BROAD AGENCY ANNOUNCEMENT (BAA)

1. **Agency Name**

Air Force Office of Scientific Research
Arlington VA

2. **Funding Opportunity Title**

Research Interests of the Air Force Office of Scientific Research

3. **Announcement Type**

This is the initial announcement.

4. **Funding Opportunity Number**

BAA-AFOSR-2012-0001

5. **Catalog of Federal Domestic Assistance (CFDA) Numbers**

12.800

6. **Due Dates**

This announcement remains open until superseded. Proposals are reviewed and evaluated as they are received. Proposals may be submitted at any time. However, because of anticipated funding, some topic area instructions recommend proposals be submitted by specific dates.

7. **Additional Overview**

The Air Force Office of Scientific Research (AFOSR) manages the basic research investment for the U.S. Air Force (USAF). As a part of the Air Force Research Laboratory (AFRL), AFOSR's technical experts foster and fund research within the Air Force Research Laboratory, universities, and industry laboratories to ensure the transition of research results to support USAF needs. Using a carefully balanced research portfolio, research managers seek to create revolutionary scientific breakthroughs, enabling the Air Force and U.S. industry to produce world-class, militarily significant, and commercially valuable products.

To accomplish this task, AFOSR solicits proposals for basic research through this general Broad Agency Announcement (BAA). This BAA outlines the Air Force Defense Research Sciences Program. AFOSR invites proposals for research in

many broad areas. These areas are described in detail in Section I, Funding Opportunity Description.

AFOSR is seeking unclassified White papers and proposals that do not contain proprietary information. We expect our research to be fundamental.

It is anticipated the awards will be made in the form of a grant, cooperative agreement or contract. AFOSR reserves the right to select and fund for award; all, some, part or none of the proposals in response to this announcement.

This announcement will remain open until replaced by a successor BAA. Proposals may be submitted at any time. However, those planning to submit proposals should consider that AFOSR commits the bulk of its funds in the Fall of each year.

AFOSR will not issue paper copies of this announcement. AFOSR provides no funding for direct reimbursement of proposal development costs. Technical and cost proposals, or any other material, submitted in response to this BAA will not be returned.

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I. Funding Opportunity Description

AFOSR plans, coordinates, and executes the Air Force Research Laboratory's (AFRL) basic research program in response to technical guidance from AFRL and requirements of the Air Force; fosters, supports, and conducts research within Air Force, university, and industry laboratories; and ensures transition of research results to support USAF needs.

The focus of AFOSR is on research areas that offer significant and comprehensive benefits to our national warfighting and peacekeeping capabilities. These areas are organized and managed in three scientific directorates: Aerospace, Chemical and Material Sciences, Physics and Electronics, and Mathematics, Information and Life Sciences. The research activities managed within each directorate are summarized in this section.

a. Aerospace, Chemical and Material Sciences (RSA)

The Aerospace, Chemical and Material Sciences Directorate leads the discovery and development of the fundamental and integrated science that advances future air and space power. The broad goal of the directorate is to discover and exploit the critical fundamental science and knowledge that will shape the future of aerospace sciences. A key emphasis is the establishment of the foundations necessary to advance the integration or convergence of the scientific disciplines critical to maintaining technological superiority. The Directorate carries out its ambitious mission through leadership of an international, highly diverse and multidisciplinary research community to find, support and foster new scientific discoveries that will ensure future novel innovations for the future Air Force.

The central research direction for this directorate focuses on meeting the basic research challenges related to future air and space power by leading the discovery and development of fundamental science and engineering across three integrated research focus areas:

Aero-Structure Interaction and Control: Focus on the characterization, modeling and exploitation of interactions between the unsteady aerodynamic flow field, the complex surface chemistry and dynamic air vehicle structure to enable unprecedented performance.

Complex Materials and Structures: Focus on complex materials, microsystems and structures by incorporating hierarchical design and functionality from the nanoscale through the mesoscale, ultimately leading to controlled well understood material or structural behavior capable of dynamic functionality and/or performance characteristics to enhance mission versatility.

Energy, Power and Propulsion: Focus on the production, storage, and utilization of energy and harnessing the power of phonons for Air Force systems including the development of novel energetic materials for new propulsion and munitions concepts

A wide range of fundamental research addressing chemistry, materials, fluid dynamics, thermophysics and structural mechanics are brought together to address these multidisciplinary topics in an effort to increase performance and achieve unprecedented operational capability.

1) Mechanics of Multifunctional Materials and Microsystems, Dr. Les Lee
2) Multi-Scale Structural Mechanics and Prognosis, Dr. David Stargel
3) Thermal Sciences, Dr. Joan Fuller
4) Organic Materials Chemistry, Dr. Charles Lee
5) Molecular Dynamics and Theoretical Chemistry, Dr. Michael Berman
6) Aerospace Materials for Extreme Environments, Dr. Ali Sayir
7) Low Density Materials, Dr. Joycelyn Harrison
8) Aerothermodynamics and Turbulence, Dr. John Schmisseur
9) Flow Interactions and Control, Dr. Douglas Smith
10) Space Power and Propulsion, Dr. Mitat Birkan
11) Energy Conversion and Combustion Sciences, Dr. Chiping Li

Research areas are described in detail in the Sub areas below.

1. Mechanics of Multifunctional Materials & Microsystems

The main goals of this program are to establish safer, more maneuverable aerospace vehicles and platforms with unprecedented performance characteristics; and to bridge the gap between the viewpoints from materials science on one side and structural engineering on the other in forming a science base for the materials development and integration criteria. Specifically, the program seeks to establish the fundamental understanding required to design and manufacture new aerospace materials and microsystems for multifunctional structures and to predict their performance and integrity based on mechanics principles. The multifunctionality implies coupling between structural performance and other as-needed functionalities (such as electrical, magnetic, optical, thermal, chemical, biological, and so forth) to deliver dramatic improvements in system-level efficiency. Structural performance includes the ability to carry the load, durability, reliability, survivability and maintainability in response to the changes in surrounding environments or operating conditions. Among various visionary contexts for developing multifunctionalities, the concepts of particular interest are: (a) “autonomic” structures which sense, diagnose and respond for adjustment with minimum external intervention, (b) “adaptive” structures allowing reconfiguration or readjustment of functionality, shape and mechanical properties on demand, and (c) structural integration of energy harvesting/storage capabilities for “self-sustaining” system. This program thus focuses on the developing new design criteria involving mechanics, physics, chemistry, biology, and information science to model and characterize the integration and performance of multifunctional materials and microsystems at multiple scales from atoms to continuum. Projected Air Force applications require material systems and devices which often consist of dissimilar constituents with different functionalities. Interaction with Air Force Research Laboratory researchers is encouraged to maintain relevance and enhance technology transition.

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2. Multi-Scale Structural Mechanics and Prognosis

This fundamental basic research program addresses the US Air Force needs in the following application areas: 1) New and revolutionary flight structures, 2) Multi-scale modeling and prognosis and 3) Structural dynamics under non-stationary conditions and extreme environments. Other game-changing and revolutionary structural mechanics problems relevant to the US Air Force are also of interest.

The structural mechanics program encourages fundamental basic research that will generate understanding, models, analytical tools, numerical codes, and predictive methodologies validated by carefully conducted experiments. The program seeks to establish the fundamental understanding required to design and manufacture new aerospace materials and structures and to predict their performance and integrity based on mechanics principles.

Fundamental basic research issues for new and revolutionary flight structures include: revolutionary structural concepts and unprecedented flight configurations; hybrid structures of dissimilar materials (metallic, composite, ceramic, etc.) with multi-material joints and/or interfaces under dynamic loads, and extreme environments; controlled-flexibility distributed-actuation smart structures. The predictive analysis and durability prognosis of hybrid-material structures that synergistically combine the best attributes of metals, composites, and ceramics, while avoiding their inherit shortcomings are of great interest.

Fundamental basic research issues of interest for multi-scale modeling and prognosis include: physics-based models that quantitatively predict the materials performance and durability of metallic and composite flight structures operating at various regimes; modeling and prediction of the structural flaws distribution and service-induced damage on each aircraft and at fleet level; structural analysis that accounts for variability due to materials, processing, fabrication, maintenance actions, changing mission profiles; novel and revolutionary on-board health monitoring and embedded NDE concepts. An area of particular research interest is the development and validation of new diagnostic techniques capable of measurements at the mesoscale. Experimental techniques capable of simultaneous measurements on multiple length scales (i.e. meso to macro) are also sought.

Fundamental basic research issues for structural dynamics include: control of dynamic response of extremely flexible nonlinear structures; control of unsteady energy flow in nonlinear structures during various flight conditions; nonlinear dynamics and vibration control of thin-wall structures of functionally graded hybrid materials with internal vascular networks under extreme loading conditions.

Researchers are highly encouraged to submit short White papers prior to developing full proposals. White papers are encouraged as an initial and valuable step prior to proposal

development and submission. White papers should briefly relate the current state-of-the-art, how the proposed effort would advance it, and the approximate yearly cost for a three to five year effort. Researchers with White papers of significant interest will be invited to submit full proposals.

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3. Thermal Sciences

The Thermal Sciences portfolio emphasizes the discovery of new techniques for modeling, measuring, and analyzing thermal phenomena at multiple time and length scales in emerging novel material systems with the ultimate goal of exploiting these phenomena to design future materials and components that break the paradigm of today's materials where the boundaries of performance/failure are defined by conduction, convection, and radiation physics.

A significant component of this portfolio is establishing the scientific foundations that will enable a sophisticated level of control of heat transfer via interfacial phenomena in materials. Heat is transported by vibrations of the atoms (phonons), excitations of the valence electrons (electrons and holes), and electromagnetic fields (photons). But it is the interactions among these elementary excitations and their interactions with the interface that engender a rich basic science of heat transport and offer exciting potential for discovery of new physical phenomena.

The current emphasis of this portfolio is on increasing the scientific understanding required to predict heat transfer across a broad range of temporal and spatial scales. Proposals addressing fundamental science are sought in the areas of phonon transport, contribution of phonon dispersion modes to thermal transport, understanding of extreme thermal conductivity, thermal conductivity in hybrid materials, and thermal rectification and thermal diodes. Proposals addressing new ideas and directions related to understanding of thermal transport, thermal memory, and phonon-assisted devices are highly encouraged. An understanding of radiative properties and their contribution to energy storage and conversion are of less interest to the portfolio at this time. Preference is for collaborative versus single investigator proposals and proposals that address both theory and experiments are encouraged.

Researchers are strongly encouraged to submit short White papers via email prior to developing full proposals. White papers should briefly relate the current state-of-the-art, how the proposed effort would advance it, and the approximate yearly cost for a three to five year effort. Researchers with White papers of significant interest will be invited to submit full proposals.

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4. Organic Materials Chemistry

The goal of this research area is to gain a better understanding of the influence of chemical structures and processing conditions on the properties and behaviors of polymeric and organic materials. This understanding will lead to development of advanced organic and polymeric materials for Air Force applications. This program's approach is to study the chemistry and physics of these materials through synthesis, processing, characterization and establishing the structure properties relationship of these materials. This area addresses both functional properties and properties pertinent to structural applications. Materials with these properties will provide capabilities for future Air Force systems to achieving global awareness, global mobility, and space operations. Research concepts that are novel, high risk with potential high payoff are encouraged.

Proposals with innovative material concepts that will extend our understanding of the structure-property relationship of these materials and achieve significant property improvement over current state-of-the-art materials are sought. Current interests include photonic polymers and liquid crystals, polymers with interesting electronic properties, polymers with controlled dielectric permittivity and magnetic permeability including negative index materials, and novel properties polymers modified with nanostructures. Applications of polymers in extreme environments, including space operation environments, are of interests. Material concepts for power management applications, power generation and storage are of interest.

In the area of photonic polymers, research emphases are on materials whose refractive index can be actively controlled. These include, but are not limited to, electrooptic polymers, liquid crystals, photorefractive polymers and magneto-optical polymers. Organic molecules with large nonlinear real and imaginary components are also of interest. Examples of electronic properties of interest include conductivity, charge mobility, electro-pumped lasing and solar energy harvesting. Material concepts related to power generation and storage will be considered.
Controlled growth and/or self assembly of nanostructures into well defined structures (e.g. carbon nanotubes with specific chirality) or hierarchical and complex structures are encouraged. Organic based materials, including inorganic hybrids, with controlled magnetic permeability and dielectric permittivity are also of interest. Material concepts that will provide low thermal conductivity but high electrical conductivity (as thermoelectric), or vice versa, (as thermally conductive electrical insulator) are of interest.

Nanotechnology approaches are encouraged to address all the above-mentioned issues. Approaches based on biological systems or other novel approaches to attain material properties that are difficult to achieve through conventional means are encouraged.

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5. Molecular Dynamics and Theoretical Chemistry

Molecular Dynamics

The objectives of the molecular dynamics program are to understand, predict, and control the reactivity and flow of energy in molecules. This program seeks experimental and joint theory-experiment studies that address key, fundamental questions in these areas that can lead to important advances in these fields. A major area of interest includes understanding processes related to the efficient storage and utilization of energy. For example, we seek to understand the fundamental reaction mechanisms of catalysis in these systems. Thus, we have interest in studying the structure, dynamics, and reactivity of molecular clusters and nanoscale systems in which the number of atoms or specific arrangement of atoms in a cluster has dramatic effects on its reactivity or properties. The ability to promote and probe these reactions and processes using surface-enhanced methods mediated by plasmon resonances is of interest, as are other novel sensitive diagnostic methods for detecting individual molecules and probing nanostructures and processes on nanostructures. Utilizing catalysts to produce storable fuels from sustainable inputs and to improve propulsion processes are topics of interest. We are also interested in using novel building blocks for creating materials. Fundamental studies aimed at developing basic understanding and predictive capabilities for chemical reactivity, bonding, and energy transfer processes are also encouraged.

Work in this program also addresses areas in which control of chemical reactivity and energy flow at a detailed molecular level is of importance. These areas include hyperthermal and ion-chemistry in the upper atmosphere and space environment, the identification of novel energetic materials for propulsion systems, and the discovery of new high-energy laser systems. The coupling of chemistry and fluid dynamics in high speed reactive flows, and in particular, dynamics at gas-surface interfaces, is also of interest.

Theoretical Chemistry

The major objective of the theoretical chemistry program is to develop new methods that can be utilized as predictive tools for designing new materials and improving processes important to the Air Force. These new methods can be applied to areas of interest to the Air Force including the structure and stability of molecular systems that can be used as advanced propellants; molecular reaction dynamics; and the structure and properties of nanostructures and interfaces. We seek new theoretical and computational tools to identify novel energetic molecules, investigate the interactions that control or limit the stability of these systems, and help identify the most promising synthetic reaction pathways and predict the effects of condensed media on synthesis. Particular interests in reaction dynamics include developing methods to seamlessly link electronic structure calculations with reaction dynamics, understanding the mechanism of catalytic processes and proton-coupled electron transfer related to storage and utilization of energy, and using theory to describe and predict the details of ion-molecule reactions and electron-ion dissociative recombination processes relevant to ionospheric and space effects on Air Force systems. Interest in nanostructures and materials includes work on catalysis and surface-enhanced processes mediated by plasmon resonances. This program also encourages the development of new methods to simulate and predict properties with chemical accuracy for systems having a very large number of atoms that span multiple time and length scales.

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6. Aerospace Materials for Extreme Environments

The objective of basic research in Aerospace Materials for Extreme Environments is to provide the fundamental knowledge required to enable revolutionary advances in future Air Force technologies through the discovery and characterization of high temperature materials (nominally temperatures above 1000°C) including: ceramics, metals, hybrid systems including composites. Specifically, the program seeks innovative and high risk proposals that advance the field of high temperature materials research through the discovery and characterization of new materials that exhibit superior structural, functional and/or multifunctional performance at temperatures above 1000°C. Representative scientific topics include the development and experimental verification of theoretical and/or computational tools that aid in the discovery of new materials and in situ characterization methods for probing microstructural evolution at elevated temperatures. There is special interest in fundamental research of high temperature structural materials focused on understanding combined mechanical behaviors; e.g. strength and toughness as a function of thermal and acoustic loads and understanding the damage initiation. This focus area provide broad scientific challenges and will require the development of new experimental and computational tools to address the complexity of thermal, acoustic, chemistry, shear or pressure loads as they relate back to the performance of the material. Another representative topic includes physics and chemistry of materials in highly stressed environments where system performance depends on, and limited by, the evolution and/or degradation of materials in the presence of high electrical, thermal, radiative, or other stresses. This area includes a wide range of activities characterized by processes that are sufficiently energetic to require the understanding and managing the non-linear response of materials to combined loads under high energy density non-equilibrium extremities.

