigator(s) should disclose and explain the relevancy of the proposal to the research interests identified in PART I.

11.1.3.6. 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.

11.2. 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.

11.2.1. 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.

11.2.2. Research Sought. Proposals are invited for research in areas described in PART I 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.).

11.2.3. Proposal Preparation. Submit proposals via www.grants.gov.

11.2.3.1. 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-EL.

11.2.3.2. 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.

11.2.4. 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.

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

11.2.5.1. 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.

11.2.5.2. 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.

11.2.5.3. 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.

11.2.5.4 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. 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.

11.3. <u>RESEARCH INSTRUMENTATION (RI) PROGRAM</u>. 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.

11.3.1. *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.

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

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

11.3.2.2. 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.

11.3.2.3. 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.

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

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

11.4. DOD PROGRAMS.

11.4.1. 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 as identified in PART I. of this BAA. Offerors are reminded that these two BAAs have definitive closing dates for receipt of proposals (see each specific BAA for details). Offerors need not at the time of submission to DEPSCoR and DURIP have a current grant or contract with the ARO, nor in the case of instrumentation, request support of research presently being carried out. Offerors must, however, review the separate BAAs for specific eligibility considerations.

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

11.4.2 Research *and Educational Program for Historically Black Colleges and Universities and Minority-Serving Institutions (HBCUs/MSIs).* The Army Research Office periodically issues solicitations for proposals from HBCUs and MSIs under the 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 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 and 5410.20 prohibits co-sponsorship of conferences and symposia with a non-federal entity 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 or provides substantial logistical support for the event. For questions regarding your organization's eligibility for a conference or symposia grant, please contact Ernie Dixon at (919) 549-4270, e-mail: ernie.dixon@us.army.mil; the Technical

POC listed throughout this BAA, in your scientific area of interest, or the ARO Legal Office, Edward Beauchamp, at (919) 549-4292, e-mail: ed.beauchamp@us.army.mil.

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 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. The form entitled Application for Federal Assistance, SF 424 (R&R) and the form entitled Research & Related Senior/Key Person Profile.

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. Research & Related Budget Sections A-K, as needed.

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 INSTITUTIONS (HBCU/MIs)

The Army has a long history of advocating and supporting research at HBCU/MIs. Through this solicitation the Army Research Office (ARO) encourages basic research proposals from the HBCU/MI 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 basic research, collaborative research proposals are also of interest. Collaborations may be between HBCU/MIs and other institutions of higher education (not limited to HBCU/MIs) and/or industry partners.

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)). Solicitations are issued annually and are available on the ARO website as well as through Grants.gov.

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.

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

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).

PART III - PROPOSAL PREPARATION AND SUBMISSION

SECTION 1 - General Information:

Preliminary Inquires: The ARO receives 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

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 ARO legal personnel (ARO: Mr. Edward Beauchamp, (919) 549-4292, e-mail: ed.beauchamp@us.army.mil,

prior to expending time and effort in preparing a proposal.

Statement of Disclosure Preference: Please complete ARO Form 52A stating your preference for release of information contained in your proposal. A copy of this form is available at http://www.aro.army.mil/forms/forms2.htm. This form must be signed by Principal Investigator and Sponsored Programs Office/Administrative Representative. This form should be attached on form named "Attachments Form" as "Attachment 7".

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 ARO has the authority to award a variety of instruments. The 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" as defined in 15 U.S.C. 3710a. No fee or profit is allowed.

Grants and cooperative agreements are governed by the following regulations:

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 another 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 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.

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 emailed directly to the Technical Point of Contact. Include "BAA # W911NF-07-R-0003-06 WHITE PAPER" in the email subject line. White papers must be submitted 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

SECTION 5: Preparation of Complete Research Proposals

1. Proposals will not be processed without : (1) Application for Federal Assistance form, SF 424 (R&R); (2) Research and Related Senior/Key Person Profile form; (3) Research and Related Other Project Information form; (4) Research and Related Budget form, sections A-K, as needed, (5) Attachments Form, and (6) Statement of Disclosure Preference (ARO Form 52A)

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. 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.

