ARMY RESEARCH OFFICE

BROAD AGENCY ANNOUNCEMENT FOR

FUNDAMENTAL RESEARCH

W911NF-17-S-0002-08
01 April 2017 – 31 March 2022

ISSUED BY:

U.S. Army Contracting Command
Aberdeen Proving Ground
Research Triangle Park Division
P. O. Box 12211
Research Triangle Park, NC 27709-2211

Special Notes

1. Formatting of the Announcement

The following table provides an overview of the outline structure of this announcement:

I.							
	A.						
		1.					
			a.				
				i.			
					(1)		
						(a)	
							(i)

2. See Appendix 1 for a Table of Acronyms used in this announcement.

3. See Appendix 2 for a Schedule of Amendments. Applicants are encouraged to frequently check Grants.gov and FBO.gov for updates and amendments to this BAA.

TABLE OF CONTENTS

I. OVERVIEW OF THE FUNDING OPPORTUNITY					1
	A. Required Overview Content				3
		1. Agency Name			3
		2. Research Opportunity Title			3
		3. Announcement Type			3
		4. Research Opportunity Number			3
		5. Catalog of Federal Domestic Assistance (CFDA) Number and Title			3
		6. Response Dates			3
	B. Additional Overview Information				4
II. DETAILED INFORMATION ABOUT THE FUNDING OPPORTUNITY					5
	A. Program Description				5
		1. RESEARCH INTERESTS FOR U.S. INSTITUTIONS			5
			a. Physical Sciences		5
				i. Chemical Sciences	5
				ii. Physics	9
				iii. Life Sciences	14
			b. Engineering Sciences		19
				i. Mechanical Sciences	20
				ii. Electronics	26
				iii. Materials Sciences	30
				iv. Earth Sciences	32
			c. Information Sciences		33
				i. Computing Sciences	33
				ii. Mathematical Sciences	39
				iii. Network Sciences	49
		2. INTERNATIONAL RESEARCH INTERESTS			57
			a. Human Dimension		57
			b. Innovations of Materials		58
		3. ARO SPECIAL PROGRAMS			60
			a. Short-Term Innovative Research (STIR) Program		60
			b. Early Career Program (ECP)		61
			c. Presidential Early Career Award for Scientists and Engineers (PECASE)		62
			d. Research Instrumentation (RI) Program		63
			e. Conference and Symposia Grants		64
			f. High School Apprenticeship Program (HSAP)/Undergraduate Research Apprenticeship Program (URAP)		65
			g. Historically Black Colleges and Universities and Minority-Serving Institutions (HBCUs/MIs)		67
		4. OTHER NON-ARO PROGRAM-RELATED INFORMATION			67
			a. Visiting Scientist Program (VSP)		67
			b. DoD Programs		68
	B. Federal Award Information				69

	C. Eligibility Information			72
		1. Eligible Applicants		72
		2. Cost Sharing or Matching		72
		3. Other		72
	D. Application and Submission Information			73
		1. Address to View Broad Agency Announcement		73
		2. Content and Form of Application Submission		73
		3. Unique Entity Identifier and System for Award Management (SAM)		86
		4. Submission Dates and Times		86
		5. Intergovernmental Review		87
		6. Funding Restrictions		87
		7. Other Submission Requirements		87
	E. Proposal Review Information			88
		1. Criteria		88
		2. Review and Selection Process		89
		3. Recipient Qualification		89
	F. Award Administration Information			92
		1. Award Notices		92
		2. Administrative and National Policy Requirements		92
			a. Required Representations and Certifications	92
			b. Policy Requirements	96
		3. Reporting		101
	G. Agency Contacts			103
	H. Other Information			104
		1. Contract Proposals		104
		2. Grant and Cooperative Agreement Proposals		111
APPENDIX 1: TABLE OF ACRONYMS				116
APPENDIX 2: SCHEDULE OF AMENDMENTS				119

I. OVERVIEW OF THE FUNDING OPPORTUNITY

The purpose of this Broad Agency Announcement (BAA) is to solicit research proposals in the engineering, physical, life, and information sciences for submission to the Army Research Office (ARO) for consideration for possible funding.

NOTE: For ease of reference and clarity, the Army Research Laboratory (ARL) has two BAAs. This BAA for ARO, and another one for the ARL Directorates (Computational and Information Sciences Directorate, Human Research and Engineering Directorate, Sensors and Electron Devices Directorate, and Weapons and Materials Research Directorate).

ARO is focused exclusively on extramural basic research, and is responsible for the vast majority of ARL's extramural research programs and funding. The ARL Directorates are focused on executing in-house research programs, with a significant emphasis on collaborative research with other organizations in an Open Campus setting (Open Campus opportunities are described in detail at https://www.arl.army.mil/opencampus/. These in-house Directorates do fund a modest amount of extramural research in certain specific areas, and ARL's BAA describes those areas of interest.

ARL's mission is to Operationalize Science for Transformational Overmatch. ARL's strategy is based on eleven Foundational Research Competencies: Biological and Biotechnology Sciences (BBS); Electromagnetic Spectrum Sciences (EMSS); Energy Sciences (ES); Humans in Complex Systems (HCxS); Mechanical Sciences (MS); Military Information Sciences (MIS); Network, Cyber and Computational Sciences (NC&CS); Photonics, Electronics, and Quantum Sciences (PE&QS); Sciences of Extreme Materials (SEM); Terminal Effects (TE); and Weapons Sciences (WS). These competencies are structured to create discovery, innovation, and transition of technologies for Army transformational overmatch. ARO is focused on creating and directing scientific discoveries for revolutionary new Army capabilities that support and inform these Competencies, as referenced in this BAA.

Proposals are sought from institutions of higher education, nonprofit organizations, state and local governments, foreign organizations, foreign public entities, and for-profit organizations (i.e. large and small businesses) for scientific research in mechanical sciences, mathematical sciences, electronics, computing science, physics, chemistry, life sciences, materials science, network science, and environmental sciences. Proposals will be evaluated only for fundamental scientific study and experimentation directed toward advancing the scientific state of the art or increasing basic knowledge and understanding. Proposals focused on specific devices or components are beyond the scope of this BAA.

Proposals are expected to be for cutting-edge innovative research that could produce discoveries that would have a significant impact on enabling new and improved Army operational capabilities and related technologies. The specific research areas and topics of interest described in this document should be viewed as suggestive, rather than limiting. ARO is always interested in considering new innovative research concepts of relevance to the Army.

In order to conserve valuable applicant and Government resources, and to facilitate determining whether a proposed research idea meets the guidelines described herein, prospective applicants contemplating submission of a whitepaper 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 applicant elects to submit a whitepaper, it should be prepared in accordance with the instructions contained in this BAA. Upon receipt, a whitepaper will be evaluated and the applicant will be advised of the results. Applicants whose whitepapers receive a favorable evaluation may be encouraged to prepare a proposal in accordance with instructions contained in this BAA. The costs of whitepapers and/or 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 Federal Acquisition Regulation (FAR) 31.205-18. ARO prefers proposals to cover a 3-year period and include a brief summary of work contemplated for each 12-month period so that awards may be negotiated for an entire 3-year program or for individual 1-year increments of the total program. Proposals may be submitted at any time while this BAA, including any amendments, is valid.

In accordance with federal statutes, regulations, and Department of Defense (DoD) 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.

Applicants submitting proposals are cautioned that only a Contracting or Grants Officer can obligate the Government to any legal instrument involving expenditure of Government funds.

This BAA is also used to solicit research proposals for submission to the U.S. Army Combat Capabilities Development Command (DEVCOM) International Technology Centers.

All administrative inquiries regarding this BAA shall be submitted in email to: usarmy.rtp.aro.mbx.baa@army.mil. Scientific and technical questions should be referred to the TPOCs shown following each research area of interest. Interested parties are encouraged to periodically check any of the following websites for updates and amendments to this BAA: www.grants.gov, beta.sam.gov, and the (ARL) website www.arl.army.mil/.

BARTON H. HALPERN
Director
Army Research Office
(End of Section)

A. Required Overview Content

1. Agency Name
U.S. Army Research Office

Issuing Acquisition Office
U.S. Army Contracting Command-Aberdeen Proving Ground, Research Triangle Park (ACC-APG-RTP) Division

2. Research Opportunity Title
ARO Broad Agency Announcement (BAA) for Fundamental Research for 01 April 2017 – 31 March 2022

3. Announcement Type
Amended Announcement

4. Research Opportunity Number
W911NF-17-S-0002-08

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

6. Response Dates
This BAA is a continuously open announcement valid throughout the period from the date of issuance through 31 March 2022, unless announced otherwise. This announcement succeeds BAA W911NF-12-R-0012 (including all modifications) dated 15 May 2012.

(End of Section)

B. Additional Overview Information

This BAA sets forth research areas of interest to the ARO. This BAA is issued under FAR 6.102(d)(2), which provides for the competitive selection of fundamental research proposals, and 10 U.S.C. 2358, 10 U.S.C. 2371, and 10 U.S.C. 2371b, which provide the authorities for issuing awards under this announcement for fundamental research. The definitions of fundamental research may be found at 32 CFR 22.105.

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.

The DoD agencies involved in this program reserve the right to select for award all, some, or none of the proposals submitted in response to this announcement. Due to Government budget uncertainties, no specific dollars have been reserved for awards under this BAA. The participating DoD agencies will provide no funding for direct reimbursement of whitepaper or proposal development costs.

Whitepapers and technical and cost proposals (or any other material) submitted in response to this BAA will not be returned to the applicant. It is the policy of participating DoD agencies to treat all proposals as sensitive, competitive information and to disclose their contents only for the purposes of evaluation.

An applicant may withdraw a proposal at any time before award by written notice or by email sent to the Government point of contact (POC) identified in Section G of this BAA.

(End of Section)

II. DETAILED INFORMATION ABOUT THE FUNDING OPPORTUNITY

A. Program Description

1. RESEARCH INTERESTS FOR U.S. INSTITUTIONS

ARL's ARO mission is to serve as the Army's principal extramural basic research agency funding research at universities, companies and not-for- profits in the engineering, physical, and information sciences. ARO's research portfolio is executed through ten scientific branches, with titles reflecting fundamental scientific disciplines familiar to academic institutions. These Branches directly support and inform the ARL Competencies.

a. Physical Sciences

Research in the Physical Sciences is focused on basic research to discover, understand, and exploit physical, chemical, and biological phenomena. This research is of a fundamental nature; however, in the long term, discoveries in this area are expected to lead to revolutionary new capabilities in warfighter performance, intelligence, synthetic biology, sensing, communications, protection, power/energy storage and generation, and materials that extend the performance of Army systems well beyond current limits.

i. Chemical Sciences

The objective of the Chemical Sciences Branch is to uncover and exploit the fundamental properties and processes governing molecules and their interactions in materials and chemical systems. The Branch encourages proposals that promote basic research to develop methods for accurately predicting the pathways, intermediates, and energy transfer of specific reactions, to understand the fundamental processes governing electrochemical reactions and transport of species, and to discover the relationships between macromolecular microstructure, architecture, functionality, and macroscopic properties. In addition, these efforts will likely lead to new methods for synthesizing and analyzing molecules and materials that will open the door to future studies not feasible with current approaches.

The Branch's research programs are currently focused on five research areas. The titles, scopes and points of contact for these programs, each of which address general aspects of basic research in chemical sciences, are listed in the following subsections. Symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Polymer Chemistry

The goal of this Program is to understand the molecular-level link between polymer microstructure, architecture, functionality, and the ensuing macroscopic properties. Research in this Program may ultimately enable the design and synthesis of functional polymeric materials that give the Soldier new and improved protective and sensing capabilities as well as capabilities not yet imagined. This Program is divided into two

research thrusts: (i) *Precision Polymeric Materials* and (ii) *Complex Adaptive Polymeric Systems*. Within these thrusts, high-risk, high-payoff research is identified and supported to pursue the Program's long-term goal.

The *Precision Polymeric Materials* thrust supports research aimed at developing new approaches for synthesizing polymers with precisely-defined molecular weight, microstructure, architecture, and functional group location. Of particular interest are research efforts that focus on novel methods for achieving sequence and tacticity control in synthetic polymers as well as enabling the synthesis of novel 2D organic polymers. Also of interest to this thrust are research efforts that further explore how precise molecular structure influences polymer morphology and bulk macroscopic properties. Bulk properties of enduring interest include mechanical, optical, and transport. An area of particular interest is the rational design of polymers with enhanced *intrinsic* thermal transport properties.

The *Complex Adaptive Polymeric Systems* thrust seeks to understand how to precisely and predictably control polymer assembly and response to achieve polymeric systems with a diversity of functions and behaviors. Of interest to this thrust are research efforts that explore how polymer structure influences interactions with dissimilar materials (e.g., inorganic or biological materials) to render functional hybrid assemblies. Also of interest is the design and synthesis of polymeric materials that exhibit programmed molecular responses to external stimuli. Of interest in this regard are research efforts related to stimuli-responsive self-immolative polymers, polymer mechanochemistry, and stimuli-mediated polymer assembly. Additionally, an emerging area of interest lies in the integration of logic-based responsive behavior, computation, and feedback mechanisms to engender complex responsive behavior.

TPOC: Dr. Dawanne Poree, dawanne.e.poree.civ@army.mil, (919) 549-4238

(2) Electrochemistry

This Program supports fundamental electrochemical studies to understand and control the physics and chemistry that govern electrochemical redox reactions and transport of species, and how these are coupled with electrode, catalysis, electrolyte, and interface. Research includes ionic conduction in electrolytes, electrocatalysis, interfacial electron transfer, transport through coatings, surface films and polymer electrolytes, activation of carbon-hydrogen and carbon-carbon bonds, and spectroscopic techniques that selectively probe electrode surfaces and electrode-electrolyte interfaces. Novel electrochemical synthesis, investigations into the effect of microenvironment on chemical reactivity, quantitative models of electrochemical systems, and electrochemistry using excited electrons are also of interest.

This Program is divided into two research thrusts, although other areas of electrochemical research may be considered: (i) *Reduction-oxidation (Redox) Chemistry and Electrocatalysis*, and (ii) *Transport of Electroactive Species*.

The *Redox Chemistry and Electrocatalysis* thrust supports research to understand how material and morphology affect electron transfer and electrocatalysis, to tailor electrodes and electrocatalysts at a molecular level, and to discover new spectroscopic and electrochemical techniques for probing surfaces and selected species on those surfaces.

The *Transport of Electroactive Species* thrust supports research to uncover the mechanisms of transport through heterogeneous, charged environments such as polymers and electrolytes, to design tailorable electrolytes based on new polymers and ionic liquids, and to explore new methodologies and computational approaches to study the selective transport of species in charged environments.

TPOC: Dr. Hugh De Long, hugh.c.delong.civ@army.mil , (919) 549- 4271

(3) Molecular Structure and Dynamics

The Molecular Structure and Dynamics program is no longer accepting new white papers or proposals.

TPOC: Dr. James K. Parker, james.k.parker30.civ@army.mil, (919) 549-4293

(4) Reactive Chemical Systems

The goal of the Reactive Chemical Systems Program is to achieve a molecular level understanding of interfacial activity and dynamic nanostructured and self-assembled chemical systems to provide unprecedented hazardous materials management capabilities and soldier survivability. This Program supports basic research with Army relevance in surfaces, catalysis, organized assemblies, and stimuli-responsive chemical systems. This program is divided into two thrusts: (i) *Nanostructure Surface Interactions and Reactivity* and (ii) *Synthetic Molecular Systems*.

The *Nanostructure Surface Interactions and Reactivity* thrust supports research on understanding the kinetics and mechanisms of reactions occurring at surfaces and interfaces and the development of new methods to achieve precise control over the structure and function of chemical and biological molecules on surfaces. Specific areas of interest include adsorption, desorption, and the catalytic processes occurring at surfaces and interfaces and the interface between nanostructures and biomolecules to generate advanced materials.

The *Synthetic Molecular Synthesis* thrust supports research that imparts multi-functionality, stimuli-responsive and dynamic behavior to completely synthetic molecular and chemical systems. Research of interest includes design and development of nanostructured scaffolds and sequential catalytic systems. This thrust also supports research aimed at exploring the properties and capabilities of self-assembled and supramolecular structures, including their functionality, and how to control assembly in different environments.

In addition, the emerging field of dynamic, responsive, multi-functional materials have great potential to provide revolutionary new capabilities. A specific technical area in this field is "targeting and triggering" in which a specific chemical (or event) is targeted (recognized) and that recognition triggers a response. Particular technical challenges of interest include selective and reversible recognition, amplification, and multi-responsive systems. Alternative approaches to selective, yet reversible, recognition are needed. Amplification includes an understanding of how to amplify the response from a single molecular recognition event to a multi-molecular response with approaches that promote chain reactions, self-amplification or cascade-type reactions within a single system. Multi-responsive systems in which specific stimuli trigger distinct responses are also of interest.

TPOC: Dr. James K. Parker, james.k.parker30.civ@army.mil, (919) 549-4293

(5) Environmental Chemistry

The Environmental Chemistry program seeks to provide a more complete and practical understanding of transport, degradation, and transformation for chemicals and compounds of interest. The goal of the research is to develop theories that comprehensively account for the interdependent nature of heterogeneous environments. The program will identify fundamental research opportunities in two main thrusts: (i) *Chemical structure and reactivity in multiphase environments* and (ii) *Novel techniques for detection and prediction*.

Chemical structure and reactivity in multiphase environments aims to determine the properties and processes that govern the fate and transport of compounds in environments where chemical reactions and transport processes occur between solid, liquid and gaseous matter. Army-relevant multiphase environments are soils, sediments, dust, water (e.g. lacustrine, riverine, subterranean, and snow and ice), and films (e.g. biological and urban). The reactions in these environments occur synergistically and dynamically and are a function of the species present, their structure and partitioning, and their chemical and physical properties. Therefore, understanding multiphase environments relies on basic research to quantify the structure and physio-chemical evolution of a compound over a wide range of spatial and temporal scales. Complementary studies involving novel experimental and computational approaches are essential to overcome the research challenges of multiphase environments.

Novel techniques for detection and prediction aims to develop cutting-edge analytical, computational, and experimental approaches to advance the theory and models required to detect and discern compounds of interest under relevant environmental conditions. Areas of interest include source partitioning, deconvolution of complex matrices for non-targeted detection, rapid recognition of compounds at ultra-trace levels, and the application of machine learning and artificial intelligence to enhance fate and transport modeling capabilities for compounds and their degradation products.

TPOC: Dr. Elizabeth King-Doonan, elizabeth.k.king-doonan.civ@army.mil, (919) 549-

4386

ii. Physics

The objective of the Physics Branch is to develop forefront concepts and approaches, particularly exploiting quantum phenomena, that will in the long-term have revolutionary consequences for Army capabilities, while in the nearer-term providing for existing Army needs. In support of this goal, the interests of the Physics Branch are primarily in the areas described in the following subsections.

The Branch's research programs are currently focused on four research areas. The titles, scopes and points of contact for these programs, each of which address general aspects of basic research in physics, are listed in the following subsections. A small number of symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Solid State Physics

The Solid State Physics program has been moved to the Electronics Branch. Please refer to the section of the BAA.

(2) Quantum Information Science

Quantum mechanics provides the opportunity to perform highly non-classical operations that can result in beyond-classical capabilities in imaging, sensing and precision measurements, exponential speed-ups in computation, or networking. This program seeks to understand, control, and exploit such non-classical phenomena for revolutionary advances beyond those possible with classical systems. An overarching interest is the exploration of small systems involving small numbers of entangled particles. There are three major areas of interest (thrusts) within this program.

Foundational Quantum Physics (FQP). Experimental investigations of a fundamental nature of quantum phenomena, potentially useful for quantum information science, are of interest. Examples include coherence properties, decoherence mechanisms, decoherence mitigation, entanglement creation and measurement, 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. Systematic materials focused research which identifies and/or mitigates decoherence mechanisms is also of interest. Models of machine learning that are based on the foundations of quantum physics are of interest. 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 (AMO) as well as other systems.

TPOC: Dr. Sara Gamble, sara.j.gamble.civ@army.mil, (919) 549-4241

Quantum Sensing, Imaging, and Metrology (QSIM). This research area seeks to explore, develop, and demonstrate multi-particle coherent systems to enable beyond classical capabilities in imaging, sensing, and metrology. Central to this research area is the exploration of small systems involving a few entangled particles. Topics of interest in this research area include the discovery and exploration of (a) multi-particle quantum states advantageous for imaging, sensing, and metrology, (b) quantum circuits that operate on multi-particle quantum states to enable beyond-classical capabilities, and (c) methods for the readout of quantum states. Other research topics of interest are: theory to explore multi-particle quantum states useful for beyond classical capabilities, quantitative assessment of capabilities and comparison to classical systems, efficient state preparation, quantum circuits for processing these states as quantum bits, readout techniques, decoherence mitigation and error-correction for improved performance, supporting algorithms as a basis for processing circuits, connections between the solution of hard computational problems and overcoming classical limitations in imaging, sensing, and metrology, entanglement as a resource, and suitable physical systems and key demonstration experiments.

TPOC: Dr. Sara Gamble, sara.j.gamble.civ@army.mil, (919) 549-4241

Quantum Computation and Quantum Networking (QCON). Quantum computing and networking will entail the control and manipulation of quantum bits with high fidelity. 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 beyond classical capabilities in information processing. Demonstrations of quantum feedback and error correction for multiple quantum bit systems are also of interest. 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. Examples include machine learning, parameter estimation, constrained optimization, and quantum chemistry, among others. The ability to transmit information through quantum entanglement distributed between spatially-separated quantum entities has opened the possibility for new approaches to information processing. Exploration of quantum networking of information and distributed quantum information processing based on entanglement is of interest. These include the exploration of long-range quantum entanglement, entanglement transfer among different quantum systems, and long-term quantum memory.

TPOC: Dr. T.R. Govindan, t.r.govindan.civ@army.mil, (919) 549-4236

(3) Atomic and Molecular Physics (AMP)

Topics of interest within the AMP Program include (i) quantum degenerate atomic gases, both Bose and Fermi, their excitations and properties, including mixed species, mixed state, and molecular, (ii) quantum enhanced precision metrology, (iii) nonlinear

atomic and molecular processes, (iv) quantum systems in cavities, (v) collective and many-body states of matter, and (vi) emerging areas. Cooling schemes for molecules are of importance for extending the range of systems that may be exploited. In addition, there is an interest in emerging areas of AMO physics such as collective states of matter, emergent lattices in quantum gases, opto-mechanical interfaces, non-equilibrium many body dynamics, and metrology in non-ideal environments. Research efforts within the AMP Program fall within two thrust areas: *Advanced Quantum Capabilities* and *Novel Quantum Methods*. It is anticipated that research efforts within these areas will lead to applications including novel materials, efficient computational platforms, and exquisite quantum sensors.

Advanced Quantum Many-body Dynamics. The focus of this thrust is the development and study of strongly correlated many-body systems. The quantum simulator portion of the thrust seeks research on novel cooling, trapping, and the expansion of atomic and molecular species. The effort seeks the validation of many-body quantum theories through the development of experimental tools including quantum gas microscopes, synthetic gauge fields, mixed species, and novel interactions. Complimenting this effort will be the inclusion of foundational investigations into quantum mechanics, such as entanglement, many-body localization, collective modes, and entropy. To take advantage of the precision inherent in future quantum devices, these systems will need to connect to the classical world in such a manner that allows them to sample the signal of interest while remaining robust to noisy environments. Investigating how to maximize both the quality and quantity of entanglement within these systems will be a priority. General issues of quantum coherence, quantum interference, entanglement growth, entanglement purity, and non-equilibrium phenomena, as well as discovering new scientific opportunities are also of interest.

Novel Quantum Metrology. The AMP Program has a general interest in exploring fundamental AMP that may impact future Army capabilities. This thrust is divided into two main areas: precision metrology beyond the standard limit and harnessing collective many-body states to improve quantum sensing. The Novel Quantum Metrology efforts will expand the foundations of quantum measurement into new areas that seek to exploit entanglement, spin-squeezing, harnessing collective-spin states, developing back-action avoidance measurements, and other areas that increase fundamental precision through interactions, including cavities and Rydberg atoms. It is expected that research in this thrust will complement efforts in the *Advanced Quantum Many-body Dynamics* thrust and *vice versa*. For example, collective many body states could be studied in optical lattices or quantum gas microscopes and foundational research of entanglement are anticipated to provide new metrological capabilities in non-ideal environments.

TPOC: Dr. Paul Baker, paul.m.baker4.civ@army.mil, (919) 549-4202

(4) Modern Optics

The objective of this program is to promote a deeper understanding of the underlying physics of the physical properties of light and the discovery of new optical effects that

can improve Army capabilities. The majority of sensing and communications systems depend on light in some way. In particular, this program seeks transformational basic science discoveries in optical physics that are needed to enable remote sensing, information routing and processing, and energy transmission. In order to accomplish this goal, the Modern Optics Program targets new or emerging phenomena related to quantum optics, light-matter interactions, and ultra-short pulse, high energy lasers.

Quantum Photonics. This thrust seeks to push beyond the state of the art in photonics and integrated optical platforms, seeking novel functionality beyond classical limits on sensitivity, accuracy, and stability. What is necessary to advance the field is deeper understanding of bulk and engineered photonic material for their nonlinear optical properties, robust or protected light routing in two and three dimensions, and optical processing at the point of collection. Research efforts may include studies addressing complexity and loss in integrated optical systems, scalable realizations of non-trivial quantum states or quantum light sources, and novel laser platforms to probe or control quantum information in physical qubits. Basic science understanding is needed to push integrated technology into the quantum regime which will be essential for next generation quantum technology.

Meta-Optics. This thrust pursues novel functionality allowed by optical metamaterials. In this area, the conventional norms of classical optics can be broken, such as resolution beyond the diffraction limit, super-lensing and related phenomena, as well as subwavelength control of optical fields. It is also timely to look at the quantum optics of such processes as well as Casimir-Polder forces near the surfaces of optical metamaterials. Proposals for new areas involving discrete symmetries, such as parity-time symmetry will be considered. A related area is non-Hermitian optics and supersymmetric optics, where these concepts are utilized to fabricate photonic structures with novel properties and sensors with precision beyond the state of the art. Other descriptions of light that lead to new capabilities are sought. In general, any phenomena arising from optical metamaterials that would benefit the Soldier and improve Army capabilities will be considered.

Extreme Light. his thrust focuses on extreme light, meaning the examination of optical fields in the extreme limits, such as the shortest pulses and the highest intensities. General areas of study under this thrust include light filamentation, particle beam acceleration and relativistic physics. In addition, application-based studies of directed energy, THz formation, broadband localized radiation, coherent control of atomic and molecular energy states, plasma effects in materials, and relativistic plasma physics are of interest. Theoretical and experimental research efforts are needed to push beyond the state of the art in ultra-short pulse, high energy laser science and to understand how extreme light propagates and interacts with matter.

TPOC: Dr. James A Joseph, james.a.joseph30.civ@army.mil, (919) 549-4213

iii. Life Sciences

The Life Sciences Branch supports basic research to advance scientific knowledge and understanding of the fundamental properties, principles, and processes governing DNA, RNA, proteins, organelles, prokaryotes, and eukaryotes, as well as multi-species communities, biofilms, individual humans, and groups of humans. Research investments are driven by exploiting new scientific opportunities with anticipated long-term payoffs, including maintaining U.S. technological superiority and developing new Army capabilities.