This program seeks bold, new basic research that addresses the design, creation, and employment of nontraditional approaches on synthesis of novel materials and nanostructures, for example, by using electric fields, lasers, microwave and other external field approaches that take into account of geometric or topological descriptors to characterize similarity and scaling between stimuli under the multi-dimensional external fields to secure revolutionary advances. Interest domain includes the fundamental science at the interface of phases of heterogeneous structures, nanotechnology and mesotechnology efforts are focused on new architectures using crystal chemistry principles to create pathways to synthesize transparent ceramics, fiber materials, actuator materials, three dimensional power structures and heterogeneous materials for high energy density applications. This program also embraces materials that are far from the thermodynamic equilibrium domain (bulk metallic glasses, highly doped polycrystalline materials and supersaturated structures etc.). Realization of these multi-component systems that are far from equilibrium may also require new approaches to how computation itself is modeled or even an entirely new understanding of computation. Often the modeling approaches make casual inference about the microstructural features and basic research methodologies and metrics are needed. The aim is to explore the possibility for the quantification of microstructure through

reliable and accurate descriptions of grain and particle shapes, and identifying sample distributions of shape descriptors to generate and predict structures which might revolutionize the design and performance. It is important to consider integrated experimental approaches that concurrently validate the length and time scales and thus may require cross-disciplinary teams with material scientist and engineers in collaboration with mathematicians, statisticians, computer scientists and physicist, and chemist, etc., are encouraged, especially when collaboration is likely to generate multidimensional benefits. Researchers with ideas relating to performance of materials in device, material integration in system level, and structural performance should refer to the other programs in this Broad Area Announcement to find the best match for those research ideas.

Researchers are highly encouraged to submit short (max 2 pages) White papers by email prior to developing full proposals. White papers should briefly describe the proposed effort and describe how it will advance the current state-of-the-art; an approximate yearly cost for a three to five year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals. Multidisciplinary team proposals also are encouraged and will be considered on a case by case basis.

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7. Low Density Materials

The Low Density Materials portfolio supports transformative, basic research in materials design and processing to enable radical reductions in system weight with concurrent enhancements in performance and function. Such materials can transform the design of future Air Force aerospace and cyber systems for applications which include airframes, satellites, and adaptive vehicles. Among the routes to achieving game-changing improvements in low density materials currently emphasized within the program are understanding the impact of nanoscale porosity on aerospace structures and the creation of hierarchical architectures that combine materials of different classes, scales, and properties to provide synergistic and tailorable performance. Proposals are sought that advance our understanding of hierarchical or hybrid materials and our ability to design, model and fabricate multi-material, multi-scale, multi-functional material systems with a high degree of precision and efficiency. Fundamental research targeting radical improvements in stimuli-responsive materials that can be used to couple structure and function in aerospace platforms is also a keen program interest. Material classes may be polymeric, ceramic, and metallic, possibly combining synthetic and biological species to engender lightweight structural integrity and multifuctionality.

Researchers are highly encouraged to submit short (max 2 pages) White papers by email prior to developing full proposals. White papers should briefly describe the proposed effort, the fundamental challenges to be addressed, and how the proposed research will advance the current state-of-the-art; an approximate yearly cost for a three to five year effort should also be

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8. Aerothermodynamics and Turbulence

The objective of the aerothermodynamics and turbulence portfolio is to develop the fundamental fluid physics knowledge base required for revolutionary advancements in Air Force capabilities including, but not limited to, Efficient Long-Range Access, Rapid Global Strike and Responsive Space Access. Research supported by this portfolio seeks to characterize, model and exploit/control critical fluid dynamic phenomena through a balanced mixture of investments in experimental, numerical and theoretical efforts.

Innovative research is sought in all aspects of turbulent and aerothermodynamic flows with particular interest in the following areas:

- Characterization and modeling of the coupled dynamics, thermodynamics and chemistry of nonequilibrium flows, including fundamental processes in high-temperature gas-surface interactions.
- Innovative insight into the control and exploitation of energy transfer within the flowfield is of particular interest. (Note: Combustion processes are addressed by other portfolios and are not within the scope of interest.)
- Shock/Boundary Layer and Shock-Shock Interactions
- Laminar-turbulent stability, transition and turbulence in high-Mach number boundary layers, especially approaches leading to greater insight into surface heat transfer.
- Characterization and modeling of the impact of realistic surface conditions on transitional and turbulent flows in all speed regimes.
- Innovative experiments and numerical simulations that identify the underlying sources and potential control mechanisms for noise radiated from high-speed hot jets.

The behavior of the boundary layer impacts the aerodynamic performance of systems across all speed regimes of interest to the Air Force. The development of accurate methods for predicting the behavior of transitional and turbulent boundary layers across a wide range of flow conditions will facilitate the design of future systems with optimized performance and fuel-economy. Aerothermodynamic research is critical to the Air Force's interest in long-range and space operations. The size and weight of a high-speed vehicle, and thus its flight trajectory and required propulsion system, are largely determined by aerothermodynamic considerations. Research areas of interest emphasize the characterization, prediction and control of high-speed fluid dynamic phenomena including boundary layer transition, shock/boundary layer, and shock/shock interactions, and other phenomena associated with airframe-propulsion integration. High-temperature gas kinetics, aerothermodynamics and interactions between the hypersonic flow and thermal protection system materials are of particular interest.

Researchers are highly encouraged to submit short (max 6 pages) White papers prior to developing full proposals. White papers are a valuable initial exercise prior to proposal development and submission. White papers should briefly describe the proposed effort and illustrate how it will advance the current state-of-the-art; an approximate yearly cost for a three year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals.

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9. Flow Interactions and Control

The Flow Interactions and Control portfolio is interested in basic research problems associated with the motion and control of laminar, transitional and turbulent shear flows, including the interactions of these flows with rigid and flexible surfaces. The portfolio seeks to advance fundamental understanding of complex, time-dependent flow interactions by integrating theoretical/analytical, numerical, and experimental approaches. The focus on the understanding of the fundamental flow physics is motivated by an interest in developing physically-based predictive models and innovative control concepts for these flows.

The portfolio is interested in aerodynamic interactions arising in both internal and external flows and extending over a wide range of Reynolds numbers. Research in this portfolio is motivated by, but not limited to, applications including unique fluid-structure interactions including those found in the human body, vortex and shear layer flows, and micro-air vehicle flows.

The portfolio emphasizes the characterization, modeling/prediction, and control of flow instabilities, turbulent fluid motions, and fluid-structure interactions for both bounded and free-shear flows with application to aero-optics, surfaces in actuated motion, flexible and compliant aerodynamic surfaces, vortical flows, and flows with novel geometric configurations. The portfolio maintains an interest in the flow physics of the dynamic interaction between unsteady aerodynamics, nonlinear structural deformations, and aerodynamic control effectors over a wide range of flight regimes. Although the portfolio has a strong emphasis in flow control, studies examining underlying flow physics with a path to enabling control of the flow will also be considered. Studies integrating modeling, control theory, and advanced sensor and/or actuator technology for application to a flow of interest are encouraged. Flow control studies are expected to involve a feedback approach based on a fundamental insight into the flow physics.

Prospective researchers are strongly encouraged to submit short (max 6 pages) White papers to the program manager prior to developing full proposals. White papers are viewed as a valuable first step in the proposal development and submission process. White papers should briefly describe the proposed effort, illustrate how it will advance the current state-of-the-art, and address the relevance to Air Force interests. Note, however, that basic research of the variety typically funded by the portfolio may not yet have a clear transition map to an application. The

integration of theoretical, numerical, and experimental tools to improve understanding is encouraged. An approximate yearly cost for a three year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals.

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10. Space Power and Propulsion

Research activities are focused as multi-disciplinary, multi-physics, multi-scale approach to complex space propulsion problems, and fall into three areas: non-chemical launch and in-space propulsion, chemical propulsion, and plume contamination resulting from both chemical and non-chemical propulsion. Research in the first area is directed primarily at advanced space propulsion, and is stimulated by the need to transfer payloads between orbits, station-keeping, and pointing, including macro- and nano-satellite propulsion. It includes studies of the sources of physical (non-chemical) energy and the mechanisms of release. Emphasis is on understanding electrically conductive flowing propellants (plasmas or charged particles) that serve to convert beamed or electrical energy into kinetic form.

Theoretical and experimental investigations focus on coupled materials and plasma processes far from equilibrium; smart, functional nanoenergetics design from the atomistic / molecular scale through mesoscale; and nonlinear, multi-scale, multi-physics high pressure combustion dynamics. Research is sought on methods to predict and suppress combustion instabilities, including propellant additives, and develop research models that can be incorporated into the design codes. Areas of research interest may include the phenomenon of energy coupling and the transfer of plasma flows in electrode and electrodeless systems under dynamic environments.

All fundamental research ideas relating to space propulsion and power are of interest to this program in addition to the examples given above, but researchers should also consult the programs in Plasma and Electro-Energetic Physics, Aerospace Materials for Extreme Environments, Theoretical Chemistry and Molecular Dynamics, Thermal Sciences, Computational Mathematics, and other programs as described in this Broad Area Announcement to find the best match for the research in question. Joint innovative science projects may develop in the areas such as: (1) design and testing of compact, highly efficient and robust chemical or electric propulsion systems with minimal power conditioning requirements; (2) thermal management, sensing, self-healing, and other fundamental concepts to increase efficiency, and lifetime of space structures; (3) innovative processes that transform structural material into high energy density propellant (e.g. phase change, or even biological process); (4) novel energetic materials; and (5) development of modeling and simulation capabilities at all relevant scales, including a general mathematical framework for stochastic modeling of such systems, and facilitate the extraction of dominant causal relationships from large data sets. Researchers are highly encouraged to consult

(**https://community.apan.org/afosr/w/researchareas/7459.space-power-and-propulsion.aspx**), for the latest information.

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11. Energy Conversion and Combustion Sciences

The objective of this portfolio is to develop fundamental understanding of key multi-physics and multi-scale phenomena in conversion of chemical energy to mechanical energy for propulsion applications of interests to the Air Force. The research focus is on identification and quantification of rate-controlling processes and scales in the key phenomena in energy conversion processes. Research proposals are sought in all aspects of energy conversion and combustion sciences with the following emphasis:
Turbulent combustion is a key phenomenon in converting chemical energy to mechanical energy in majority of Air-Force propulsion systems. It is one of most important factors in determining operability, performance, size and weight of such systems. It is also one of least understood areas in basic combustion research with, in general, rather large model/prediction uncertainties. In this area, the research focus will be on key combustion phenomena and characteristics, including but not limited to: flame propagation, flammability limit and combustion instability, at multi-phase conditions applicable to development of the Air Force propulsion systems. Proposals for well designed experiments will be considered with priority for providing data for the following aspects:

• Understanding the above key combustion phenomena and characteristics;
• Quantifying rate-controlling processes and scales that govern those phenomena and characteristics;
• Validating as directly as possible and further developing basic model assumptions used in the numerical simulation for turbulence combustion;
• In such experiments, controlling and quantifying turbulence properties at corresponding flow conditions will be essential.

In combustion modeling and theory, in addition to validating and further developing basic model assumptions discussed above, the following sub-areas will be emphasized:
• Using numerical simulations as an experimental tools (numerical experiments), with help of theoretical combustion research, to qualitatively explore key combustion phenomena to obtain fundamental understanding and to identify rate-controlling processes and scales in different ranges of flow (including turbulence) and fueling conditions;
• Capability to analyze large-scale data sets from numerical simulations to extract key physics;
• Combined experimental-numerical approaches using numerical simulations directly coupled and fused with experimental data to provide quantitative information, which is otherwise not available through experimental measurements. This serves as a foundation

for further developments of more experiment-independent, quantitative numerical experimental approaches;
• Analytical and numerical approaches to simplify and reduce complex mathematical systems applicable to combustion modeling.

Advance of diagnostic tools is crucial to gathering data to understand key phenomena in the energy conversion. Therefore, development in this area will be continuously supported with the following focuses:
• New signal generating processes and related basic spectroscopic approaches for key properties in chemically reacting flows;
• Three-dimensional (volumetric or scanning two-dimensional) imaging approaches;
• Post processing capability to extract key physics from large-scale, multi-dimensional experimental data sets.

Proposals for other game-changing research activities will also be considered for converting chemical energy to mechanical energy for the Air Force propulsion applications. Potential areas include but not limited to:
• Flameless combustion;
• Direct conversion from chemical energy to mechanical energy;
• Alternative fuel of superior physical and combustion/energy-conversion properties with favorable source-characteristics.

Multi-disciplinary collaborations and interactions are strongly desired, and joint experimental, theoretical and numerical efforts are highly appreciated.

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b. Physics and Electronics (RSE)

Research in physics and electronics generates the fundamental knowledge needed to advance Air Force operational capabilities. Research directions are categorized in three broad areas:

Complex Electronics and Fundamental Quantum Processes: This includes exploration and understanding of a wide range of complex engineered materials and devices, including non-linear optical materials, optoelectronics, metamaterials, cathodes, dielectric and magnetic materials, high energy lasers, semiconductor lasers, new classes of high temperature superconductors, quantum dots, quantum wells, and graphene. Research into new classes of devices based on quantum phenomena can include new generations of ultra compact or ultrasensitive electronics to improve conventional devices for sensing or information processing and such new concepts as quantum computing. This area also includes generating and controlling quantum states, such as superposition

and entanglement, in photons and ultra cold atoms and molecules (e.g. Bose Einstein Condensates). In addition to research into underlying materials and fundamental physical processes, this area considers how they might be integrated into new classes of devices, seeking breakthroughs in quantum information processing, secure communication, multi-modal sensing, and memory, as well as high speed communication and fundamental understanding of materials that are not amenable to conventional computational means (e.g., using optical lattices to model high-temperature superconductors).

Plasma Physics and High Energy Density Nonequilibrium Processes: This area includes a wide range of activities characterized by processes that are sufficiently energetic to require the understanding and managing of plasma phenomenology and the non-linear response of materials to high electric and magnetic fields. This includes such endeavors as space weather, plasma control of boundary layers in turbulent flow, plasma discharges, RF propagation and RF-plasma interaction, and high power beam-driven microwave devices. It also includes topics where plasma phenomenology is not necessarily central to the activity but is nonetheless an important aspect, such as laser-matter interaction (including high energy as well as ultra short pulse lasers) and pulsed power. This area pursues advances in the understanding of fundamental plasma and non-linear electromagnetic phenomenology, including modeling and simulations, as well a wide range of novel potential applications involving matter at high energy density.

Optics, Electromagnetics, Communication, and Signal Processing: This area considers all aspects of producing and receiving complex electromagnetic and electro optical signals, as well as their propagation through complex media, including adaptive optics and optical imaging. It also covers aspects of the phenomenology of lasers and non-linear optics. This area not only considers the advancement of physical devices to enable such activities, but also includes sophisticated mathematics and algorithm development for extracting information from complex and/or sparse signals This cross-cutting activity impacts such diverse efforts as space object imaging, secure reliable communication, on-demand sensing modalities, distributed multilayered sensing, automatic target recognition, and navigation.

The physics and electronics program includes theoretical and experimental physics from all disciplines, as well as engineering issues such as those found in microwave or photonic systems or materials-processing techniques. One main objective of the program is to balance innovative science and Air Force relevance, the first element being forward looking and the second being dependent on the current state-of-the-art. Research areas of interest to the Air Force program managers are described in detail in the sub areas below.

(Note: some additional funds may be added to the budgets of new grants if the proposal requests the hire of US-citizen undergraduates as part-time and/or summer laboratory assistants. Please coordinate any requests with the Program Manager.)

1. Plasma and Electro-Energetic Physics

The objective of this program is to understand and control the interaction of electromagnetic energy and charged particles to produce useful work in a variety of arenas, including directed energy weapons, sensors and radar, electronic warfare, communications, novel compact accelerators, and innovative applications of plasma chemistry, such as plasma-enhanced combustion and plasma aerodynamics. While the focus of this effort is the generation and collective interaction of electromagnetic fields and plasmas, advances in the enabling technology of compact pulsed power, including innovative dielectric and magnetic materials for high-density energy storage, switching devices, and non-linear transmission lines are also of fundamental interest. Ideas for advancing the state-of-the-art in the following areas are strongly encouraged: highly efficient electron-beam-driven sources of microwave, millimeter-wave, and sub-millimeter coherent radiation (high power microwaves [HPM] and/or vacuum electronics), novel dispersion engineering via meta-material and photonic band gap structures, compact pulsed power, particle-field interaction physics, power-efficient methods to generate and maintain significant free-electron densities in ambient air, plasma chemistry at high pressure, and the physics of strongly coupled plasmas. New concepts for the theory, modeling, and simulation of these physical phenomena are also of interest, including combined experimental/theoretical/simulation efforts that verify and validate innovative models.

Ideas relating to plasmas and electro-energetic physics in space are of interest to this program, but researchers should also consult the programs in Space Power and Propulsion and in Space Sciences as described in this Broad Agency Announcement to find the best match for the research in question. Innovative science that combines plasma and electro-energetic physics with the high-energy density associated with nuclear forces (e.g. nuclear batteries where radiation produces currents in semiconductors and propulsion plasmas sustained via fusion) will be considered. Nuclear fission or fusion for large-scale energy production is not of prime interest to this portfolio.

Interested parties are encouraged to contact the program manager before submission of White papers on their ideas. Collaborative effort with the researchers at the Air Force Research Laboratory is encouraged, but not required.