STATEMENT OF DISCLOSURE PREFERENCE : Complete ARO Form 52A. stating your preference for release of information contained in your proposal. A copy of this form is available at http://www.aro.army.mil/forms/forms2.htm. This form must be signed by Principal Investigator and Sponsored Programs Office/Administrative Representative. This form should be attached on form named "Attachments Form" as "Attachment 7".

PROJECT ABSTRACT: **MAXIMUM 200 WORDS,** in a form suitable for release under the Freedom of Information Act, 5 U.S.C. 552, as amended.

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. Add the Project Abstract data at item # 6, Project Summary/Abstract of the form entitled Research & Related Other Project Information.

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. Add this data at item # 7, Project Narrative of the form entitled Research & Related Other Project Information.

2. A brief description of your organization. If the offeror has extensive government contracting experience and has previously provided the information to the ARO, 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 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:

Attach a biographical sketch where indicated after the profile for each key person on the form named Research & Related Senior/Key Person Profile.

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.

e. **Educational Information**: The years the PI/CO-PI's degree(s) were conferred and the scientific discipline of degree(s). Attach this information along with Biographical Sketch at item entitled "Attach Biographical Sketch, Add Attachment", on the form named Research & Related Senior/Key Person Profile. Label this part of the attachment as 'Educational Information'.

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.

<u>BIBLIOGRAPHY</u>: A bibliography of pertinent literature is required. Citations must be complete (including full name of author(s), title, and location in the literature). Attach this information at Item # 8, Bibliography and References Cited on the Research and Related Other Project Information form.

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). Attach this information after each individual profile where indicated on the Research & Related Senior/Key Person Profile form.

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. Attach this information at Item #9, on the Research & Related Other Project Information form.

BUDGET PROPOSAL (including DD Form 1861): Please attach the DD Form 1861 at item #11, on the Research and Related Other Project Information form. Label this attachment as 'Contract Facilities Capital Cost of Money'. This form can be found at http://www.aro.army.mil/forms/forms2.htm . **Note: This form is used for contract proposals only and is usually only associated with commercial "for-profit" entities.**

Each proposal must contain a budget for each year of support requested and a cumulative budget for the full term of requested support. The data must be entered on the Research & Related Budget form in the appropriate sections for each period needed. The need for each item should be explained clearly. 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.*

1. 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.

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: This data is required to be entered at item # 11, Other Attachments, on the Research & Related Other Project Information form. Label this attachment '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 be prepared to submit a subcontracting plan for small business and small disadvantaged business concerns. A mutually agreeable plan will be included in 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 (FCMM) (DD Form 1861) is required. Please attach the DD Form 1861 at item #11, on the Research and Related Other Project Information form. Label this attachment as 'Contract Facilities Capital Cost of Money'. This form can be found at http://www.aro.army.mil/forms/forms2.htm. **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.

1, All proposals must be submitted to www. Grants.gov with the following mandatory forms:

(a) Application for Federal Assistance form, SF 424 (R&R). (This replaces ARO Form 51/Cover Page);

(b) Research and Related Senior/Key Person Profile form (Is used for up to "8" Co-PIs, if more please use the "Expanded Form");

(c) Research & Related Other Project Information form (Replaces the ARO Form 51 GG.) This form is also used for Project Summary/Abstract, Project Narrative, Bibliography & References Cited, Facilities & Other Resources, Equipment and "Other Attachments";

(d) Research and Related Budget form, Sections A-K (as needed);

(e) The Attachments Form;

(f) Statement of Disclosure Preference (ARO Form 52A).

2. Proposed documents (excluding mandatory 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-0003-06.

(a) The Application for Federal Assistance form, 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 I.

(b) 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.

(c) You MUST open and complete the form entitled Application for Federal Assistance, 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@dlis.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. Adobe Acrobat instead of PureEdge – 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@dlis.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 certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification 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 certification 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 o 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.

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://cmra.army.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 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 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 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.