The interests of the Life Sciences Branch are primarily in the following areas: synthetic biology, biochemistry, neuroscience, microbiology, molecular biology, genetics, genomics, proteomics, epigenetics, systems biology, bioinformatics, and behavioral science. The results of fundamental research supported by this Branch are expected to enable the creation of new technologies for improving warfighters' physical and cognitive performance capabilities, for protecting warfighters, to create new human-machine synergistic capabilities for identifying causes of and tipping points for social/political instability, and for creating new Army capabilities in the areas of biomaterials, energy, logistics, forensics and intelligence.

The Branch's research programs are currently focused on five research areas. The titles, scopes, and points of contact for these programs (each of which address general aspects of basic research in life sciences) are listed in the following subsections. A small number of symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Biochemistry

This program emphasizes basic research focused on understanding and controlling the activity and assembly of biomolecules. Scientific advances supported by this program are anticipated to enable the development of novel systems, materials and processes that enhance Soldier protection and performance. Overarching goals of the program are to provide the scientific foundations to expand the chemical diversity accessible by biomolecules and to support biological activity outside of the cellular environment, including integration of biological systems with synthetic systems.

The *Biomolecular Specificity and Regulation* thrust is focused on novel approaches to engineer the specificity and regulation of biomolecules, either via modulation of natural mechanisms or via design of non-natural mechanisms. Approaches to expand the chemical diversity of ligands/substrates that are recognized/accepted by biomolecules and/or the products of biocatalytic reactions beyond elements and chemical bonds common to natural biological systems are of particular interest. This includes both individual enzymatic reactions as well as multi-step biocatalytic pathways. The goal of this thrust is to develop novel engineered approaches to modulate and control biomolecular activity, with emphasis on expanding the chemical diversity accessible by biomolecules and achieving biomolecular control in non-cellular contexts.

The *Biomolecular Assembly and Organization* thrust is focused on understanding the molecular interactions and design rules that govern self-assembly of biomolecules into both naturally occurring biomolecular structures and non-natural human-designed architectures. This thrust aims to elucidate fundamental understanding of sequence-structure-property relationships in natural biomolecular assemblies, biomaterials, and biological composites to enable rational design of biological and hybrid biological/abiological assemblies with tailored properties and functions. Biomolecular assembly across length scales is of interest, including discrete multi-protein complexes or nucleic acid structures, as well as hierarchical protein or nucleic acid assemblies and biological composites. This thrust includes homogeneous assemblies utilizing a single building block, as well as heterogeneous systems in which a mixture of different biomolecules and/or non-biological species (e.g., minerals, synthetic polymers) self-assemble. Of particular interest are approaches to expand the chemical diversity of biomolecular architectures beyond elements and chemical bonds common to natural biological systems. This research thrust also includes the design of self-assembled biomolecular or hybrid biological/abiological architectures that provide control over the chemical environment and spatial organization necessary to support complex biomolecular function in non-cellular contexts, including artificial cells and cell-free systems.

TPOC: Dr. Stephanie McElhinny, stephanie.a.mcelhinny.civ@army.mil , (919) 549-4240

(2) Genetics

This program supports fundamental basic research in genetics, molecular biology, genomics, epigenetics, and systems biology in areas that are anticipated to enable improved cognitive and physical performance capabilities, increased survivability, and new Army capabilities in areas such as biomaterials, sensing, energy, and intelligence. This program emphasizes innovative high-risk fundamental research in areas such as identification and characterization of genetic variation, gene function, gene regulation, genetic interactions, gene pathways, gene expression patterns, epigenetics, mitochondrial regulation and biogenesis, and nuclear and mitochondrial DNA Stability and instability.

The *Eukaryotic Genetics, Genomics, Epigenetics and Molecular Biology* thrust is focused on identifying and characterizing genes, genetic pathways and genetic regulation in small and large eukaryotes. This program is interested in identifying and understanding the molecular factors and genetic polymorphisms that affect human physical and cognitive performance capabilities as well as human survival and protection under normal conditions and when affected by a variety of stressors likely to be encountered in battlefield situations, such as dehydration, heat, cold, sleep deprivation, fatigue, caloric insufficiency, pathogens, and physical and psychological stress. This program also supports pollen identification and species distribution models, mitochondrial regulation, activity and integrity, nuclear and mitochondrial DNA stability and instability, alternative animal systems, social insects, biological components of social instability, trust, plant genetics, synthetic biology, endosymbionts, and biological

autonomous systems for sensing and detecting.

The *Prokaryotic Genetics, Genomics, Epigenetics and Molecular Biology* thrust is focused on understanding prokaryotic genes, genomes, molecular biology epigenetics and genetic variation. Areas of interest include mechanisms of prokaryotic adaptation at a molecular, individual and population level, prokaryotic genetic stability and instability, and synthetic biology.

TPOC: Dr. Micheline Strand, micheline.k.strand.civ@army.mil, (919) 549-4343

(3) Microbiology

This program supports basic research in fundamental microbiology that can help advance needs in Soldier protection and performance. There are two primary research thrusts within this program: (i) *Prokaryotic Survival Mechanisms in Challenging and Extreme Environments* and (ii) *Analysis and Engineering of Microbial Communities*.

The *Prokaryotic Survival Mechanisms in Challenging and Extreme Environments* thrust focuses on the study of the cellular and genetic mechanisms and responses that underlie not just microbial survival in the face of environmental stress, but also the ability of specific microbes to thrive under those conditions. These stressors include extremes in temperature, pH, or salinity; the presence of toxins including metals and toxic organic molecules; oxidative stress; and cellular starvation and the depletion of specific nutrients. Included here is the study of microbial metabolism under conditions of slow growth and the transitions into and out of slow growth phases. Research approaches can include fundamental studies of microbial physiology and metabolism, cell biology, and molecular genetics that examine key cellular networks linked to survival and environmental adaptation, microbial cell membrane structure and the dissection of relevant critical signal transduction pathways and other sense-and-respond mechanisms.

The *Analysis and Engineering of Microbial Communities* thrust supports basic research that addresses the fundamental principles that drive the formation, proliferation, sustenance and robustness of microbial communities through reductionist, systems-level, ecological and evolutionary approaches. Bottom-up analysis of nutrient consumption, information exchange, signaling interactions, spatial/temporal effects structure-function relationships and biosynthetic output for single and multi-species communities within the context of planktonic and both native and engineered biofilm architectures is considered. The use of these approaches for the analysis of model microbial systems that address the biology of the mammalian microbiome are welcome. Of joint interest with the ARO Biomathematics Program, research efforts that advance the ability to work with complex biological data sets to increase understanding of microbiological systems marked by ever-increasing complexity are encouraged.

TPOC: Dr. Robert Kokoska, robert.j.kokoska2.civ@army.mil, (919) 549-4342

(4) Neurophysiology of Cognition

The Neurophysiology of Cognition program supports non-medically oriented basic research in neuroscience, the behavioral sciences, physiology and neuroengineering that might enable the optimization of Soldier's cognitive and physical performance capabilities. An overarching goal of the program is to provide foundational knowledge of molecular, cellular and systems-level neural codes underlying cognition and performance across multiple length and time scales. Research in this program can include a broad range of methodological and theoretical approaches applied to animal and human experimental systems including electrophysiology, neuroimaging and computational neurobiology. This includes the study of the psycho-physiological implications of brain-machine interfaces, the measurement and modeling of individual cognitive dynamics and decision making during real-world activity, and identifying how neuronal circuits generate desirable computations. In the long term, research in this area may enable the development of interfaces enabling humans to more efficiently control machines, new training methods and devices to predict and optimize individual performance, and the potential restoration from injury at the neural level. Basic research opportunities are sought in two primary research thrusts within this program: (i) *Multisensory Synthesis* and (ii) *Neuronal Computation*.

Multisensory Synthesis. The Multisensory Synthesis thrust aims to understand how the human brain functions in relation to the interaction of sensory, cognitive and motor processes during its performance of real-world tasks. Research focuses on mapping, quantifying and modeling distributed neural processes, physiological processes and mind-body interfaces that mediate these features to ultimately develop better understanding of cognition for eventual application to Soldier performance.

Neuronal Computation. The Neuronal Computation thrust is focused on understanding how living neuronal circuits generate desirable computations, affect how information is represented, show robustness to damage, incorporate learning and facilitate evolutionary change. Research focuses on determining how brains structure, process and refine inputs into efficient decisions and behaviors, and how these multiscale features are altered under stresses. Cell culture, brain slice and *in vivo* models are used to develop better understanding of small and large-scale living neural networks for eventual application in Army systems.

TPOC: Dr. Frederick Gregory, frederick.d.gregory5.civ@army.mil, +44 (0)1895-626517

(5) Behavioral Science

The goal of this program is to promote basic research on social behavior to discover the theoretical foundations of social behavior at all levels, from single agents to collectives and global societies, with an emphasis on the perspective that humans are a part of complex systems, including other humans, natural environments, and physical environments (including human-built infrastructures and technologies).). The thrusts of this program are (1) discovering new signals of social dynamics and models that represent those dynamics; (2) modeling social structural vulnerabilities to non-kinetic

threats; and (3) generating new cross-cultural models of the impact of social institutions on the scientific enterprise.

Signals of Social Dynamics. While social systems are comprised of individual agents, individual behaviors, dispositions, perceptions, and states cannot be summed to accurately depict or predict collective states and dynamics. Collective processes (e.g., polarization, evaluation apprehension, risky-shift, information transfer biases, inter- and intra-group dominance, and social risk) lead to system-wide adjustments and outcomes, such as shifts from peaceful protest to violence, emergence of influential factions in a society, and fragmentation of regimes. Methods to detect these processes, however, are often fraught with bias, relying on subjective self-reports, reliance on instruments that are not cross-culturally consistent, observer/experimenter bias, demand effects in experiments, and non-representative sampling frames. Also, traditional methods of modeling social dynamics are often deficient -- using statistical techniques that rely on assumptions that are not borne out in the social phenomena being studied (e.g., assumptions of linear relationships, continuous change, non-independence of observations, normally distributed data). The aim of this thrust is to inform and advance social science theories by developing and validating signals of social dynamics to objectively capture collective processes at group-to-population levels. It also seeks new methods that capture how signals from different sources at different levels of granularity can be integrated to model social dynamics within and among collectives. The thrust looks favorably on the use of emerging technologies in biophysiological and geophysical signaling. It also encourages non-traditional modeling strategies that overcome deficiencies of using continuous linear models and normal distributions when social phenomena are not continuous, linear, or normally distributed. This thrust will enable new capabilities for the Army to more accurately predict risks posed by social groups at different scales, as well as provide a foundation for understanding the basis for improving performance in and outcomes of collectives and populations.

Social Structural Vulnerabilities. Security threats arise not only from electromagnetic and kinetic spheres of operations; increasingly they arise from non-kinetic attacks, including malevolent mis-/dis-information campaigns, intellectual property theft, manipulation of financial markets, and infiltration of governance processes at both domestic and global levels. Preventing these non-kinetic risks is increasingly important to Army overmatch in multi-domain operations. Non-kinetic attacks pose the risk of rapidly de-stabilizing groups and entire societies for extended time periods, if not permanently. Understanding the interdependencies among humans and complex systems requires investigating their role and impact on them in several types of systems. Characteristics of social systems (e.g., governance, economic, educational systems), interdependence among systems, and robustness of systems may offer advantages over adversaries, but also pose risks. Also, the susceptibility of these social systems to naturally occurring disruptions (e.g., floods, droughts) can create far-reaching instabilities. Furthermore, human social systems are increasingly integrated with complex physical systems (i.e., human-built systems like dense urban environments, cyber systems, utility and transportation infrastructures, and emerging artificial intelligence-based technologies), and while this interdependency may afford

technological advantages, it may also exacerbate or mitigate such risks. To date, there are currently no social science theories or models that capture the interactions of these factors and systems and risks to social stability. Research is needed to develop models that capture these risks and identify vulnerabilities in complex interdependent systems that can undermine both domestic and global stability, as well as factors that may contribute to more secure systems.

Modeling the Scientific Enterprise. Science is an inherently social activity and while recent research has explored the social networks of science (e.g., who publishes with whom, who mentors whom) and the demographics of actors in those networks, there is very little rigorous research on the overall enterprise of science and the impact of social institutions, like economic, political, educational, and religious systems on the trajectory of science: what leads to a discovery; how do discoveries transition to application; why do some discoveries lie dormant for decades before an application is realized, while others are almost immediately translated to application. Taxonomies related to science have been developed for example to describe (a) categories of science (e.g., Pasteur's Quadrant), (b) relations between funding and scientific activities in the research and development pathway (e.g., 6.1 – 6.7), (c) pathways from basic science to obsolescence (e.g., "cradle-to-grave"), (d) types of research strategies (e.g., "exploration vs. exploitation"),and (e) changing states of discoveries (e.g., "Sleeping Beauty Effect"). But these are merely systems of categorization and fail to capture the dynamic and socially embedded nature of science that leads to scientific discovery and leads scientific discovery to transition from one state to another. There is a long history in the philosophy of science that does recognize the social dynamics of science, but has yet to be operationalized. Organizational science has developed case studies of organizations that rapidly generate discoveries and transition them to swiftly seize market dominance. While rich in description, case studies fall short of a generalizable theory of the scientific enterprise. The aim of this thrust is to pursue new models that capture the socially embedded dynamic nature of science by focusing on science not as only a local team-driven or organizationally specific phenomena, but also investigate science as a macro institutionally motivated enterprise. A macro perspective on science will provide new insights on factors that enable both discovery and inventions that improve lives and capabilities. This thrust encourages formal modeling strategies using cross-cultural data to depict the impact of culturally unique configurations of social processes and institutions that affect science, discovery, and transitions. Success in this thrust will result in new insights on how social institutions catalyze and impede science.

TPOC: Dr. Lisa Troyer, lisa.l.troyer.civ@army.mil, (919) 549-4230

b. Engineering Sciences

Research in the Engineering Sciences is focused on basic research to discover, understand, and exploit new material systems, mechanical systems, electronics, and earth sciences that are expected to create revolutionary capabilities for the Army. Discoveries in this area are expected to lead to capabilities in materials, the sciences for propulsion, the information

domain, the ballistics sciences, the protection sciences, and human sciences augmentation, well beyond the limits facing today's Army.

i. Mechanical Sciences

The Mechanical Sciences Branch supports research in a broad spectrum of fundamental investigations in the disciplines of fluid dynamics, solid mechanics, and complex dynamics and systems. 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, complex dynamics and systems, 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 complex dynamics and systems area is focused on investigations in vehicle structural dynamics, and simulation and air vehicle dynamics including rotor aeromechanics. The following narratives describe the details of the scope and emphasis in each of these sub disciplinary areas.

The Branch's research programs are currently focused on four research areas. The titles, scopes and points of contact for these programs, each of which address general aspects of basic research in mechanical sciences, are listed in the following subsections. Symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Fluid Dynamics

Fluid dynamics plays a critical role in many Army operational capabilities. Accurate and efficient prediction of the flow physics required for the design of future advanced capabilities and improvements to the performance of existing systems is challenged by the nonlinear and high-dimensional character of the governing equations. In addition, Army relevant platforms are often dominated by flows with high degrees of unsteadiness, turbulence, multiple and widely separated spatio-temporal scales, and geometrical complexity of solid or flexible boundaries.

In light of these difficulties, the Fluid Dynamics program seeks to support basic research investigations of fundamental and novel flow physics to gain the necessary physical insights underpinning future concepts and capabilities spanning Army vehicles, munitions, manufacturing, and logistics.

The program is divided roughly into three areas of interest.

Dynamics of Unsteady and Separated Flows.
Efforts in this research area require novel and aggressive strategies for examination of the interplay between disparate spatio-temporal scales, the inclusion of physically significant sources of three dimensionality, and the characterization of the role of flow instabilities and nonlinear interactions across a range of Mach and Reynolds numbers appropriate to Army aerial vehicle and weapons systems. In all cases, the flow is characterized by a high degree of unsteadiness. Criteria for identifying the signature of unsteady separation and/or incipient separation are of particular interest. Historical management of complexity has often resulted in scientific approaches that lead to the elimination of potentially critical flow physics. Research efforts capable of gaining deep understanding of highly complicated flows are likely to allow these critical physics to be exploited. As an example, shortcomings in understanding the details of unsteady flow separation, reverse flow phenomena, and dynamic stall continue to limit the capabilities of Army rotorcraft vehicle platforms. While much progress has been made towards unraveling these details, it is apparent that revolutionary advances are impossible if physical complexity is oversimplified.

Nonlinear Flow Interactions and Turbulence
As mentioned above, many Army relevant flows are governed by strong nonlinearities and turbulent behaviors. Historically, many analysis tools developed for linear dynamics have been applied to gain understanding of flow behaviors. The practical usefulness of such techniques has saturated; the ability to gain global understanding of the evolution of flows requires the development and use of approaches that are capable of dealing directly with inherent nonlinearities. Operator theoretic methods are making great strides in tackling the perennial difficulties associated with the Navier-Stokes equations. Turbulent dynamics are also benefitting from new approaches based in dynamical systems theory to build frameworks beyond the notions based on Reynolds averaging and stochastic dynamics. By leveraging the existence of underlying deterministic structures, significant advances in the ability to design systems capable of not just dealing with turbulence but exploiting its dynamics. Modeling flows near walls is a continuing challenge to accurate numerical prediction of complex physics that may benefit from novel non-intrusive diagnostics to inform creative numerical and theoretical constructs capable of efficiently producing a high degree of fidelity near physical boundaries.

Dynamics of Particle-Laden Flows.
Understanding the dynamics and control of particle-laden flows has the potential to permit flow-assisted assembly of heterogeneous materials and address the role of dust, sand, and other particulates in degraded performance of Army systems. Accurate prediction and description of the interactional physics of particle-fluid, particle-particle, and particle-boundary interactions represents an exciting opportunity to contribute to the creation of next-generation materials and capabilities. Use of a variety of mechanisms, including (but not limited to) electro-kinetics, diffuseophoretics, or selective permeability, should allow the identification of fundamental mechanisms related to the dynamics and control of such multi-phase flows. Research focused on atmospheric

particle-laden flows are of lesser interest, but may be related to the Earth Materials and Processes program and could be eligible for cross-discipline support.

In addition to the above areas, revolutionary advances in fluid dynamics research tools are also of great interest; advanced experimental methods, sophisticated computational techniques, and breakthrough theoretical advances will be critical for gaining the required fundamental understanding in all of the above areas.

TPOC: Dr. Matthew J. Munson, matthew.j.munson6.civ@army.mil, (919) 549-4284

(2) Solid Mechanics

The Solid Mechanics Program supports investigations of the behavior of material systems under extreme high loading and loading rate events, such as impact and blast, repetitive loading, temperature and pressure extremes, and prolonged operation. Development of new computational and experimental techniques and enhanced understanding of the physical processes taking place during deformation, fracture initiation, and failure are sought.

Advances in computational techniques should aim to connect phenomena occurring at different spatial and/or temporal scales, substantially improve efficiency and/or accuracy of predictions, integrate new physical relationships, apply a novel approach to studying a physical process, or expand the range of conditions at which processes can be studied. Development of experimental methods that can validate new models or visualize stress fields in complex situations are also of interest.

Maximizing strength and damage tolerance while minimizing weight and cost are key considerations for the development of new material systems; therefore, studies of all material types will be considered, and novel composites, geometries, and bioinspired structures are particularly encouraged. The effects of structure, geometry, composition, defects, and bonding across interfaces on the damage propagation across a material system are of interest.

TPOC: Dr. Denise C. Ford, denise.c.ford2.civ@army.mil, (919) 549-4244

(3) Complex Dynamics and Systems

The Complex Dynamics and Systems program emphasizes fundamental understanding of the dynamics, both physical and information theoretic, of nonlinear and nonconservative systems as well as innovative scientific approaches for engineering and exploiting nonlinear and nonequilibrium physical and information theoretic dynamics for a broad range of future capabilities (e.g. novel energetic and entropic transduction, agile motion, and force generation). The program seeks to understand how information, momentum, energy, and entropy is directed, flows, and transforms in nonlinear systems

due to interactions with the system's surroundings or within the system itself. Research efforts are not solely limited to descriptive understanding, however. Central to the mission of the program is the additional emphasis on pushing beyond descriptive understanding toward engineering and exploiting time-varying interactions, fluctuations, inertial dynamics, phase space structures, modal interplay and other nonlinearity in novel ways to enable the generation of useful work, agile motion, and engineered energetic and entropic transformations. Further information on the current scientific thrust areas are detailed in the paragraphs that follow.

High-Dimensional Nonlinear Dynamics. Classical dynamics has produced limited fundamental insight and theoretical methods concerning strongly nonlinear, high-dimensional, dissipative, and time-varying systems. For over a century, qualitative geometric approaches in low-dimensions have dominated research in dynamics. These approaches of reduced-order-modeling of high-dimensional dynamics are often premised on empirical and statistical model fitting and are incapable of capturing the effects of slowly growing instabilities and memory. The program seeks to develop novel theoretical and experimental methods for understanding the physical and information dynamics of driven dissipative continuous systems. It also seeks novel reduced-order-modeling methodologies capable of retaining time-dependent and global nonlinearities. Novel research pertaining to the analysis and fundamental physics of time-varying nonlinear systems and transient dynamics is a high-priority.

Nonlinear Mechanical Metastructures. Another emerging area in this thrust concerns nonlinear mechanical metastructures. Emphasis is on exploiting nonlinear behavior within nonlinear mechanical lattices and lattices of nonlinear mechanical modules from the millimeter to meter scale. Proposals exploring interactions between nonlinear meta-structures with fluids, especially if such interactions augment desired dynamic behavior, are strongly encouraged.

Embodied and Distributed Control, Sensing, and Actuation. This thrust develops deeper understanding, through supporting theory and experiment, of the role of embodiment and dynamics on a physical system's capability to process information and transform energy. Proposals emphasizing the mechanics and control of soft, continuous bodies are encouraged along with novel experimental paradigms leveraging programmable printed matter. Generally, this thrust strongly leverages advances in, and approaches from, sensory biomechanics, neuromechanics, underactuated systems theory, and mechanical locomotion dynamics to understand the motion of both articulated and continuum dynamical systems operating in highly-dynamic environments. The scientific principles sought, however, are not limited to biological movement and manipulation. Proposals are strongly encouraged that view morphology in an abstract sense. For example, understanding morphology as a system's symmetry, its confinement (e.g. chemical reactions), or its coupling topology.

Statistical Physics of Control and Learning. The program seeks to lay the foundations for an algorithmic theory of control and learning that goes significantly beyond the state-of-the-art in model predictive control and integrates novel learning methodologies that

are not mere variations of artificial neural networks and deep learning. Additional goals of this program is to develop an experimentally tested theoretical framework for controlling and creating new types of critical dynamics, phase transitions, and universality classes by bringing together theory and physical principles in statistical dynamics with control and dynamical systems theory (controlling statistical dynamics). Topics of interest relating to this include: nonlinear control of distributions with non-Gaussian uncertainty; non-Gaussian uncertainty representations; understanding relationships between work absorption and dynamics in the presence of fluctuations leading to emergent prediction and emergent centralization; steering multi-critical interacting dynamical systems toward desired universal scaling behaviors; externally controlling the strength of stochastic fluctuations and intrinsic noise in systems that are driven far from thermal equilibrium and display generic scale invariance; and selectively targeting and stabilizing specific self-generated spatio-temporal patterns in strongly fluctuating reaction-diffusion systems. Stochastic control at the microscale to enable novel manipulation of the dynamics of synthetic and natural biomolecular machines is also of interest.

TPOC: Dean R. Culver, dean.r.culver.civ@army.mil

(4) Propulsion and Energetics

The Propulsion and Energetics program is no longer accepting new white papers or proposals.

TPOC: Dr. Ralph A. Anthenien, ralph.a.anthenien2.civ@army.mil, (919) 549-4317

(5) Earth Materials and Processes

The Earth Materials and Processes program seeks to enable maneuver, communication and situational awareness in all terrain through understanding and prediction of the physical and mechanical properties and behaviors of rocks, soil, and man-made earth surfaces and their interactions with their surrounding environment.

The Program supports research addressing the following questions:

How can earth surface interaction with air and water be predicted at Warfighter-relevant spatio-temporal scales (microns to 100s of kilometers)? Of special interest is the built environment, as related to how natural and artificial surfaces (e.g., soil, sand, or concrete) store and conduct energy depending on their spatial relationships, inherent material properties, and imparted features such as moisture storage and evapotranspiration, and to determine how these surfaces affect flows in complex terrain. Research focused on atmospheric flows may be coordinated with the Fluid Dynamics program and could be eligible for cross-discipline support.

How is information (e.g., seismic, acoustic, or radio frequency) transmitted in challenging environments? Of special interest are urban, high-latitude, high-altitude,

and forested environments. Access to new field areas and high-resolution data collection and modeling provide opportunities to differentiate sources and characterize terrain.

TPOC: Dr. Julia Barzyk, julia.g.barzyk.civ@army.mil, (919) 549-4379

ii. Electronics

The Electronics Branch 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 Branch is concerned with generating basic knowledge about processes, mechanisms and device-level phenomena. The Electronic research sub-areas are (1) Biotronics, (2) Optoelectronics, (3) Electronic Sensing, (4) Solid State Electronics and Electromagnetics, and (5) Solid State Physics. The titles, scopes and points of contact for these programs, each of which address general aspects of basic research in electronics, are listed in the following subsections. Proposals are sought that advance fundamental understanding of electronic and photonic processes leading to new or improved devices with a strong prospect for exploitation in future Army technology. Symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Biotronics

This research area focuses on the discovery and manipulation of phenomena and the creation of new processes where electronics and biology overlap at the cellular / sub-cellular level. This length scale is where the amplitudes of many types of energies (e.g., electrostatic, mechanical, and chemical terms) converge, and correspondingly, where electronics can have fundamental biological impacts and where leveraging electronics capabilities at the nanoscale can yield unique new understanding of the cellular and intracellular processes. New electronic structures and materials are now able to focus localized static electric and magnetic fields and electromagnetic fields at the nanoscale, which presents the opportunity to selectively address and manipulate the organelles and membranes making up the structure of the cell. Moreover, cell constituents can have a frequency dependent response to mechanical and electromagnetic excitation, resulting in unique electronically enabled and controlled biological experiments. Molecular and subcellular events at the biological interfaces or surfaces are key to downstream biological dynamics. The stimulation or manipulation of these events by electronic means provides the opportunity for unique control and experimentation that are orthogonal to existing biochemical or genetic approaches. Ion flow, which is fundamental to inter- and intra-cellular signaling and process control, is susceptible to electromagnetic influence and produces electromagnetic signatures of cellular processes. The dynamics of charged and polarized cellular components also produces minute displacement currents, and can produce very large field distributions in a confined nanoscale space (e.g., within a protein scaffold or across a lipid bilayer); both of which are subject to electromagnetic probing and analysis. The different geometries of organelles within a cell result in different electromagnetic signatures and sensitivities which can be leveraged for selective control of cellular processes. Proteins play a role in

almost every cellular process. As extremely large and complex molecules, they should have electromagnetic and mechanical responses that can be exploited for control. The skeletal protein assemblies of the cell, in particular, may offer a highway for the introduction of electrical currents or mechanical vibrations. Bio-chemical or genetic alteration of the interface of the cell and its components can introduce new electromagnetic properties, for example a new capability for photosynthesis in bacteria or new electromagnetic responses. Cellular engineering of membranes, cellular organelles, and proteins by the introduction of nano-particles and bio-molecules can introduce new sensitivities and new functionality. Opto-genetics is a well-established procedure for interrogating cells. Early attempts at "magneto-genetics" have been controversial, however "electro- or RF-genetics" may offer new opportunities. There may also be inherently non-trivial quantum mechanical mechanisms linked to biological behaviors, such as navigation. Inherently quantum phenomena such as the tunneling of electrons and protons play a critical role in many intracellular processes and can be modulated or manipulated with nanoscale electric fields. This research area seeks understanding and control of inter- and intra-cellular phenomena at the micro- and nano-scale.