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2. Atomic and Molecular Physics

This program encompasses fundamental experimental and theoretical Atomic and Molecular physics research that is primarily focused on studies of cold and ultracold quantum gases, precision measurement, and quantum information science (QIS) with

atoms, molecules, and light. These research areas support technological advances in application areas of interest to the Air Force, including precision navigation, timekeeping, remote sensing, secure communication, metrology, and novel materials for Air Force needs in the future.

AMO (Atomic, Molecular and Optical) physics today offers an unprecedented level of coherent control and manipulation of atoms and molecules and their interactions, allowing for significant scientific advances in the areas of cold and ultracold matter and precision measurement. Specific research topics of interest in this program include, but are not limited to, the following: physics of quantum degenerate atomic and molecular gases; strongly-interacting quantum gases; new phases of matter; non-equilibrium dynamics of cold quantum gases; cold/ultracold plasmas; ultracold chemistry; precision spectroscopy; novel clocks; and high-precision techniques for navigation, guidance, and remote sensing.

Quantum information science (QIS) is a field that encompasses many disciplines of physics. AMO physics plays an important role in the development of QIS. This program is primarily focused on the following research areas in QIS: quantum simulation of strongly-correlated condensed-matter systems with cold atoms and molecules; enabling science for secure long-distance quantum communication; utilization of non-classical states of matter and light for high-precision metrology and sensing; quantum optomechanics; application of controlled coherent interactions to direct the dynamics of quantum systems; and novel approaches to quantum information processing.

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3. Multi-scale Modeling

This program supports research in the mathematics of bridging molecular/atomic to continuum (linear and nonlinear partial differential equations) descriptions of media in order to develop accurate models of physical phenomena to enhance the fidelity of simulation. It conceives and investigates the properties of mathematical approaches which can provide direct passages from molecular/atomic level to continuum level descriptions (for example emphasizing suitable functional analytic approaches).

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4. Electromagnetics

This portfolio supports research in electromagnetics (EM) to produce conceptual descriptions of electromagnetic properties of novel materials/composites (such as photonic band gap media, negative index media, Parity-Time symmetry media, etc.) and the simulation of their uses in various operational settings. Basic research to evaluate methods to recognize (the inverse scattering problem) and track targets (including Improvised Explosive Devices) and identify suitable wideband radar waveforms (precursors or Airy beams for example) to penetrate foliage, clouds, buildings, the ionosphere, or other dispersive/random/turbulent media and design transmitters to produce such pulses is also supported. Research which develops the mathematical underpinning for computational electromagnetic simulation codes (both frequency domain and time domain) that are rapid and whose claims of accuracy are accompanied by rigorous error estimates/controls is also supported. In the area of nonlinear Maxwell's equations (commonly called nonlinear optics--NLO), research which pursues descriptions of nonlinear EM phenomena such as the propagation of ultrashort laser pulses through air, clouds, etc and any possible exploitation of these pulses is supported. Such mathematical descriptions are anticipated to be a coupled system of nonlinear partial differential equations. Basic research in other nonlinear EM phenomena include the dynamics of the EM field within solid state laser cavities and fiber lasers, the propagation of light through various nonlinear crystals (including graphene), as well as other nonlinear optical media. All such modeling/simulation research is complementary to the experimental/empirical portfolios within the Physics & Electronics Directorate. Another area of interest is the description and understanding of any chaos in circuitry which can possibly be created by exposure to suitable EM fields.

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5. Laser and Optical Physics

This Air Force program seeks innovative approaches and novel concepts that could lead to transformational advances in high average power lasers for future applications related to directed-energy. Examples of such areas include novel processing techniques for high quality ceramic laser materials with control over spatial distributions of dopants and index of refraction, and processing methods for achieving low loss laser ceramics with non-isotropic, and therefore necessarily aligned, grains. Aligned grain ceramic materials are also of interest as large size, high average power nonlinear optical materials using quasi-phasematching techniques. New ideas for high average power fiber lasers are of interest, including new materials, and large mode area structures, novel ways of mitigating nonlinear issues, and studies of coupling multiple fiber lasers which can withstand very high average power. Novel compact, particularly tunable or wavelength flexible, potentially inexpensive, infrared lasers are of interest for infrared countermeasures or for gas sensing applications. Relatively small novel sources of monochromatic x-rays are also of interest. The Laser and Optical Physics program is

interested and will consider any novel and potentially transformational ideas within the broad confines of its title.

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6. Remote Sensing and Imaging Physics

This program investigates fundamental issues concerning remote sensing and the physics of imaging, including image formation processes, non-imaging sensing, propagation of electromagnetic radiation, the interaction of radiation with matter, remote target detection and identification, the effect of the atmosphere or space environment on imaging systems and sensors, and the detection and tracking of resident space objects, including orbital prediction and dynamics. Proposals are sought in all areas of ground, air, and space-based remote sensing and imaging, but particularly in the detection, characterization, and identification of space objects. This program includes the investigation of fundamental processes that affect space situational awareness. Technological advances are driving the requirement for innovative methods to detect, identify, and predict trajectories of smaller and/or more distant objects in space. New optical capabilities that complement traditional radar tracking of satellites, as well as increased resolution and sensitivity, are leading to the need for faster and more accurate methods of characterization. Research goals include, but are not limited to:

1. Theoretical foundations of remote sensing and imaging.
2. Enhancement of remote sensing capabilities, including novel solutions to system limitations such as limited aperture size, imperfections in the optics, and irregularities in the optical path.
3. Propagation of coherent and incoherent electromagnetic radiation through a turbulent atmosphere. (Theoretical and mathematical aspects of this area should also see the BAA input for Electromagnetics - AFOSR PM is Dr. Arje Nachman.)
4. Innovative methods of remote target location, characterization, and tracking, as well as non-imaging methods of target identification.
5. Understanding and predicting dynamics of space objects as it relates to space object identification and space situational awareness.
6. Rigorous theory and models to describe the spectral and polarimetric signature from targets of interest using basic material physical properties with the goal of providing better understanding of the physics of the reflection and/or emission from objects in space and the instrumentation requirements for next generation space surveillance systems.
7. Remote sensing signatures and backgrounds of both ground-based and space-based observations.

8. The interaction of Air Force imaging systems and sensors with the space environment. This includes the understanding of conditions that affect target identification, such as environmental changes and surface aging or weathering.

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7. Space Sciences

The AFOSR Space Sciences program supports basic research on the solar-terrestrial environment extending from the Sun through Earth's magnetosphere and radiation belts to the mesosphere and lower thermosphere region. This geospace system is subject to solar radiation, particles, and eruptive events, variable interplanetary magnetic fields, and cosmic rays. Perturbations to the system can disrupt the detection and tracking of aircraft, missiles, satellites, and other targets; distort communications and navigation signals; interfere with global command, control, and surveillance operations; and negatively impact the performance and longevity of Air Force space assets.

A long-term goal for the program is development of a physics-based predictive coupled solar-terrestrial model that connects solar activity and emissions with resultant effects on Earth's radiation belts, magnetosphere, ionosphere, and neutral atmosphere. To achieve this, fundamental research focused on improving understanding of the physical processes in the geospace environment is encouraged. Particular goals are to improve operational forecasting and specification of solar activity, thermospheric neutral densities, and ionospheric irregularities and scintillations. Activities that support these goals may include validating, enhancing, or extending solar, ionospheric, or thermospheric models; investigating or applying data assimilation techniques; and developing or extending statistical or empirical models. An important aspect of the physics is understanding and representing the coupling between regions, such as between the solar corona and solar wind, between the magnetosphere and ionosphere, between the lower atmosphere and the thermosphere/ionosphere, and between the equatorial, middle latitude, and polar regions.

Research areas of interest include:

- The structure and dynamics of the solar interior and its role in driving solar eruptive activity;
- The mechanism(s) heating the solar corona and accelerating it outward as the solar wind;
- The triggers of coronal mass ejections (CMEs), solar energetic particles (SEPs), and solar flares;
- The coupling between the solar wind, the magnetosphere, and the ionosphere;

- The origin and energization of magnetospheric plasma;
- The triggering and temporal evolution of geomagnetic storms;
- The variations in solar radiation received at Earth and its effects on satellite drag;
- The impacts of geomagnetic disturbances on the thermosphere and ionosphere;
- Electron density structures and ionospheric scintillations;
- Ionospheric plasma turbulence and dynamics;
- The effects of neutral winds, atmospheric tides, and planetary and gravity waves on the neutral atmosphere densities and on the ionosphere.

Researchers are strongly encouraged to submit short White papers (three pages max) prior to developing full proposals. White papers should briefly describe the proposed effort and how it will advance the current state-of-the-art. It should include a list of any collaborators and an approximate yearly cost for the effort.

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8. Quantum Electronic Solids

This program focuses on materials that exhibit cooperative quantum electronic behavior. The primary emphasis is on superconductors, metamaterials, and on nanoscopic electronic devices based mainly upon graphene, and on pure and doped nanotubes, with low power dissipation and the ability to provide denser non-volatile memory, logic and/or sensing elements that have the potential to impact future Air Force electronic systems.

The superconductivity portion of this program is now wholly devoted to a search for new classes of superconducting materials that either have higher transition temperatures or have isotropic superconducting properties at temperatures in the range of the transition temperatures of the cuprates, e.g., YBCO. While the 2008 discovery of iron-pnictide superconductors has provided new insights, these materials are not sufficiently promising. This major change in emphasis is part of a coordinated international activity that is multidisciplinary in nature, and proposals that address both the physics and chemistry of potential new types of superconductors are welcome, as are multinational research efforts. However, major awards under this program were made in FY09, so while any promising new ideas will be considered, funding for new projects in this area will be somewhat limited for the next couple of years. The program is primarily an experimental one, but theorists who interact with experimental groups constructively are welcome. The primary goal of this part of the program is to uncover superconducting materials that can be made into forms that are amenable to Air Force applications.

The metamaterials portion of this program is devoted to the production of 2-D and 3-D metamaterials that operate over a wide swath of the electromagnetic spectrum, from microwaves, to IR and the visible. The long-term goal is to produce materials that

improve the efficiency and selectivity of, and reduce the size of communications system components such as antennas, filters and lenses. Another important aspect is to study the ability to create sub-wavelength, near-field (and possibly far-field) imaging. These desired properties could lead to denser information storage and retrieval.

A new area of interest involves thin-film, oxide-based materials that are critical for the development of devices with the new functionalities that will lead to useful, reprogrammable, controllable and active systems at the nanoscale with properties difficult to attain by other means. The utilization of oxides for revolutionary technologies critically relies on acquiring fundamental understanding of the physical processes that underlie spin, charge and energy flow in these nanostructured materials. The oxides to be considered are generally complex, multi-element materials with complicated crystal structures, and that can be synthesized in unusual nanostructured geometries which exhibit strong electronic correlations.

A relatively minor part of this program is the inclusion of nanoscopic techniques to fabricate, characterize, and manipulate atomic, molecular and nanometer-scale structures (including graphene, and nanotubes of carbon and other elements), with the aim of producing a new generation of improved communications components, sensors and non-volatile, ultra-dense memory, resulting in the ultimate miniaturization of analog and digital circuitry. This aspect of the program includes the use of polarized electrons to produce nuclear magnetic polarization as a basis for dense, non-volatile memory, with possible application to quantum computing at room temperature.

Finally, there is a continuing (albeit small) interest in the development of new soft and hard magnetic material with high energy product at elevated temperatures to aid in providing power devices, switches and bearings for a new generation of more-electric aircraft that dispense with hydraulics and which rely heavily on magnetic actuation.

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9. Adaptive Combinatorial Remote Sensing Physics & Methods

This program seeks to discover and exploit scientific breakthroughs in natural and artificial (meta) solid-state electronic and photonic materials, micro-/nanostructures, novel device physics concepts, and sensing & data exploitation schemes potentially enabling for future transformational capabilities in adaptive combinatorial multimodal sensing methods. Breakthrough novel EO/IR sensor designs and methods are essential for meeting envisioned long-term game-changing USAF C4ISR capability needs. Future USAF universal situational awareness needs include near real-time detection, tracking, and identification of low-contrast and complex targets in broad areas and highly-cluttered dynamic environments, integrated with near real-time communication of resultant

actionable data to battlefield commanders. Resulting near instantaneous sensor-to-shooter capability will require remote and autonomous real-time-closed-loop controlled target spectra sensing, data fusion and processing, knowledge objective exploitation, and communications.

A promising approach for near real-time *sensor-to-shooter* capability is *performance-driven sensing* (PDS). PDS relies on sensing, processing and exploiting only the most decision-relevant sets of target/scene spectra data in order to reduce by many orders-of-magnitude (OoM) requirements on data processing throughput and communications bandwidth. The key to PDS is the ability in near real-time to autonomously and dynamically select and process data from only the most judicious sets of sensor pixels (spatial locations) and pixel photon modes (wavelength, polarization, and perhaps phase). It is well known that the fusion of optimum sets of mixed-mode target spectra data can exponentially quicken exploitation (e.g., target ID) and dramatically reduce false alarms. The basic advantage of multi-spectral (λ_i) sensing includes enhanced clutter filtering to improve target-scene contrast, and reflectance spectroscopy to identify component chemicals and specific material type. Spectral polarimetry ($S\lambda$) enables discrimination of natural versus manmade objects, object shape, and material surface roughness. Phase-shift (ϕ) sensing holds significant promise for LIDAR-based 3D imaging. Spatial discrimination (r) yields object shape, internal features, context, and range profiling. The dimension of time (t) is essential for recording evolution of r, λi, $S\lambda$, □, crucial for tracking objects. Further, for a given target/scene and specified knowledge objective, there exists some optimum combination of fused r, λ_i, S_λ, ϕ & t modalities for which exploitation can be optimized in terms of minimum processing time for a defined acceptable false alarm rate and resultant data communications bandwidth. Herein lies a significant C4ISR capability breakthrough opportunity; the optimum minimum combination of mixed modality target/scene information will reduce by many OoM the time required to sense, process & communicate actionable data to commanders.

One can envision a hypothetical imaging focal plane array possessing individually addressable pixels of one construct or another, and each pixel having tunable wavelength, polarization, and phase set-and-read capability, i.e., a multimodal-sensor-in-a-pixel. Then in principal one could find the optimum minimum number of pixels and pixel modalities needed to achieve a specified knowledge objective as governed by closed-loop decision and exploitation algorithms. However, a fully adaptive and integrated multimodal sensing (AIMS) capability, along with complimentary closed-loop sensor-mode decision and control algorithms, do not yet exist. Today, a majority of military ISR platforms are single-mode and operate independently, forwarding data via their own specialized (stovepiped) ground processing channels; interoperability is poor. As well, many ISR assets generate enormous volumes of data that greatly bottleneck communications bandwidth (e.g., Gbps-Pbps are possible versus CDL's 275Mbps) and completely overwhelm ground C2 man-in-loop exploitation and recognition capabilities. In fact in many cases the vast majority of collected and transmitted ISR data is deemed redundant and/or useless. Hence, again herein lies a crucial breakthrough opportunity for PDS, whereby one senses, processes, exploits, and communicates only the most decision-relevant target/scene spectra data. However, very significant and substantial

basic and applied research challenges presently confront the realization of PDS. These challenges span multidisciplinary topics in electronics and photonics; novel solid-state materials sciences, novel electromagnetic (EM) spectra//micro-/nanostructures interactions and phenomenology, innovative compact mixed-mode device constructs and physics, and breakthrough closed-loop decision and exploitation algorithms.

Basic Research Opportunities:

Fundamental solid-state materials science and device physics challenges facing many envisioned multimodal sensing concepts, found in the literature and other, are primarily driven by three factors: first, incompatible electronic and optical interactions at complex device heterointerfaces, where lattice-mismatched layers produce a plethora of deleterious structural & electrical defect states that enhance photo-carrier generation and, more importantly, recombination, second, interface electronic band-discontinuities yield deleterious potential barriers that retard carrier transport, and third, the paramount challenge associated with non-demolition interrogation of mixed-mode spectra; preserving EM wave properties under test. For example, methods are needed to determine the number of photons in some range $\Delta\lambda$, while preserving the photon (or a large fraction of them) properties long enough to query their polarization state.

Principal basic research interests include, but are not limited to 1) Novel methods for combining, modeling, simulating, and synthesizing multiple low-dimensional heterogeneous micro-/nanostructures (e.g., Q-dots/wires/wells, CNT, graphene, nanorods, core-shell nanocrystals, plasmonic structures, nano-antenna structures, metamaterials, transparent films and interconnects, etc.) to generate entirely new and useful photon//media phenomenological interactions, 2) Novel methods for capturing and/or interpreting novel phenomenological interactions between photons (wave or particle nature) and electronic states of novel materials/structures to yield unique signature spectra modality (r, λ_i, S_λ, ϕ) information, 3) Novel methods for circumventing deleterious effects of heterogeneous media and structures integration, 4) Approaches for real-time dynamic tuning and/or manipulating absorber media bulk and heterointerface properties, such as bandgap, absorption coefficient, transport properties, band-offsets, defect levels, etc., 5) Novel sensor materials/device physics methods for enhanced Auger recombination lifetime for increased detector S/N and effective operating temperature, and 6) Innovative approaches for non-demolition light-wave property interrogation.

Additionally, novel multimodal sensor device constructs, concepts and methods are desired for achieving co-bore sighted multimodal spectra imaging in a starring format, as well as non-image detection and spectral discrimination techniques. Novel concepts are sought for tunable and/or reconfigurable ‘pixel’ and/or detector element approaches offering multiple-modes in one or more UV-LWIR bands; novel concepts for same-pixel multicolor (4+ λ-bands) designs with suitable pixel-to-ROIC interconnect schemes are of interest; and novel biologically inspired multimodal detection processes and devices concepts are sought. Possible sensor structures include, but are not limited to integrated monolithic and/or hybrid approaches utilizing homogeneous and/or heterogeneous

material layers and structures; multi-dimensional quantum and nano-based structures, and any combination thereof, with a requirement that novel sensor device concepts should have a reasonable expectation of yielding external quantum efficiencies in excess of 50%.

White papers: The deadline for accepting whitepapers for fiscal year 2012 is June 15th, 2012.

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10. Optoelectronics: Components, Integration and Information Processing and Storage

The major objective is to explore new fundamental concepts in photonics, improve the fundamental understanding of photonic devices and components, and enable discovery and innovation in advancing the frontier of nanophotonics and associated nanoscience and nanotechnology.

This program supports Air Force requirements for information dominance by increasing capabilities in image capture; processing, storage, and transmission for surveillance, communications and computation; target discrimination; and autonomous navigation. In addition, high bandwidth interconnects enhance performance of distributed processor computations that provide real-time simulation, visualization, and battle management environments. Further important considerations for this program are the airborne and space environment in which there is a need to record, read, and change digital data at extremely high speeds. Six major areas of interest include Optoelectronic Components and Information Processing, Nanophotonics (including photonic crystals, plasmonics, metamaterials), Compact Terahertz Sources and Detectors, Optical Buffering and Storage, Quantum Computing using Optical Approaches, and Reconfigurable Photonics.

The thrusts in components and information processing include investigations in two affiliated areas: (1) the development of optoelectronic devices and supportive materials and processing technology, and (2) the insertion of these components into optoelectronic computational, information processing and imaging systems. Device exploration and architectural development for processors are coordinated; synergistic interaction of these areas is expected, both in structuring architectural designs to reflect advancing device capabilities and in focusing device enhancements according to system needs. Research in optoelectronic or photonic devices and associated optical material emphasizes the insertion of optical technologies into computing, image-processing, and signal-processing systems. To this end, this program continues to foster interconnection capabilities, combining arrays of sources or modulators with arrays of detectors, with both being coupled to local electronic or potentially optical processors. Understanding the

fundamental limits of the interaction of light with matter is important for achieving these device characteristics. Semiconductor materials, insulators, metals and associated electromagnetic materials and structures are the basis for the photonic device technologies. Numerous device approaches (such as silicon photonics) are part of the program as are techniques for optoelectronic integration.

The program is interested in the design, growth and fabrication of nanostructures that can serve as building blocks for nano-optical systems. The research goals include integration of nanocavity lasers, filters, waveguides, detectors and diffractive optics, which can form nanofabricated photonic integrated circuits. Specific areas of current interest include nanophotonics, use of nanotechnology in photonics, exploring light at the nanoscale, nonlinear nanophotonics, plasmonics & excitonics, sub-wavelength components, photonic crystal and negative index materials, optical logic, optical signal processing, reconfigurable nanophotonics, nanophotonics enhanced detectors, chip scale optical networks, integrated nanophotonics and silicon-based photonics. Coupled somewhat to these areas are optoelectronic solutions to enable practical quantum computing schemes plus novel approaches to nanopower such as thermoelectrics.

In bridging the gap between electronics and photonics, the program also explores opportunities in terahertz (THz) technologies and its associated applications in non-destructive evaluation, communications, navigation aids, and security. Diverse approaches have been taken to create THz sources and detectors over the 0.3 to 10 THz range. Desired are THz sources and detectors that are compact, room-temperature, efficient, solid-state devices capable of integration with other solid-state components. Integration of transmit and receive functions on the same chip is another goal.

To support next generation processor architectures, image processing and capture and new multi-media application software, computer data buffering and storage research is needed. As devices are being developed that emit, modulate, transmit, filter, switch, and detect multi-spectral signals, for both parallel interconnects and quasi-serial transmission, it is important to develop the capability to buffer, store, and retrieve data at the rates and in the quantity anticipated by these devices. Architectural problems are also of interest that include, but are not limited to, optical access and storage in memory devices to obviate capacity, access latency, and input/output bandwidth concerns. Of interest has been the ability to slow, store, and process light pulses. Materials with such capabilities could be used for tunable optical delay lines, optical buffers, high extinction optical switches, novel image processing hardware, and highly efficient wavelength converters.

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11. Sensing, Surveillance, Navigation

This research activity is concerned with the systematic analysis and interpretation of variable quantities that represent critical working knowledge and understanding of the changing Battlespace. "Signals Communication" is a sub-area referring to the conveyance of information physically through a channel. Surveillance images are of special importance in targeting, damage assessment and resource location. Signals are either generated naturally or deliberately transmitted, propagated as electromagnetic waves or other media, and recaptured at the receiving sensor. Modern radar, infrared, and electro-optical sensing systems produce large quantities of raw signaling that exhibit hidden correlations, are distorted by noise, but still retain features tied to their particular physical origin. Statistical research that treats spatial and temporal dependencies in such data is necessary to exploit its usable information. An outstanding need in the treatment of signals is to develop resilient algorithms for data representation in fewer bits (compression), image reconstruction/enhancement, and spectral/frequency estimation in the presence of external corrupting factors. These factors can involve deliberate interference, noise, ground clutter, and multi-path effects. This AFOSR program searches for application of sophisticated mathematical methods, including time-frequency analysis and generalizations of the Fourier and wavelet transforms, that deal effectively with the degradation of signaling transmission across a channel. These methods hold promise in the detection and recognition of characteristic transient features, the synthesis of hard-to-intercept communications links, and the achievement of faithful compression and fast reconstruction for audio, video, and multi-spectral data. New combinations of known methods of asset location and navigation are being sought, based on analysis and high-performance computation that bring a force-multiplier effect to command/control capabilities. Continued upgrade and reliance on Global Positioning System makes it critical to achieve GPS-quality positioning in situations where GPS by itself is not sufficient. Ongoing research in Inertial and non-Inertial navigation methods (including optical flow and use of signals of opportunity) will bring location precision and reliability to a superlative level. Continuous improvement in its repertoire of signal processing and statistical tools will enable the Air Force to maintain its lead in Battlespace awareness through navigation and surveillance. Communications are what hold together the networked Infosphere and cost-effective systems innovations that enable phenomenal air power projection.

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12. Dynamic Data Driven Applications Systems (DDDAS)

Program Description: The DDDAS concept entails the ability to dynamically incorporate additional data into an executing application, and in reverse, the ability of an application to dynamically steer the measurement (instrumentation and control) components of the application system. DDDAS is a key concept for improving modeling of systems under dynamic conditions, more effective management of instrumentation systems, and is a key

concept in architecting and controlling dynamic and heterogeneous resources, including, sensor networks, networks of embedded controllers, and other networked resources. DDDAS transformative advances in computational modeling of applications and in instrumentation and control systems (and in particular those that represent dynamic systems) require multidisciplinary research, and specifically need synergistic and systematic collaborations between applications domain researchers with researchers in mathematics and statistics, researchers computer sciences, and researchers involved in the design/ implementation of measurement and control systems (instruments, and instrumentation methods, and other sensors and embedded controllers).

Basic Research Objectives: Individual and multidisciplinary research, technology development, and cyberInfrastructure software frameworks needed for DDDAS applications and their environments are sought, along four key science and technology frontiers: Applications modeling: In DDDAS an application/simulation must be able to accept data at execution time and be dynamically steered by such dynamic data inputs. This requires research advances in application models that: describe the application system at different levels of detail and modalities; are able to dynamically invoke appropriate models as needed by the dynamically injected data into the application; and include interfaces of applications to measurements and other data systems. DDDAS will, for example, engender an integration of large scale simulation with traditional controls systems methods, thus provide an impetus of new directions to traditional controls methods. Advances in Mathematical and Statistical Algorithms include creating algorithms with stable and robust convergence properties under perturbations induced by dynamic data inputs: algorithmic stability under dynamic data injection/streaming; algorithmic tolerance to data perturbations; multiple scales and model reduction; enhanced asynchronous algorithms with stable convergence properties; multimodal, multiscale modeling and uncertainty quantification, and in cases where the multiple scales or modalities are invoked dynamically and there is need for fast methods of uncertainty quantification and uncertainty propagation across dynamically invoked models. Such aspects push to new levels of challenges the traditional computational math approaches. Application Measurement Systems and Methods include improvements and innovations in instrumentation platforms, and improvements in the means and methods for collecting data, focusing in a region of relevant measurements, controlling sampling rates, multiplexing, multisource information fusion, and determining the architecture of heterogeneous and distributed sensor networks and/or networks of embedded controllers. The advances here will create new instrumentation and control capabilities. Advances in Systems Software runtime support and infrastructures to support the execution of applications whose computational systems resource requirements are dynamically dependent on dynamic data inputs, and include: dynamic selection at runtime of application components embodying algorithms suitable for the kinds of solution approaches depending on the streamed data, and depending on the underlying resources, dynamic workflow driven systems, coupling domain specific workflow for interoperation with computational software, general execution workflow, software engineering techniques. The systems software environments required are those that can support execution in dynamically integrated platforms ranging from the high-end to the real-time data acquisition and control - cross-systems integrated.

Software Infrastructures and other systems software (OS, data-management systems and other middleware) services to address the “real time” coupling of data and computations across a wide area heterogeneous dynamic resources and associated adaptations while ensuring application correctness and consistency, and satisfying time and policy constraints. Specific features include the ability to process large volume, high rate data from different sources including sensor systems, archives, other computations, instruments, etc.; interfaces to physical devices (including sensor systems and actuators), and dynamic data management requirements.

Areas of interest to the AF, which can benefit from DDDAS transformative advances, include: areas driven by the AF Technology Horizons report, including: autonomous systems (e.g. swarms of unmanned or remotely piloted vehicles) ; autonomous mission planning; complex adaptive systems with resilient autonomy; collaborative/cooperative control; autonomous reasoning and learning; sensor-based processing; ad-hoc, agile networks; multi-scale simulation technologies and coupled multi-physics simulations; decision support systems with the accuracy of full scale models (e.g. high-performance aircraft health monitoring, materials stresses and degradation); embedded diagnostics and V&V for complex adaptive systems; automated software generation; cognitive modeling; cognitive performance augmentation; human-machine interfaces. Other examples include: Advanced electromagnetic sources with extremely high power densities, leading to a variety of phenomena such as plasma formation, require holistic approaches to very large data sets (>1TB) and incorporate nonlinear, multi-scale, and multi-physics effects in a common framework. DDDAS provides new approaches for combining computational, theoretical, and experimental data sets for high interactive testing of multiple physical hypotheses at once.

Programmatic activities that will be launched under this initiative will support research in individual areas, but mostly in the context of multidisciplinary research across two of the four components above, or at least two of the four.

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13. Ultrashort Pulse Laser-Matter Interactions

The objective of this program is to explore and understand the broad range of physical phenomena accessible via the interaction of ultrashort pulse laser sources with matter in order to further capabilities of interest to the Air Force, including directed energy, remote sensing, communications, diagnostics, and materials processing. The program aims to understand and control light sources exhibiting extreme temporal, bandwidth and peak power characteristics. Specifically, this program seeks innovative science concepts in the areas of attosecond science, femtosecond optical frequency combs and high-field laser physics:

Attosecond science: The development of intense light pulses with attosecond durations has resulted in stroboscopic probes with the unprecedented ability to observe atomic-scale electron dynamics with attosecond temporal resolution. Topics of interest in this area include, but are not limited to, new concepts for improved attosecond sources (e.g. increased efficiency, higher flux, shorter pulses, and higher photon energy), development of pump-probe methods that investigate interactions with systems ranging from isolated atoms / molecules to condensed matter, attosecond pulse propagation, novel concepts for attosecond experiments and fundamental interpretations of attosecond measurements.

Optical frequency combs: Frequency combs, which can be made to be ultra broad (i.e. octave spanning) and exceedingly phase-stabilized (e.g. via carrier-envelope offset control), are revolutionizing precision spectroscopy, time transfer and arbitrary waveform generation. Research topics in this thrust area include, but are not limited to, dispersion management techniques to increase the spectral coverage to exceed an octave while maintaining high powers per comb, new concepts to extend frequency combs from the extreme ultraviolet into the mid-wave and long-wave infrared spectral regimes, development of novel resonator designs (e.g. micro-resonator based) and ultra-broadband pulse shaping.

High-field laser physics: Over the last two decades, progress in laser pulse amplification techniques has resulted in a six order of magnitude increase in achieved focused intensities. The interaction of such intense radiation with matter results in rapid electron ionization and a rich assortment of subsequent interaction physics. Topics of interest in this area include, but are not limited to, techniques for ultrafast- laser processing (e.g. machining, patterning), mechanisms to control dynamics of femtosecond laser propagation in transparent media (e.g. filamentation), concepts for monochromatic, tunable laser-based sources of secondary photons (e.g. extreme ultraviolet, terahertz, x-rays) and particle beams (e.g. electrons, protons, neutrons), laser-based compact particle accelerators and concepts for high peak power laser architectures and technology that efficiently scale up to high repetition rates and/or new wavelengths of operation.

High quality efforts from single individual investigators or collaborative, multi-investigator teams will be considered. Prior to submitting a basic research proposal, interested parties are highly encouraged to contact the AFOSR program manager to discuss the proposed research project. If interested, the program manager will request a White paper on the proposed effort. Researchers with White papers of significant interest will subsequently be invited to submit full proposals.

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14. GHz-THz Electronics

This program seeks scientific breakthroughs in solid-state materials and device that are vital for game-changing capabilities in sub-millimeter-wave radar, ultra-wideband communications, chemical/biological/nuclear remote sensing, and ultra-high-speed on-board and front-end data processing. Such capabilities are crucial for long-term USAF C4ISR capability breakthroughs. Research proposals are sought that address high-risk, high-payoff topics having fundamental challenges that are scientifically interesting as well as technologically relevant. Currently, the research portfolio is organized in three thrusts:

I) THz Electronics: These include devices that are mainly based on covalent-bond semiconductors such as C, Si, Ge, GaAs, InP, GaN, and related compounds. The main challenges are in perfecting crystals, interfaces, transports and hetero-structures, as well as scaling to nanometer dimensions for THz operations, while maintaining adequate device characteristics such as on/off current ratio, sub-threshold turn-on slope, and breakdown voltage. Particular emphasis will be placed on approaches that can lead to high-power THz sources, such as MOSFETs or MISFETs with high-K gate stack on wide-bandgap semiconductors capable of high channel trans-conductance and low electron tunneling.

II) Novel GHz Electronics: These include devices that are mainly based on ionic-bond semiconductors such as complex oxides of transition metals, with less overlapped electron orbitals and much higher bandgaps that may relax the requirement on crystalline perfectness while delivering much higher power than covalent-bond semiconductors can. The main challenges are in understanding different mechanisms for higher-quality, larger-area, and lower-cost growth on flexible or conforming substrates, as well as in understanding doping mechanism, correlated transport, and metal-insulator transitions, especially in terms of high-concentration p-type doping and transport in oxide hetero-structures. Scaling to advance operation speed from the GHz range toward the THz range will also be explored.

III) Tunable Electronics: These include devices that are mainly based on non-semiconductors that can perform multiple electronic, magnetic and optical functions. Devices based on meta-materials, artificial dielectrics, ferrites, multi-ferroics, nano-magnetics, and micro/nano electromechanical systems for reconfigurable radio-frequency front-ends will be of interest. The main challenges are in understanding the interaction between electromagnetic waves and electrons, plasmons and phonons on the nanometer scale. Additional challenges involve understandings for reproducible material preparation and approaches for devices that are compact, light, low-power-consumption, and low-cost.

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c. Mathematics, Information, and Life Sciences (RSL)

The Directorate is responsible for research activities in mathematics, information and life sciences. A wide range of fundamental mathematics, information and computer science, biological sciences, and human behavioral/performance research are supported to provide novel options that increase operational flexibility and performance of systems and environments of relevance to the Air Force. The Directorate is responsible for research primarily encompassed in four of the ten focus areas outlined in the AFOSR Strategic Plan. The four areas and their descriptions are as follows:

Information and Complex Networks Research: This area focuses on research required to enable reliable and secure exchange of information and predictable operation of networks and systems. Though it includes traditional aspects of information assurance and research into reliable systems, the emphasis is on the mathematics that underlies fundamental new secure-by-design architectures of networked communications and decision-making platforms. Subareas that support this scientific focus area are system and network performance prediction, design, and analysis; information operations and security; and modeling of human-machine systems.