TPOC: Dr. Albena Ivanisevic, albena.ivanisevic.civ@army.mil, (919) 549-4314

(2) Optoelectronics

Research in this subarea includes novel semiconductor structures, processing techniques, and integrated optical components. The generation, guidance and control of UV through infrared signals in semiconductor, dielectric, and metallic 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, infrared countermeasures, and free space/integrated data links. Components and sources in the UV/visible spectral ranges (particularly < 300 nm) may be of interest as well. Research is necessary in semiconductor materials growth and device processing to improve the efficiency and reliability of the output of devices at these wavelengths.

Research that leads to an increase in the data rate of optoelectronic structures is sought. 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 high-speed optical signal processing as well as potential for power scaling, research on individual and 1 or 2-D arrays of surface or edge-emitting lasers is necessary. Research addressing efficient, novel optical components for high speed switching based on plasmonics, quantum dots, metamaterials or other regimes may be of interest. Emitters and architectures for novel display and processing of battlefield imagery are important.

Recent advances in neuromorphic photonic information processing (neurophotonics for short) and computation are highlighted a thrust of interest. Neurophotonic processing within a photonic IC (PIC) requires smaller and more energy efficient modulator devices on the order of 5 microns or less and 1 femtojoule/bit. Speeds of modulation should be several Gb/s or higher, and the insertion loss should be < 0.1 dB to achieve cascaded modulators of < 1 dB/cm. Modulation at 16 bit or higher resolution will be required for neurophotonic processor implementations. Other advances leading to enhanced neurophotonic regimes including energy efficient and high-speed photodetectors and light sources (most likely coherent) are sought. Exploration of ideas leading to enhanced performance in both 2D and 3D architectures that take advantage of bosonic properties of light (over the limited fermionic charge) will be considered. While single photon, quantum communications and quantum integrated photonics are not focused upon here, low photon (<100) count signals can be considered. Such research could impact single photon regime work with overlap due to similar quantum optics considerations.

TPOC: Dr. Michael Gerhold, michael.d.gerhold.civ@army.mil, (919) 549-4357

(3) Electronic Sensing

This program focuses on basic research investigations leading to new electronic sensing concepts that enable 100% situational awareness to include day/night, all weather, non-line-of-sight and through natural and man-made obstructions for sensing of personnel, weapons, chemical and biological threats, projectiles, explosives, landmines, improvised explosive devices and motion. Novel techniques that enhance the stimulus-response characteristics of nano-structures and semiconductor devices and explore the trade-offs between sensing and cooling are of interest. This includes ways to improve the absorption of the signal, conversion (transduction) of the signal to another form with higher efficiency, and techniques to lower the noise while increasing the detector sensitivity. Sensing modalities of interest to this research sub-area currently include acoustic; seismic; passive electromagnetic; magnetic, and light-matter interactions. Other modalities that meet an Army needs for light, tunable and flexible sensors are also welcome.

The ES program supports research focused on device engineering and associated materials development, including experimental and computational studies that design, create, and understand novel materials functionalities and device operation principles through advances in the fields of electronics, photonics, photoacoustics and piezo-phototronics to enhance or enable new detection capabilities in both infrared and deep ultra-violet spectral regions. In both regions, fundamental studies involving growth, defects, interfaces, substrates, doping, and other material properties and device characteristics will be considered. Beyond the current detection paradigms, new artificially engineered nanomaterials, metamaterials and metasurfaces, microcavity and 2D stacked or twisted heterostructures in conjunction with photonics are sought to address current limitations and open new opportunities.

TPOC: Dr. Tania Paskova, tania.m.paskova.civ@army.mil, (919) 549-4334

(4) Solid State Electronics and Electromagnetics

This research area emphasizes efforts to discover and create unique electromagnetic phenomena in solid-state materials and structures. Innovative research is sought in areas involving quantum phenomena, internally and externally induced stimulus, and novel transport and electromagnetic interaction effects in solid-state electronic structures. This basic research will address issues related to design, modeling, fabrication, testing and characterization to include the ability to individually address, control, and modify structures, materials and devices, and the assembly of such structures with atomic-scale control into systems. It will seek to realize advanced device concepts with revolutionary capabilities.

This program will explore the latest developments in semiconductor materials and device physics, such as negative capacitance transistors, tunneling field effect transistors and ultra-wide bandgap materials. More importantly, it will emphasize scientific discoveries in the frontier of nanoelectronic materials and structures. Scientific opportunities in this research include, but are not limited to, quantum-confined structures (nano-tubes/-wires/-dots) and large- scale precise alignment and integration of these structures to create collective behaviors; 2D atomic crystals and their heterostructures; complex heterostructures of 2D crystals, topological insulators, Dirac and Wely semimetals and other dissimilar nanoelectronic materials potentially leading to unique interfacial phenomena; spintronic, valleytronic, and mixed domain (charge/spin/quantum degrees of freedom) device concepts. Of interest are quantum transport phenomena such as ballistic transport and hydrodynamic flow, dissipationless transport in topologically protected edge states, and pseudo-relativistic transport of massless Dirac fermions. Exotic electromagnetic phenomena which require theoretical formulations beyond the well-established Maxwell's equations, such as axion electrodynamics, chiral anomaly and spontaneous symmetry breaking, are also relevant. Interfacial proximity effects in these heterostructures that lead to unique electromagnetic properties will also be considered.

TPOC: Dr. Joe Qiu, joe.x.qiu.civ@army.mil, (919) 549-4297

(5) Solid State Physics (SSP)

The SSP Program strives to drive research that looks beyond the current understanding of natural and designed condensed matter, to lay a foundation for revolutionary electronic device concepts for future generations of warfighters.

Strong Correlations and Novel Quantum Phases of Matter. Understanding, predicting, and experimentally demonstrating novel phases of matter in strongly correlated solid state materials will lay a foundation for new technology paradigms for applications ranging from information processing to sensing to novel functional materials. Interest primarily involves strong correlations of electrons, but those of other particles or excitations are not excluded. This thrust also emphasizes dynamically-stabilized

electronic states and metastable phases of materials that are not adiabatically accessible from known ground states. Also of interest are interactions between materials and engineered fluctuations of the vacuum. The program seeks to foster novel experimental and theoretical research targeting the discovery and rational design of new quantum phases of matter in the solid state, along with exploring how excitations within these phases can be probed and controlled.

Topologically Non-Trivial Phases in Condensed Matter. Topologically non-trivial states of matter in solid state materials beyond the quantum Hall phases have shown a remarkable opportunity to advance our understanding of physics and provide a foundation for novel device concepts. This thrust emphasizes the interaction between magnetic order and topological states. A deeper understanding of these interactions is necessary to determine if meaningful device concepts can be built upont them. The thrust is also broadly interested in the discovery and engineering of new non-trivial phases, verification of non-trivial topologies and phase transitions between trivial and non-trivial topological states.

Unique Instrumentation Development. Advanced studies of SSP phenomena often require unique experimental techniques with tools that are not readily available.. The construction and demonstration of new methods for probing and controlling unique quantum phenomena in solid state materials is of particular interest.

TPOC: Dr. Marc Ulrich, marc.d.ulrich.civ@army.mil, (919) 549-4319

iii. Materials Science

The Materials Science Branch of the ARO seeks to realize unprecedented material properties by embracing long-term, high risk, high-payoff opportunities for the U.S. Army with special emphasis on: Materials Design, Mechanical Behavior of Materials, Physical Properties of Materials, and Synthesis and Processing of Materials. Research supported by the Branch seeks 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. Fundamental research that lays the foundation for the design and manufacture of multi-component and complex materials is of particular interest. Foundational research that integrates novel experimental work with the development of new predictive materials theory is also of significant interest. Furthermore, there is lasting interest in new ideas and cross-disciplinary concepts in materials science that may have future applications for the Army.

The Branch's research programs are currently focused on four research areas. The titles, scopes and points of contact for these programs, each of which address general aspects of basic research in materials science, are listed in the following subsections. Symposia, conferences

and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Materials Design

The overarching goal of the Materials Design program is to establish new smart materials concepts by pursuing fundamental science that exploits multiple physical and chemical forces at play during directed self-assembly to create stimuli-responsive, multifunctional materials with designer geometries, hierarchical complexity, and the ability to dynamically switch among configurations, thereby enabling the future Warfighter to adapt to any environment or situation. Bottom-up materials science, functional materials, and soft materials are the unifying themes of the Materials Design program. The program supports experimental, theoretical, and computational advances to better design, create, understand, and manipulate novel functional materials from the bottom up. The foundations established here support the realization of 3D metamaterials, reconfigurable optics and electronics, bio-mimetic materials, and multi-functional materials that dynamically respond to their environment.

The Science of Self-Assembly supports basic research into the multiple physical and chemical forces at play during directed, bottom-up 3-D assembly into super-structures incorporating multiple components. The goal is to design novel self-assembled materials that would be impossible to create using top-down techniques. Self-assembling materials systems of interest include: polymers; colloids; nanocrystals; liquid crystals; functional biomaterials; and/or hybrids of these materials. Emerging research foci include: non-equilibrium and dissipative self-assembly; one-pot self-assembly and self-replicating materials; non-traditional assembly directing forces (e.g., turbulence); and in situ reinforcement learning or evolutionary algorithms to direct assembly towards desired targets.

Reconfigurable and Hierarchical Materials supports the design and synthesis of materials capable of reversible transformations, as well as hierarchically structured materials. The goal is to elucidate the design rules for creating novel functional materials with dynamic property contrast and/or emergent behavior, and develop new methods to "program" materials with the ability to respond in specific ways to external stimuli. Reconfigurable and hierarchical materials systems of interest include: bio-mimetic materials; liquid crystal elastomers; colloidal metamaterials; 3D/4D metamaterials; and active matter. Emerging research foci include: 3D/4D printing of functional materials with molecular-scale precision; materials that form reconfigurable networks; and "natural" (i.e., non-robotic) active matter capable of autonomous collective behavior and/or computation.

Computer-aided Materials Design seeks to leverage recent advances in machine learning, artificial intelligence, computational materials science, and other numerical approaches to solve difficult materials design problems, particularly those in soft matter, self-assembly, and reconfigurable materials. Points of interest include inverse design of self-assembled materials; data-driven design of heterogeneous hierarchical

materials; and novel models or algorithms for solving materials-specific problems. Emerging research foci include: "self-driving" materials simulations; unified simulation approaches that bridge all time- and length-scales of interest; and designing soft materials to perform AI/ML computations (e.g., physical artificial neural networks).

TPOC: Dr. Evan Runnerstrom, evan.l.runnerstrom.civ@army.mil, (919) 549-4259

(2) Mechanical Behavior of Materials

This program focuses on basic research investigations that enable unprecedented mechanical behaviors across a broad spectrum of advanced structural materials in order to ensure high performance under a variety of extreme and highly variable operational conditions. Experimental, theoretical, and numerical efforts are encouraged, particularly those that promote understanding of the underlying physical mechanisms leading to extraordinary behaviors. Studies may focus on a variety of materials, including: metals, ceramics, polymers, composites, and hybrid structures. Research efforts that leverage recent discoveries in other scientific fields, such as Physics, Chemistry, Biology, and Data Science, are also highly encouraged. These investigations are expected to enable transformative capabilities for the Soldier in the areas of protection, movement and maneuver, and sustainability. Current focus areas for this portfolio include, but are not limited to, the following:

Extreme Mechanical Behaviors. This thrust emphasizes novel concepts that enable materials with dramatic improvements in the state-of-the-art for mechanical behaviors, including: energy dissipation, toughness, stiffness, hardness, and resiliency. Areas of interest include new understanding, control, or confinement of deformation mechanisms; exploiting heterogeneous material systems and interface/interphase interactions to enable unprecedented properties while avoiding inherent sub-system weaknesses; and novel approaches for materials to perform in extreme thermomechanical environments. Of particular interest are concepts for exploiting the energy available in extreme mechanical and/or thermomechanical environments to enable materials with extraordinary behaviors.

Active Mechanical Response. This thrust focuses on structural materials that actively respond to dynamic loading environments and other external stimuli through rapid adaptation of shape, topology, and/or mechanical properties. Areas of interest include mitigation or manipulation of stress wave propagation; novel actuation schemes that generate extraordinary forces or that require minimal input energies; and novel material responses initiated through multiaxial loading. Also of interest are concepts for manipulating mechanical forces within materials to lessen or concentrate stress at certain spatial locations, particularly with the consideration of inelastic mechanical behaviors.

TPOC: Dr. Dan Cole, daniel.p.cole.civ@army.mil, (919)-549-4371

(3) Physical Properties of Materials

The Physical Properties of Materials program seeks to discover novel functional materials and elucidate fundamental mechanisms responsible for achieving extraordinary electronic, photonic/optical, magnetic and thermal properties in materials to enable future innovative Army applications. There are mainly two focus areas in this program:

Novel Functional Materials Discovery area supports the discovery of novel functional materials with unique compositions and/or structures to realize unique physical properties. Examples of materials include oxides, nitrides, carbides, chalcogenides, super-lattices, free-standing low dimensional (1D, 2D organic / inorganic) materials, hetero-structures, organic-inorganic hybrids, co-crystals, etc. Basic research ideas in the areas such as synthesis (thin films as well as bulk materials), modeling, novel characterization techniques, and influence of external stimuli etc. to determine unprecedented functional properties (semiconducting, superconducting, ferroelectric/multiferroic, photonic, magnetic, thermal etc.) are encouraged.

Science & Engineering of Crystal Imperfections area explores the influence (either positive or negative) of various crystalline imperfections (e.g. point, line, area, volume defects etc.) on the physical properties (electronic, optical, magnetic, and thermal) in functional materials. Basic research ideas in the areas such as elucidation of different mechanisms of incorporation/elimination of the defects during thin film growth/bulk materials processing of materials, characterization of novel defects, and influence of them on the extraordinary functional properties of the materials etc. are encouraged.

TPOC: Dr. Pani Varanasi, chakrapani.v.varanasi.civ@army.mil, (919) 549-4325

(4) Synthesis and Processing of Materials

The Synthesis and Processing of Materials program seeks to discover and illuminate the governing processing-microstructure-property relationships to enable optimal design and fabrication of nano or micro structural bulk structural materials. Structural materials refers to materials such as metals, ceramics, and composites that in bulk are used in applications that support or transmit mechanical stresses.

Elucidation of Phase Transformations supports research focused on understanding the mechanisms by which materials transition from one state of matter to another in order to enable the creation of new structural materials. Potential research directions include but are not limited to: discovering the kinetic mechanisms governing phase transformations and new means of manipulating them to encourage or impair phase transformations, defining the relationships between properties of the prior phase and the structural properties of the transformed phase, the creation of specific short-range orders in amorphous materials with unique mechanical characteristics, and new routes or methods for synthesizing structural material phases previously accessible only via extreme pressures or temperatures.

Advanced Methods for Structural Materials Processing supports research focused on developing alternatives to conventional methods for the synthesis and processing of structural materials. Potential research should involve exploring new means and forces in order to establish the technical foundation for new processing methods for structural materials, or further exploring the underlying mechanisms of existing advanced manufacturing methods to enhance their capabilities. Examples of directions to potentially be explored include but are not limited to: ultrasonic arrangement, plasma manipulation and interactions, biological precursors, electromagnetic field interactions, and developing consistency in additive manufacturing processes.

TPOC: Dr. Michael P. Bakas, michael.p.bakas.civ@army.mil, (919) 549-4247

c. Information Sciences

Research in the Information Sciences is focused on discovering, understanding, and exploiting the mathematical, computational, and algorithmic foundations that are expected to create revolutionary capabilities for the future Army. Discoveries in this area are expected to lead to capabilities in materials, the information domain, and Soldier performance augmentation, well beyond the limits facing today's Army.

i. Computing Sciences

The principal objective of the ARO Computing Science Branch is to provide increased performance and capability for processing signals and data, and to extract critical information and actionable intelligence to enhance the warfighters' situational awareness, decision making, command and control, and weapons systems performance. The Branch supports research efforts to advance the Army and nation's knowledge and understanding, of the fundamental principles and theories governing intelligent and trusted computing. More specifically, the Branch aims to promote basic research to establish new computing architectures, models for intelligent computing, novel data fusion algorithms, and decision aides to make information available at the right time, at the right place, and at the right granularity to enable both commanders and soldiers to achieve transformational overmatch in the fight against U.S. adversaries. The research topics described in this section of the BAA are those needed to provide the warfighters with the latest information science and technology to achieve the vision of future Army operations.

The Branch's research is currently focused on four research areas. The titles, scopes, and points of contact for these programs, each of which address general aspects of basic research in computing science, are listed in the following subsections. A small number of symposia, conferences, and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Computational Architectures and Visualization

The Computational Architectures and Visualization program is currently not accepting new white papers or proposals.

TPOC: Dr. J. Michael Coyle, joseph.m.coyle14.civ@army.mil, (919) 549-4256

(2) Information Processing & Fusion

With ubiquitous data acquisition capabilities, effective data and information processing is of critical importance to defense missions. The Information Processing and Fusion program is concerned with the creation of innovative theories and algorithms for extracting actionable intelligence from diverse, distributed multimodal data to support Army operations.

Foundations of Image and Multimodal Data Analysis. Innovative research is sought concerning: (1) novel representations of multimodal data to enable the understanding of multimodal sensor data and contextual information, with particular emphasis on data in complex forms such as image or video data; (2) detection, localization, and recognition of objects and locations from image data with particular emphasis on provable performance guarantees; (3) detection of events, actions, and activities to extract activity-based intelligence, especially when no extensive training data is available; and (4) integrated approaches that enable semantic descriptions of objects and events including relations. Learning and adaptation should enable the representation at both low and high-levels, where inputs from actual users of the systems are used to improve the performance of the algorithms and the fidelity of models at all levels of the modeling hierarchy. Also of interest are methods to exploit the structure of the data, capture its intrinsic dimensionality, and extract information content of data. The development of an "information/complexity theory" and a "learning theory" specific for remote sensing, imaging data, and decision tasks is highly desirable.

Data and Information Fusion. Multimodal data acquisition systems are increasingly prevalent with disparate sensors and other information sources. This thrust seeks advanced mathematical theories and approaches for integrating multimodal data and contextual information to provide actionable intelligence. Of particular interest are systematic and unifying approaches for data and information fusion from diverse sources. Scalable methods are needed for efficiently handling vast amounts of data. Fusion in networked environments addressing issues such as adaptive, distributed, and cooperative fusion is emphasized. Theories and principles for performance analysis and guarantees at all fusion levels to support robust data and information fusion are important to ensure successful military operations.

Active and Collaborative Sensing. Modern sensing systems typically include multiple networked sensors with communication capabilities where the whole network can be thought of as a Meta sensor that can be controlled, in addition to each individual node having some controllable degrees of freedom such as mobility for unmanned aerial/ground systems, pan-tilt-zoom for infrastructure sensors, or waveform for agile radar. Depending on the task or query, it is desirable for the system to control the data acquisition process so as to acquire the "most informative data" for the specific task or

query. Consequently, of particular interest are methods that address the integration of mobility, sensor-selection, modality selection, and active observation for real-time assessment and improvements of sensing performance. Another research area of interest is performance-driven active data collection. A query is given to the system together with a desired performance bound. Where the confidence in answering the query is insufficient, the system should actively interrogate or control sensors in order to achieve the desired confidence. Such an active learning and information-driven sensor control should include the Soldier in the feedback loop.

TPOC: Dr. Hamid Krim, hamid.krim.civ@army.mil, (919) 549-44375

(3) Knowledge Systems

The overall objective of the Knowledge Systems 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 which is in line with the DoD's adoption of net-centric warfare, variously defined as flattening the information space to interconnect Soldiers and commanders to provide instantaneous access to information, knowledge, and situational awareness. Given this goal, it becomes necessary to understand (a) fundamentals of what intelligence means in the context of autonomous systems and how to build intelligent systems especially as it relates to interaction amongst a network of humans and machines, and (b) foundational algorithmic issues in representation and reasoning about networks inherent in societies and nature.

Information Networks. In order to model network effects it is necessary to algorithmically represent large networks and reason about them. Unfortunately, information about networks is seldom complete – data available might be missing crucial pieces of information, might have contradictory pieces of information, or could be approximate (with associated notions of uncertainty). Representing and reasoning about these networks requires advances in knowledge representation, graph and data mining, natural language processing, algorithmic graph theory, machine learning, and uncertainty quantification and reasoning. Examples include the emerging area of Graphons which provide new tools for generating and reasoning about graphs that occur in practice (satisfying power law distributions), but also provide new tools for Machine Learning. In particular, a major goal of this thrust are tools and techniques that allow data driven approaches to capturing latent relationships with powers to both explain and predict. Advances in this thrust would not only lead to improved autonomous systems and algorithms, but also enhanced-embedded battlefield intelligence with tools for creating necessary situational awareness, reconnaissance, and decision making. Finally, it should be noted that algorithmic notions of approximations, tight performance bounds, probabilistic guarantees, etc., would be major concerns of the solution space.

Adversarial Reasoning. Development of appropriate mathematical tools to model and reason about societies and cultures, that brings together tools from Game Theory, Social

Sciences and Knowledge Representation. Research of interest includes, but is not limited to, Game Theory for security applications while accounting for bounded rationality, development of Game Theory based on data regarding cultural and adversarial groups, and Behavioral Game Theory that can explain intelligence in groups and societies. In particular, the role of human biases in decision making and game theory is of importance to this thrust of the program.

Natural Language Processing and Affective Computing. Inference algorithms work incredibly well when data is in a structured format. However, most reports, email, and conversations are written out as text with information embedded in them. This thrust seeks advances in purposeful Natural Language Processing at scale that can account for context and mode-switches by bringing together statistical and logical methods. Indeed, when combined with other signals, such as video signals, the inter-play of non-verbal and verbal/ textual communication provides rich contextual information, which, in turn, leads to accurate information being gleaned from an interaction.

Engineering AI Systems. AI systems are insular, brittle, dependent on massive amounts of data, and with no avenues for composition. While notions of type systems, effect systems, assume-guarantee assertions, and procedural and process abstractions are all now available to describe and compose software components, similar notions of modularity are critically needed for building AI systems from small learning-based components. There are examples such as model-cards and data-sheets that are now available, which along with notions of Probabilistic Programming could provide the necessary basis. However, there are a number of problems, especially in the context of Deep Neural Networks, that still need to be addressed. The necessary science required to address AI safety – rigorous specifications for composition, run-time monitoring, self-healing, reasoning, etc., are all of interest to this program.

TPOC: Dr. Purush Iyer, s.p.iyer.civ@army.mil, (919) 549-4204

(4) Advanced Learning Intelligent Cyber Physical Systems

Advanced Learning Intelligent Cyber Physical Systems, including both embodied systems and software agents, play an increasingly important role in civilian and military settings. With few exceptions, current intelligent systems are restricted to highly constrained environments for short duration missions. Future systems will need to perform a variety of tasks in complex, possibly contested, open worlds for extended periods of time. One important characteristic of open worlds is that the intelligent system will encounter new contexts, activities, and objects that will require it to adapt previously trained algorithms. Advanced capabilities in learning, knowledge representation and reasoning, interaction, and assured operations are essential to the development of intelligent systems that can greatly enhance the Army's mobility, agility, lethality, and survivability in future conflicts.

Learning Theory, Methodology, and Techniques. Over the past 50 years, machine learning has made great strides in classification, natural language processing, and task

learning. However, machine learning still lacks the rigor, agility, and flexibility necessary to operate in complex, contested open worlds. This thrust focuses on establishing a theoretical foundation for on-line or continuous machine learning. New learning approaches will need to address both the dimensionality challenges and temporal characteristics that may be evolving continuously. In addition, new techniques must address robustness to enable the learning system to deal with novelty, noise, observation errors, and potentially malicious input that aims to disrupt learning. Innovative approaches to continuous learning will allow systems to adapt to changing contexts and environments while maintaining previously learned knowledge. Under this thrust, we investigate approaches that help the intelligent systems deal with dynamic environments, devise new, transferable skills, and cope with unknown situations. Skill acquisition focuses on developing new theories for learning, creating, and combining low-level skills into more sophisticated behaviors.

Knowledge Representation, Reasoning and Decision Making. Long duration autonomy requires intelligent systems to manage information from different sources, including humans, knowledge bases, and external and on-board sensors. Data collected at different times and locations needs to be fused into a consistent understanding of objects and events in the environment, to support decision making and efficient communication with humans or other entities. Long duration autonomy requires reflecting on past experiences, combining, comparing, and using those experiences in new contexts to make decisions. Innovative research in representation and reasoning will enable future intelligent systems to manage information in both short and long-term memory systems, and develop new information through reflection and learning. Concepts from cognitive science may impact both the representation and storage of information and the ability to quickly retrieve pertinent information. New approaches are needed to combine reasoning with deep learning enabling systems to discover and use relationships between objects and concepts in learning, inference and reasoning tasks.

Interaction. Future autonomous systems must interact physically with humans and other intelligent systems operating in the same space, remotely with spatially distant entities, and virtually in cyberspace with intelligent software agents. New research in human-robot interaction and robot-robot teaming will enable humans and robots to share the same space and work together on complex tasks. Advanced concepts for networks of intelligent agents will enable robots at the tactical edge to draw upon off-board resources such as, software agents, humans, or other robots to solve local problems as well as contribute to a shared knowledge base, and coordinate and collaborate with others for larger problems in dynamic environments. New research in game theory, deception, and other approaches will enable intelligent systems to operate effectively in a contested environment. Future battlefields pose a number of challenges in communications including, limited bandwidth and the availability of secure communication channels. New concepts are needed to build and maintain shared, but possibly distributed, information models for these environments.

Assured Operations. Test, Evaluation, and Verification and Validation for intelligent

systems is a nascent field that needs rigorous theoretical underpinnings and practical tools. Long duration missions require intelligent systems that can operate safely and reliably in an open world environment. Extending techniques from computer science and control theory, such as control barrier functions and model checking, can help ensure safe operations during both learning and execution of mission-related activities, but these techniques by themselves are not sufficient for assured operations. Theoretical advances in architectures, control theory, and introspection are needed to enable systems to adapt to temporary or permanent changes to internal and external conditions in a timely manner. Advances in risk-aware online planning will enable autonomous systems to balance conflicting objectives and operate safely in poorly understood environments.