Decision-Making Research: This thrust focuses on the discovery of mathematical laws; foundational scientific principles; and new, reliable and robust algorithms that underlie intelligent, mixed human-machine decision-making to achieve accurate real-time projection of expertise and knowledge into and out of the battlespace. It includes both efforts to advance the critical knowledge base in information sciences and information fusion and data-driven models of individual and group cognitive processing and decision-making. It includes the scientific foundations of human reliance decisions and research in the science of influence.

Dynamical Systems, Optimization, and Control Research: This area emphasizes mathematical research for discovering new scientific concepts supported by rigorous analysis for advancing the science of autonomy and promoting the understanding necessary to analyze and design complex multiscale systems as well as provide guaranteed levels of performance. It includes novel adaptive control strategies for coordinating heterogeneous autonomous or semi-autonomous aerospace vehicles in uncertain, information rich, dynamically changing, adversarial, and networked environments.

Natural Materials and Systems Research: This area focuses on multidisciplinary approaches for studying, using, mimicking, or altering the novel ways that natural systems accomplish their required tasks. Nature has used evolution to build exquisite materials and sensors that often outperform manmade versions. This scientific thrust discovers how to mimic existing natural sensory systems, and adds existing capabilities to these organisms for more precise control over their material production.

The program descriptions that follow address specific sub-areas of interest as well as explore novel ideas to bridge disciplines across the research scoped through the four broad areas above. Many critical research activities fostered under the programs discussed here are multidisciplinary and involve support from the other scientific directorates within AFOSR. Research at the interfaces across disciplines often provides insights necessary for and leading

to new technological advances. Creativity is highly encouraged in proposing novel scientific approaches for our consideration.

1. Computational Mathematics

Program Description: This program seeks to develop innovative mathematical methods and fast, reliable algorithms aimed at making radical advances in computational science. Research in computational mathematics underpins foundational understanding of complex physical phenomena and leads to capabilities for analysis and prediction of phenomena crucial to design and control of future Air Force systems and processes. Proposals to this program should focus on fundamental scientific and mathematical innovations. Additionally, it is desirable to frame basic research ideas in the context of applications of relevance to the Air Force which can serve simultaneously to focus the research and to provide avenues for transition of basic research outcomes into practice. Applications of current interest include, but are not limited to, unsteady aerodynamics, plasma dynamics, propulsion, combustion, directed energy, information science, and material science.

Basic Research Objectives: Research under this program has traditionally emphasized schemes that address the discretization and numerical solution of complex systems of equations, generally partial differential equations that arise from physics. Nevertheless, alternative phenomenological models and computational approaches are of interest, particularly in connection with emerging applications involving information, biological, and social sciences. One area of increasing emphasis is simulation of complex systems with dynamic data integration. Issues such as multiscale and multi-modal description of the system, dynamic invocation of appropriate models based on interjection of data into the simulation systems, stable and convergent algorithms which are robust under perturbations from dynamic-data inputs, and Uncertainty Quantification (UQ) analysis for these systems are of importance.
To meet the formidable computational challenges entailed in simulating nonlinear, discontinuous, multi-physics and multi-scale problems of interest to the Air Force, the program is examining numerical algorithms that include multi-scale and multi-physics approaches with particular emphasis on convergence, error analysis, and adaptivity. A spectrum of numerical methods in these areas are being developed and improved within the scope of the program, including high-order spatial and temporal algorithms, mesh-free and particle methods, high-order moving interface algorithms, and hybrid methods. The other areas of interest are rigorous model reduction techniques with quantifiable fidelity for efficient and robust multidisciplinary design and optimization, scalable algorithms for multi-core platforms and also uncertainty quantification. The active areas of interest in UQ include development of high accuracy stochastic numerical methods, stochastic model reduction and long term integration techniques. Given the emerging computing platforms, including multicore-based platforms with complex architectures, the program is considering fundamental research on the mathematical aspects of scalable solvers with emphasis on parallelism across scales, high-order discretization, and multi-level domain decomposition techniques. Research in the Computational Mathematics program also supports the national program in high performance computing.

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2. Dynamics and Control

Program Description: This program emphasizes the interplay of dynamical systems and control theories with the aim of developing innovative synergistic strategies for the design and analysis of controlled systems that enable radically enhanced capabilities, including performance and operational efficiency for future Air Force systems. Proposals should focus on the fundamental science and mathematics, but should include connectivity to appropriate Air Force applications. These applications currently include information systems, as well as autonomous/semi-autonomous aerial vehicles, munitions, and space vehicles.
The dramatic increase in complexity of Air Force systems provides unique challenges for the Dynamics and Control Program. Meeting these challenges may require interdisciplinary approaches as well as deeper studies within single disciplines. Lastly, note that the Dynamics and Control Program places special emphasis on techniques addressing realistic treatment of applications, complexity management, semi-autonomous systems, and real-time operation in stochastic and adversarial environments.

Basic Research Objectives: Current research interests include: adaptive control and decision making for coordinated autonomous/semi-autonomous aerospace vehicles in uncertain, information rich, dynamically changing, networked environments; understanding how to optimally include humans in the design space; novel schemes that enable challenging multi-agent aerospace tracking in complex, cluttered scenarios; robust and adaptive non-equilibrium control of nonlinear processes where the primary objective is enhanced operability rather than just local stability; new methods for understanding and mitigating the effects of uncertainties in dynamical processes; novel hybrid control systems that can intelligently manage actuator, sensor, and processor communications in a complex, spatially distributed and evolving system of systems; sensor rich, data driven adaptive control; novel approaches and methods where dynamic resources in sensor networks and networks of controllers are adaptively managed through a dynamic feed-back loop symbiotically integrating simulations and models with real-time data-acquisition and control systems; managing adversarial and stability issues for systems in cyberspace; applying control concepts motivated by studies of biological systems; and the control of unsteady fluid-structure interactions.
In general, support in the program for research in linear systems theory is declining, while interest in the control of complex, multi-scale, hybrid, highly uncertain nonlinear systems is increasing. Further, new mathematics in clear support of dynamics and control is of fundamental importance. In this regard, some areas of interest include, but are not limited to, stochastic and adversarial systems, partial and corrupted information, max-plus and idempotent methods, game theory, nonlinear control and estimation, and novel computational techniques specifically aimed at games, control and systems theory.

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3. Optimization and Discrete Mathematics

Program Description: The program goal is the development of mathematical methods for the optimization of large and complex models that will address future decision problems of interest to the Air Force. Areas of fundamental interest include resource allocation, planning, logistics, engineering design and scheduling. Increasingly, the decision models will address problems that arise in the design, management and defense of complex networks, in robust decision making, in performance, operational efficiency, and optimal control of dynamical systems, and in artificial intelligence and information technology applications.

Basic Research Objectives: There will be a focus on the development of new nonlinear, integer and combinatorial optimization algorithms, including those with stochastic components. Techniques designed to handle data that are uncertain, evolving, incomplete, conflicting, or overlapping are particularly important.
As basic research aimed at having the broadest possible impact, the development of new computational methods will include an emphasis on theoretical underpinnings, on rigorous convergence analysis, and on establishing provable bounds for (meta-) heuristics and other approximation methods.

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4. Systems and Software

Program Description: The program is seeking proposals with ideas engendering transformational research in systems software to address the growing scale of software supporting Air Force systems and platforms and meet future Air Force needs in the air, space, and cyber domains. To this end, the program is seeking to foster bold, new basic research that addresses the design, creation, and employment of software-intensive systems. Broad areas of interest include disciplinary and mostly multidisciplinary research on: 1) software methods to support distributed, heterogeneous platforms, as well as need for capabilities for autonomic systems, resilient autonomy, adaptive software systems, and verification for software systems; 2) new, multi-level and multi-modal approaches as well as representations, abstractions, and composition of models and measurements into comprehensive software frameworks to represent and manage the diverse interactions among the software, the systems on which the software resides, and the dynamic environments in which these systems operate, and in particular as such capabilities apply to support; 3) Human-in-the-loop interacting with, and supported by, such software systems, and autonomous reasoning and learning.

Basic Research Objectives: In the area of distributed computational platforms and their environments, transformative opportunities derived from exploiting the next generation of multicore-based systems and new paradigms of complex applications' computational approaches motivate fundamental research in programming environments, application development, and compiler/runtime support. Of particular interest are directions and efforts on

new compiler-embedded-in-the-runtime approaches ("runtime-compiler") to support adaptive and optimized application mapping, runtime, and composition. Environments motivating us to address such research consist of distributed and heterogeneous computational platforms ranging from the high-end to small clusters, as well as emerging unified computational environments which dynamically integrate high-end systems with real-time data-acquisition and control systems (including those spanning emerging peta- and exascale-range platforms on the high-end side, and networks of heterogeneous sensors and networks of controllers, on the data-acquisition and control side, all of which will be multicore-based). These classes of platforms will exhibit multilevel heterogeneity in terms of their processor interconnects, memory-levels, and latencies. They will entail environments where the resources available to and required by the executing applications will vary during execution. New insights are also sought into the human's role and interactions with heterogeneous software: we seek new theories for modeling and developing systems that have human and machine components. It is important to consider integrated modeling approaches that jointly address the hardware, software, and human components of large-scale systems. Realization of these mixed-component (human-machine) systems may also require new approaches to how computation itself is modeled or even an entirely new understanding of computation.

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5. Complex Networks

Program Description: Network behavior is influenced at many levels by fundamental theories of information exchange in the network protocols and policies developed. The Complex Networks program seeks to understand mathematically how such fundamental approaches to information exchange influence overall network performance and behavior. From this analysis we wish to develop strategies to assess and influence the predictability and performance of heterogeneous types of Air Force communication networks that must provide reliable transfer of data in dynamic, hostile and high interference environments. Accordingly, we wish to develop approaches to describe information content, protocol, policy, structure, and dynamic behavior of a network by mathematically connecting observed network data to analytic and geometric representation. We can then exploit such mathematical tools in the formulation of network design and engineering approaches in areas such as information and communication theory, signal processing, optimization, and control theory. Examples of such tools might include methods derived from algebraic geometry, algebraic statistics, spectral graph theory, sparse approximation theory, random matrix theory, algebraic graph theory, random field theory, nonparametric estimation theory, algebraic topology, differential geometry, and dynamical systems theory. Advances in these mathematical methods will then enable specific ways to model, characterize, design, and manage Air Force networks and capture and predict the performance of these networks under many diverse conditions.

Basic Research Objectives: Thus methods of consideration in network modeling might include characterizing overall network performance by finding geometric descriptions of embedded parameters of network performance, specific analytic expressions for network behavior derived

from inverse methods on network data, and divergence analysis of parameters characterizing one state of a network from another. Characterization of network behavior might include methods classify network behavior and structure through multi-scale vector space and convexity analysis, inference and estimation of networks through algebraic, graph theoretic, and Markov random field descriptions, and understanding of the robustness of given norms and metrics in representing network behavior. Design of networks might involve understanding the efficiency, scaling behavior, and robustness of methods of information exchange including those that use both self and mutual information paradigms. Management of networks may involve assessment of stability and convergence of network protocol and policy for various network dynamical conditions with such properties as curvature, homology class, or geometric flow. Approaches should have specific applicability to Air Force communications problems but may be drawn from techniques in network analysis from a broad set of disciplines including materials science and statistical mechanics, molecular and systems biology, quantum and wave propagation physics, decision, economics, and game theory to name just a few. From this we can conceive of new directions toward a science of networked systems.

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6. Information Operations and Security

Program Description: The goal of this program is to provide the science foundation to enable development of advanced cyber security methods, models, and algorithms to support future Air Force systems. Research is sought to meet the Information Operations challenges of Computer Network Defense (CND), Computer Network Attack (CNA) and the management of the cyber security enterprise.

Basic Research Objectives: The development of a Science of Cyber Security is the holy grail of this program. The development of the mathematical foundations of system software, hardware, human users and attackers, and network architectures with respect to cyber security (implemented in policy), including key metrics, abstractions, and analytical tools is a critical issue. Security policy research is of high interest to this program. Formal modeling and understanding of the human users and attackers in these systems is of high interest.
Developing the theory and methods to operate securely on distributed and cloud systems is of high interest.
New approaches for cyber forensics, active response, moving target, fight through and recovery related to cyber attack is of high interest. Attack attribution is of particular interest. Basic research that predicts and anticipates the nature of future information system attacks is of high interest. Research that leads to methods to discover malicious code already imbedded in software or hardware is a high priority. The theory and modeling of covert and side channels is of high interest.

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7. Science of Information, Computation and Fusion

Program Description: The Air Force collects vast amounts of data through various modes at various times in order to extract and derive needed "information" from these large and heterogeneous (mixed types) data sets. Some data, such as those collected from magnetometers, register limited information content which is more identifiable at the sensor level but beyond human's sensory reception. Other types of data, such as video cameras or text reports, possess more semantic information that is closer to human's cognition and understanding. Nevertheless, these are instances of disparate data which encapsulate different types of "information" pertained to, perhaps, the same event(s) captured by different modalities through sensing and collection.

The most general but relevant question is "what do these data mean?" Without a precise definition of information, it would be difficult, if not impossible, to formulate and implement abstract concepts in a consistent manner. The lack of a formal definition of information together with a supporting computational model explains why today's technology requires a great deal of instructions from human operators. A mere definition of information without a supporting framework for computation will be of minimal value. In this case, we can only transmit or convey but cannot manipulate information. For instance, when we operate close to or at the sensor level, Shannon's information theory has provided an unambiguous means to quantify the information capacity of a communication channel. Shannon's theory, however, makes no reference to information content.

In view of these scientific challenges, this program seeks fundamental research with innovative approaches that can advance the forefront of the science of information. Successes in answering the questions stated below would give the Air Force capabilities to: (1) shift emphasis from sensing to information; (2) understand the underpinning of autonomy; (3) design new information systems that can cope with different data types; (4) relieve human's cognitive overload in dealing with the data deluge problem.

Basic Research Objectives: A proposed technical approach towards answering the questions below should contain scientific rigor with provable properties. (1) What are the foundational building blocks or the structural components that make up "information"? (2) Is there a computational paradigm, perhaps, beyond the traditional Turing model, which can perform computation on these building blocks and what is a/the correct formulation of computational complexity in this case? (3) From these structural components, can one discover a new information theory that encompasses or generalizes the classical Information Theory à la Shannon? (4) What does fusion/integration of different information sources or data types mean, besides known examples in sensor/data fusion, database schema integration, ontology integration, compositionality of software modules, etc.? (5) Is there new mathematics that may lead to better understanding of signal, data, and information?

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8. Sensory Information Systems

Program Description: This program coordinates multi-disciplinary experimental research with mathematical, neuromorphic, and computational modeling to develop the basic scientific foundation to understand and emulate sensory information systems. Emphasis is on (a) acoustic information analysis, especially in relation to human auditory perception, and (b) sensory and sensorimotor systems that enable 3D airborne navigation and control of natural flight, e.g., in insects or bats, especially in relation to capabilities of autonomous biological systems not yet emulated in engineered flight.

Basic Research Objectives: One program goal is to forge new capabilities in acoustic analysis, especially to enhance the intelligibility and usefulness of acoustic information. The primary approach is to discover, develop, and test principles derived from an advanced understanding of cortical and sub-cortical processes in the auditory brain. Included are efforts to model and control effects of noise interference and reverberation, understand the psychoacoustic basis of informational masking, develop new methods for automatic speech detection, classification, and identification, and enable efficient 3D spatial segregation of multiple overlapping acoustic sources. Signal analysis methods based upon purely statistical or other conventional “blind source” approaches are not as likely to receive support as approaches based upon auditory system concepts that emphasize higher-level neural processes not yet fully exploited in engineered algorithms for acoustic information processing. Examples of such higher-level approaches recently supported are time-domain (modulation) filtering and representation, vocal tract/glottal pulse normalization, and spectro-temporal analysis based upon properties of cortical receptive fields. Although this program’s grantees have built a rich tradition of technical innovation in the acoustics area, with many important engineering applications for the Air Force, as well as for other governmental entities and the commercial sector, this program’s priority remains the advancement of the basic science that serves as a foundation for technical progress. The program is multidisciplinary, drawing upon expertise in areas such as computer and electrical engineering, neuroscience, and mathematics. Applicants are encouraged to develop collaborative relationships with scientists in the Air Force Research Laboratory (AFRL).

Another program goal is to deepen the scientific understanding of the sensory and sensorimotor processes that enable agile maneuvering and successful spatial navigation in natural flying organisms. Emphasis is on the discovery of fundamental mechanisms that could be emulated for the control of small, automated air vehicles, yet have no current analogue in engineered systems. Recent efforts have included investigations of information processing in wide field-of-view compound eye optics, receptor systems for linear and circular polarization sensing, and mathematical modeling of invertebrate sensorimotor control of path selection, obstacle avoidance and intercept/avoidance of moving targets. All of these areas link fundamental experimental science with neuromorphic or other mathematical implementations to generate and test hypotheses. Current efforts also include innovations in control science to explain and emulate complex behaviors, such as aerial foraging and swarm cohesion, as possible outcomes of simpler sensory-dominated behaviors with minimal cognitive support. As in the acoustic and

psychoacoustic areas described above, applicants are encouraged to develop collaborations with AFRL scientists. However, consistent with AFOSR's basic science mission, all proposals to this program are evaluated for their potential transformative advance in scientific areas, not for their potential to effect technical improvements in current Air Force systems.

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9. Mathematical and Computational Cognition

Program Description: This program supports innovative basic research on high-order cognitive processes that are responsible for human performance in complex problem solving and decision making tasks. The overall objective is to understand these processes by developing and empirically testing mathematical, statistical or computational models of human attention, memory, categorization, reasoning, problem solving, learning and motivation, and decision making. We are especially interested in the development and evaluation of formal cognitive models that provide an integrative and cumulative account of scientific progress, are truly predictive, as opposed to postdictive, and finally, are generalizable beyond controlled laboratory tasks to information-rich and dynamic real-world tasks

Basic Research Objectives: Research to elucidate core computational algorithms such as those that pertain to understanding of the mind and brain, often posed as finding solutions to well-formulated optimization or statistical estimation problems, has proven to be particularly valuable in providing a benchmark against which human cognitive performance can be measured. Selected examples of such algorithms include (the list is not exhaustive): (1) reinforcement- and machine-learning algorithms for planning and control in sequential decision making, where short and long term goals of an action are optimally balanced; (2) sequential sampling algorithms for trading between speed and accuracy in decision-making under time pressure, where optimal stopping rules take into consideration payoff for a prompt but inaccurate decision and cost for delaying it; (3) classification algorithms from supervised or semi-supervised learning, where optimal generalization from examples during categorization learning is achieved through regularizing the complexity of data-fitting models; (4) hierarchical or nonparametric Bayesian algorithms for reasoning, causal inference and prediction, where prior knowledge and data/evidence are optimally combined; (5) active learning algorithms for adaptive information sampling.

In relating formal models to human cognition and performance, research projects should not only ascertain their descriptive validity but also their predictive validity. To this end, the program welcomes the work that (1) creates a statistical and machine learning framework that semi-autonomously integrates model development, evaluation, selection, and revision; (2) bridges the gap between the fields of cognitive modeling and artificial general intelligence by simultaneously emphasizing important improvements to functionality and also explanatory evaluation against specific empirical results. The program also encourages the development and application of novel and innovative mathematical and neurocomputational approaches to tackle the fundamental mechanisms of the brain, that is, how cognitive behavior emerges from the

complex interactions of individual neurobiological systems and neuronal circuits. Cross-disciplinary teams with cognitive scientists in collaboration with mathematicians, statisticians, computer scientists and engineers, operation and management science researchers, information scientists, econometricians and game theoreticians, etc., are encouraged, especially when the research pertains to common issues and when collaboration is likely to generate bidirectional benefits.

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10. Trust and Influence

Program Description: The Trust and Influence program is aimed to develop a basic research portfolio that will provide the empirical foundation for the science of reliance and contemporary influence. This R&D portfolio specializes in basic research focused on: 1) Empirical science of trust in both interpersonal/cross-cultural domains and in complex human-machine/robot interactions, 2) Science of influence effects including the psychological and behavioral impact of air power, non-lethal weapons, and cyber, 3) Understanding the cognitive and social avenues of influence in different cultural groups, and 4) Empirical or theoretical studies to understand and harness the power of social networks/social media. The resulting portfolio directly enhances the Air Force's impact on policies and operations related to national security by investing in the discovery of the foundational concepts of effective influence, deterrence, trust-building, trust calibration with technological systems, counter-terrorism and paths to violent radicalization. The AFOSR trust and influence R&D portfolio specifically invests in multi-disciplinary approaches ranging from psychology to computer science. Research designs that incorporate field research or laboratory research are encouraged to apply as are conceptual studies aimed at developing transformative novel theories.

Basic Research Objectives: This program encourages collaboration between psychologists, anthropologists, sociologists, linguists, behavioral, cognitive, and neuro-econometric scientists as well as computational researchers in disciplines such as mathematics, computer science, and modeling. Example topics include: (1) Empirical science to reveal the antecedents of trust in cross-cultural interactions (2) Empirical studies to examine the malleable elements of trust calibration during complex human-machine/human-robot interactions (3) Field studies or new theoretical studies to examine the psychological/behavioral impact of air power including UAV platforms, (4) Empirical studies to indentify the cognitive mechanisms associated with persuasion and social influence in a digitized world – “socio-digital influence” (5) Conceptual, empirical, or modeling studies to examine the psychological/behavioral impact of new weapon technologies such as non-lethal weapons and cyber tactics.

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11. Natural Materials and Systems

Program Description: The goals of this multidisciplinary program are to study, use, mimic, or alter how living systems accomplish their natural functions. Nature has used evolution to build materials and sensors that outperform current sensors (for example, a spider's haircells can detect air flow at low levels even in a noisy background). This program not only wants to mimic existing natural sensory systems, but also add existing capabilities to these organisms for more precise control over their material production. The research will encompass four general areas: sensory mimics, natural materials, natural/synthetic interfaces, and physical mechanisms of natural systems under environmental distress.
Sensory mimetic research attempts to mimic novel sensors that organisms use in their daily lives, and to learn engineering processes and mechanisms for control of those systems. This program also focuses on natural chromophores and photoluminescent materials found in microbial and protein-based systems as well as the mimicking of sensor denial systems, such as active and passive camouflage developed in certain organisms addressing predator-prey issues.

Basic Research Objectives: The natural materials area is focused on synthesis of novel materials and nanostructures using organisms as material factories. The program also focuses on understanding the structure and properties of the synthetic materials. The use of extremophiles is added to address the development of materials not accessible due to environmental extremes. We are also interested in organisms that disrupt or deny a material's function or existence in some way.
The natural/synthetic interfaces area is focused on the fundamental science at the biotic and abiotic interface. The nanotechnology and mesotechnology sub-efforts are focused on surface structure and new architectures using nature's idea of directed assembly at the nanoscale to mesoscale to create desired effects, such as quantum electronic or three dimensional power structures. The use of these structures is in the design of patterned and templated surfaces, new catalysts, and natural materials based-optics/electronics (biophotonics).
The "physical mechanisms of natural systems under environmental distress" area is focused on discovering and understanding basic natural mechanisms used by organisms that could be used to either harden or repair soft material-based devices. This will enable the Air Force to employ biological systems with optimum performance and extended lifetimes. As protein and nucleic acid molecules are increasingly used as catalysts, sensors, and as materials, it will be necessary to understand how we can utilize these molecules in extreme environments, with the ability to regulate the desired function as conditions change, and to store the device for prolonged periods of time. Areas of interest include: the mechanisms for survival and protein stability in extremophilic archaea, fundamental studies of bacterial sporulation, and enzymatic engineering for faster catalysis in materials identification or degradation.

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12. Human Performance and Biosystems

Program Description: The U.S. Air Force is currently interested in improving human capabilities through the development of advanced human-machine interfaces and the establishment of methods to augment human performance. The primary goal for the basic research program is to gain a better understanding of the genetic, cellular, tissue, physiological, and cognitive mechanisms that would augment human performance.

Basic Research Objectives: This program is interested in defining the mechanisms associated with enhancing human performance, as well as understanding the associated biomarkers, and neuronal pathways involved with increasing performance capabilities especially as they relate to aircrew member performance. In addition, this program aims to explore natural and synthetic processes, mechanisms and/or pathways for understanding energy production in bio-systems (specifically enzymatic and microbial fuel cells as well as photosynthesis). We are also interested in understanding the interaction of fatigue or toxicology on the neuronal pathways and processes involved in performance decrements in the aviation environment i.e. exploring processes that generate signals associated with fatigue or performance change. We wish to define and understand the biomarkers and genetic changes associated with human performance decrement after the administration of toxicological agents, specific interest in toxicology mechanisms that may or may not exhibit toxic effects at a minimal dose level. The mechanism associated with the effects of photo-electro-magnetic stimulation as they relate to performance change is of interest to us. We wish to define and understand the biomarkers and genetic changes associated with human performance decrement after the administration of toxicological agents, specific interest in toxicology mechanisms that may or may not exhibit toxic effects at a minimal dose level and toxicological effects of flight line equipment).

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13. Foundations of Information Systems

Description: The Foundations of Information Systems program intends to foster fundamental research on new methods for analysis, management, and design of complex information systems. Traditional approaches to systems methods involve verification or equivalence model checking paradigms for software and hardware components, and are limited to analysis of individual-components in the design cycle. We seek to enable comprehensive system-level analysis, optimized performance, function, behavior, operation, fault-tolerance, robustness, adaptability and cyber-security among other properties. These approaches should be considered throughout the design, operation, and expansion of the system. Foundations of Information Systems seeks to characterize the analysis of systems in multi-scale representations of sub-components and system-layers, derived from specifications, models and measurements. Because of the heterogeneous and dynamic nature of information systems, increasing emphasis on measurement-based performance analysis is necessary to develop the capabilities sought here. Therefore, we seek methods that allow integration between specifications-based methods and measurement-based methods which involve statistical analysis and dynamical systems theory to estimate the current true state and performance of

the system as a whole. Such new methods should enable quantifiable, performance-driven systems-engineering, and more powerful analysis capabilities for managing the design, operation, and scalability of systems that need to be adaptive and interoperable.

Basic Research Objectives: Fundamental strategies that integrate specification or model based methods with measurement based, statistics, risk, and dynamical system methods into a unified framework are thus of great interest. Of particular interest are multidisciplinary research efforts creating new approaches and methods that bridge across analytic, agent-based, graph-based, event-driven, and statistical Bayesian approaches, with techniques utilizing methods from model equivalency checking. Techniques in verification drawn from probabilistic process algebras, model checking, categorical logic theory, and algebraic representation theory are of interest as are methods in sparse approximation, parametric and nonparametric estimation, functional analysis, and geometric inference for system measurement and identification. Also of interest are entropy-based systems metrics, mean-field-theory, information-flow analysis and nonlinear optimization for risk assessment; operator and sheaf theoretic methods, computational homology, rigidity theory, and algebraic methods for invariant systems analysis. Any such theoretical approaches should be linked to compatible strategies which can involve techniques from systems analysis at multiple levels of abstraction, software and hardware modeling languages, software and system interfaces that improve component integration, and new methods for instrumentation and measurement. Application areas of interest, but not limited to: distributed, autonomous, and heterogeneous systems, distributed computational and cloud computing systems, information security applications, and efforts in dynamic resource management. Other related systems examples could be drawn from such diverse areas as quantum, biological, or sociological systems. These application areas should have relevancy to current Air Force needs.

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14. Computational and Machine Intelligence

Program Description: This program supports basic research in computational intelligence This program supports innovative basic research on fundamental principles and methodologies of computational intelligence necessary to create robust intelligent autonomous systems. Robustness is defined as the ability to achieve high performance given at least some or all of the following factors: uncertainty, incompleteness or errors in knowledge; limitations on sensing; real-world complexity and dynamic change; adversarial factors; unexpected events including system faults; and out-of-scope requirements on system behavior. The vision of this program is that future computational intelligence systems will achieve high performance, adaptation, flexibility, self-repair, and other forms of intelligent behavior in the complex, uncertain, adversarial, and highly dynamic environments faced by the Air Force.

Basic Research Objectives: The program encourages research on building computational intelligence systems that derive from and/or integrate cognitive and biological models of human

and animal intelligence. The investigative methodology may be theoretical, computational, or experimental, or a combination of thereof. Proposals to advances in the basic principles of machine intelligence for memory, reasoning, learning, action, and communication are desired insofar as these contribute directly towards robustness as defined above. Research proposals on computational reasoning methodologies of any type and combination, including algorithmic, heuristic, or evolutionary, are encouraged as long as the proof of success is the ability to act autonomously or in concert with human teammates to achieve robustness as defined above. Computational intelligence systems often act as human intelligence amplifiers in such areas as planning, sensing, situation assessment and projection; will monitor, diagnose, and control aircraft or spacecraft; and will directly interact with humans and the physical world through robotic devices. Therefore, research that that enables mixed-initiative interaction and teaming between autonomous systems and human individuals or teams is an important part of the program. Basic research that bridges the conceptual gaps between state-of-the-art statistical/machine learning algorithms and human cognition and performance are also welcomed. The program encourages multidisciplinary research teams, international collaborations, and multi-agency partnerships. This program is aggressive, accepts risk, and seeks to be a pathfinder for Air Force research in this area. Proposals that may lead to breakthroughs or highly disruptive results are especially encouraged.

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15. Robust Decision Making in Human-System Interface

Program Description: The need for mixed human-machine decision making appears at all levels of Air Force operations and pervades every stage of Air Force missions. However, new theoretical and empirical guidance is needed to prescribe maximally effective mixtures of human and machine decision making in environments that are becoming increasingly complex and demanding as a result of the high uncertainty, complexity, time urgency, and rapidly changing nature of military missions. Massive amounts of relevant data are now available from powerful sensing systems to inform these decisions; however, the task of quickly extracting knowledge to guide human actions from an overwhelming flow of information is daunting. Basic research is needed to produce cognitive systems that are capable of communicating with humans in a natural manner that builds trust, are proficient at condensing intensive streams of sensory data into useful conceptual information in an efficient, real-time manner, and are competent at making rapid, adaptive, and robust prescriptions for prediction, inference, decision, and planning. New computational and mathematical principles of cognition are needed to form a symbiosis between human and machine systems, which coordinates and allocates responsibility between these entities in an optimal collaborative manner, achieving comprehensive situation awareness and anticipatory command and control.

Basic Research Objectives: In the area of a) data collection, processing, and exploitation technologies, there is a need for (a.1) attention systems for optimally

allocating sensor resources depending on current state of knowledge, (a.2) reasoning systems for fusing information and building actionable knowledge out of raw sensory data, (a.3) inference systems for real time accumulation of evidence from conflicting sources of information for recognition and identification. In the area of b) command and control technologies, there is a need for (b.1) prediction systems for anticipating future behavior of adversarial agents based on past experience and current conditions, (b.2) rapid decision systems with flexible mixtures of man and machine responsibilities for reactive decision making under high time pressure, (b.3) robust strategic planning systems designed to allow for sudden changes in mission objectives, unexpected changes in environment, and possible irrational actions by adversaries. In the area of c) situation awareness technologies, there is a need for a human-system interface that (c.1) faithfully simulates the content of a human operator's working memory buffer and its update thus modeling the operator's dynamic awareness of inputs, constraints, goals, and problems, (c.2) optimizes information delivery, routing, refreshing, retrieval, and clearance to/from the human operator's awareness while utilizing the latter's long- term store for expert knowledge, memory and skills for robust decision making, (c.3) achieves symbiosis between human and machine systems in delegating and coordinating responsibilities for command and control decisions. In sum, new empirical and theoretical research is needed that provides a deeper understanding of the cognitive requirements for command and control by a decision maker with enhanced capability for situation awareness, allows for greater degree of uncertainty in terms of reasoning systems, produces greater robustness and adaptability in planning algorithms in dealing with unexpected interruptions and rapidly changing objectives, generates greater flexibility in terms of assumptions about adversarial agents, and gives clearer guidance for dealing with the complexities encountered in network-centric decision tasks.

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d. Basic Research Initiatives (BRIs)

This section outlines cross-cutting multi-disciplinary topics that support the AFOSR's Basic Research Initiatives. These Initiatives are new research opportunities of interest to AFOSR. Proposers are highly encouraged to confer with the appropriate AFOSR program manager(s). White papers briefly summarizing your ideas and why they are different from what others are doing are highly encouraged, but not required.

Air Force program managers are listed by Sub areas below.

1. Layered Structured 2D-Materials for Extreme Environments

The ultimate aim of this focused topic is to establish the framework required to develop a new revolutionary class of materials capable of sustained operation in an extreme environment e.g. temperatures above 200^{o}C by exploiting the electro-physical properties of solid-state interfaces. The objectives of the proposed effort are: (1) develop the science based understanding to build Q-2D-EG heterointerface and reveal the fundamentals of electron gas formation and (2) model to predict the structure of Q-2D-EG heterointerface, and (3) elucidate thermodynamically stable regimes of hetero-interfaces that form electron gas (phase diagrams) and simulation for property prediction within the extreme environment. These objectives require the systematic study of the insulator couples and first principles electronic-structure calculations based on density functional theory to improve models, to elucidate the role of dopants and investigation of multiaxial stress state and it's relation to thermodynamically stable electron gas formation. Realization of the Q-2D-EG science of multi-component systems that are far from equilibrium may require new approaches to how computation itself is modeled or even an entirely new understanding of computation (atomistic to multiscale integration). Specific interest is related to elucidation of the heterointerface through computational mathematics framework that allows quantification in the analysis. The design of multiscale Q-2D-EG-forming hetero-interfaces toward performance assurance will advance our scientific understanding of complex physical systems. Development of rigorous mathematical approaches for understanding thermodynamic stability regime of electron gas formation can decouple the science by elucidating the mechanisms rather than extrinsic thickness effects. The designing new materials with properties specifically tailored to withstand thermomechanical extremes (external temperatures and internal strain fields of dissimilar materials) require fundamental understanding thermomechanical extremes. This entails learning how atoms and electrons move within the material under extreme loads (i.e., heat and chemical potential gradients) and will provide insight into the defect production and eventual evaluation of microstructural components such as point defects, dislocations, and heterointerfaces. Once these processes are understood, it will be possible to predict responses of Q-2D-EG interfaces under thermomechanical extremes using computational tools.