TPOC: Dr. MaryAnne Fields, mary.a.fields22.civ@army.mil, (919) 549-4350

ii. Mathematical Sciences

The objective of the Mathematical Sciences Branch is to support research to develop a foundational framework for the understanding and modeling of complex nonlinear systems, for stochastic networks and systems, for mechanistic models of adaptive biological systems and networks, and for a variety of partial differential equation (PDE) based phenomena in various media. These research areas focus on discovering nonlinear structures and metrics for modeling and studying complex systems, creating theory for the control of stochastic systems, spatial-temporal statistical inference, data classification and regression analysis, predicting and controlling biology through new hierarchical and adaptive models, enabling new capabilities through new bio-inspired techniques, creating new high-fidelity computational principles for sharp-interface flows, coefficient inverse problems, reduced-order methods, and computational linguistic models.

Research in the Mathematical Sciences Branch will reveal previously unexplored avenues for new Army capabilities while also providing fundamental results to support ARL's (i) Information Sciences Competency goal of image and video sampling and reconstruction through investigations of sparsity in combinations of distributions with unknown parameters; (ii) Computational Sciences Competency goals of stochastic simulation methods, interfaces and evolving topologies, and uncertainty propagation, through investigations of fast separable methods for stochastic PDEs, of novel meshes for both front tracking and domain-fitting, and of weak-interaction processes; (iii) Computational Sciences Competency goals of computational social sciences by establishing a general theory of crisis/change through new mathematical models that go beyond network models to incorporate morphisms as model elements; (iv) Human Sciences Competency goals of brain networks and of cognitive and neural modeling, through investigations of neural dynamic models and their computation; and (v) Computational Sciences Competency goals of stochastic optimization and modeling through investigations of fast separable methods for stochastic PDEs.

The Branch's research programs are currently focused on four research areas. The titles, scopes and points of contact for these programs, each of which address general aspects of basic

research in mathematical science, are listed in the following subsections. A small number of symposia, conferences and workshops are also supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Modeling of Complex Systems

The Modeling of Complex Systems Program is a program of fundamental mathematics oriented research, the broad objectives of which are twofold. First, the program seeks to develop and analyze new, innovative, and robust modeling frameworks that may be adapted and generally applied across a variety of disciplines. The second goal is to develop both quantitative and qualitative models of specific complex phenomena in areas in which current models are either not fully based on first/basic principles or are based on empirical and ad hoc metrics for which the first/basic principles are not yet well known. Although they break down into more specific research directions, the three thrust areas of interest to the Modeling of Complex Systems Program are 1) development and analysis of new, general modeling frameworks, 2) geometric and topological modeling – which can be further broken down into more specific thrust areas, as noted below – and 3) small and large group social modeling and social informatics.

Metrics – in the general, non-mathematical sense of the word – are a natural part of the mathematical modeling framework. 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. As is the case for the modeling effort, these metrics should preferably be in a complete mathematical analytical framework, which is to say, in part, that they should derive from the problem in question as opposed to a situation in which one forces the model to fit an *a priori* chosen metric. The research in modeling of complex phenomena supported by the Modeling of Complex Systems Program is primarily mathematical analysis and *not* numerical analysis or computational mathematics. One expects computation to play some role in any modeling endeavor, but the innovation in research carried out in the Modeling of Complex Systems program should be largely in the areas of modeling and analysis, and not in the computational techniques.

Furthermore, any modeling research effort that could be of benefit to military or intelligence applications but that might not fall directly under one or more of the program thrust areas will still be considered, particularly if the innovation in the modeling and analysis are significant and noteworthy.

The three major areas of research of the Modeling of Complex Systems Program are:

Modeling Frameworks and Analysis. Mathematical and physical modeling is fundamental to nearly every other direction of research in the physical, social, and computational sciences. A common element of modeling – even if the phenomenon in question is highly complex – is to incorporate simplifying assumptions that sacrifice

realistic application and utility for computational ability. For Army and DoD applications, however, such simplifications often render the model impractical. Modeling frameworks are desired that are able to eschew the usual computational simplification assumptions and realistically capture, adequately govern and/or control, and effectively operate within the particular complexities of real world environments and phenomena, while still maintaining some degree of computational tractability. Of specific interest are causal and predictive modeling frameworks, hybrid model frameworks that capture both causal and predictive features, statistical modeling frameworks, and abstract categorical models (cf. Homotopy Type Theory).

Models of particular complex systems that address and are to be utilized for more specific purposes and objectives will be assessed within the context of one of the program's other modeling thrust areas described below. Research carried out under this section should address the general theory and analysis of mathematical modeling from a broader perspective.

Geometric and Topological Modeling. Representation of complex, irregular geometric objects and complicated, often high-dimensional, abstract phenomena, functions, and processes is fundamental for Army, DoD, and civilian needs. Such needs arise in the modeling of urban and natural terrain, geophysical features, biological objects (e.g. human brain mapping), information flow, and many other contexts. Any research that incorporates an innovative commutative and noncommutative geometric and/or topological approach to address a problem with military, defense, and intelligence applications is welcome and will be considered, but there are two specific threads that are of particular interest to this thrust of the program: 1) geometric data analysis, and 2) multiscale geometric modeling, including dynamics and physical modeling on domains with fine, complex, geometric and/or topological structure.

Geometric data analysis includes – among other subfields – topological data analysis, subspace analysis, principal component analysis, and dimension reduction techniques. Current research directions of importance to Army applications include video, audio, and image processing (i.e. mathematical signal analysis), fast and accurate face/object recognition (i.e. reconstructing and matching geometric data through queries over a database), geometrically motivated methods and structures for working effectively with large – and often real-time extracted – data sets that may be corrupted in some way (e.g. missing or distorted data), and the application of persistent homology in the detection and classification of signals by shape. For instance, although good progress has been made in this direction, real-time capture, representation, and visual reproduction of 3D terrain – not just as a height field but with multivalent height functions and clearly defined topological obstructions – obtained directly from real-time or stored point-cloud data cannot be fully achieved with current techniques like the multitude of variations of piecewise planar surfaces that are presently studied. New approximation theory that does not require the classical assumptions – primarily smoothness – and that provides structure for the many new non-smooth approximation techniques currently under investigation is required. Concurrently, research on the metrics by which we measure and evaluate the approximation is needed.

Additionally, approximation theory for information flow and other abstract phenomena in large wireless communication, sensor and social networks is also 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.

Multiscale geometric modeling, analysis, and dynamics are of particular interest, both in the context of models of physical phenomena over real-world terrain and in the aforementioned complex, high-dimensional data structures. Models that make use of self-similar structures and recursively defined spaces (e.g. fractals, solenoids, etc.) would be of great interest in adapting or enhancing current techniques in areas such as data mining, fluid and heat flow, and search, evasion, deployment, and maneuver over complex terrain that exhibits self-similar properties (e.g. urban or mountainous terrain). Current techniques for dealing with complex dynamical processes and large, noisy, and possibly corrupted data sets could be greatly improved in both the time and efficiency realms by employing techniques from scale symmetry, which often allows one to reduce a large and unwieldy number of variables to a more manageable problem if the variables are appropriately scaled. Models that adapt self-similarity and automata theory, in particular, can oftentimes lead to mapping complex dynamical systems problems into an algebraic and/or topological category, which then may allow for entirely new tools and approaches to be used. Homotopy Type Theory and its applications are such an area that is of significant interest in military applications.

TPOC: Dr. Rad Balu, radhakrishnan.balu.civ@usa.army.mil (Acting), (301) 394-4302

(2) Probability and Statistics

The Probability and Statistics (P&S) program is no longer accepting new white papers or proposals.

TPOC: Dr. Joseph Myers, joseph.d.myers8.civ@army.mil, (919) 549-4245

(3) Biomathematics

The introduction of Biomathematics as a separate area of basic research recognizes the importance and specialized nature of quantitative methods, specifically mechanistic modeling, 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 spatial and temporal scales. Understanding how dynamics at different spatial scales come together to form a biological system and understanding the dynamics of a system at intermediate timescales, as opposed to its long term, asymptotic behavior, are critically important in biology, more so than in many other fields.

This complexity makes biomathematics a highly interdisciplinary field that requires

unique and highly specialized mathematical competencies to quantify structure in these relationships. In fact, progress in mathematical models of biological systems has traditionally been achieved by making convenient simplifications; major advances in Biomathematics research continue to require removing these assumptions (for example, stationarity, ergodicity and deterministic nature) and finding ways to effectively model the essential complexity. Modeling techniques currently utilized in the field range from agent-based approaches for determining the results of individual behavior, whether those individuals be molecules, zooplankton, or humans, to multi-compartmental modeling in physiology, epidemiology and neurobiology, to network models involved in understanding ecosystem and human social dynamics, as well as encompassing both deterministic and stochastic approaches. Research in control techniques is also valuable for its potential application in militarily important areas such as bio warfare and disease spread. Exciting new opportunities to advance the field are found in high risk attempts to develop modeling techniques in areas of mathematics, such as algebra and topology, not traditionally brought to bear on biological problems, advances in Bayesian statistics, a growing recognition that the diffusion approximation is not necessarily adequate for many systems, and the availability of large amounts of complex biological data.

The ultimate goal of the Biomathematics Program focuses on adapting 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. One area of special interest to the program is Neuromathematics, the mechanistic mathematical modeling of neural processes. Recent advances in neuroscience provide important foundations to begin understanding how the brain works. Combined with experimental data, innovative mathematical modeling provides an unparalleled opportunity to gain a revolutionary new understanding of brain physiology, cognition (including sensory processing, attention, decision-making, etc.), and neurological disease. With this new understanding, improved soldier performance, as well as treatments for Post-Traumatic Stress Disorder, Traumatic Brain Injury, and other brain-related disorders suffered by the warfighter will be able to be achieved more effectively, efficiently, and ethically than via experimentation alone.

Thrust areas of the Biomathematics Program are as follows:

Fundamental Laws of Biology. The field of physics has long been “mathematized” so that fundamental principles such as Newton’s Laws are not considered the application of mathematics to physics but physics itself. The field of biology is far behind physics in this respect; a similar process of mathematization is a basic and high-risk goal of the ARO Biomathematics Program. The identification and mathematical formulation of the fundamental principles of biological structure, function, and development applying across systems and scales will not only revolutionize the field of biology but will motivate the creation of new mathematics that will contribute in as-yet-unforeseen ways to biology and the field of mathematics itself. For example, heterogeneity/stochasticity is ubiquitous in biological systems; is heterogeneity necessary for tipping points that result in diseased individuals and epidemics and if so, what is its role? More generally,

is heterogeneity in biological systems necessary for their functioning or a problem to be overcome, or is the answer system/function dependent?

Multiscale Modeling/Inverse Problems. Biological systems function through diversity, with large scale function emerging from the collective behavior of smaller scale heterogeneous elements. This "forward" problem includes creating mechanistic mathematical models at different biological scales and synchronizing their connections from one level of organization to another, as well as an important sub problem, how to represent the heterogeneity of individual elements and how much heterogeneity to include in the model. For example, the currently increasing ability to generate large volumes of molecular data provides a significant opportunity for biomathematical modelers to develop advanced analytical procedures to elucidate the fundamental principles by which genes, proteins, cells, etc., are integrated and function as systems through the use of innovative mathematical and statistical techniques. The task is complicated by the fact that data collection methods are noisy, many biological mechanisms are not well understood, and, somewhat ironically, large volumes of data tend to obscure meaningful relationships. However, traditionally "pure" mathematical fields such as differential geometry, algebra and topology, integration of Bayesian statistical methods with mathematical methods, and the new field of topological data analysis, among others, show promise in approaching these problems. Solutions to these types of multiscale problems will elucidate the connection, for example, of stem cells to tissue and organ development or of disease processes within the human body to the behavior of epidemics.

The "inverse" problem is just as important as the forward problem. From an understanding of the overall behavior of a system, is it possible to determine the nature of the individual elements? For example, from knowledge of cell signaling, can we go back and retrieve information about the cell? Although inverse problems have been studied for a long time, significant progress has been elusive. This thrust area involves innovations in spatial and/or temporal modeling of multi-level biological elements with the goal of achieving a deeper understanding of biological systems and eventually connecting top-down (data-driven) and bottom-up (model-based) approaches.

Hybrid Modeling. While the Biomathematics Program has primarily been concerned with developing and using mathematical modeling techniques to understand the mechanisms behind biological system function, future predictions about a system have typically been achieved through statistical modeling using available data; these methods are limited by their ability to make trustworthy predictions only under the same situations under which the data was collected. This thrust seeks to develop new methods that will take advantage of the strengths of both types of modeling, still allowing the hypothesis and testing of biological mechanism while also allowing prediction under an expanded set of conditions. These new methods will facilitate the utilization of the increasingly available data in many areas of biology to expand our ability to understand and predict biological systems and may be furthered through the use and development of existing and new data analysis techniques. For example, can we develop a mechanistic model to understand a cell's ability to repair damage to its DNA by incorporating Machine Learning?

TPOC: Dr. Virginia Pasour, virginia.b.pasour.civ@army.mil, (919) 549-4254

(4) Computational Mathematics

The research strategy of this program is to focus on the following opportunities for crucial discoveries: innovative methodologies for solving currently intractable problems that take advantage of symmetry, conservation, and recurrence, that can adapt to both the evolving solution and to the evolving run-time resource allocation of modern computer architectures; novel algorithms that accommodate different mathematical models at different scales, interacting subsystems, and coupling between models and scales; methods that incorporate nonlocality through integral operators with advantageous representations. Research in this area will ultimately lead to the development of new mathematical principles that enable faster and higher fidelity computational methods, and new methods that will enable modeling of future problems.

Scientific computation is an essential component of scientific inquiry, complementing theory and experiment, and is also an essential element of engineering in both design and in failure autopsy. Simulations in support of inquiry, design, or autopsy often require expert knowledge in order to select methods that are compatible with the assumptions of the scenario at hand, require considerable skill to properly set up, require considerable time, memory, and storage on large scale parallel/distributed/heterogeneous systems to compute, and require considerable skill and effort to distill useful information from the massive data sets which result. Expert knowledge is also required to quantitatively estimate solution accuracy and to estimate the time and effort required to achieve a desired accuracy. Data has become ubiquitous and is potentially very valuable in increasing solution accuracy and/or decreasing the effort required to solve, but mathematically sound methods for incorporating data into accurate simulations are incomplete. Simulations are not always timely, with results often not being available until after they are needed, for example in calculating failure of New Orleans levees during Katrina and in revising those estimates based on real time surge data. The emphasis in the Computational Mathematics program is on mathematical research directed towards developing capabilities in these and related areas.

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

Advances in Numerical Analysis. Novel methodologies are sought for solving currently intractable problems. New ways of taking advantage of symmetry, conservation, and recurrence are of interest, as are new ways of creating sparsity and new computational structures which can adapt to both the evolving solution and to the evolving run-time resource allocation of modern computer architectures. Rigorous analysis is sought for each in order to enable error bounds, error distribution, and error control.

Fast Methods for Atmospheric Physics. Modeling and prediction of local and mid-

range atmospheric physics are a key part of the domain of operations. New exploratory efforts in fast algorithms for atmospheric physics have been identified as an area where new computational methods could make an important impact on problems of current and future Army interest. The emphasis of these efforts is on mathematical methods which have some promise of wider application rather than methods limited only to specific application areas.

Fractional Order Methods. As an alternative to high order methods and other less-local operators, fractional operators are another nonlocal operator that have proven to work well in modeling and have the advantage of not enforcing dubious assumptions of smoothness, especially at discontinuities and interfaces. However, the nonlocality of fractional operators also typically introduces a significant increase in computational load. Advances in novel efficient computational methods for these operators are of interest.

Army systems often operate under rapidly-changing unpredictable and adverse conditions. It is desirable for models to be computationally simulated and fast enough to drive decision making, exercise control, and to help avoid disaster. Such simulations need to be created, run, and interpreted in better than real time. Research directed towards making this goal achievable is of interest, such as:

Reduced Order Models. Full scale simulations are often not realizable in real time. In order to investigate the behavior of systems under a variety of possible scenarios, many runs are required. Reduced order models are one way to enable this. Possible methods to create these models include adaptive simplification methods based on singular value decompositions and reduced order numerics. To be useful, all such models should be equipped with reliable estimates of accuracy.

Problem Solving Environments. To enable rapid decision making that is 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. What are other approaches?

Embedded Simulation. As algorithms become more efficient and computational devices shrink, it will become increasingly possible to use real-time simulation to drive control systems. New methods which address this goal are welcome, especially those which permit user- controlled and/or adaptively-controlled tradeoffs between speed and accuracy.

Decision Making. One valid criticism of numerical simulation is that it takes so long to set up, run, and post-process the results that they cannot be used in a timely manner to guide decision making. Mathematical ideas that help address this problem are of interest.

TPOC: Dr. Joseph Myers, joseph.d.myers8.civ@army.mil, (919) 549-4245

iii. Network Science

The objective of the Network Sciences Branch is to discover mathematical principles to describe ever present networks in all walks of life (e.g., organic, social, electronic) and, in particular, the emergent properties of networks. Study of Network Science is necessarily multi-disciplinary drawing on tools and techniques from statistical mechanics, information theory, computer science, control theory and social sciences to studies interactions at large scale, be they in swarms of insects or ant colonies, human societies, or networked autonomous systems. The basic principles discovered should, in turn, lead to creation of algorithms and autonomous systems that can be used to reason across data generated from disparate sources, including, sensor networks, wireless networks, and adversarial human networks. Research in this Branch has applications to a wide variety of developmental efforts and contributes to the solution of technology-related problems throughout the Army's Future Force operational goals engendered by principles such as the Net-Centric Warfare and Third Offset strategy.

Research in the Network Science Branch, while primarily driven by discovery of foundational principles, will, however, be cognizant of and contribute to providing crucial underpinning support to ARL's Network & Information Sciences Competency. In particular, the following goals within ARL's Network & Information Sciences Competency are explicitly addressed including: (i) assessment and control of behavior goal by creating new methods in design and controllability of composite and multi-genre networks; (ii) social effects and human-machine interaction through the exploration of social and cognitive networks, and generation of intelligent actions in a mix of information agents and humans; (iii) unconventional communication networks and adaptive by making information available at the tactical edge while taking limited bandwidth and human-information interaction modalities into account, and (iv) taming flash-flood of information available at the tactical edge; (v) highly trusted and resilient communication systems for mission assurance.

The Network Science Branch hosts four main programs in Wireless and Hybrid Communication Networks, Social and Cognitive Networks, Multi-Agent Network Control, and Information Assurance. The boundary between these programs is fluid and, thus, a research topic might fall in more than one program area. Furthermore, there are shared interests between the Social Sciences program in Physical Sciences Directorate and Social and Cognitive Networks (SCN) program in Network Science, with SCN paying special attention to the human dimension from a network science perspective, including study of connections between interdependent people (such as teams), between social systems and cognitive processes of humans embedded in large social, interconnected systems. It is perhaps worth emphasizing that research which elucidates and defines the common underpinning science cutting across different types of networks is particularly of interest to Network Science Branch.

For the Branch's four research areas, each of which addresses general aspects of basic research in network science, their titles, scopes and points of contact for these programs are listed in the following subsections. A small number of symposia, conferences and workshops are also

supported in part or in whole to provide an exchange of ideas in areas of Army interest.

(1) Wireless and Hybrid Communications Networks

This program is concerned with the investigation and advancing of network science applied to communication networks, in particular in wireless and tactical environments, with focus on Department of Defense and Army unique problems. These include, but not limited to, infrastructure-less wireless networks operating in congested and contested spectrum. Also of interest is the analysis of mutual interaction among the communications, social and information networks.

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 of multi-hop wireless networks with mobility, node loss, natural and man-made impairments and unpredictable, bursty traffic. Of particular importance is the extension of these findings in millimeter wave networks where spectrum is abundant, but connections are fragile and distances are short. Novel analytical tools and simulation techniques may be necessary to allow for the modeling of very large networking scenarios without losing the fidelity at the physical layer, which is critical in millimeter wave networks.

Emerging communications network paradigms of Software Defined Networking (SDN) and Network Function Virtualization (NFV) are also of interest as applied to wireless and hybrid networks. Concepts from SDN/NVF could be adapted for wireless ad hoc networks, using innovative methods. Complete centralization may not be desirable, but policy control and hierarchical control of semi-autonomous systems could be useful. Exploitation of SDN control architecture to tailor virtualized network resources according to the needs and objectives of the users is desired. Also, exposure of signaling traffic in wireless SDN creates significant security challenges which need to be resolved.

Mobile Ad Hoc and Sensor Networks. Networks serving Army needs operate in highly dynamic environments with limited or no infrastructure support. Available spectrum may be highly congested and contested, and mobile nodes may only have access to noisy local information with limited awareness of remote nodes in the network. Novel networking approaches may be needed to account for the lack of full network state information and reduce the penalty incurred due to coordination while sustaining acceptable performance.

Adaptive and specialized machine learning techniques are needed for dynamic allocation of network resources based on operation needs, traffic characteristics, mobility, natural and man-made spectrum interference conditions, and security considerations. Techniques to discover and capitalize on communication and networking opportunities. Networking and sensing architectures for cognitive mobile ad hoc networks needs to be developed with qualitative and quantitative performance measures, and the impacts of mobility, fading, and multi-user interference needs to be

investigated. Concepts and constructs observed in networks encountered in nature could inspire adaptation strategies for ad hoc wireless networks.

Networking in combat operations may need to cope with the presence adversarial actions of various types, including strategically inserted spectral impediments. New signal processing, information theory, game theory and network science methodologies are needed to provide reliable and efficient communications in the presence of various adversarial actions. The analysis and characterization of fundamental tradeoffs among conflicting objectives such as Low Probability of Detection (LPD) vs. rate of communications vs. operating in a limited frequency spectrum are needed, along with novel techniques to achieve optimally located areas in the trade-off boundaries.

Providing energy efficient sensor networking under possibly hostile operating conditions presents considerable challenges. Such networks involve short packets and very large number of users, for which standard network access methods are known to be neither spectrum, nor energy efficient. Investigation of fundamental limits in network access methods which pertain to short packets, many users and hostile environments is desired, along with the discovery of protocols which could approximate these bounds.

Novel and Revolutionary Methods in Networking. The synergy among social networking and communication networking, particularly in a tactical mobile ad-hoc scenario, is a research area that could advance the design of new communication approaches. There are many social networking aspects that are common to mobile ad-hoc networking needs such as distributed decision making, robustness, cooperation, self-organization, cluster formation, search and exploration, to name a few. Social Networking Analysis concepts have been recently used in routing and storing of information for tactical wireless networks, with some encouraging results.

Distributed authentication methods, such as block-chain could be useful in tactical environments, but they may require excessive computation and storage burden. Rethinking of distributed authentication methods to fit tactical environments where links may be unreliable, energy and storage is limited is desired.

Among novel and revolutionary methods in networking, exploration of quantum information processing, teleportation and networked quantum information theory is of interest.

TPOC: Dr. Robert Ulman, robert.j.ulman.civ@army.mil, (919) 549-4330

(1) Social and Cognitive Networks

The goal of the Social and Cognitive Networks program is to understand human behaviors and cognitive processes leading to collective level phenomena particularly relevant in military settings with an emphasis on high performance teams and computational social science. Social networks are the underlying structure of

interaction and exchanges between humans within both strategically designed and emergent or self-organized systems. Social networks allow for collective actions in which groups of people can communicate, collaborate, organize, mobilize, attack, and defend. The changing nature of DoD's missions greatly increase the need for models that capture the cognitive, organizational, and cultural factors that drive activities of co-present, virtual, or distributed groups, teams, and populations. Better understanding the human dimension of complexity will provide critical insights about emerging phenomena, social diffusion and propagation, thresholds, and tipping points.

The Social and Cognitive Networks program supports projects that contribute substantive knowledge to theories about human behavior and interaction and make methodological advancements in modeling and analyzing social network structures. The U.S. Army is particularly interested in research that uses defense-relevant empirical data to feed into computational and mathematical models of human interaction. As such, this program funds projects successful in blending theories and methods from the social sciences with rigorous computational methods from computer science and mathematical modeling. Advances in this program are expected to lead to development of measures, theories, and models that capture behavioral and cognitive processes leading to emergent phenomena in teams, organizations, and populations.

Human Behavior and Interaction. This program supports research from disciplines such as communication, health and behavioral science, Industrial and organizational and social psychology, library and information science, management science, and sociology that use a social networks lens to focus on the ways people think and interact whereby creating higher-order systems. Topics of interest include social influence, leadership, trust, team science, cooperation and competition, and crisis management. Such social influence and opinion dynamics research could focus on the formation and dissolution of civic-minded and violent ideological networks, mobilization of benign to hostile political movements, propagation of and enduring changes in attitudes leading to populations reaching consensus or contested states, and network-based interventions. Furthermore, topics of particular interest include social effects of human-machine teaming; multi-team systems and multilevel (nested) systems; and health topics related to education, healthcare behaviors, disease propagation, and wellness from a social networks perspective.

Information and Knowledge Management. This program supports social network centric research to study the ways people learn individually and collectively and how they utilize that information for decision making and goal attainment. Examples of relevant topics include transactive memories, public goods, collective action, information sharing, information fidelity, diffusion and propagation dynamics, and collective decision-making. Diffusion dynamics research will develop mechanistic understanding of opinion and behavior change associated with influence, contagion, and other social propagation processes. Collective decision-making research will contribute fundamental theories and models to predict, evaluate and simulate how teams organize, exchange information, build knowledge, influence, adapt, learn, and build consensus using cooperative strategies and emergent capabilities.

Social Network Analysis. In addition to the topical areas identified above, this program supports methodological advancements for social network analysis. Methodological research in this program will focus on important advances in exponential random graph models (ERGMs or *p**), object oriented agent-based models, computational models, and dynamic simulations that resolve network modeling issues. Such research will focus on scalability of networks, hierarchical or multilevel (nested) systems, longitudinal networks, social influence models, network resilience, techniques to deal with missing, incomplete, or inaccurate network data, and techniques to deal with visualizing multilevel multimodal networks. Scalability and dimensionality research will identify overarching mechanisms that span scales and dimensions of human systems that will parameterize, model, and predict both small group and big data network models. Data accuracy research focuses on investigating effects of measurement error on metrics and inferences due to incomplete (missing or inaccurate) network data. These projects could include research examining small group dynamics within big data sets; multi-level models that account for nested cognitive, social, cultural, physical dimensions of systems; or link and subgroup estimation algorithms to deal with incomplete data and clandestine activities.

TPOC: Dr. Edward T. Palazzolo, edward.t.palazzolo.civ@army.mil, (919) 549-4234

(2) Information Assurance

From the Army perspective, Information Assurance must provide authentic, accurate, secure, reliable, timely information to warfighters in order to achieve information dominance, regardless of threat conditions. Computing and information processes may be carried out over distributed and heterogeneous systems, which may include mobile computing and communications systems, and high performance information process systems that are inter-connected through both tactical and strategic communication systems.