Areas of interest include, but are not limited to the following:

1. The ability to write/erase/read information at the Q-2D-EG-forming hetero-interfaces depends on solid-state electron gas phenomena (intrinsic) and processing (extrinsic) related parameters. Unlike the atoms in (conventional) semiconductors, the ions in most oxides do not have a fixed valance state. Therefore, multiple paths exist for charge rearrangement. By controlling the layer thickness, it is possible to obtain interfaces that exhibit insulating to metallic behavior – depending upon the charge density distribution. Hence, initial research concentration area should be decoupling the fundamental science from the processing. The focus then to elucidate charge rearrangement of an internally-polarized insulator (i.e., A3+B3+O3; "III–III" perovskite) combined with a non-polar insulator ((i.e., A2+B4+O3; "II–IV" oxide ceramic), oxide ceramic.

2. First-principles electronic-structure calculations based on density functional theory (DFT) can provide predictive and detailed theoretical insights into the atomistic and electronic structures of heterophase interfaces, which are very valuable in supporting and augmenting the understanding of micro-characterization and property measurements. Often the modeling approaches make casual inference about the microstructural features of heterointerfaces. Basic research methodologies and metrics are needed to elucidate the meaning of "critical thicknesses" range from 2 to 6 unit cells – an attractive magnitude for designing nano-devices.

3. Development of experimental techniques, analytical tools and validation methods are necessary to differentiate between two explanations that have been proposed for Q-2D-EG formation: (i) intrinsic, – based on built-in polarity discontinuity, and (ii) extrinsic– based on oxygen vacancies. To validate the modeling and theoretical results and clarify the formation mechanism, suggested research areas include but are not limited to: (a) electron microscopy and spectroscopy techniques to characterize the structure and stacking sequence of charged layers, (b) interfacial strain and associated defects at the interfaces, (c) chemical analytical techniques to resolve A-site modulation, valence change, and effect of homo-charged interfaces.

4. Systematic studies are required to understand the fundamentals of the thermodynamic stability regime of electron gas formation, as well as to reveal their potential as extreme environment electronics. The electrical behavior, structure and defect mechanism has to be determined at harsh conditions to establish the operating range of the heterointerfaces. These techniques are of specific interest as research tools for characterizing materials required for the USAF applications that require higher temperatures and longer life cycles under harsh conditions; thermal shock, combined external loads; i.e., heat and radiation.

Researchers are highly encouraged to submit short (max 2 pages) White papers by email prior to developing full proposals. White papers should briefly describe the proposed effort and describe how it will advance the current state-of-the-art; an approximate yearly cost for a three to five year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals. Multidisciplinary team proposals also are preferred over single investigator efforts; however, smaller, single investigator proposals will be considered on a case by case basis.

Awards average $225,000 per year and may be proposed for up to five years.
Awards may start any time during the fiscal year.

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2. Autonomic Material Systems Utilizing Biomolecular Transduction

Background: Nature is rich with examples of systems that exhibit autonomic behavior. The healing of tissue and organs in animals, the motion of plants to track sunlight, and color change and mimicry of certain species of insects and fish are all examples of processes that spontaneously occur under proper sets of internal conditions and external stimuli. To date most of the research to create manmade autonomic systems has focused on the incorporation of "biomimetic" micro- or nano-morphologies or "active" materials (such as piezoelectric polymers and ceramics, shape memory alloys, electroactive polymers, and electro- and magneto-rheological fluids) into structures. Autonomic behavior is derived by combining biomimetic morphologies or active materials that exhibit useful coupling with intelligent control mechanisms. A number of successful demonstrations of this technology have been produced in the cases of noise and vibration control systems for aircraft and ground vehicles, health monitoring systems for structures and machines, microvascular network for self-healing and self-cooling of structural materials, and self-sustaining structures with integrated energy harvesting/storage devices. However, none of these systems exhibits the diverse array and robustness of autonomic functions inherent in biological systems. The grand vision of proposed research effort is to develop materials and material systems that can exhibit autonomic behavior through the incorporation of naturally-derived biomolecules into synthetic materials. This new direction is motivated by the fact that macroscale autonomic behavior in biological systems is controlled by charge and mass transport at the nanoscale, which, in turn, is controlled by the dynamic signaling response of a vast array of biomolecules.

Objectives: (a) To develop the scientific understanding of stimuli-responsive properties and resulting autonomic response of biomolecules for sensing, actuation, and energy conversion, (b) to establish how to incorporate naturally-derived stimuli-responsive biomolecules into synthetic active materials as transduction elements to enable the control of charge and mass transport at the nanoscale, and (c) to design and build new classes of autonomous engineering devices such as sensors, actuators, pumps and novel energy conversion devices.

Research Concentration Areas: Suggested research areas are as follows: (1) Theoretical and experimental understanding of self-assembly properties of biomolecules due to the spatial separation of hydrophobic and hydrophilic regions in the molecule; (2) Demonstration of biomolecules such as phospholipid organized into interfacial bilayers that mimic the properties of living cell membranes; (3) Synthesis, processing and manufacturing scale-up for the incorporation of phospholipid bilayers onto synthetic porous substrates as a scaffold for the insertion of stimuli-responsive biomolecules; (4) Incorporation of electrically-responsive ion channels into durable substrates and demonstration of the ability to control charge transport with applied electrical stimulus; (5)

Demonstration of the relationship between the transducer sensitivity and the applied potential across the bilayers; (6) Demonstration of self-healing behavior of phospholipid membrane formed over a micron-scale silicon pore due to their ability to self-assemble into bilayers; (7) Development of new sensors relating the nanometer-level vibration of the bilayers to the electrical response; (8) Design of a fluid pump that responds to local chemical concentration; (9) Development of a micron-scale hydraulic actuator based on the pressurization of a closed volume; (10) Construction of chemoelectric power sources that produce power output on the order of 1-10 μW/cm2, which is similar to the power output of solar cells in an indoor environment; (11) Design of individually-addressable biomolecular arrays for sensing and energy conversion; (12) Validation of multi-scale models to understand the physics of stimuli-responsive behavior and how the properties of the biomolecules effect the bulk properties of the materials.

Awards average $150,000 per year and may be proposed for up to five years. Awards may start any time during the fiscal year.

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3. Transformational Computing via Co-Design of High-Performance Algorithms and Hardware

Background: The history of high-performance computing, indeed computational modeling in general, has been portrayed as an arms race between ever faster computer hardware, often characterized by the ubiquitous Moore's law describing the exponential growth in our ability to put computing machinery onto integrated circuits, and the equally advancing capability of complex software and algorithm designers to exhaust the memory and processors of this hardware in pursuit of ever more accurate and speedy simulation technology. In actuality, this process has always been a symbiotic relationship. For example, algorithms for the simulation of thermonuclear fusion have advanced by 18 orders of magnitude while Moore's law has only produced 6 orders of magnitude in gains. In this example, the algorithms in question require large parallel computers simply to fit the complex algorithms into memory, and thus are enabled by the advances in hardware. Now, despite the decades of progress from this paradigm, our ability to develop high-performance chips is starting to slow from Moore's goals. Additionally, the shear cost of electricity to drive these systems is pushing the community at large to consider new methods to continue the advance of computational science and engineering.

The effects of both power consumption and the slowing from Moore's law can already be observed in the computer industry. A bewildering array of new

architectures has emerged: A buyer of computer hardware must now choose between various configurations of multi-core central processing units, graphical processing units, multi-threading programming methods, and new computer languages to program these different architectures. Some communities have gone even further with the design of specialty chips that only perform a single algorithm. As an example, the astrophysics community has developed the GRAPE chip (for GRAvity PipE), which only performs N-body gravitational problems, but at a speed dwarfing general purpose CPUs, with a saving in both cost and energy to perform a given calculation relative to building a large general purpose parallel computer. Between these extremes is the philosophy of "co-design," where the hardware is commercial equipment, but the topology is tuned to a specific algorithm. This approach has demonstrated three orders of magnitude performance improvement over the same number of chips in a standard configuration for certain applications. The challenge, however, for this emerging field is that much of the effort is currently focused on tuning hardware to existing algorithms in a process that is highly experimental, often using surrogate hardware, such as field-programmable gate arrays, to develop the computational system. Thus, there is a clear need for a fundamental basic research program wherein the hardware and algorithms are placed on an equal footing to develop specialized, heterogeneous, and very high-performance systems to answer the computational objectives of the Air Force and the Department of Defense.

Objective: This effort looks to bring together the computational hardware, software, aerospace sciences, physics, and applied mathematics communities to develop a novel and unique capability to design, optimize, build, and deploy specialized high-performance computing platforms to speed development of Air Force systems. This effort will produce the fundamental research to enable highly focused, potentially heterogeneous, computational platforms that offer orders of magnitude better performance for single application areas. Examples include, but are not limited to, specialized systems for (a) virtual wind tunnels, (b) material performance, degradation, and lifetime studies in the "virtual twin" concept where a model tracks the performance history of an actual component (wing or airframe), and (c) dedicated software systems that link physics software for the design of directed energy weapons with electromagnetic propagation/engagement tools to advance the state-of-the-art in both technology and operational concepts of lasers and high power microwave devices.

Concentration Area: This effort is envisioned as a "MURI-like" effort with collaborative grants to teams that will create a new community of researchers skilled in the design, development, and deployment of systems tuned to maximize the synergy of advanced algorithms and high-performance hardware. Thus, this effort will be focused on fundamental and interdisciplinary research in computational hardware, computational software, and mathematical models, and is especially interested in work that characterizes the relationship between hardware and algorithms. In the hardware context, fundamental study of both processing units, such as central processors, graphical processors, dedicated

digital signal processing chips (e.g. fast Fourier transforms chips), specialty single purpose chips (e.g. "GRAPE" chips) and heterogeneous combinations of the various processing units as well as novel means to design memory architecture for fast and accurate calculations will be necessary. Tools from the hardware community for design and characterization will be important as well. For computational codes and software, scalable algorithms that benefit from specific instantiations in hardware, either due to routines that perform well on specific processing chips or data structures that exploit novel memory configurations, will be supported. Finally, efforts in applied mathematics to jointly model both hardware and software will be supported, as will research on how to optimize the multiple and conflicting requirements between these interdisciplinary systems. Preference will be given to teams that integrate these research threads into a coherent agenda for specialized, high-performance computing architectures for Air Force and Department of Defense applications. The total anticipated level of funding for this initiative is $2,400,000/year for five years with anticipated awards to at least two teams.

Due to anticipated funding, proposals for this effort are encouraged by 1 June 2012. White paper submissions to the program managers are encouraged.

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4. High Peak Power, Ultrashort Pulse Laser Processing of Materials

Program Description: Ultrashort pulse (USP) lasers, exhibiting very short (sub-picosecond) pulse duration and high peak power, have found widespread impact in laboratory-scale, scientific research. Their recent application to material processing has demonstrated many unique benefits which highlight the fundamentally different interaction mechanisms between ultrashort laser radiation and solid matter. Contrary to irradiation with conventional laser sources, the laser energy deposition occurs on timescales shorter than the electron-phonon coupling time leading to high quality, reproducible material processing with minimal thermal collateral damage. USP lasers are finding increasing potential applications in numerous areas including thin film and coating deposition, laser surgery, micro/nano machining, precision cutting of materials, waveguide writing in glass, synthesis of nanoscale materials as well as modification of optical and surface wetting properties. Many of these studies are phenomenological; the physical processes are not understood in detail and many open questions remain unanswered. For example, although it is understood empirically that surface

properties are modified by the formation of complex surface structures at the nano- and micro-scales, the underlying nonlinear, highly non-equilibrium physical mechanisms remain unclear. Systematic, fundamental studies of the materials interaction with such lasers would open the potential for controlled tailoring of material surfaces for many applications.

Basic Research Objectives: The goal of this Basic Research Initiative is to develop a rigorous understanding of the fundamental interaction mechanisms between ultrashort, high peak power laser radiation and materials. Such a rigorous understanding is expected to result in the ability to control and optimize laser properties to predictably and controllably perform material processing as desired for important technological applications. Research areas relevant to this topic include but are not limited to the following: laser ablation & machining, modification of surface properties with controlled properties, formation of nano- and micro-scales surface structures, material processing approaches suitable for high-speed and high-volume manufacturing, novel applications, etc.

Approximately $1.4M is available annually to support three year efforts awarded through this topic. Efforts from collaborative, multi-investigator teams are highly encouraged. Prior to submitting a basic research proposal, interested parties should contact the AFOSR program managers to discuss the proposed research project. If interested, the program managers will request a White paper on the proposed effort (due NLT April 13, 2012). Researchers with White papers of significant interest will subsequently be invited to submit full proposals (encouraged to submit NLT June 15, 2012).

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5. Sustainable Alloy Design: Rare Earth Materials Challenge

The objective of this basic research announcement is building the foundation for the discovery, characterization and predictability of non rare-earth containing high temperature aerospace alloys for high temperature applications. The program seeks highly innovative and nontraditional approaches that advance the fields of high temperature structural materials, and electro-physics research through the discovery and characterization of new non rare-earth containing high temperature metallic alloys that exhibit superior performance at conditions of thermomechanical and physical extremes. AFOSR is involved in the discovery of Air Force relevant high temperature aerospace materials and the development of high temperature characterization tools that capture the complexity of the Air Force operational environment and this BAA will be able to develop concentrated the science base to discover substitutes of rare earth element in tandem with other AFOSR funded research.

Realization of the full potential of non rare-earth containing high temperature aerospace alloys requires, (1) tailoring and designing materials at the molecular level through crystal chemistry principles and combinatorial approaches, and elucidating the fundamental chemical and physical processes involved in materials performance, extending the understanding from the nanoscale to the collective (global) behavior at the microscale; (2) learning how atoms and electrons move within a material under extreme loads to provide insight into the defect production and eventual evaluation into microstructural components, such as dislocations, voids, and grain boundaries, and (3) development of measurement techniques that capture the complex environment and prediction of performance in the operational environment, under static, quasistatic and thermomechanical extremes of temperature fields, magnetic fields and fluxes. To achieve these unmatched combinations of properties that can provide unique application possibilities requires multiscale modeling tools. It is expected that molecular dynamics models, meso- and micro-scale modeling of complex structures over a broad range of size and time scales necessitates multi-scale modeling tools that are linking atomic structure to macro-properties. It is important to consider integrated experimental approaches that concurrently validates the length and time scales of the models and thus may require cross-disciplinary teams. This program seeks bold, new basic research that addresses the design, creation, and employment of nontraditional approaches on synthesis of novel high temperature alloys and nanostructures that take into account geometric or topological descriptors to characterize similarity and scaling between stimuli under the multi-dimensional external fields to secure revolutionary advances. Interest domain includes the fundamental science at the interface of phases of heterogeneous structures, nanotechnology and mesotechnology efforts are focused on new architectures using crystal chemistry principles to create pathways to synthesize alloys for high temperature applications.

Researchers are highly encouraged to submit short (max 2 pages) White papers by email prior to developing full proposals. White papers should briefly describe the proposed effort and describe how it will advance the current state-of-the-art; an approximate yearly cost for a three to five year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals. Multidisciplinary team proposals also are preferred over single investigator efforts; however, smaller, single investigator proposals will be considered on a case by case basis.

Awards average $225,000 per year and may be proposed for up to five years. Awards may start any time during the fiscal year.

Research Topic Chiefs:

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6. Catalytic Reactions in Endothermic Cooling Systems

Background

Hypersonic propulsion systems operating beyond Mach 5 require sufficient cooling for the engine structure. The heat-sink capability of the fuel, used as coolant, is a rate-controlling parameter of the thermal management system. In addition to the sensible heat ($Cp\Delta T$), the endothermic decomposition process of the fuel also provides significant cooling capacity. The products of the endothermic reaction are often smaller hydrocarbons that enhance ignition and maintain combustion stability of the engine. Such cooling processes can also benefit other Air Force propulsion systems, e.g. turbine engines and detonation based engines.

The challenges are to promote the endothermic decomposition to achieve more cooling while avoiding the detrimental coking process that can clog the narrow channels in heat exchangers. Catalysts can be used to facilitate the endothermic decomposition. Preventing coking is a major challenge to maintain the catalyst effectiveness. Currently, only limited industrial experimental data are available, showing the potential effectiveness of catalytic agents. Fundamental understanding is required for the catalyzed decomposition and associated coking processes. Furthermore, it would be valuable to identify more effective catalysts as well as alternative endothermic fuels, e.g. bio-based fuels.

Objectives

The central objective of this BRI is to use combined experimental and first-principle based theoretical approaches to understand and quantify endothermic catalytic reaction mechanisms at elevated pressures and temperatures and other relevant conditions in cooling channels that resemble hypersonic engine conditions. Innovative and fundamental approaches for developing kinetics models for gas-phase, catalysis and surface-heterogeneous reactions are to be explored, including those approaches developed to study surface properties in the material sciences area. This will provide a scientific foundation for developing more effective catalytic systems and endothermic fuels.