Robust and Trusted Wireless Communication. Research is needed in the areas of theory, protocols, and techniques that will assure delivery of trustworthy data to support battlefield missions. 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. The Army requires a fully mobile, fully-communicating, agile, and situation-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 (UAVs), robotics, and unattended sensor networks such as battlefield internet of things (IoT) that operate in a complex wireless environment. Information theory has played a foundational role in the study of security. Across a wide range of application domains and security objectives, information theory leads to insight to the underlying tradeoffs between security and performance. The Army seeks novel ideas in fundamental research areas such as information-theoretic security and the science of security that will provide direct guidance in the design of secure tactical wireless

systems. In particular, topics of interest include new paradigms for physical layer security (ranging from confidentiality to authentication to trustworthiness in physical layer communications), the fundamental bounds in trust management and data integrity in distributed systems, the exploitation of trust establishment and key/credential distribution protocols, and assured information delivery and dissemination in mobile environments. The corresponding constructions that would arise from such an investigation represents a significant avenue for improving future wireless communication as well as the corresponding secrecy capacity limits that could serve as valuable guidelines in developing future systems with confidential and authenticated communications. New computing and communication protocols and techniques are needed to assure critical information processing and delivery even when such systems are under severe resource constraints or under persistent attacks.

Models and Metrics for Next Generation Robust Systems. The field of information assurance needs a foundational science to guide the design of systems and to quantitatively measure safety and the level of assurance of complex systems that the Soldier depends upon today. Assurance principles and metrics are needed to help define, develop, and evaluate future robust and resilient systems and network architectures that would survive sophisticated attacks and intrusions with measurable confidence. The program seeks the capability to measure a complex system and to provide trustworthiness and robustness guarantee of that system. In addition, human users need to be in the loop for system assurance analysis. Developing human centric security-usability metrics, computational models for usable security in stressful situations, and adaptive security protocols according to perceived threats are some of the research areas of interest for improving warfighter performance while maintaining sufficient security requirements. One new challenging area of research that offers great promise in stronger system robustness is the modeling of adversaries and defender interactions, since ultimately systems need to defend effectively against their attacks. A deeper understanding and more accurate modeling of adversarial behaviors will improve future system development. New concepts such as anti-fragility theory for better resiliency are also of interests.

Cyber Deception. Cyber deception is a proactive technique to manipulate the mental state and decision process of the adversary so that we can degrade and mitigate their attack effectiveness. Unique aspects of cyber deception may offer more opportunities but add more complexity to model and analyze: 1) Cyber artifacts (both genuine and fake) can be created easily and are not bounded by the laws of physical space. The velocity of cyber situation change could be very high; 2) while deceptions are normally played out between a defender and an attacker, users could be directly or indirectly entangled in the game due to the nature of shared infrastructure. Usability issues or negative impact to the mission need to be considered; 3) Social and cultural aspects are important elements in the cyber deception game. Key scientific understanding is still lacking in 1) Establishing effective mental models for understanding and tracking the adversaries' intent, capability, and decision process, and 2) deception information formulation and communication techniques, which requires new thinking in order to provide a quantifiable measure on how a given deception approach will drive metal

state change. Recent honeypots/decoy experiences gave initial insights on how to engage adversaries through fake cyber artifacts, but a clear understanding of the dynamics (especially mental interactions) between attackers and defenders is missing. A better learned adversarial model will be critical to the success of cyber deception. In addition, advanced honeypot like schemes are desired to engage adversaries in order to gain understanding of adversaries so that effective deception schemes can be crafted.

Principles of Moving Target Defense. Current cyber defenses are often static and governed by lengthy processes, while adversaries can plan their attacks carefully over time and launch the attacks at cyber speeds at times of their choosing. The program seeks a new class of defensive strategies to present adversaries with a moving target where the attack surface of a system keeps changing. Although such an idea of a "moving target" is a powerful paradigm for building systems robust to security threats, many fundamental aspects associated with such a strategy need to be further investigated and understood. For example, such a "moving target" system may operate under many different contexts, ranging from the use of frequency hopping in spread spectrum to software diversification. It is critical to establish new theories and models that can provide trade-off analysis between system robustness against attacks vs. performance/usability, and quantify the risks associated with system adaptation under an adversarial setting. Ultimately the understandings and analytical models obtained will establish an important foundation for creating robust tactical systems capable of maximizing the difficulties for the adversaries to attack while minimizing the impact to system performance and usability.

Trusted Learning for Cyber Autonomy. Future Army autonomous systems, especially cyber-physical systems working side-by-side with Soldiers, are subject to various adversarial attacks during operations such as data poisoning or fault injection. While current testing and verification techniques help assure system integrity prior to deployment, few of them can help mitigate runtime risk or achieve automatic recovery after a compromise, nor can these systems adapt due to varying operational environments or adversarial conditions, which is inevitable for any cyber autonomous system. It is critical to establish fundamental principles that can allow future systems to perform trusted learning, introspection and self-updating at mission time in order to adapt to changing operational environments and to defend against attacks that may lead to mission failures. New research is sought in driving both the correctness and robustness in cyber domain learning, decision making and adaptation so that these autonomous defense systems can maintain critical mission assurance. To help survive varying adversarial conditions, new concepts such as robustness certification or domain constraints at both the data processing layer and the knowledge/decision layer may lead to better resiliency against adversarial manipulation and exploits and more effectiveness in sustaining missions
TPOC: Dr. Cliff Wang, cliff.x.wang.civ@army.mil, (919) 549-4207

(3) Multi-Agent Network Control

The objective of the Multi-Agent Network Control program is to establish the physical,

mathematical and information processing foundations for the control of complex dynamic networks with possibly multiple controllers. The research program is concerned with developing novel mathematical abstractions and methods for the modeling and control of the collective behavior of large scale networks of heterogeneous multi-agent systems. Autonomy is central to program efforts as anticipated dynamics of the future battle space will require a greatly increased level of autonomy to enable the necessary mobility, sensor coverage, information flow, and responsiveness to support the military goals of information superiority, dominant maneuver, and precision engagement.

Distributed Control of Networked Systems. Distributed control techniques play a major role in the study of networked systems. For example, they have been successfully used in robotics for replicating self-organized behaviors found in nature (e.g. bird flocking, fish schooling, and synchronization) and in developing applications such as formation control, rendezvous, robot coordination, and distributed estimation. In many dynamic systems, consensus based classical solutions may not be suitable, due to time varying and abrupt transitions of the states, hard to quantify uncertainties and unknown objectives of the agents. More sophisticated distributed control methods that go beyond consensus formulations are needed. Analysis of interactions between information and control is a fundamental research topic with implications in distributed systems design. Methods for computing bounds and derivation of optimal or near optimal solutions under incomplete and local information for agents, as well as design techniques that quantify trade-offs between information delivery costs and system optimality are of interest. Analysis of distributed non-linear systems where linearization is not sufficiently applicable is also sought. Use of innovative techniques such as geometry, graph theory, topological analysis and other approaches are encouraged. Also of interest are modeling and analyses of interacting and co-evolving multi-genre networks that have their own focuses and functions, but still interact with and impact each other.

Adaptive Control and Reinforcement Learning. Control of uncertain systems in and methods to reduce uncertainties is part of mainstream control systems research, one example being Reinforcement Learning (RL). Stochastic Dynamic Programming approach has led to powerful formulations in RL, with impressive results in many applications. However, challenges still remain, such as computational complexity, very long convergence times, and lack of sufficient training data. Hybrid approaches that properly incorporate prior or learned models of the systems to be controlled into the RL formulation are encouraged. Research to address fundamental issues in RL such as computational complexity, convergence times and training with sparse data are sought. Also, novel approaches to RL which may extend, modify or replace state space based Dynamic Programming paradigms are welcome. Extensions of RL techniques to networked systems featuring multiple controllers with applications to autonomy and coordination are sought. Innovative research focused on system identification techniques to reduce uncertainty and facilitate optimal or near-optimal control is also in scope for this program.

Novel Application Areas in Control Theory: Sophisticated tools and methodology

from control theory could conceivably provide new insights and adaptations that could be helpful in solving some of the important and challenging problems such as control and stability of Quantum Qubits, and identification and of control functions occurring in the brain. Computational capabilities enabled by quantum computers are expected to far surpass their classical counterparts. However, control and stability of clusters of qubits remains a fundamental problem in quantum computing. Adaptation of control theoretical tools and approaches into precise control of qubits and stability of coherence times of interacting qubits could provide new research opportunities in the control of networked systems. Cognitive functions in the brain are controlled by interactions among neural circuits, but fundamental principles describing these interactions are not well understood. Modeling and analysis of these phenomena could provide novel research opportunities in the control of networked systems. Similarly, study of biological systems has unveiled control architectures that are not encountered in industrial control systems. Understanding the effectiveness of such naturally occurring control systems and their potential adaptation to the control of man-made applications could also be an area of fertile research.

TPOC: Dr. Derya Cansever, derya.h.cansever.civ@army.mil, (919) 549-4282

2. INTERNATIONAL RESEARCH INTERESTS

The U.S. Army Research Office has international research programs which are focused in specific research areas supporting the 9 scientific branches described in the previous section. These research areas and information provided in the following are opportunities for foreign organizations and foreign public entities.

a. Human Dimension

The Human Dimension Program is focused on supporting multidisciplinary research at institutions outside of the U.S., with the goal of identifying and modeling the co-evolutionary multiscale dynamics of human neural, cognitive, physical and social systems. Potential investigators should contact the Program's TPOC for any questions regarding the geographic regions that can be considered for research proposals in this area.

The Human Dimension Program supports multidisciplinary basic research in areas that include neural and cognitive sciences, behavioral and social sciences and human factors and neural engineering with an emphasis on modeling, predicting and enhancing human perceptual, cognitive, affective, physical, and social performance in individuals, groups and societies. An overarching goal of the program is to provide foundational knowledge of neural, biophysiological and cognitive-based mechanisms underlying individual, group and societal cognition and performance across multiple time scales. In the long term, research in this area may enable new training tools to predict and optimize cognitive/physical performance and team intelligence, interfaces enabling humans to more

efficiently control machines and psychophysiologically-based predictive models of complex individual – societal dynamics. Basic research opportunities are sought in two primary research thrusts within this program: (i) Cognitive-Physical Interactions and (ii) Cognitive-Social Interactions.

Cognitive-Physical Interactions. The Cognitive-Physical Interactions thrust seeks to support high-risk seed projects that use multimodal approaches to uncover dynamic and multiscale interactions of neural-cognitive and physiological systems. The goal of this thrust area is to advance the experimental and analytical tools available to develop comprehensive understanding of the impact of group and individual state-trait variability on human performance, human-systems interfaces and team intelligence. Research topics are supported in diverse areas that can include the neurobiological mechanisms of expert skill learning, closed-loop brain-computer interfaces and novel mind-body interfaces such as the microbiome-gut-brain axis.

Cognitive-Social Interactions. The Cognitive-Social Interactions thrust seeks to develop new theories to understand the dynamic interrelationships between individual/group cognition, decision-making and the role that these influences play on interactions with large and small social systems. Multidisciplinary seed projects are supported that seek to advance the necessary analytical and experimental tools required to describe the underlying mechanistic interactions as they co-evolve in time and space. Research topics are supported in diverse areas that may include modeling the impact of mindfulness on state transitions of human cognitive, physical and social systems and describing the longitudinal neural, cognitive and social mechanisms mediating development of leadership, expertise and intelligent teams.

TPOC: Dr. Frederick Gregory, frederick.d.gregory5.civ@army.mil, +44 (0)1895-626517 (London, UK)

b. Innovations in Materials

As one of the ARO International Programs the Innovations in Materials Program is focused on supporting multidisciplinary research at institutions outside of the U.S., with the goal of accelerating new discoveries in materials science. Potential investigators should contact the Program's TPOC for any questions regarding the geographic regions that can be considered for research proposals in this area.

The Innovations in Materials program seeks to determine unique strategies and designs for optimizing materials with uncharacteristic or unexpected properties, architectures, and compositions. Research is focused on, but not limited to, areas such as: reconfigurable materials, predictive design of materials, multi-component materials incorporating hierarchical constructs, materials compositions and architectures for unprecedented property development, functional integration of materials, analytical techniques for interrogating multi-dimensional evolution of structures, properties and failure, and defect science and engineering.

Over time, new areas of research in fundamental materials science can develop that provide previously unforeseen opportunities for accelerating scientific progress, and this BAA is intended to cover these cases as well.

TPOC: Dr. James Harvey, james.f.harvey.civ@army.mil , +44 (0)1895-626518 (London, UK)

ARO SPECIAL PROGRAMS

a. Short-Term Innovative Research (STIR) Program

The objectives of the STIR program are to support rapid, short-term investigations to assess the merit of innovative new concepts in basic research. STIR program awards provide an excellent opportunity to showcase new concepts and explore new areas in basic research. Historically STIR program awards have helped shape new directions in research for the Army.

i. Eligibility. Proposals are sought from institutions of higher education, nonprofit organizations, state and local governments, foreign organizations, foreign public entities, and for-profit organizations (i.e. large and small businesses). Prospective applicants of a STIR proposal are encouraged to contact the appropriate TPOC/ Program Manager identified earlier in the research areas of this BAA, to ascertain the extent of interest in the specific research project.

ii. Research Sought. Proposals in the amount of $60,000 or less are sought for research in the areas identified earlier in the research areas of this BAA.

iii. Proposal Preparation.

(1) Eligible applicants should submit proposals that are no more than twenty (20) pages in length, inclusive of the budget, transmittal letter, and attachments. No brochures or explanatory material should be submitted with the proposal.

(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 applicant. Research must be completed within nine (9) months of award of the agreement.

(3) The research proposal should follow the format set forth in Section II.D (Application and Submission Information) of this BAA. Limited rights in technical data and restricted rights in computer software should be identified as an attachment to the proposal. Otherwise, it will be concluded that the proposal does not contain any such limitations or restrictions

(4) No capital equipment may be purchased under a STIR Program award. Report preparation costs must not exceed $100. Fee is not permitted under STIR Program awards. Due to the relatively small dollar amount and short-term nature of these awards, applicants are encouraged to maximize the benefit derived from this funding by prioritizing labor and employing other cost-saving measures in support of the STIR program effort. In particular, applicants are strongly encouraged to contribute as a cost-share or significantly reduce the indirect costs associated with proposed efforts.

(5) The principal investigator(s) (PI) should disclose and explain the relevance of the proposal to the research interests identified earlier in the research areas of this BAA.

(6) A brief, final technical report is required. Please note that your award document will

reference Form 18, "Reporting Instructions," as found at http://www.arl.army.mil/www/default.cfm?page=29 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.

b. Early Career Program (ECP)

ECP awards are one of the most prestigious honors bestowed by the Army on outstanding scientists beginning their independent careers. The objective of the ECP is to attract outstanding early career university faculty members to pursue fundamental research in areas relevant to the Army, to support their research in these areas, and to encourage their teaching and research careers. Early career investigators meeting eligibility requirements may submit an ECP proposal. Outstanding ECP projects meeting additional eligibility requirements may also be considered for a Presidential Early Career Award for Scientists and Engineers (PECASE).

i. Eligibility. This program is open to U.S. citizens, U.S. Nationals, and Permanent Resident Aliens who have held a tenure-track position at a U.S. institution of higher education 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 fact is so indicated in the proposal, and the supporting letter from the institute states that the faculty member submitting the proposal will be considered for a permanent appointment.

ii. Research Sought. Proposals are encouraged for research in areas described earlier in the research areas of this BAA. Proposals may be submitted at any time. As is the case for all other research programs, discussions with the cognizant TPOC/ Program Manager identified earlier in the research areas of this BAA is strongly recommended before submission of a formal proposal. An award in each topic area is not guaranteed. ECP awards will not exceed $120,000 per year for three years.

iii. Proposal Preparation.

(1) An individual applying for an ECP award must submit a proposal and a supporting letter, both through official channels in the institution of higher education where the individual is employed. Any resulting award will be made to the institution, not to the investigator. The proposal should follow the format set forth in Section II.D (Application and Submission Information) of this BAA.

TPOC: Contact the relevant Program Manager identified earlier in the research areas of this BAA.

(2) The supporting letter must be from the individual's Department Chairperson, Dean, or other official who speaks for the institution of higher education, and should address support for, and commitment to, the applicant. Strong university support for the applicant is essential. This support can include the applicant's nine-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 institution of higher education views the individual as a truly outstanding, faculty member, and is making a long-term commitment to the proposal and the research.

iv. Evaluation Criteria. The evaluation criteria to be used in determining which proposals are selected for funding are described in Section II.E.1.a and Section II.E.1.b of this BAA. ECP proposals will be selected for award on a competitive basis after a peer scientific review.

v. Continued Support. Support under the ECP is limited to three years. Upon completion of the ECP award, an early career investigator, through their institution, may apply and be considered for continued support in the research areas of this BAA.

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

i. Individuals holding tenure-track positions at U.S. institutions of higher education and who have held their graduate degrees (Ph.D. or equivalent) for fewer than five years at the time of application are eligible to be considered for the PECASE award. An individual may not directly apply for a PECASE award. Instead, once a year, ARO technical program managers will nominate PECASE candidates from among all ARO ECP and other proposals and whitepapers (if any) received. A technical program manager will make the PECASE nomination based on strong endorsement of the proposal by the external scientific reviewers and on the potential shown by the individual to contribute to science and to the mission of the Army.

ii. Following nomination of a PECASE candidate, a supplemental PECASE proposal will be requested in which the candidate will indicate how PECASE funding would augment the ECP award. PECASE awards are not to exceed $200,000 per year for five years. The following supporting information at minimum is required in the PECASE proposal:

(1) Letters (non-federal government) of recommendation;
(2) Detailed scientific biographical information including a description of the candidate's leadership in the scientific community;
(3) Description of the proposed candidate's publications (such as refereed journals, peer-reviewed conference papers, and books or book chapters; however, this is not an inclusive list);
(4) Description of the candidate's presentations (such as invited talks and plenary presentations; however, this is not an inclusive list);
(5) Summary of the candidate's past research accomplishments;
(6) Summary of the candidate's community outreach efforts; and
(7) Letters of commitment from institution(s) of higher education.

iii. Complete PECASE proposal packages will be evaluated by 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 evaluation criteria to be used in determining which proposals are selected for funding are described in Section II.E.1.d of this BAA.

iv. Continued Support. Support under PECASE is limited to five years from date of award. Upon completion of the PECASE award, an individual, through their institution of higher education, may apply and be considered for continued support in the areas identified earlier in the research areas of this BAA.

TPOC: Contact the relevant Program Manager identified earlier in the research areas of this BAA.

d. Research Instrumentation (RI) Program

RI is designed to improve the capabilities of U.S. institutions of higher education to conduct research and educate scientists and engineers in areas important to national defense. Of the funds available to support ARO mission research described in this BAA, funds may be provided to purchase instrumentation in support of this research or in the development of new research capabilities.

i. Eligibility and Areas of Interest. It is highly recommended that potential applicants contact the appropriate TPOC/ Program Manager identified earlier in the research areas of this BAA for advice and assistance before preparation of an instrumentation proposal.

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

(1) A concise abstract (approximately 300 words but not to exceed 4,000 characters) that describes the instrumentation requested and the research to be supported by that instrumentation.

(2) A budget that addresses the instrumentation to be purchased, cost per item, and total cost. Indicate the proposed source of the instrumentation 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.

(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.

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

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

Note: Costs associated with equipment/facility modifications are generally considered unallowable and require the review and approval of the Grants Officer.

iii. The evaluation criteria to be used in determining which proposals are selected for funding are described in Section II.E.1.a and II.E.1.c of this BAA.

e. Conference and Symposia Grants

i. Introduction. The Army supports conferences and symposia (as defined in the DoD Travel Regulations) in 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.

ii. Eligibility. Notwithstanding the Army's authority to provide grant support for such events, only non-commercial scientific, technical, or professional organizations that qualify for tax exemption may receive a conference grant/symposia grant. Those who meet this requirement should also be aware that the DoD does not permit "co-sponsorship" (as defined in DoD 5500.07-R) absent additional high level staffing and approval. In other words, the conference grant support identified in this BAA is NOT DoD sponsorship or co-sponsorship since ARL/ARO is neither an organizer, nor provider, of any substantial logistical support for the conferences addressed in this section.

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

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

(1) A one page or less summary indicating the objectives of the project.
(2) The topics to be covered.
(3) The location and probable date(s) and why the conference is considered appropriate at the time specified.
(4) 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 in general and activities as outlined earlier in the research areas of this BAA.
(5) The name of chairperson(s)/(PI)(s) and his/her biographical information.
(6) A list of proposed participants and the methods of announcement or invitation.
(7) The number of Army personnel who will be admitted to the conference without charge. Optional- This information is for Army planning purposes, and will not affect evaluation of the proposal.
(8) A signed cover page.

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

(1) Total project conference costs by major cost elements.
(2) Anticipated sources of conference income and amount from each.
(3) Anticipated use of funds requested.
(4) A signed budget.

vi. 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.

vii. Cognizant ARO TPOC/ Program Manager. It is highly recommended that potential applicants contact the appropriate TPOC/ Program Manager identified earlier in the research areas of this BAA for advice and assistance before preparation of a conference/symposia proposal.

f. High School Apprenticeship Program (HSAP)/Undergraduate Research Apprenticeship Program (URAP)

i. The HSAP funds the Science, Technology, Engineering, and Mathematics (STEM) apprenticeship of promising rising high school juniors and seniors to work in a university structured research environment under the direction of ARO sponsored principal investigators (PIs) serving as mentors. The URAP provides similar opportunities for undergraduate students. HSAP and URAP participants must be U.S. citizens or have permanent resident status. Awards will be made as add-ons to single investigator research grants, Multidisciplinary University Research Initiative (MURIs), University-Affiliated Research Contracts (UARCs), and other cooperative agreements managed by the Army that have at least 12 months period of performance remaining from the date of HSAP/URAP proposal submission.

ii. HSAP/URAP program goals are to:

(1) Provide authentic science and engineering research experience to high school students interested in pursuing STEM, and undergraduate students pursuing science and engineering majors;
(2) Introduce students to the Army's interest and investment in science and engineering research and the associated educational opportunities available to students through the Army's Educational Outreach Program (AEOP) and DoD;
(3) Provide students with experience in developing and presenting scientific research;
(4) Provide students with experience to develop an independent research program in preparation for research fellowships, graduate school, and careers in science and engineering research;
(5) Provide opportunities for the student to benefit from the expertise of a scientist or engineer as a mentor for professional and academic development purposes; and
(6) Develop student's skills and background to prepare them for competitive entry to science and engineering undergraduate programs

iii. The HSAP/URAP is designed as an add-on to larger research projects and limited funding is available annually for PIs interested in participating. Due to the brief duration of the HSAP/URAP and limited funding we make every effort to maximize the number of student apprenticeship opportunities. PIs should submit a short proposal that clearly

articulates the meaningful research that the student will conduct, along with the strategy for mentorship and facilitation of follow-on opportunities (e.g., university attendance, participation in other AEOP opportunities and other research experiences, etc). PIs must determine what aspect(s) of their current research program the student will be working on, desired deliverables, and anticipated research outcomes (based on the HSAP/URAP program goals in f. ii. of this section). PIs should describe who within their organization will be responsible for day-to-day mentoring of the students (e.g. PI, research associate, graduate student, etc.). If direct supervision of students will be someone other than the PI, the mentor's resume or curriculum vitae (CV) must be provided. The proposal should identify the gains for the student and the organization for HSAP and URAP participation in terms of technical skills, scientific reasoning in specific domains, or publication opportunities. Follow-on opportunities and relationships for students within the organization are encouraged.

Proposals should include provisions to pay HSAP students a stipend equivalent to approximately $10 per hour and URAP students a stipend equivalent to approximately $15 per hour; not to exceed 300 hours total per student. Students are not considered university employees whose hours must be tracked and therefore stipends are not required to be paid as an hourly wage but can be paid as a lump sum or divided as partial payments, at the university's discretion. Proposals should generally be limited to two students per PI, except for UARC and MURI awards on which up to 6 students are allowed. Up to four students will be considered under a single investigator if the proposal demonstrates sufficient senior research staffing to ensure effective student guidance and mentoring. Student stipends must be listed under "participant support costs" on ARO Form 99 as described in Section II.H.2.e of this BAA.

If more than one student is proposed by a PI, there must be a near equal mix of HSAP and URAP (i.e. proposals should not be for multiple URAP students only unless approved by ARO). The institution of higher education must describe in its proposal how it will ensure the protection of minors through provision of a safe working environment.

(1) Evaluation Criteria. The evaluation criteria to be used in determining which proposals are selected for funding are described in Section II.E.1.e and II.E.2.c-d of this BAA.

(2) Describing an Outreach Strategy and Student Application Process. A primary objective of the HSAP and URAP is to expose new students to research opportunities in a research laboratory. Thus, PIs must describe a plan to attract and engage students not related to the PI (family member) or already working with the PI, laboratory, or research project. The proposal shall also include a short description (3 to 5 sentences) of the project and specific student requirements (GPA, letters of recommendation, dates of the apprenticeship, etc.). For approved proposals, the project description and requirements submitted by the PI will be marketed on the AEOP website and used in addition to the PIs outreach strategy to attract applicants. All student applications for the HSAP and URAP programs must be collected through the AEOP student application portal (www.usaeop.com). After initial AEOP eligibility screening, applications will be forward to the PI for evaluation and final

candidate(s) selection. PIs must include in the proposal a plan to conduct local outreach to promote awareness of the opportunity among students/schools, and then direct them to the AEOP website to apply. HSAP/URAP is a commuter program and PIs are encouraged to perform outreach to students who are able to commute daily. PIs and mentors must also complete a brief registration annually on the AEOP website and complete two 21st Century Skills Assessment for each apprentice during the apprenticeship (web links will be emailed to the PI before the start of the summer program). At the conclusion of the apprenticeship student participants are required to develop a brief (one-page) abstract of their work to be included in an AEOP program booklet. PIs shall review and approve these abstracts before submission to ARO.

(3) Timeline. Consistent with the BAA, proposals are accepted on a rolling basis. PIs interested in receiving HSAP/URAP funding should submit proposals no later than (NLT) August 31 of the prior year to provide sufficient time for proposal review, award processing, and student outreach/recruitment. For example, to receive funding for use in summer 2022, proposals should be submitted by August 31, 2021. PIs will be notified of proposal evaluation results by mid-November and the student application website will open during the first week of January through February.

(4) Proposal Submission. Proposals should not exceed three pages (excluding supplemental information (budget, CVs, etc.) in length and must be submitted through www.grants.gov utilizing solicitation number W911NF-17-S-0002. Complete forms Standard Form (SF) 424, ARO Form 99 (clearly distinguishing high school students from undergraduates), and upload the proposal as an attachment. Please include the title of the research project, the grant number, and the specific number of HSAP and/or URAP opportunities requested on the first page of the proposal.

TPOC: Ms. Ivory Chaney, usarmy.rtp.ccdc-arl.mbx.hsap-urap@mil.mil, (919) 549- 4323

g. Historically Black Colleges and Universities and Minority-Serving Institutions (HBCUs/MIs)

The Army has a long history of advocating and supporting research at HBCU/MIs. Through this BAA, ARO actively seeks proposals from the HBCU/MI community in full and open competition with all applicants. Utilizing delegated authority provided by 10 U.S.C. 2362, ARO encourages research program TPOCs to develop whitepapers and proposals with the HBCU/MI community to broaden and diversity the research base. Proposals may relate to any research topic described herein. In addition to single investigator research proposals, collaborative research proposals are also encouraged. Collaborations may be between HBCU/MIs and other institutions of higher education (not limited to HBCU/MIs) and/or partners. Also included are special emphasis programs such as STIR and the ECP, described in detail elsewhere in this announcement.

TPOC: Ms. Patricia Huff, patricia.a.huff26.civ@army.mil, (919) 549-4283

4. OTHER NON-ARO PROGRAM-RELATED INFORMATION

a. Visiting Scientist Program (VSP)

The VSP supports short-term travel opportunities for foreign/international scientists to the United States and to international conferences to socialize new S&T ideas or findings with the Army that support advancing basic research through collaboration. For additional information, contact the DEVCOM International Technology Center at usarmy.blenheimcrescent.rdecom.mbx.rfec-atlantic@mail.mil.

b. DoD Programs

Each year the ARO, along with the Office of Naval Research (ONR) and the Air Force Office of Scientific Research (AFOSR), participates in three programs sponsored by the Office of the Assistant Secretary of Defense for Research and Engineering. These three programs, titled the Defense University Research Instrumentation Program (DURIP), Multidisciplinary University Research Initiative (MURI), and the Research and Educational Program (REP) for HBCU/MIs are conducted under separate BAAs that are posted yearly on Grants.gov and the ARO website under "Funding Opportunities". These BAAs have a definite closing date for proposal submission, and applicants are advised to review the BAAs for eligibility considerations.

For the purpose of Army funding under these three programs, the areas of interest for submitting proposals are limited to the research areas identified in this BAA.

(End of Section)

B. Federal Award Information

The ACC-APG RTP Division has the authority to award a variety of instruments on behalf of ARO. Anticipated awards will be made in the form of contracts, grants, cooperative agreements, technology investment agreements (TIAs), or other transactions for prototypes (OTAs). The ACC-APG RTP Division reserves the right to select the type of instrument most appropriate for the effort proposed. Applicants 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, consistent with 31 U.S.C. 6303, which reflects a relationship between the Federal Government and a state government, a local government, or other entity/contractor when the principal purpose of the instrument is to acquire property or services for the direct benefit or use of the Federal Government.

Contracts are primarily governed by the following regulations:

a. Federal Acquisition Regulation (FAR)
b. Defense Federal Acquisition Regulation Supplement (DFARS)
c. Army Federal Acquisition Regulation Supplement (AFARS)

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 Federal Government's direct benefit or use.

b. In which substantial involvement is not expected between the Federal Government 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 Federal Government 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.

4. Technology Investment Agreement (TIA). Assistance Transaction other than a Grant or Cooperative Agreement (see 32 CFR Part 37). 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 a TIA shall not be duplicative of research being conducted under an existing DoD program. To the maximum extent practicable, TIAs shall provide for a 50/50 cost share between the Government and the applicant. An applicant's cost share may take the form of cash, independent research and development (IR&D), foregone intellectual property rights, equipment, access to unique facilities, and/or other means. Due to the extent of cost share, and the fact that a TIA does not qualify as a "funding agreement" as defined at 37 CFR 401.2(a), the intellectual property provisions of a TIA can be negotiated to provide expanded protection to an applicant's intellectual property. No fee or profit is allowed on TIAs.

5. Other Transaction for Prototype (OTA). A legal instrument, consistent with 10 U.S.C. 2371, 10 U.S.C. 2371b, or 10 U.S.C. 2371b(f), which provide DoD the flexibility necessary to adopt and incorporate business practices that reflect commercial industry standards and best practices into its award instruments. Other Transaction Agreements are not FAR-based procurement contracts, grants, cooperative agreements, or Cooperative Research and Development Agreements. Other Transaction Awards have specific applications and conditions for use (see Appendix C of the Other Transactions Guide). The effort covered under an OTA shall not be duplicative of effort being conducted under an existing DoD program (please refer to the "Other Transactions Guide" dated November 2018 (Version 1.0)). Follow-on production contracts and/or transactions may be awarded to a Prototype Other Transaction Awardee, if applicable. The Guide, may be accessed at the following link:
https://www.dau.mil/guidebooks/Shared%20Documents/Other%20Transactions%20(OT)%20Guide.pdf

6. Grants and cooperative agreements for institutions of higher education, nonprofit organizations, foreign organizations, and foreign public entities are primarily governed by the following:

a. Federal statutes
b. Federal regulations
c. 2 CFR Part 200, as modified and supplemented by DoD's interim implementation found at 2 CFR Part 1103
d. 32 CFR Parts 21, 22, 26, and 28
e. DoD Research and Development General Terms and Conditions
f. Agency-specific Research Terms and Conditions

7. Grants and cooperative agreements for for-profit and nonprofit organizations exempted from Subpart E—Cost Principles of 2 CFR Part 200, are primarily governed by the following:

a. Federal statutes
b. Federal regulations
c. 32 CFR Part 34 - Administrative Requirements for Grants and Agreements with For-Profit Organizations
d. 32 CFR Parts 21, 22, 26, and 28
e. DoD Research and Development General Terms and Conditions

f. Agency-specific Research Terms and Conditions

8. TIAs are primarily governed by the following:
   a. Federal statutes
   b. Federal regulations
   c. 32 CFR Part 37 – Technology Investment Agreements
   d. DoD Research and Development General Terms and Conditions
   e. Agency-specific Research Terms and Conditions

9. OTAs are primarily governed by the following:
   a. Federal statutes
   b. Federal regulations
   c. Office of Secretary of Defense implementation guidance titled Other Transactions (OT) Guide for Prototype Projects

10. The following websites may be accessed to obtain an electronic copy of the governing regulations and terms and conditions:

   a. FAR, DFARS, and AFARS: http://farsite.hill.af.mil/
   b. Code of Federal Regulations (CFR): http://www.ecfr.gov
   c. DoD Research and Development General Terms and Conditions: https://www.onr.navy.mil/en/work-with-us/manage-your-award/manage-grant-award/grants-terms-conditions
   d. Agency-specific Research Terms and Conditions: http://www.arl.army.mil/www/default.cfm?page=8

(End of Section)

C. Eligibility Information

1. Eligible Applicants

Eligible applicants under this BAA include institutions of higher education, nonprofit organizations, state and local governments, foreign organizations, foreign public entities, and for-profit organizations (i.e. large and small businesses) for scientific research in mechanical sciences, mathematical sciences, electronics, computing science, physics, chemistry, life sciences, materials science, network science, and environmental sciences. Whitepapers and proposals will be evaluated only if they are for fundamental scientific study and experimentation directed toward advancing the scientific state of the art or increasing basic knowledge and understanding. Whitepapers and proposals focused on specific devices or components are beyond the scope of this BAA.

2. Cost Sharing or Matching

Generally, there is no requirement for cost sharing, matching, or cost participation to be eligible for award under this BAA. Cost sharing and matching is not an evaluation factor used under this BAA. Exceptions may exist if the applicant is proposing the use of a TIA or an OTA as an award instrument. Cost-sharing requirements may be found at 32 CFR 37 for TIAs. Cost-sharing requirements for OTAs may be found at Section C2.16 COST SHARING in the January 2017 document titled "Other Transactions" OT Guide for Prototype Projects.

In addition, if cost sharing is proposed on a grant or cooperative agreement proposal submitted by a nonprofit or institution of higher education, the award will be subject to the restrictions at 2 CFR 200.306. If cost sharing is proposed on a contract proposal, the award will be subject to the restrictions at FAR 35.003.

3. Other

Pursuant to the policy of FAR 35.017 and supplements, selected Federally Funded Research and Development Centers (FFRDC) may propose under this BAA as allowed by their sponsoring agency and in accordance with their sponsoring agency policy.

(End of Section)

D. Application and Submission Information

1. Address to View Broad Agency Announcement

This BAA may be accessed via the following websites:

a. Grants.gov (www.grants.gov)
b. Contract Opportunities (beta.sam.gov)
c. ARL website https://www.arl.army.mil/business/broad-agency-announcements/.

Amendments to this BAA, if any, will be posted to these websites when they occur. Interested parties are encouraged to periodically check these websites for updates and amendments.

The following information is for those wishing to respond to the BAA:

2. Content and Form of Application Submission

a. General Information

i. Preliminary Inquiries: 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 the preparation of a research proposal often represents a substantial investment of time and effort by the applicant. Therefore, in an attempt to minimize this burden, we strongly encourage applicants interested in submitting proposals to make preliminary inquiries as to the general need for the type of research effort contemplated, before expending extensive effort in preparing a whitepaper and/or detailed proposal or submitting proprietary information. The TPOC names, telephone numbers, and email addresses are listed immediately after each research area of interest and they should be contacted, as appropriate, prior to the submission of whitepapers or proposals.

*NOTE: The Government will not be obligated by any discussion that arises out of preliminary inquiries.

ii. Classified Submissions: Classified proposals are not accepted under this BAA.

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

iv. Post-Employment Conflict of Interest: There are certain post-employment restrictions on former federal employees, including special government employees (18 U.S.C. 207). If a prospective applicant believes a conflict of interest may exist, the situation should be discussed with the TPOC listed in the BAA for their area of scientific research who will then

coordinate with appropriate ARO legal counsel prior to the applicant expending time and effort in preparing a proposal.

v. Statement of Disclosure Preference: In accordance with Section II.D.2.e.iii of this BAA, Form 52 or 52A shall be completed stating your preference for release of information contained in your proposal. Copies of these forms may be downloaded from the ARO web site at https://www.arl.army.mil/business/broad-agency-announcements/baa-forms/.

NOTE: Proposals may be handled for administrative purposes by support contractors. These support contractors are prohibited from submitting proposals under this BAA and are bound by non-disclosure and/or conflict of interest requirements as deemed appropriate.

vi. Equipment (see instrument-specific regulations provided in Section II.B of this BAA): Normally, title to equipment or other tangible property purchased with Government funds vests with nonprofit institutions of higher education or with nonprofit organizations whose primary purpose is conducting scientific research if vesting will facilitate scientific research performed for the Government. For-profit organizations are expected to possess the necessary plant and equipment to conduct the proposed research. Deviations may be made on a case-by-case basis to allow for-profit organizations to purchase equipment but regulatory disposition instructions must be followed.

b. The Application Process

The application process is in three stages as follows:

i. Stage 1- Verify the accuracy of your Unique Entity Identifier (formerly DUNS) at the Dun and Bradstreet (D&B) website http://fedgov.dnb.com/webform before registering with the System for Award Management System (SAM) at https://www.sam.gov. Prospective applicants must be registered in SAM prior to submitting an application or plan. The SAM 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 SAM; they will be pre-populated using D&B Unique Entity Identifier record data. When D&B confirms the correction has been made, the registrant must then re-visit sam.gov and click a “yes”" to D&B's changes. Only at this point will the D&B data be accepted into the SAM record. Allow a minimum of two (2) business days for D&B to send the modified data to SAM.

ii. Stage 2 - Prospective proposers are requested to submit whitepapers prior to the submission of a complete, more detailed proposal. The purpose of whitepapers 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 whitepapers, feedback will be provided to the proposers to encourage or discourage them from submitting proposals. Whitepapers should present the effort in sufficient detail to allow evaluation of the concept's scientific merit and its potential contributions of the effort to the Army mission.

iii. Stage 3 - Interested applicants are required to submit proposals. All proposals submitted

under the terms and conditions cited in this BAA will be reviewed regardless of the feedback on, or lack of submission of, a whitepaper. If applicants have not submitted whitepapers, proposals may still be submitted for funding consideration. Proposals must be submitted in order for the applicant to be considered for funding.

All proposals for Assistance Instruments must be submitted electronically through Grants.gov using Workspace. Proposals for Contracts may be submitted via either Grants.gov or email to: usarmy.rtp.aro.mbx.baa@army.mil. See Section II.D.f of this BAA for information on the proposal submission process.

Requests for waiver of electronic submission requirements may be submitted via email to: usarmy.rtp.aro.mbx.baa@army.mil or regular mail:

Army Research Office
ATTN: FCDD-RLR (Proposal Processing)
P.O. Box 12211
RTP, NC 27709-2211

All required forms for proposals may be downloaded from the ARO web site at https://www.arl.army.mil/business/broad-agency-announcements/baa-forms/ under "For the Researcher" (Forms, ARO BAA Forms).

c. Whitepaper Preparation

i. Whitepapers should focus on describing details of the proposed research, including how it is innovative, how it could substantially increase the scientific state of the art, Army relevance, and potential impact.

ii. Whitepapers are limited to seven (7) total pages; five (5) pages for whitepaper technical content, one (1) cover page and a one (1) page addendum as discussed below. Evaluators will only review the whitepaper cover page, up to five whitepaper technical content pages, and the one-page addendum.

Whitepapers must be in the following format but do not require any special forms:

- Page Size: 8 ½ x 11 inches
- Margins – 1 inch
- Spacing – single
- Font – Times New Roman, 12 point

iii. Combine all files and forms into a single PDF before submitting.

iv. Format and content of whitepapers:

(1) <u>COVER PAGE (not to exceed one page)</u>:

The whitepaper cover page shall include at a minimum: Title of the whitepaper, name of the

individual and organization submitting the whitepaper, the research area and number against which the whitepaper is submitted, and the TPOC name.

(2) TECHNICAL CONTENT (not to exceed five pages):

(a) A detailed discussion of the effort's scientific research objective, approach, relationship to similar research, 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 the Army's mission and how this contribution would be demonstrated.

(b) The type of support, if any, the applicant 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). Applicants 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.

(c) The cost portion of the whitepaper shall contain a brief cost estimate revealing all the component parts of the proposal, including research hours, burden, material costs, travel, etc.

(3) ADDENDUM (not to exceed one page):

Include biographical sketches of the key personnel who will perform the research, highlighting their qualifications and experience.

v. RESTRICTIVE MARKINGS ON WHITEPAPERS:

(1) Any proprietary data that the applicant intends to be used only by the Government for evaluation purposes must be clearly marked. The applicant must also identify any technical data or computer software contained in the whitepaper that is to be treated by the Government as limited rights in technical data and restricted rights in computer software. In the absence of such identification, the Government will conclude there are no limitations or restrictions on technical data or computer software included in the whitepaper. Records or data bearing a restrictive legend may be included in the whitepaper. It is the intent of the Army to treat all whitepapers as procurement sensitive before award and to disclose their contents only for the purpose of evaluation.

Care must be exercised to ensure that classified, sensitive, and critical technologies are not included in a whitepaper. If such information is required, appropriate restrictive markings and procedures should be applied prior to submission of the whitepaper.
(2) Applicants are cautioned, however, that portions of the whitepapers may be subject to release under terms of the Freedom of Information Act, 5 U.S.C. 552, as amended.

vi. EVALUATION AND DISPOSITION OF WHITEPAPERS:

(1) Evaluation Process: Applicants are advised that invitations for proposals will be made based on the whitepaper submission and the availability of funding. The whitepaper will be evaluated for the concept's scientific merit and potential contributions of the effort to the Army mission. Applicants whose whitepapers are evaluated as having significant scientific merit may be invited to submit a proposal. However, an applicant may submit a proposal despite not submitting a whitepaper or receiving a proposal invite from the Government.

(2) Disposition Process: The applicant will be notified in writing after completion of the evaluation. Whitepapers will not be returned to applicants.

d. Whitepaper Submission

All whitepapers must be emailed directly to the TPOC. In the email subject line, include the phrase "Whitepaper Submission," the BAA number W911NF-17-S-0002, and the research topic number from Section II.A of this BAA. Whitepapers submitted via email must be in a single PDF formatted file as an email attachment.

e. Preparation of Proposals

i. COVER PAGE:

(1) A Cover Page is required. For contract proposals submitted by email, use ARO Form 51. For all Assistance instruments and contract proposals submitted via Grants.gov, use the SF 424 (R&R) Form. Proposals will not be processed without either: (1) a signed Cover Page, ARO Form 51, or (2) a SF 424 (R&R) Form.

(2) Should the project be carried out at a branch campus or other component of the applicant, that branch campus or component should be identified in the space provided (Block 11 on the ARO Form 51 and Block 12 on the SF 424 (R&R) Form).

(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 domain.

(4) The proposed duration for which support is requested should be consistent with the nature and complexity of the proposed activity. For research areas listed at Sections II.A.1 through II.A.3 of this BAA applicants shall discuss the preferred performance period with the TPOC.

(5) Specification of a desired starting date for the project is important and helpful; however, requested effective dates cannot be guaranteed.

(6) 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] and implemented by 32 CFR 22.420(d), federal agencies shall obtain each awardees' Taxpayer Identification Number (TIN). 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.

(7) Applicants shall provide their organization's Unique Entity Identifier (formerly DUNS). This number is a nine-digit number assigned by D&B Information Services. See Section II.D.3 of this BAA for requirements pertaining to the Unique Entity Identifier.

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

ii. TABLE OF CONTENTS:

Use the following format for the Table of Contents. Forms are available at https://www.arl.army.mil/business/broad-agency-announcements/baa-forms/

SECTION	PAGE NUMBER
Table of Contents	A-1
Statement of Disclosure Preference (Form 52 or 52A)	B-1
Research and Related Other Project Information	B-2
Project Abstract	C-1
Project Description (Technical Proposal)	D-1 - D-☐
Biographical Sketch	E-1 - E-☐
Bibliography	F-1 - F-☐
Current and Pending Support	G-1 - G-☐
Facilities, Equipment, and Other Resources	H-1 - H-☐
Proposal Budget	I-1 - I-☐
Contract Facilities Capital Cost of Money (DD Form 1861)	J-1
Appendices List Appendix Items: _____	K-☐

This format applies to all proposals submitted via email and via Grants.gov. Applicants' should show the location of each section of the proposal, as well as major subdivisions of the project description.

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

iv. RESEARCH AND RELATED OTHER PROJECT INFORMATION: Must be completed and signed by all applicants.

v. PROJECT ABSTRACT:

(1) The project abstract shall be completed on the form entitled "Publicly Releasable Project Abstract" found at the following website: https://www.arl.army.mil/business/broad-agency-announcements/baa-forms/

(2) Unless otherwise instructed in this BAA, 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 scientific objectives, methods to be employed, and the significance of the proposed effort to the advancement of scientific knowledge.

(3) The abstract should be no longer than one (1) page (maximum 4,000 characters).

(4) The project abstract shall be marked by the applicant as publically releasable. By submission of the project abstract, the applicant confirms that the abstract is releasable to the public. For a proposal that results in a grant award, the project abstract will be posted to a searchable website available to the general public to meet the requirements of Section 8123 of the DoD Appropriations Act, 2015. The website address is https://dodgrantawards.dtic.mil/grants.

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

(1) A complete discussion stating the background and objectives of the proposed work, the scientific approaches to be considered, the relationship to competing or related research, and the level of effort to be employed. Include also the nature and extent of the anticipated results and how they will significantly advance the scientific state-of-the-art. Also, if known, include the manner in which the work will contribute to the accomplishment of the Army's mission. Ensure the proposal identifies any scientific uncertainties and describes specific approaches for the resolution or mitigation of the uncertainties.

(2) A brief description of your organization. If the applicant has extensive government contracting experience and has previously provided the information to the ARL, the information need not be provided again. A statement setting forth this condition should be made.

(3) The names of other federal, state, local agencies, or other parties receiving the proposal and/or funding the proposed effort. If none, state so. Concurrent or later submission of the proposal to other organizations will not prejudice its review by the ARO 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) A statement regarding the use of Class I and Class II ozone- depleting substances. Ozone-depleting substances are any substance designated as Class I by EPA, including but not limited to chlorofluorocarbons, halons, carbon tetrachloride, and methyl chloroform, and any substance designated as Class II by EPA, including but not limited to hydrochlorofluorocarbons. See 40 CFR Part 82 for detailed information. If Class I or II substances are to be utilized, a list shall be provided as part of the applicant's proposal. If none, state so.

(6) The type of support, if any, requested by the applicant (e.g., facilities, equipment, and materials).

vii. BIOGRAPHICAL SKETCH:

(1) This section shall contain the biographical sketches for key personnel only.

(a) Primary PI: The Primary PI provides a single or initial point of communication between the ARO 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 to ARO. ARO does not infer any additional scientific stature to this role among collaborating investigators.

(b) Co-PIs: 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 ARO. 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. ARO does not infer any distinction among multiple PIs.

(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 publications most closely related to the proposed project and up to five 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 years. Include pending publications and submissions. Otherwise, state "None."

(d) Names of each investigator's own graduate or post-graduate advisors and advisees.

NOTE: The information provided in (c) and (d) is used to help identify potential conflicts or bias in the selection of reviewers.

(3) For the personnel categories of postdoctoral associates, other professionals, and students

(research assistants), the proposal may include information on exceptional qualifications of these individuals that merit consideration in the evaluation of the proposal.

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

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

ix. 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 PI's and other key personnel's time, even if they receive no salary support from the project(s).

(2) The information should include, as a minimum: (i) the project/proposal title and brief description, (ii) the name and location of the organization or agency presently funding the work or requested to fund such work, (iii) the award amount or annual dollar volume of the effort, (iv) the period of performance, and (v) a breakdown of the time required of the PI and/or other key personnel.

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

xi. PROPOSAL BUDGET (including DD Form 1861):

(1) Each proposal must contain a budget for each year of support requested and a cumulative budget for the full term of requested support. Each budget year and the cumulative budget for the full term must be documented on ARO Form 99. ARO Form 99 may be reproduced, but you may not make substitutions in prescribed budget categories nor alter or rearrange the cost categories as they appear on the form. The proposal may request funds under any of the categories listed so long as the item is considered necessary to perform the proposed work and is not precluded by applicable cost principles. In addition to the forms, the budget proposal should include budget justification for each year.

(2) A signed summary budget page must be included. The documentation pages should be titled "Budget Explanation Page" and numbered chronologically starting with the budget form. The need for each item should be explained clearly.

(3) All cost data must be current and complete. Costs proposed must conform to the following principles and procedures:

Institutions of Higher Education: 2 CFR Part 200
Nonprofit Organizations: 2 CFR Part 200
For-Profit/Commercial Organizations: FAR Part 31, DFARS Part 231, FAR Subsection 15.403-5, and DFARS Subsection 215.403-5.

*For those nonprofit organizations specifically exempt from the provisions of Subpart E of 2 CFR Part 200 (see 2 CFR 200.401(c)), FAR Part 31 and DFARS Part 231 shall apply.

(4) Sample itemized budgets and the information they must include for a contract and for grants and cooperative agreements can be found at Section II.H of this BAA (Other Information). Before award of a cost-type contract or assistance instrument it must be established that an approved accounting system and financial management system exist.

xii. 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.

(1) To evaluate compliance with Title IX of the Education Amendments of 1972 (20 U.S.C. A Section 1681 Et. Seq.), the Department of Defense is collecting certain demographic and career information to be able to assess the success rates of women who are proposed for key roles in applications in STEM disciplines. To enable this assessment, each application must include the following forms completed as indicated.

(A) Research and Related Senior/Key Person Profile (Expanded) form:

The Degree Type and Degree Year fields on the Research and Related Senior/Key Person Profile (Expanded) form will be used by DoD as the source for career information. In addition to the required fields on the form, applicants must complete these two fields for all individuals that are identified as having the project role of PD/PI or Co-PD/PI on the form. Additional senior/key persons can be added by selecting the "Next Person" button.

(B) Research and Related Personal Data form:

This form will be used by DoD as the source of demographic information, such as gender, race, ethnicity, and disability information for the Project Director/Principal Investigator and all other persons identified as Co-Project Director(s)/Co-Principal Investigator(s). Each application must include this form with the name fields of the Project Director/Principal Investigator or any Co-Project Director(s)/Co-Principal Investigator(s) completed; however, provision of the demographic information in the form is voluntary. If completing the form for multiple individuals, each Co-Project Director/Co-Principal Investigator can be added by selecting the "Next Person" button. The demographic information, if provided, will be used for statistical purposed only and will not be made available to merit reviewers. Applicants who do not wish to provide some or all of the information should check or select the "Do not wish to provide" option.

f. Submission of Proposals

Proposals must be submitted by email (only when a contract is requested) or through Grants.gov. Proposals must be submitted through the applicant's organizational office having responsibility for Government business relations. All signatures must be that of an official authorized to commit the organization in business and financial affairs.

Proposal content requirements remain the same for both email and Grants.gov submission.

i. EMAIL SUBMISSION (only when a **Contract is the requested form of agreement**):

(1) Proposals requesting a Contract may be emailed directly to usarmy.rtp.aro.mbx.baa@army.mil. Do not email full proposals to the TPOC. All emailed proposals must adhere to the format requirements and contain the information outlined in Section II.D.2.e of this BAA.

(2) The applicant must include with its proposal submission the representations required by Section II.F.2.a.i of this BAA. The representations must include applicant POC information and be signed by an authorized representative. Note: If the applicant's SAM Representations and Certifications include its response to the representations a hard copy representation is not required with proposal submission.

(3) All forms requiring signature must be completed, printed, signed, and scanned into a PDF document. All documents must be combined into a single PDF formatted file to be attached to the email.

(4) Proposal documents (excluding required forms) must use the following format:
- Page Size – 8 ½ x 11 inches
- Margins – 1 inch
- Spacing – single
- Font – Times New Roman, 12 point, single-sided pages

ii. GRANTS.GOV SUBMISSION (For **all proposals requesting Assistance agreements).** Proposals requesting a Contract may be submitted either via Grants.gov or email:

(1) Grants.gov Registration (See Section II.D.2.g below) must be accomplished prior to application submission in Grants.gov.

NOTE: All web links referenced in this section are subject to change by Grants.gov and may not be updated here.

(2) Specific forms are required for submission of a proposal. The forms are contained in the Application Package available through the Grants.gov application process. To access these materials, go to http://www.grants.gov, select "Apply for Grants," and then select "Get Application Package." A Grant Application Package and Application Instructions are available through the Grants.Gov Apply portal under CFDA Number 12.431/Funding Opportunity Number W911NF-17-S-0002. Select "Apply" and then "Apply Now Using Workspace."

*NOTE: Effective 31 December 2017, the legacy PDF application package on Grants.gov will be retired and applicants must apply online at Grants.gov using the application Workspace. For access to complete instructions on how to apply for opportunities using Workspace refer to https://www.grants.gov/web/grants/applicants/workspace-overview.html.

The following documents are mandatory: (1) Application for Federal Assistance (R&R) (SF 424 (R&R)), and (4) Attachments form.

(3) The SF 424 (R&R) form is to be used as the cover page for all proposals submitted via Grants.gov. The SF 424 (R&R) must be fully completed. Authorized Organization Representative (AOR) usernames and passwords serve as "electronic signatures" when your organization submits applications through Grants.gov. By using the SF 424 (R&R), proposers are providing the certification required by 32 CFR Part 28 regarding lobbying (see Section II.F.2.a.ii of this BAA). 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 Section II.A of this BAA.

(4) The Attachments form must contain the documents outlined in Section II.D.2.e.ii entitled "Table of Contents". All documents must be combined into separate and single PDF formatted files using the Table of Contents names. Include "W911NF-17-S-0002" in the title so the proposal will be distinguished from other BAA submissions and upload each document to the mandatory Attachments form.

(5) The applicant must include with its proposal submission the representations required by Section II.F.2.a.ii of this BAA. The representations must include applicant POC information and be signed by an authorized representative. Attach the representations document to an available field within the Attachments form. Note: If the applicant's SAM Representations and Certifications include its response to the representations a hard copy representation is not required with proposal submission.

(6) The Grants.gov User Guide at: https://www.grants.gov/help/html/help/index.htm?callingApp=custom#t=GetStarted%2FGetStarted.htm&rhsearch=user%20guide&rhhlterm=user%20guide&rhsyns=%20 will assist AORs in the application process. Remember that you must open and complete the Application for Federal Assistance (R&R) (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".

(7) As it is possible for Grants.gov to reject the proposal during this process, it is strongly recommended that proposals be uploaded at least two days before any established deadline in the BAA so that they will not be received late and be ineligible for award consideration. It is also recommended to start uploading proposals at least two days before the deadline to plan ahead for any potential technical and/or input problems involving the applicant's own equipment.

g. Grants.gov Registration

i. Each organization that desires to submit applications via Grants.Gov must complete a one-time registration. There are several one-time actions your organization must complete in order to submit applications through Grants.gov (e.g., obtain a Unique Entity Identifier, register with the SAM, register with the credential provider, register with Grants.gov and obtain approval for an

AOR to submit applications on behalf of the organization). To register please see http://www.grants.gov/web/grants/applicants/organization-registration.html

ii. Please note the registration process for an Organization or an Individual can take between three to five business days or as long as four weeks if all steps are not completed in a timely manner.

iii. Questions relating to the registration process, system requirements, how an application form works, or the submittal process should be directed to Grants.gov at 1-800-518-4726 or support@grants.gov.

3. Unique Entity Identifier and System for Award Management (SAM)

a. Each applicant (unless the applicant is an individual or Federal awarding agency that is exempt from those requirements under 2 CFR 25.110(b) or (c), or has an exemption approved by the Federal awarding agency under 2 CFR 25.110(d)) is required to:

i. Be registered in SAM prior to submitting its application;
ii. Provide a valid unique entity identifier (formerly DUNS) in its application; and
iii. Maintain an active SAM registration with current information at all times during which it has an active Federal award or an application or plan under consideration by a Federal awarding agency.

b. The Federal awarding agency may not make a Federal award to an applicant until the applicant has complied with all applicable unique entity identifier and SAM requirements. If an applicant has not fully complied with the requirements by the time the Federal awarding agency is ready to make a Federal award, the Federal awarding agency may determine that the applicant is not qualified to receive a Federal award and use that determination as a basis for making a Federal award to another applicant.

4. Submission Dates and Times

a. Proposals

Proposals will be considered until and including the closing date of this announcement (see cover page of this announcement for opening/closing dates), except for special programs identified in this BAA that may announce specific opening/closing dates. Proposals submitted after the closing date will not be considered by the Government.

b. Proposal Receipt Notices

i. Grants.gov: After a proposal is submitted to Grants.gov, the AOR will receive a series of three emails from Grants.gov. The first two emails will be received within 24 to 48 hours after submission. The first email will confirm time of receipt of the proposal by the Grants.gov system and the second will indicate that the proposal has either been successfully validated by the system prior to transmission to the grantor agency or has been rejected due to errors. A third email will be received once the grantor agency has confirmed receipt of the proposal. Reference the Grants.gov User Guide at

https://www.grants.gov/help/html/help/index.htm?callingApp=custom#t=GetStarted%2FGetStarted.htm&rhsearch=user%20guide&rhhlterm=user%20guide&rhsyns=%20 for information on how to track your application package.

For the purposes of this BAA, an applicant's proposal is not considered received by ARO until the AOR receives email #3.

ii. Email Submission: After a proposal is submitted to usarmy.rtp.aro.mbx.baa@army.mil, the AOR will receive an email confirming time of receipt of the proposal by the grantor agency. For the purposes of this BAA, an applicant's proposal is not considered received by the grantor agency until the AOR receives the email confirming receipt of the proposal.

5. Intergovernmental Review

Not Applicable

6. Funding Restrictions

There are no specific funding restrictions associated with this BAA (e.g. direct costs, indirect costs, etc.).

7. Other Submission Requirements

a. Information to Be Requested from Successful Applicants: Applicants whose proposals are accepted for funding will be contacted before award to provide additional information required for award. The required information may include requests to clarifying budget explanations, representations, certifications, and some technical aspects.

b. For Contracts Only: Performance Work Statements (PWS). Prior to award the Contracting Officer may request that the contractor submit a PWS for the effort to be performed, which will be incorporated into the contract at the time of award.

(End of Section)

E. Proposal Review Information

1. Criteria

a. Except for the PECASE and HSAP/URAP programs, proposals submitted in response to this BAA will be evaluated using the criteria listed below (in descending order of importance):

i. The overall scientific and/or technical merits of the proposal.

ii. The potential contributions of the effort to the Army mission.

iii. The qualifications, capabilities, and experience of the proposed PI, team leader, or other key personnel who are critical to achievement of the proposed objectives.

b. The following criterion will be evaluated, in addition to the criteria listed in Section II.E.1.a, in the evaluation of proposals submitted against the ECP. This criterion is of least importance:

Long-term commitment by the institution of higher education to the early career investigator and the proposed research.

c. The following criterion will be evaluated, in addition to the criteria listed in Section II.E.1.a, in the evaluation of proposals submitted against the RI Program. This criterion is of least importance.

The applicant's capabilities, related experience, facilities, techniques, or unique combinations of these, which are integral factors for achieving the proposed objectives.

d. Proposals submitted in response to the PECASE program will be evaluated using the criteria listed below. The criteria are listed in descending order of importance (NOTE: Criteria i, ii, and iii are of equal importance):

i. The overall scientific and/or technical merits of the proposal.
ii. Scientific leadership.
iii. Publications.
iv. The potential contributions of the effort to the Army mission.
v. Presentations.
vi. Commitment letters from institution of higher education.
vii. Community outreach.

e. Proposals submitted in response to the HSAP/URAP program will be evaluated using the criteria listed below (in descending order of importance):

i. The overall scientific and/or technical merits of the proposal.

ii. The potential contributions of the effort to the Army mission.

iii. Educational merit to include the proposed student research, mentorship strategy, anticipated outcomes for the student and applicant, student qualifications, and number of proposed students.

**NOTE: Cost sharing will not be a consideration in proposal evaluation.

2. Review and Selection Process

a. 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 not receive further review.

b. All proposals are treated as procurement sensitive and 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 applicant 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 applicant must indicate on the appropriate proposal form (Form 52 or 52A) any limitation to be placed on disclosure of information contained in the proposal.

c. Each proposal will be evaluated based on the evaluation criteria in Section II.E.1 of this BAA rather than against other proposals for research in the same general area.

d. Upon completion of an evaluation against the criteria in Section II.E.1, a proposal selected for possible award will be analyzed for the realism and reasonableness of costs. Proposal costs must be determined reasonable and realistic before the Government can make an award.

3. Recipient Qualification

a. <u>Grant, Cooperative Agreement, and TIA Proposals</u>:

i. The Grants Officer is responsible for determining a recipient's qualification prior to award. In general, a Grants Officer will award grants or cooperative agreements only to qualified recipients that meet the standards at 32 CFR 22.415. To be qualified, a potential recipient must:

(1) Have the management capability and adequate financial and technical resources, given those that would be made available through the grant or cooperative agreement, to execute the program of activities envisioned under the grant or cooperative agreement;

(2) Have a satisfactory record of executing such programs or activities (if a prior recipient of an award);

(3) Have a satisfactory record of integrity and business ethics; and

(4) Be otherwise qualified and eligible to receive a grant or cooperative agreement under applicable laws and regulations.

Applicants are requested to provide information with proposal submissions to assist the Grants Officer's evaluation of recipient qualification.

ii. In accordance with Office of Management and Budget (OMB) guidance in parts 180 and 200 of Title 2, CFR, it is DoD policy that DoD Components must report and use integrity and performance information in the Federal Awardee Performance and Integrity Information System (FAPIIS), or any successor system designated by OMB, concerning grants, cooperative agreements, and TIAs as follows:

If the total Federal share will be greater than the simplified acquisition threshold on any Federal award under a notice of funding opportunity (see 2 CFR 200.88 Simplified Acquisition Threshold):

(1) The Federal awarding agency, prior to making a Federal award with a total amount of Federal share greater than the simplified acquisition threshold, will review and consider any information about the applicant that is in the designated integrity and performance system accessible through SAM (currently FAPIIS) (see 41 U.S.C. 2313);

(2) An applicant, at its option, may review information in the designated integrity and performance systems accessible through SAM and comment on any information about itself that a Federal awarding agency previously entered and is currently in the designated integrity and performance system accessible through SAM;

(3) The Federal awarding agency will consider any comments by the applicant, in addition to the other information in the designated integrity and performance system, in making a judgment about the applicant's integrity, business ethics, and record of performance under Federal awards when completing the review of risk posed by applicants as described in 2 CFR 200.205 Federal awarding agency review of risk posed by applicants.

b. Contract Proposals:

i. Contracts shall be awarded to responsible prospective contractors only. See FAR 9.104-1 for a listing of the general standards against which an applicant will be assessed to determine responsibility.

Applicants are requested to provide information with proposal submission to assist the Contracting Officer's evaluation of responsibility.

ii. FAPIIS will be checked prior to making an award. The web address is: https://www.fapiis.gov/fapiis/index.action. The applicant representing the entity may comment in this system on any information about the entity that a federal government official entered. The information in FAPIIS will be used in making a judgment about the entity's

integrity, business ethics, and record of performance under Federal awards that may affect the official's determination that the applicant is qualified to receive an award.

(End of Section)

F. Award Administration Information

1. Award Notices

Applicants whose proposals are recommended for award may be contacted by a Contract/Grant Specialist to discuss additional information required for award. This may include representations and certifications, revised budgets or budget explanations, certificate of current cost or pricing data, subcontracting plan for small businesses, and/or other information as applicable to the proposed award. The anticipated start date will be determined at that time.

The notification email must not be regarded as an authorization to commit or expend funds. The Government is not obligated to provide any funding until a Government Contracting/ Grants Officer signs the award document.

The award document signed by the Government Contracting/Grants Officer is the official and authorizing award instrument. The authorizing award instrument, signed by the Contracting/ Grants Officer, will be emailed to the PI and AOR.

2. Administrative and National Policy Requirements

a. Required Representations and Certifications:

i. Contract Proposals:

(1) Representations and certifications shall be completed by successful applicants prior to award. FAR Online Representations and Certifications are to be completed through SAM at https://www.sam.gov. As appropriate, DFARS and contract-specific certification packages will be provided to the contractor for completion prior to award.

(2) FAR 52.203-18, PROHIBITION ON CONTRACTING WITH ENTITIES THAT REQUIRE CERTAIN CONFIDENTIALITY AGREEMENTS OR STATEMENTS—REPRESENTATION (JAN 2017)

(a) Definition. As used in this provision--

"Internal confidentiality agreement or statement", "subcontract", and "subcontractor", are defined in the clause at 52.203-19, Prohibition on Requiring Certain Internal Confidentiality Agreements or Statements.

(b) In accordance with section 743 of Division E, Title VII, of the Consolidated and Further Continuing Appropriations Act, 2015 (Pub. L. 113-235) and its successor provisions in subsequent appropriations acts (and as extended in continuing resolutions), Government agencies are not permitted to use funds appropriated (or otherwise made available) for contracts with an entity that requires employees or subcontractors of such entity seeking to report waste, fraud, or abuse to sign internal confidentiality agreements or statements prohibiting or otherwise restricting such employees or subcontractors from lawfully reporting such waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

(c) The prohibition in paragraph (b) of this provision does not contravene requirements applicable to SF 312, (Classified Information Nondisclosure Agreement), Form 4414 (Sensitive Compartmented Information Nondisclosure Agreement), or any other form issued by a Federal department or agency governing the nondisclosure of classified information.

(d) Representation. By submission of its offer, the applicant represents that it will not require its employees or subcontractors to sign or comply with internal confidentiality agreements or statements prohibiting or otherwise restricting such employees or subcontractors from lawfully reporting waste, fraud, or abuse related to the performance of a Government contract to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information (e.g., agency Office of the Inspector General).

(3) FAR 52.209-11, REPRESENTATION BY CORPORATIONS REGARDING DELINQUENT TAX LIABILITY OR A FELONY CONVICTION UNDER FEDERAL LAW (FEB 2016)

As required by sections 744 and 745 of Division E of the Consolidated and Further Continuing Appropriations Act, 2015 (Pub. L 113-235), and similar provisions, if contained in subsequent appropriations acts, the Government will not enter into a contract with any corporation that--

Has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability, where the awarding agency is aware of the unpaid tax liability, unless an agency has considered suspension or debarment of the corporation and made a determination that suspension or debarment is not necessary to protect the interests of the Government; or

Was convicted of a felony criminal violation under any Federal law within the preceding 24 months, where the awarding agency is aware of the conviction, unless an agency has considered suspension or debarment of the corporation and made a determination that this action is not necessary to protect the interests of the Government.

The applicant represents that—

It is [ ] is not [ ] a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability; and

It is [ ] is not [ ] a corporation that was convicted of a felony criminal violation under a Federal law within the preceding 24 months.

ii. Grant and Cooperative Agreement Proposals:

(1) Grant awards greater than $100,000 require a certification of compliance with a national policy mandate concerning lobbying. Statutes and Government-wide regulations require the certification to be submitted prior to award. When submitting your grant through Grants.gov, by completing blocks 18 and 19 of the SF 424 (R&R) Form, the grant applicant is providing the certification on lobbying required by 32 CFR Part 28; otherwise a copy signed by the AOR must be provided. Below is the required certification:

> CERTIFICATION AT APPENDIX A TO 32 CFR PART 28 REGARDING LOBBYING: Certification for Contracts, Grants, Loans, and Cooperative Agreements the undersigned certifies, to the best of his or her knowledge and belief, that:
>
> > (1) 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.
> >
> > (2) 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 SF-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.
> >
> > (3) 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 31 U.S.C. 1352. 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) In accordance with Continuing Appropriations Act, 2017 (Pub. L. 114-223), or any other Act that extends to fiscal year (FY) 2017 funds the same prohibitions as contained in section 743, division E, title VII, of the Consolidated Appropriations Act, 2016 (Pub. L. 114-113), none of the funds appropriated or otherwise made available by that or any other Act may be made available for a grant or cooperative agreement with an entity that requires its employees or contractors seeking to report fraud, waste, or abuse to sign internal confidentiality agreements or statements prohibiting or otherwise restricting those employees or contractors from lawfully reporting that

waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive the information.

PROHIBITION ON CONTRACTING WITH ENTITIES THAT REQUIRED CERTAIN INTERNAL CONFIDENTIALITY AGREEMENTS – REPRESENTATION

Agreement with the representation below will be affirmed by checking the "I agree" box in block 17 of the SF424 (R&R) as part of the electronic proposal submitted via Grants.gov. The representation reads as follows:

By submission of its proposal or application, the applicant represents that it does not require any of its employees, contractors, or subrecipients seeking to report fraud, waste, or abuse to sign or comply with internal confidentiality agreements or statements prohibiting or otherwise restricting those employees, contractors, subrecipients from lawfully reporting that waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

*Note that: Section 743 states that it does not contravene requirements applicable to SF 312, Form 4414, or any other form issued by a Federal department or agency governing the nondisclosure of classified information.

(3) Recipients are required to submit the following representation with the application package IAW the instructions at Section II.D.2.f.ii of this BAA:

REPRESENTATIONS UNDER DOD ASSISTANCE AGREEMENTS:

APPROPRIATIONS PROVISIONS ON TAX DELINQUENCY AND FELONY CONVICTIONS

The applicant is ( ) is not ( ) a "Corporation" meaning any entity, including any institution of higher education, other nonprofit organization, or for-profit entity that has filed articles of incorporation.

If the applicant is a "Corporation" please complete the following representations:

(a) The applicant represents that it is () is not ( ) a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

(b) The applicant represents that it is () is not ( ) is not a corporation that was convicted of a criminal violation under any Federal law within the preceding 24 months.

NOTE: If an applicant responds in the affirmative to either of the above representations,

the applicant is ineligible to receive an award unless the agency suspension and debarment official (SDO) has considered suspension or debarment and determined that further action is not required to protect the Government's interests. The applicant therefore should provide information about its tax liability or conviction to the agency's SDO as soon as it can do so, to facilitate completion of the required considerations before award decisions are made.

PROHIBITION ON CONTRACTING WITH ENTITIES USING CERTAIN TELECOMMUNICATIONS AND VIDEO SURVEILLANCE SERVICES OR EQUIPMENT

Section 889 of the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2019 (Public Law 115-232) prohibits the head of an executive agency from obligating or expending loan or grant funds to procure or obtain, extend, or renew a contract to procure or obtain, or enter into a contract (or extend or 105 renew a contract) to procure or obtain the equipment, services, or systems prohibited systems as identified in section 889 of the NDAA for FY 2019. For more information on how this applies to all grant recipients and sub-recipients after August 13, 2020, please see DoD Research General Terms and Conditions (SEP 2020) NP Article IV. Other national policy requirements, paragraph 18.

b. Policy Requirements:

The following list provides notable national policy requirements that may be applicable to an award. NOTE: The following is not an all-inclusive list of policy requirements. For assistance awards, refer to the DoD Research and Development General Terms and Conditions at https://www.onr.navy.mil/en/work-with-us/manage-your-award/manage-grant-award/grants-terms-conditions for additional national policy requirements that may apply. For contract awards, appropriate clauses will be added to award documents.

i. PROTECTION OF HUMAN SUBJECTS

(1) Assistance Instruments:

(a) The recipient must protect the rights and welfare of individuals who participate as human subjects in research under this award and comply with the requirements at 32 CFR part 219, Department of Defense Instruction (DoDI) 3216.02, 10 U.S.C. 980, and when applicable, Food and Drug Administration (FDA) regulations.

(b) The recipient must not begin performance of research involving human subjects, also known as human subjects research (HSR), that is covered under 32 CFR part 219, or that meets exemption criteria under 32 CFR 219.101(b), until you receive a formal notification of approval from a DoD Human Research Protection Official (HRPO). Approval to perform HSR under this award is received after the HRPO has performed a review of the recipient's documentation of planned HSR activities and has officially furnished a concurrence with the recipient's determination as presented in the documentation.

(c) In order for the HRPO to accomplish this concurrence review, the recipient must provide sufficient documentation to enable his or her assessment as follows:

(i) If the HSR meets an exemption criteria under 32 CFR 219.101(b), the documentation must include a citation of the exemption category under 32 CFR 219.101(b) and a rationale statement.

(ii) If the recipient's activity is determined as "non-exempt research involving human subjects", the documentation must include:

- Assurance of Compliance (i.e., Department of Health and Human Services Office for Human Research Protections (OHRP) Federal Wide Assurance (FWA)) appropriate for the scope of work or program plan; and

- Institutional Review Board (IRB) approval, as well as all documentation reviewed by the IRB to make their determination.

(d) The HRPO retains final judgment on what activities constitute HSR, whether an exempt category applies, whether the risk determination is appropriate, and whether the planned HSR activities comply with the requirements in paragraph (a) of this section.

(e) The recipient must notify the HRPO immediately of any suspensions or terminations of the Assurance of Compliance.

(f) DoD staff, consultants, and advisory groups may independently review and inspect the recipient's research and research procedures involving human subjects and, based on such findings, DoD may prohibit research that presents unacceptable hazards or otherwise fails to comply with DoD requirements.

(g) Definitions for terms used in this article are found in DoDI 3216.02.

(2) Contracts: The appropriate clauses shall be added to the award.
NOTE: The Human Subjects DFARS clause is currently under revision and may be changed prior to any awards resulting from the BAA. At time of award, the applicable clause that is current and approved will apply.

ii. ANIMAL USE:

(1) Assistance Instruments:

(a) Prior to initiating any animal work under the award, the recipient must:

(i) Register the recipient's research, development, test, and evaluation or training facility with the Secretary of Agriculture in accordance with 7 U.S.C. 2136 and 9 CFR section 2.30, unless otherwise exempt from this requirement by meeting the conditions in 7 U.S.C. 2136 and 9 CFR parts 1-4 for the duration of the activity.

(ii) Have the recipient's proposed animal use approved in accordance with DoDI 3216.01, Use of Animals in DoD Programs by a DoD Component Headquarters Oversight Office.

(iii) Furnish evidence of such registration and approval to the grants officer.

(b) The recipient must make the animals on which the research is being conducted, and all premises, facilities, vehicles, equipment, and records that support animal care and use available during business hours and at other times mutually agreeable to the recipient, the United States Department of Agriculture Office of Animal and Plant Health Inspection Service (USDA/APHIS) representative, personnel representing the DoD component oversight offices, as well as the grants officer, to ascertain that the recipient is compliant with 7 U.S.C. 2131 et seq., 9 CFR parts 1-4, and DoDI 3216.01.

(c) The recipient's care and use of animals must conform with the pertinent laws of the United States, regulations of the Department of Agriculture, and regulations, policies, and procedures of the DoD (see 7 U.S.C. 2131 et seq., 9 CFR parts 1-4, and DoDI 3216.01).

(d) The recipient must acquire animals in accordance with DoDI 3216.01.

(2) Contracts: The appropriate clauses shall be added to the award.

iii. BIOLOGICAL SAFETY PROGRAM REQUIREMENTS:

(1) Assistance Instruments and Contracts: Awards may be subject to biological safety program requirements IAW:

(a) Army Regulation (AR) 385-10, Chapter 20
https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN16777_ARN16343_AR385_10_FINAL.pdf

(b) Department of Army (DA) Pamphlet (PAM) 385-69
https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/p385_69.pdf
(c) DoD Manual 6055.18-M, Enclosure 4, Section 13 https://www.hsdl.org/?view&did=24365

iv. MILITARY RECRUITING:

(1) Assistance Instruments: This is to notify potential applicants that each grant or cooperative agreement awarded under this announcement to an institution of higher education must include the following term and condition:

(a) As a condition for receiving funds available to the DoD under this award, you agree that you are not an institution of higher education (as defined in 32 CFR part 216) that has a policy or practice that either prohibits, or in effect prevents:

(i) The Secretary of a Military Department from maintaining, establishing, or operating a

unit of the Senior Reserve Officers Training Corps (ROTC)—-in accordance with 10 U.S.C. 654 and other applicable Federal laws—-at that institution (or any sub-element of that institution);

(ii) Any student at that institution (or any sub-element of that institution) from enrolling in a unit of the Senior ROTC at another institution of higher education.

(iii) The Secretary of a Military Department or Secretary of Homeland Security from gaining access to campuses, or access to students (who are 17 years of age or older) on campuses, for purposes of military recruiting in a manner that is at least equal in quality and scope to the access to campuses and to students that is provided to any other employer; or

(iv) Access by military recruiters for purposes of military recruiting to the names of students (who are 17 years of age or older and enrolled at that institution or any sub-element of that institution); their addresses, telephone listings, dates and places of birth, levels of education, academic majors, and degrees received; and the most recent educational institutions in which they were enrolled.

(b) If you are determined, using the procedures in 32 CFR part 216, to be such an institution of higher education during the period of performance of this award, we:

(i) Will cease all payments to you of DoD funds under this award and all other DoD grants and cooperative agreements; and

(ii) May suspend or terminate those awards unilaterally for material failure to comply with the award terms and conditions.

(2) Contracts: Each contract awarded under this announcement to an institution of higher education shall include the following clause: DFARS 252.209-7005, Military Recruiting on Campus.

v. SUBCONTRACTING:

(1) Assistance Instruments: N/A

(2) Contracts: 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 and small disadvantaged business (SDB) concerns to be considered fairly as subcontractors. All other than U.S. small businesses proposing contracts expected to exceed $700,000 and that have subcontracting possibilities are required to submit a subcontracting plan IAW FAR 19.702(a), and shall do so with their proposal.

Subcontracting plans are determined to be acceptable or unacceptable based on the criteria established at FAR 19.705-4, DFARS 219.705-4, and AFARS 5119.705-4. Goals are established on an individual contract basis and should result in realistic, challenging and attainable goals that, to the greatest extent possible, maximize small business participation in

subcontracting for Small Business, SDB, Woman-Owned Small Business (WOSB), Economically-Disadvantaged Women-Owned Small Business (EDWOSB), Service-Disabled Veteran-Owned Small Business (SDVOSB), Veteran-Owned Small Business (VOSB), and Historically Underutilized Business Zone (HUBZone) Small Business consistent with applicants' make-or-buy policy, the pool of and availability of qualified and capable small business subcontractors, their performance on subcontracts, and existing relationships with suppliers.

Subcontracting goals should result in efficient contract performance in terms of cost, schedule, and performance and should not result in increased costs to the Government or undue administrative burden to the prime contractor. More information on the Subcontracting program and the DoD Subcontracting goals may be found at: https://business.defense.gov/About/Goals-and-Performance/

vi. EXPORT CONTROL LAWS:

(1) Assistance Instruments: N/A

(2) Contracts: Applicants should be aware of current export control laws and are responsible for ensuring compliance with all International Traffic in Arms Regulation (ITAR) (22 CFR 120 et. Seq.) requirements, as applicable. In some cases, developmental items funded by the Department of Defense are now included on the United States Munition List (USML) and are therefore subject to ITAR jurisdiction. Applicants should address in their proposals whether ITAR restrictions apply or do not apply, such as in the case when research products would have both civil and military application, to the work they are proposing to perform for the Department of Defense. The USML is available online at http://www.ecfr.gov/cgi-bin/text-idx?node=pt22.1.121. Additional information regarding the President's Export Control Reform Initiative can be found at http://export.gov/ecr/index.asp.

vii. DRUG-FREE WORKPLACE:

(1) Assistance Instruments: The recipient must comply with drug-free workplace requirements in Subpart B of 2 CFR part 26, which is the DoD implementation of 41 U.S.C. chapter 81, "Drug-Free Workplace."

(2) Contracts: The appropriate clause(s) shall be added to the award.

viii. DEBARMENT AND SUSPENSION:

(1) Assistance Instruments: The recipient must comply with requirements regarding debarment and suspension in Subpart C of 2 CFR part 180, as adopted by DoD at 2 CFR part 1125. This includes requirements concerning the recipient's principals under an award, as well as requirements concerning the recipient's procurement transactions and subawards that are implemented in DoD Research and Development General Terms and Conditions PROC Articles I through III and SUB Article II.

(2) Contracts: The appropriate clause(s) shall be added to the award.

ix. REPORTING SUBAWARDS AND EXECUTIVE COMPENSATION:

(1) Assistance Instruments: The recipient must report information about subawards and executive compensation as specified in the award term in Appendix A to 2 CFR part 170, "Reporting subaward and executive compensation information," modified as follows:

(a) To accommodate any future designation of a different Government wide Web site for reporting subaward information, the Web site "http://www.fsrs.gov" cited in paragraphs a.2.i. and a.3 of the award provision is replaced by the phrase "http://www.fsrs.gov or successor OMB-designated Web site for reporting subaward information";

(b) To accommodate any future designation of a different Government wide Web site for reporting executive compensation information, the Web site "http://www.sam.gov" cited in paragraph b.2.i. of the award provision is replaced by the phrase "https://www.sam.gov or successor OMB-designated Web site for reporting information on total compensation"; and

(c) The reference to "Sec. ___.210 of the attachment to OMB Circular A-133, "Audits of States, Local Governments, and Non-Profit Organizations" in paragraph e.3.ii of the award term is replaced by "2 CFR 200.330, as implemented in DoD Research and Development General Terms and Conditions SUB Article I of this award."

(2) Contracts: The appropriate clause(s) shall be added to the award.

x. NATIONAL SECURITY:

(1) This announcement requires that all current and pending research support, as defined by Section 223 of the FY21 National Defense Authorization Act must be disclosed annually, for all covered individuals identified in the proposal. Such disclosure will be updated annually during the performance of any research project selected for funding, and whenever covered individuals are added or identified as performing under the project.

(2) Any decision to accept a proposal for funding under this announcement will include full reliance on the applicant's statements. Failure to report fully and completely all sources of project support and outside positions and affiliations may be considered a material statement within the meaning of the federal False Claims Act, and constitute a violation of law.

(3) The funding agency will conduct a pre-award security review of any proposal selected for funding, and may impose additional security requirements on a resulting award, based on that review. Additional award requirements, where applicable, may include requirements for personnel or facility security clearances, additional background reporting on participants, including students and post graduate researchers, and/or imposition of citizenship requirements on participants. Offerors are advised that any significant national security risk identified may be a basis for the rejection of an otherwise awardable proposal.

3. Reporting

a. Additional reports including number and types will be specified in the award document, but will include as a minimum monthly financial status reports. The reports shall be prepared and submitted in accordance with the procedures contained in the award document and mutually agreed upon before award. Reports and briefing material will also be required as appropriate to document progress in accomplishing program metrics. A final report that summarizes the project and tasks will be required at the conclusion of the performance period for the award.

b. ARMY MANPOWER CONTRACTOR REPORTING: For Contracts Only. 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 subcontractor6 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://www.sam.gov/SAM/. 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, email 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 FY 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.

c. If the total Federal share exceeds $500,000 on any Federal award under a notice of funding opportunity, the post-award reporting requirements reflected in Appendix XII to 2 CFR 200 will

be included in the award document. This requirement also applies to modifications of awards that: 1) increase the scope of the award, 2) are issued on or after January 1, 2016, and 3) increase the federal share of the award's total value to an amount that exceeds $500,000.

(End of Section)

G. Agency Contacts

1. Questions of a technical or programmatic nature shall be directed to the TPOC for each research area of interest. The TPOC information may be found in the description of each research area of interest in Section II.A of this BAA.

2. Questions of a business or administrative nature are to be directed to the following email: usarmy.rtp.aro.mbx.baa@army.mil

3. Comments or questions submitted should be concise and to the point, eliminating any unnecessary verbiage. In addition, the relevant part and paragraph of the announcement should be referenced.

4. Requests to withdraw a proposal shall be directed to usarmy.rtp.aro.mbx.baa@army.mil.

(End of Section)

H. Other Information

Below are two separate outlines of the informational requirements for a sample cost proposal. Section H.1 is for a procurement contract and Section H.2 is for grants and cooperative agreements.

1. CONTRACT Proposals

Cost Proposal – {No Page Limit}

Cover sheet to include:

1	BAA number
2	Technical area
3	Lead organization submitting proposal
4	Type of business, selected among the following categories: “LARGE BUSINESS”, “SDB”, “OTHER SMALL BUSINESS”, “HBCU”, “MI”, “OTHER EDUCATIONAL”, OR “OTHER NONPROFIT”
5	Contractor’s reference number (if any)
6	Other team members (if applicable) and type of business for each
7	Proposal title
8	TPOC to include: salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), electronic mail (if available)
9	Administrative point of contact to include: salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), and electronic mail (if available)
10	Award instrument requested: cost plus fixed fee (CPFF), cost-contract—no fee, cost sharing contract – no fee, or other type of procurement contract (specify)
11	Place(s) and period(s) of performance
12	Total proposed cost separated by basic award and option(s) (if any)
13	Name, address, and telephone number of the proposer’s cognizant Defense Contract Management Agency (DCMA) administration office (if known)
14	Name, address, and telephone number of the proposer’s cognizant Defense Contract Audit Agency (DCAA) audit office (if known)
15	Date proposal was prepared
16	DUNS number

17	TIN number
18	CAGE code
19	Subcontractor information
20	Proposal validity period
21	Any Forward Pricing Rate Agreement, other such approved rate information, or such other documentation that may assist in expediting negotiations (if available)

a. Reasoning for Submitting a Strong Cost Proposal

The ultimate responsibility of the Contracting Officer is to ensure that all prices offered in a proposal are fair and reasonable before contract award. To establish the reasonableness of the offered prices, the Contracting Officer may ask the applicant to provide supporting documentation that assists in this determination. The applicant's ability to be responsive to the Contracting Officer's requests can expedite contract award. As specified in Section 808 of Public Law 105-261, an applicant who does not comply with a requirement to submit information for a contract or subcontract in accordance with paragraph (a)(1) of FAR 15.403-3 may be ineligible for award.

b. DCAA-Accepted Accounting System

i. Before a cost-type contract can be awarded, the Contracting Officer must confirm that the applicant has a DCAA-accepted accounting system in place for accumulating and billing costs under Government contracts [FAR 53.209-1(f)]. If the applicant has DCAA correspondence, which documents the acceptance of its accounting system, this should be provided to the Contracting Officer (i.e. attached or referenced in the proposal). Otherwise, the Contracting Officer will submit an inquiry directly to the appropriate DCAA office and request a review of the applicant's accounting system.

ii. If an applicant does not have a DCAA-accepted accounting system in place, the DCAA review process can take several months depending upon the availability of the DCAA auditors and the applicant's internal processes. This will delay contract award.

iii. For more information about cost proposals and accounting standards, view the link titled "Information for Contractors" on the main menu of the DCAA website.

c. Field Pricing Assistance

During the pre-award cost audit process, the Contracting Officer may solicit support from DCAA to determine commerciality and price reasonableness of the proposal [FAR 15.404-2]. Any proprietary information or reports obtained from DCAA field audits will be appropriately identified and protected within the Government.

d. Sample Cost Proposal – "Piece by Piece"

To help guide applicant s through the pre-award cost audit process, a sample cost proposal is detailed below. This sample allows the applicant to see exactly what the Government is looking for so that all cost and pricing back-up data can be provided to the Government in the first cost proposal submission. Review each cost element within the proposal, and take note of the types of documentation that the Contracting Officer will require from the applicant.

i. *Direct Labor*: The first cost element included in the cost proposal is Direct Labor. Each proposed employee must be listed by name and labor category.

Below is the Direct Labor as proposed by our sample applicant:

DIRECT LABOR		**YEAR 1**			**YEAR 2**		
Employee Name	**Labor Category**	**Direct Hourly Rate**	**Hours**	**Total Direct Labor**	**Direct Hourly Rate**	**Hours**	**Total Direct Labor**
Andy Smith	Program Manager	$55.00	720.00	$39,600.00	$56.65	720.00	$40,788.00
Bryan Andrews	Senior Engineer	$40.00	672.00	$26,880.00	$41.20	672.00	$27,686.40
Cindy Thomas	Principal Engineer	$50.00	512.00	$25,600.00	$51.50	512.00	$26,368.00
David Porter	Entry Level Engineer	$10.00	400.00	$4,000.00	$10.30	400.00	$4,120.00
Edward Bean	Project Administrator	$25.00	48.00	$1,200.00	$25.75	48.00	$1,236.00
Subtotal Direct Labor (DL)				$97,280.00			$100,198.40

(1) For this cost element, the Contracting Officer requires the applicant to provide adequate documentation in order to determine that the labor rate for each employee/labor category is fair and reasonable. The documentation must explain how these labor rates were derived. For example, if the rates are DCAA-approved labor rates, provide the Contracting Officer with copies of the DCAA documents stating the approval. This is the most acceptable means of documentation to determine the rates fair and reasonable. Other types of supporting documentation may include General Service Administration (GSA) contract price lists, actual payroll journals, or Salary.com research. If an employee listed in a cost proposal is not a current employee (maybe a new employee, or one contingent upon the award of this contract), a copy of the offer letter stating the hourly rate, signed and accepted by the employee, may be provided as adequate documentation.

Sometimes the hourly rates listed in a proposal are derived through subjective processes, i.e., blending of multiple employees in one labor category, or averaged over the course of the year to include scheduled payroll increases, etc. These situations should be clearly documented for the Contracting Officer.

(2) Another cost element in Direct Labor is labor escalation, or the increase in labor rates from year to year. In the example above, the proposed labor escalation is 3% (ex., Andy Smith's direct labor rate increased by 3% from $55.00/hour in Year 1 to $56.65/hour in Year 2). Often times, an applicant may not propose escalation on labor rates during a 24-month period. Whatever the proposed escalation rate is, please be prepared to explain why it is fair and reasonable. For example, a sufficient explanation for our sample escalation rate would be "The Government's General Schedule Increase and Locality Pay for the same time period (name FY) in the same location (name location) was published as 3.5%; therefore a 3% increase is fair and reasonable".

ii. *Other Direct Costs (ODCs)*: This section of the cost proposal includes all other directly-related costs required in support of the effort (i.e., materials, subcontractors, consultants, travel, etc.). Any cost element that includes various items must be detailed in a cost breakdown.

(1) Direct Material Costs: This subsection of the cost proposal will include any special tooling, test equipment, and material costs necessary to perform the project. Items included in this section must be carefully reviewed relative to need and appropriateness for the work proposed, and must, in the opinion of the Contracting Officer, be advantageous to the Government and directly related to the specific topic.

The Contracting Officer will require adequate documentation from the applicant to determine the cost reasonableness for each material cost proposed. The following methods are ways in which the Contracting Officer can determine this [FAR 15.403-1]:

> (a) Adequate Price Competition. A price is based on adequate price competition when the applicant solicits and receives quotes from two or more responsible vendors for the same or similar items or services. Based on these quotes, the applicant selects the vendor who represents the best value to the Government. The applicant will be required to provide to the Contracting Officer copies of all vendor quotes received.
>
> *NOTE: Price competition is not required for items at or below the micro-purchase threshold ($10,000FAR 15.403-1]. If an item's unit cost is less than or equal to $10,000, price competition is not necessary. However, if an item's total cost over the period of performance (unit cost x quantity) is higher than $10,000, two or more quotes must be obtained by the applicant.
>
> (b) Commercial Prices. Commercial prices are those published on current price lists, catalogs, or market prices. This includes vendors who have prices published on a GSA-schedule contract. The applicant will be required to provide copies of such price lists to the Contracting Officer.

(c) Prices set by law or regulation. If a price is mandated by the Government (i.e. pronouncements in the form of periodic rulings, reviews, or similar actions of a governmental body, or embodied in the laws) that is sufficient to set a price.

Below is the list of Direct Material costs included in our sample proposal:

DIRECT MATERIAL COSTS	YEAR 1	YEAR 2
Raw Materials	$35,000.00	$12,000.00
Computer for experiments	$4,215.00	$0.00
Cable (item #12-3657, 300 ft)	$1,275.00	$0.00
Software	$1,825.00	$1,825.00
Subtotal Direct Materials Costs	$42,315.00	$13,825.00

"Raw Materials": This is a generic label used to group many material items into one cost item within the proposal. The Contracting Officer will require a detailed breakout of all the items that make up this cost. For each separate item over $10,000 (total for Year 1 + Year 2), the applicant must be able to provide either competitive quotes received, or show that published pricing was used.

"Computer for experiments": This item is most likely a grouping of several components that make up one system. The Contracting Officer will require a detailed breakout of all the items that make up this cost. For each separate item over $10,000 (total for Year 1 + Year 2), the applicant must be able to provide either competitive quotes received, or show that published pricing was used.

"Cable": Since this item is under the micro-purchase threshold of $10,000, competitive quotes or published pricing are not required. Simply provide documentation to show the Contracting Officer where this price came from.

"Software": This cost item could include either one software product, or multiple products. If this includes a price for multiple items, please provide the detailed cost breakdown. Note: The price for Year 1 ($1,825) is below the micro-purchase threshold; however, in total (Year 1 + Year 2) the price is over $10,000, so competitive quotes or published pricing documentation must be provided.

Due to the specialized types of products and services necessary to perform these projects, it may not always be possible to obtain competitive quotes from more than one reliable source. Each cost element over the micro-purchase threshold ($10,000) must be substantiated. There is always an explanation for how the cost of an item was derived; document how you came up with that price.

When it is not possible for an applicant to obtain a vendor price through competitive quotes or published price lists, the Contracting Officer may accept other methods to determine cost reasonableness. Below are some examples of other documentation, which the Contracting Officer may accept to substantiate costs:

(a) Evidence that a vendor/supplier charged another applicant a similar price for similar services. Has the vendor charged someone else for the same product? Two (2) to three (3) invoices from that vendor to different customers may be used as evidence.

(b) Previous contract prices. Has the applicant charged the Government a similar price under another Government contract for similar services? If the Government has already paid a certain price for services, then that price may already be considered fair and reasonable. Provide the contract number, and billing rates for reference.

(c) DCAA approved. Has DCAA already accepted or verified specific cost items included in your proposal? Provide a copy of DCAA correspondence that addressed these costs.

(2) ODCs: Below is the remaining ODC portion of our proposal including equipment, subcontractors, consultants, and travel. Assume in this scenario that competitive quotes or catalog prices were not available for these items:

ODCs	YEAR 1	YEAR 2
Equipment Rental for Analysis	$5,500.00	$5,600.00
Subcontractor – Widget, Inc.	$25,000.00	$0.00
Consultant: John Bowers	$0.00	$12,000.00
Travel	$1,250.00	$1,250.00
Subtotal: ODCs	$31,750.00	$18,850.00

"Equipment Rental for Analysis": The applicant explains that the Year 1 cost of $5,500 is based upon 250 hours of equipment rental at an hourly rate of $22.00/hr. One (1) invoice from the vendor charging another vendor the same price for the same service is provided to the Contracting Officer as evidence. Since this cost is over the micro-purchase threshold, further documentation to determine cost reasonableness is required. The applicant is able to furnish another invoice charging a second vendor the same price for the same service.

"Subcontractor – Widget, Inc.": The applicant provides a copy of the subcontractor quote to the Contracting Officer in support of the $25,000 cost. This subcontractor quote must include sufficient detailed information (equivalent to the data included in the prime's proposal to the Government), so that the Contracting Officer can make a determination of cost reasonableness.

(a) As stated in Section 3.5(c)(6) of the DoD Cost Proposal guidance, "All subcontractor costs and consultant costs must be detailed at the same level as prime contractor costs in regards to labor, travel, equipment, etc. Provide detailed substantiation of subcontractor costs in your cost proposal."

(b) In accordance with FAR 15.404-3, "the Contracting Officer is responsible for the determination of price reasonableness for the prime contract, including subcontracting costs". This means that the subcontractor's quote/proposal may be subject to the same scrutiny by the Contracting Officer as the cost proposal submitted by the prime. The

Contracting Officer will need to determine whether the subcontractor has an accepted purchasing system in place and/or conduct appropriate cost or price analyses to establish the reasonableness of proposed subcontract prices. Due to the proprietary nature of cost data, the subcontractor may choose to submit their pricing information directly to the Contracting Officer and not through the prime. This is understood and encouraged.

(c) When a subcontractor is selected to provide support under the prime contract due to its specialized experience, the Contracting Officer may request sole source justification from the applicant.

"Consultant – John Bowers": The applicant shall provide a copy of the consultant's quote to the Contracting Officer as evidence. In this example, the consultant will be charging an hourly rate of $125 an hour for 96 hours of support. The applicant indicates to the Contracting Officer that this particular consultant was used on a previous contract with the Government (provide contract number), and will be charging the same rate. A copy of the consultant's invoice to the applicant under the prior contract is available as supporting evidence. Since the Government has paid this price for the same services in the past, determination has already been made that the price is fair.

"Travel": The Contracting Officer will require a detailed cost breakdown for travel expenses to determine whether the total cost is reasonable based on Government per diem and mileage rates. This breakdown shall include the number of trips, the destinations, and the number of travelers. It will also need to include the estimated airfare per round trip, estimated car rental, lodging rate per trip, tax on lodging, and per diem rate per trip. The lodging and per diem rates must comply with the Joint Travel Regulations. Please see the following website to determine the appropriate lodging and per diem rates: http://www.defensetravel.dod.mil. Additionally, the applicant must provide why the airfare is fair and reasonable as well. Sufficient back up for both airfare and car rental would include print outs of online research at the various travel search engines (Expedia, Travelocity, etc.), documenting the prices for airfare and car rentals are fair and reasonable.

Below is a sample of the travel portion:

TRAVEL	Unit	Trips	Travelers	Nights	Days	Unit Cost	Total Travel
Airfare	roundtrip	1	1			$996.00	$996.00
Lodging	day	1	1	1		$75.00	$75.00
Tax on Lodging (12%)	day	1	1	1		$9.00	$9.00
Per Diem	day	1	1		2	$44.00	$88.00
Automobile Rental	day	1	1		2	$41.00	$82.00
Subtotal Travel							$1,250.00

iii. *Indirect Costs*: Indirect costs include elements such as fringe benefits, general and administrative (G&A), overhead, and material handling costs. The applicant shall indicate in the cost proposal both the indirect rates (as a percentage) as well as how those rates are allocated to the costs in the proposal.

Below is the indirect portion of our sample proposal:

INDIRECTS	YEAR 1	YEAR 2
Subtotal Direct Labor (DL):	$97,280.00	$100,198.40
Fringe Benefits, if not included in Overhead, rate (15.0000 %) X DL =	$14,592.00	$15,029.76
Labor Overhead (rate 45.0000 %) X (DL + Fringe) =	$50,342.40	$51,852.67
Total Direct Labor (TDL):	$162,214.40	$167,080.83

In this example, the applicant includes a fringe benefit rate of 15.00% that it allocated to the direct labor costs. The applicant also proposes a labor overhead rate of 45.00% that is allocated to the direct labor costs plus the fringe benefits.

All indirect rates and the allocation methods of those rates must be verified by the Contracting Officer. In most cases, DCAA documentation supporting the indirect rates and allocation methods can be obtained through a DCAA field audit or proposal review. Many applicants have already completed such reviews and have this documentation readily available. If an applicant is unable to participate in a DCAA review to substantiate indirect rates, the Contracting Officer may request other accounting data from the applicant to make a determination.

iv. *Facilities Capital Cost of Money (FCCM)*: Cost of money is an imputed cost that is not a form of interest on borrowings (see FAR 31.205-20). FCCM is an "incurred cost" for cost-reimbursement purposes under applicable cost-reimbursement contracts and for progress payment purposes under fixed-price contracts. It refers to (1) FCCM (48 CFR 9904.414) and (2) cost of money as an element of the cost of capital assets under construction (48 CFR 9904.417). If cost of money is proposed in accordance with FAR 31.205-10, a DD Form 1861 is required to be completed and submitted with the applicant's proposal.

v. *Fee/Profit*: The proposed fee percentage will be analyzed in accordance with DFARS 215.404, the Weighted Guidelines Method.

vi. *Subcontracting Plan*: If the total amount of the proposal exceeds $700,000 and the applicant is a large business or an institute of higher education (other than HBCU/MI) and the resultant award is a contract, the applicant shall be prepared to submit a subcontracting plan for small business and SDB concerns. A mutually agreeable plan will be included in and made a part of the contract (see Section II.F.2.b.v).

2. GRANT and COOPERATIVE AGREEMENT Proposals

Before award it must be established that an approved accounting system and financial management system exist.

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 PI(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:

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

ii. 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;

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

iv. The total annual salary charged to the research project; and

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

Note: There is no page limitation for budget proposals or budget justifications.

b. *Fringe Benefits and Indirect Costs (Overhead, G&A, 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, applicants must provide sufficient detail to enable a determination to be made that the costs included in the forecast rate are allocable according to applicable cost provisions. Applicants' 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:

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

ii. Basis used to prorate indirect expenses to cost pools, if any;

iii. How the rate(s) was calculated;

iv. Distribution basis of the developed rate(s);

v. Basis on which the overhead rate is calculated, such as "salaries and wages" or "total costs;" and

vi. The period of the applicant's FY.

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. Applicants 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:

i. Vendor Quote: Show name of vendor, number of quotes received and justification, if intended award is to other than lowest bidder.

ii. Historical Cost: Identify vendor, date of purchase, and whether or not cost represents lowest bid. Include reason(s) for not soliciting current quotes.

iii. Engineering Estimate: Include rationale for quote and reason for not soliciting current quotes.

If applicable, the following additional information shall be disclosed in the applicant’s cost proposal:

iv. Special test equipment to be fabricated by the awardee for specific research purposes and its cost.

v. Standard equipment to be acquired and modified to meet specific requirements, including acquisition and modification costs, listed separately.

vi. 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.

vii. Grants and cooperative agreements 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 per the governing laws and regulations.

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. Separate, prior approval by the ARL is required for all foreign travel (i.e., travel outside the continental U.S., its possessions and Canada). Travel may be requested to visit 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 ARO-sponsored conferences, meetings, symposia, training activities, apprenticeships and workshops (see the "Other Programs" section as described earlier in this BAA). 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: Applicants 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:

- A clear description of the work to be performed;
- If known, the identification of the proposed subawardee and an explanation of why and how the subawardee was selected or will be selected;

i. The identification of the type of award to be used (cost reimbursement, fixed price, etc.);

ii. Whether or not the award will be competitive and, if noncompetitive, rationale to justify the absence of competition; and

iii. A detailed cost summary.

k. *ODCs*: 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 must be fully explained and justified.

l. *Profit/ Fee*: Profit/fee is not allowed for the recipient of or subaward to an assistance instrument, where the principal purpose of the activity to be carried out is to stimulate or support a public purpose (i.e., to provide assistance), rather than acquisition (i.e., to acquire goods and services for the direct benefit of the Government). A subaward is an award of financial assistance in the form of money, or property in lieu of money, made under a DoD grant or cooperative agreement by a recipient to an eligible subrecipient. The term includes financial assistance for substantive program performance by the subrecipient of a portion of the program for which the DoD grant or cooperative agreement was made. It does not include the recipient's procurement of goods and services needed to carry out the program.

m. *Subcontracting Plan*: Subcontracting plans do not apply to assistance instruments.

n. *FCCM*: If cost of money is proposed, a completed FCCM (DD Form 1861) is required.

(End of Section)

APPENDIX 1: TABLE OF ACRONYMS

ACC	Army Contracting Command
AEOP	Army Educational Outreach Program
AFARS	Army Federal Acquisition Regulation Supplement
AFOSR	Air Force Office of Scientific Research
AMO	Atomic, Molecular, and Optical
AMP	Atomic and Molecular Physics
AOR	Authorized Organization Representative
APG	Aberdeen Proving Ground
AR	Army Regulation
ARL	Army Research Laboratory
ARO	Army Research Office
BAA	Broad Agency Announcement
CAGE	Commercial and Government Entity
CCE	Core Campaign Enablers
CFR	Code of Federal Regulations
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CFDA	Catalog of Federal Domestic Assistance
CCDC	Combat Capabilities Development Command
CMP	Condensed Matter Physics
CPFF	Cost Plus Fixed Fee
DA	Department of Army
D&B	Dun and Bradstreet
DBA	Doing Business Name
DCAA	Defense Contract Audit Agency

DCMA	Defense Contract Management Agency
DFARS	Defense Federal Acquisition Regulation Supplement
DLSC	Defense Logistics Service Center
DoD	Department of Defense
DoDI	Department of Defense Instruction
DTN	Disruption (or Delay) Tolerant Networks
DURIP	Defense University Research Instrumentation Program
ECP	Early Career Program
EDWOSB	Economically-Disadvantaged Woman-Owned Small Business
ERGM	Exponential Random Graph Model
FAPIIS	Federal Awardee Performance and Integrity Information System
FAR	Federal Acquisition Regulation
FCCM	Facilities Capital Cost of Money
FFRDC	Federally Funded Research and Development Center
FQP	Foundational Quantum Physics
FSC	Federal Service Code
FWA	Federal Wide Assurance
FY	Fiscal Year
G&A	General and Administrative
GFD	Government Furnished Data
GFE	Government Furnished Equipment
GFI	Government Furnished Information
GFP	Government Furnished Property
GPGPU	General Purpose Computation on Graphics Processing Unit
GSA	General Service Administration
HBCU/MI	Historically Black Colleges and Universities and Minority-Serving Institutions
HSAP	High School Apprenticeship Program
HRPO	Human Research Protection Official
HSR	Human Subjects Research
HUBZone	Historically Underutilized Business Zone
IED	Improvised Explosive Device
IoT	Internet of Things
IR&D	Independent Research and Development
IRB	Institutional Review Board
ITAR	International Traffic in Arms Regulation
MURI	Multidisciplinary University Research Initiative
NFV	Network Function Virtualization
ODC	Other Direct Cost
OMB	Office of Management and Budget
OHRP	Office for Human Research Protections
ONR	Office of Naval Research
OTA	Other Transaction for Prototype
PAM	Pamphlet
PCM	Phase Change Material

PDE	Partial Differential Equation
PDF	Portable Document Format
PECASE	Presidential Early Career Award for Scientists and Engineers
PI	Principal Investigator
POC	Point of Contact
PWS	Performance Work Statement
QCON	Quantum Computation and Quantum Networking
QoI	Quality of Information
QoS	Quality of Service
QSIM	Quantum Sensing, Imaging, and Metrology
RDX	Royal Demolition eXplosive
REP	Research and Educational Program
ROTC	Reserve Officer Training Corps
R&R	Research and Related
RTP	Research Triangle Park
SAM	System for Award Management
SCN	Social and Cognitive Networks
SDB	Small Disadvantaged Business
SDO	Suspension and Debarment Official
SDN	Software Defined Networking
SDVOSB	Service-Disabled Veteran-Owned Small Business
SF	Standard Form
SLV	Survivability, Lethality, and Vulnerability
SO	Supersymmetric Optics
S&T	Science & Technology
STEM	Science, Technology, Engineering, and Mathematics
STIR	Short-Term Innovative Research
TIA	Technology Investment Agreement
TIN	Taxpayer Identification Number
TPOC	Technical Point of Contact
UARC	University-Affiliated Research Contract
UAV	Unmanned Aerial Vehicle
UGA	Unmanned Ground Vehicle
UIC	Unit Identification Code
URAP	Undergraduate Research Apprenticeship Program
U.S.C.	United States Code
USDA/APHIS	Department of Agriculture Office of Animal and Plant Health Inspection Service
USML	United States Munition List
VOSB	Veteran-Owned Small Business
VSP	Visiting Scientist Program
WOSB	Woman-Owned Small Business

(End Section)

APPENDIX 2: SCHEDULE OF AMENDMENTS

Amendments to this BAA will be issued according to the following schedule to incorporate programmatic or administrative changes to this document, if necessary.

NOTE: Amendments may be issued more frequently at the discretion of the Government.

Estimated Date of Issuance
November 1, 2017
March 1, 2018
June 1, 2018
November 1, 2018
March 29, 2019
June 28, 2019
November 29, 2019
March 30, 2020
June 29, 2020
November 30, 2020
March 1, 2021
June 1, 2021

(End Section)