Relevant Research Topics:

1) Fuel Flow Conditions: In order to determine conditions at which chemical reactions occur in pyrolysis and catalytic processes, the fuel flow conditions inside the cooling channels need to be quantified by numerical and experimental means. This typically requires conjugated fluid-thermal simulation/analysis to resolve details of fuel conditions in the interior of flow and near/at the wall. Numerical simulations need to be further anchored by experimental measurements. Since the fuel is most likely to be supercritical, fuel properties under those conditions are needed and, if not available, additional efforts will be required.

2) Pyrolysis: Characterize energetic and dynamic reaction processes, including primary reactions, intermediates, products and kinetics for hydrocarbons in legacy and alternative fuels at high pressures and temperatures.
3) Catalysis for Fuels: Identify robust and active catalysts with respect to composition and morphology for endothermic fuels reactions and propensity for coking. Catalytic reactions, intermediates, products, and mechanisms as a function of catalyst and substrate material will be identified. Studies of catalytic behavior will be fed back to efforts to model and design new catalysts generating a synergistic loop to guide the synthesis of new and effective catalyst systems. Studies will be conducted with a variety of fuels including new alternative fuels systems such as biofuels to study their ability to perform endothermic cooling. Effective fuel/catalyst pairs will be identified.
4) Heterogeneous reactions: Surface reactions between fuel/decomposed fuel and different channel surfaces and coated surfaces will be identified. The mechanism for coke deposition will be explored to identify new methods to control and reduce it on various substrates. The use of novel in-situ diagnostics to study catalytic reaction mechanisms is encouraged.
5) Evaluating physical and combustion properties of decomposed fuel: After the fuel undergoes the endothermic process, its composition and other properties will be quantified. Combustion characteristics will be evaluated. Along with the cooling capability of the endothermic process, the combustion characteristics will be identified and evaluated as the basis for performance metrics of the endothermic process and catalytic agents used within.

Proposals:
This is expected to be a multi-disciplinary initiative involving experimental, theoretical and numerical investigators in combustion science, catalytic chemistry and other necessary areas. We plan funding for several multi-investigator, multi-institution efforts of $1.0-1.5M, supplemented with limited individual efforts in key areas.

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7. Foundations of Energy Transfer in Multi-Physics Flow Phenomena

Background: A fundamental limitation to our understanding of many physical processes is a rational description of the direction and rate of energy flow within the process. With the exception of a small handful of isolated research breakthroughs, we continue to struggle with understanding the complex energy transfer mechanisms within flows of practical interest and with identifying potential approaches for control. Until recently, research in this area was limited to identification of correlative behavior based on observations of the macroscopic flowfield. With the assistance of breakthroughs in large-scale parallel computing

and highly-resolved optical diagnostic methods, researchers are now equipped to explore and characterize rate-dependent micro- and molecular-scale energy transfer processes and the critical role they play in shaping the macro-scale behavior of the flowfield.

Objective: Once identified, knowledge of dominant energy transfer mechanisms could be exploited to enable a revolutionary approach to the control of macroscopic flow behavior. Specifically, flowfields could be designed to favor preferred energy transfer mechanisms that result in an application-optimized flow state. To the authors' knowledge such an approach has not been considered within the scope of prior fluid dynamics research and a broad spectrum of technological benefits could be realized by breakthroughs driven by progress in this area.

This initiative will serve as a nexus for the integration of contributions from a variety of scientific disciplines to explore novel approaches for inherent flow control from a multidisciplinary perspective. The key first step in establishing this area will be the exploration of canonical problems that capture the fundamental behavior of representative mechanisms and build a cohesive understanding of the energy transfer processes, adding complexity along the way in a controlled and fundamental way. Energy transfer mechanisms to be explored within the scope of this initiative include, but are not limited to, interactions between the following modes: kinetic modes (turbulence and instabilities), internal energy states (rotational, vibrational), chemical reactions, ionization, and mechanical interactions (aeroelasticity, surface acoustic impedance). The approach will be multidisciplinary by necessity since the critical energy transfer mechanisms span those traditionally considered by single portfolios.

Concentration Area: Initially, research will focus on the discovery and characterization of fundamental intermodal energy transfer processes including, for example, identification of transfer/reaction rates, catalytic phenomena, probability of occurrence and theoretical limits. Later stages of research will examine the interplay of various transfer mechanisms and the exploitation of rate-dependent processes to tailor flowfields of interest to the Air Force. It is anticipated that progress will demand a close integration of numerical simulation and experiments and the development or refinement of computational and experimental methods specifically suited to this research area. To ensure that the multidisciplinary requirements of this emerging area are adequately addressed, projects supported under this initiative must cut across the AFOSR portfolios listed below with multi-PI awards considered in the $300-$750k/yr range.

- Aerothermodynamics and Turbulence
- Energy Conversion and Combustion Sciences
- Flow Interactions and Control
- Molecular Dynamics and Theoretical Chemistry

- Plasma and Electroenergetic Physics

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $4M/yr in the research supported by this initiative. Proposals submitted under this initiative should support small teams of typically 2-4 investigators with awards ranging from $300k-750k/yr for 3-5 years. Please note that this initiative emphasizes research that bridges the boundaries across multiple AFOSR portfolios. The submission of a White paper to one of the Program Managers for this initiative is strongly encouraged prior to the submission of a full proposal. Full proposals are encouraged by 30 June 2012.

POCs:

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8. Cyber Trust and Suspicion

Background: Cyberspace operations (CO) rely heavily on the degree to which users trust, or are suspicious, of their information technology systems. On the defensive side, computer network defense service providers hope that users will remain cognizant of threats, such as phishing and other social engineering attacks, to apply security policies, standards and procedures so that any manifestation of IT behaviors indicative of an actual intrusion are reported, but those related to an innocent system anomaly are not. On the offensive side,

operators need to know the potential effect and probability of success their attacks might have. Despite the significant impact trust and suspicion plays in the cyber environment, almost no works has been done to characterize it. As the primary response to this, the cyber war has been technology-centric, largely ignoring the role of the human operator.

Objective: This BRI's objective is to initiate a basic research program that begins to build the foundational understanding of human trust and suspicion in the cyberspace domain. The intent is to elevate our understanding of the human role in cyberspace operations, thereby providing guidance for previously untapped capabilities in this critical domain. On a practical level, the final deliverable for this effort would be a defined methodology that developers and operators could use to characterize both the effect, and the probability of detection, for any computer based defensive or offensive operation.

An in-depth understanding of the integral role the human operator (user, defender or attacker) plays in the cyber domain will provide numerous novel capabilities. On the defensive side, this research will enable the development of superior cyber defense technology as it will identify systemic human vulnerabilities that must be considered if the technology is to be effective. For example, host-based, adaptive, mission-centric computer security policies incorporating operational conditions and individual user competencies and beliefs significantly mitigate both internal and external threat events. Combined computational and Social Science constructs can help illuminate relationships between user and system trust and suspicion. This research will also enable the design of novel warning systems that function in response to identified human vulnerabilities (e.g., cognitive or behavioral signals of decreased vigilance detected). With a thorough understanding of how trust and suspicion operate and the vulnerabilities associated with them, cyber operations can be targeted at key individuals, populations, and times to greatly increase the effectiveness of the operations. Furthermore, such an understanding will provide the capability of modeling secondary and tertiary effects of cyber operations at the human level. For example, in addition to system failure from a denial-of-service attack, there are secondary and tertiary effects on subsequent human trust in systems. Understanding and modeling these effects will inform timing and targeting of subsequent operations, be they cyber or other.

Research Concentration Areas: Suggested research areas include but are not limited to: (1) Experimental Psychology to examine human cognition, behavior, and decision making as they relate to trust and suspicion in a cyberspace domain; (2) Neuroscience to establish correlates and a biological basis for said cognition and behavior; (3) Computer Science to "close the loop" and integrate the foundational human understanding with the cyberspace platforms of interest; (4) Cyber security performance metrics associated with human users and operators for cyber platforms of interest; (5) game theory to understand attacker/defender optimal strategies, (6) examination of the critical antecedents of trust and

suspicion such that systemic human vulnerabilities that result in susceptibility to cyber attacks can be identified and mitigated.

Execution: Proposals that are multi-disciplinary and multi-university teamed with AFRL In-house laboratory tasks are encouraged. I prefer to fund only between 1-3 grants with size between $500k-$1500k per year for three years. Submission of a brief white paper (1-3 pages) describing the potential research effort is strongly encouraged prior to proposal submission. Full proposals are encouraged by 1 June 2012.

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9. Ultra-Scale and Fault-Resilient Algorithms: Mathematical Algorithms for Ultra-Parallel Computing

Background: Today scientific computing is faced with serious challenges for fully realizing and harnessing the impressively increasing computational power on present and emerging platforms, including multicore-based platforms with complex architectures encompassing multiple levels of processors, and interconnected hierarchies. One of the major bottlenecks in large-scale simulations in aerodynamics or plasma dynamics which are traditional areas of interest to US Air Force has been the lack of scalability of algorithms for large-scale discrete problems. For time-dependent multiscale problems in particular governed by PDEs, implicit temporal discretization leads to solution of very large linear systems, e.g. the solution of the Poisson equation, with the corresponding matrix having an extremely large condition number. Current solvers typically fail to scale beyond 1,000 processors whereas the new petaflop systems are based on more than 100,000 processors. Moreover, while for the underlying ill-conditioned matrices of these solvers effective preconditioners can be used, these preconditioners also tend to suffer from lack of scalability. Another issue hampering parallel efficiency is that existing parallel algorithms focus only on spatial decomposition and do not take advantage of any possible parallelism in time which can be very effective for time-dependent systems, including molecular dynamics simulations for materials or fluids. To reach extreme scalability required of the emerging computing systems, the new algorithms need to address the fundamental issues in these systems such as memory constraints and reduction in global communication among others. Another major bottleneck in the new trans-petaflop computing environments is the problem of resiliency of these systems where about 10% to 20% of processors (at any given time) could produce faulty results due to hardware or software errors. While there have been ongoing efforts to develop new robust middleware, e.g. fault-tolerant MPI, the new scalable algorithms have to be robust and fault-oblivious as well in the absence of any possibilities for full in-disk check pointing due to the enormous size of restart files. To this end, new computational frameworks should be developed to detect silent

errors or faults in a timely fashion, and also recover from possible gaps in the restart data.

Objective: The goals of this initiative are development of fundamentally new approaches in addressing the issues of scalability and resilience for large-scale simulations of aerodynamic and plasma problems of primary interest to US Air Force. The issue of scalability goes well beyond the specifics of an efficient iterative solver and it is ultimately related to the mathematical type of the problem we address. This is especially true for multi-physics and multiscale problems, where one can exploit the structure and spatio-temporal scale separation using domain decomposition techniques. That is, the mathematical algorithm naturally will accommodate the multi-core architectures via the proper domain decomposition. The mathematical challenge is then to develop proper interface conditions, which lead to stable decompositions, preserve the global accuracy of the numerical solution (comparable to the solution in each individual patch) while at the same time minimize communications that tax the networks heavily in large-scale simulations. We can imagine that this will also apply to mathematically heterogeneous subdomains, e.g. coupling a hyperbolic with a parabolic domain, e.g. in coupling Navier-Stokes to Euler equation in unsteady aerodynamics; here the multi-physics dictates the decomposition at some level but patch discretization can be also pursued within each separate physical subdomain.

Concentration area: The two open issues of scalability and fault-resilience are very challenging, and while advances in numerical linear algebra are essential to addressing these challenges, progress can be made by combining different ideas from diverse fields beyond numerical linear algebra , e.g. from dynamical systems theory, probabilistic modeling, and even data assimilation. That is, we need to address the issue of effective dimensionality of the system we simulate as a function of time, the stochastic nature of faults, and the reconstruction of initial fields from restarts with partial only data. Fundamental research is needed on the mathematical aspects of scalable solvers with emphasis on parallelism across scales (spatial and temporal), high-order discretization, and multi-level domain decomposition techniques. Specific topics include but are not limited to Robin-Robin interface conditions, new developments of the parareal algorithm for convection-dominated problem, physics-based and multi-level additive Schwarz preconditioners, asynchronous and implicit multi-rate time discretization, novel restarts for iterative methods, Jacobean-free Newton-Krylov methods, and general interface algorithms that improve data locality. Also in the area of fault-tolerant algorithms, there should be effort in development of new robust techniques for fault detection and solution recovery on-the-fly.

For this topic, while single investigator proposals with novel ideas on any of the research challenges will be considered, preference will be given to multi-disciplinary teams comprised of computational scientists, applied mathematicians and application scientists (in plasma physics or aerodynamics) that would address the multitude of scientific challenges in the topic call.

Proposals for this effort are encouraged by 1 June 2012. White paper submissions to the program managers are encouraged.

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e. Other Innovative Research Concepts

AFOSR is always looking for new research ideas and is open to considering unique and revolutionary concepts. If you have an exciting idea that doesn't seem to fit within one of the more specific topic descriptions of this Broad Agency Announcements (BAA) detailing our current technical programs, you may submit it under this section of the BAA.

AFOSR's goal is to create revolutionary scientific breakthroughs. This BAA seeks to invest in high payoff science and to identify challenging fundamental scientific problems relevant to the USAF in the 21st century. It is expected that proposals will describe cutting-edge efforts on basic scientific problems. Proposed research should investigate truly new and unique approaches and techniques that may enable revolutionary concepts with potentially high payoff relevant to Air Force mission.

Submission of a brief White paper (1-3 pages) describing the potential research effort is strongly encouraged prior to proposal submission. White papers should briefly summarize your ideas, their scientific impact, and how they differ from what others are doing. Proposals not based on sound scientific or engineering principles will be quickly rejected. White papers will be reviewed by AFRL researchers familiar with the AF research interests in this area as well as suitable experts from academia. Copies of publications or student theses will not be considered as White papers.

Please include contact information including your mailing address, email address, telephone number, and fax number. This allows us to give prompt feedback to the proposer on the likelihood of a proposal being selected. We encourage you to send your White paper to:

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Air Force Office of Scientific Research
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Arlington, VA 22203-1768

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f. Education and Outreach Programs

The Scientific and Technology Divisions of the Air Force Office of Scientific Research (AFOSR), Policy and Integration Directorate (RSP), the International Office (IO), and three overseas detachments, AOARD and EOARD and SOARD, are responsible for the management of several programs that improve science and engineering education in the U.S., and stimulate interactions between Air Force researchers and the broader international, as well as domestic, research community. Applications for these programs do not always require proposals but generally have specific deadlines, formats, and qualifications. Researchers applying for these programs should communicate with the point-of-contact (POC) listed in each program description.

1. United States Air Force National Research Council Resident Research Associateship (NRC/RRA) Program

The NRC/RRA Program offers postdoctoral and senior scientists and engineers opportunities to perform research at sponsoring Air Force laboratory sites. The objectives of this program are: (1) to provide researchers of unusual promise and ability opportunities to solve problems, largely of their own choice, that are compatible with the interests of the hosting laboratories; and (2) to contribute to the overall efforts of the Air Force laboratories.

Postdoctoral Research Associateships are awarded to U.S. citizens and permanent residents who have held doctorates for less than five years at the time of application. The awards are made initially for one year and may be renewed for a second year, and in some cases, a third year. A small number of associateships may be available for foreign citizens if laboratory funds are available.

Senior Research Associateships are awarded to individuals who have held doctorates for more than five years, have significant research experience, and are recognized internationally as experts in their specialized fields, as evidenced by numerous refereed journal publications, invited presentations, authorship of books or book chapters, and professional society awards of international stature. Although awards to senior associates are usually for one year, awards for periods of three months or longer may be considered. Renewals for a second and third year are possible. U.S. citizenship is not a requirement. Senior associates must be eligible for access to unclassified government information systems; eligibility is also subject to a successful background review and visit authorization that includes approved access to the Air Force base and its laboratory facilities.
Associates are considered independent contractors, and receive a stipend from the NRC while carrying out their proposed research. Annual stipends increase with

additional years past the Ph.D. An appropriately higher stipend is offered to senior associates. Awardees also receive a relocation reimbursement and may be supported with limited funds for professional travel.

An on-line application is available at: **http://www.nationalacademies.org/rap**.

The program is currently administered by The National Research Council (NRC):
Research Associateship Programs (Keck 568)
National Research Council
500 Fifth St, NW, Washington DC 20001
(202) 334-2760
E-mail: **rap@nas.edu**
http://www.national-academies.org/rap

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2. United States Air Force-Summer Faculty Fellowship Program (SFFP)

The SFFP offers fellowships to university faculty to conduct research at one of the Air Force research facilities in the summer. The objectives of the Summer Faculty Fellowship Program are to: (1) stimulate professional relationships among SFFP fellows and the scientists and engineers in AFRL Technical Directorates and other Air Force research facilities; (2) elevate the awareness in the U.S. academic community of Air Force research needs and foster continued research at SFFP fellows' institutions; and (3) provide the faculty opportunities to perform high-quality research at AFRL Technical Directorates and other Air Force research facilities.

SFFP fellows conduct research in collaboration with Air Force researchers for a continuous summer period of eight to twelve weeks at the Technical Directorates of the Air Force Research Laboratory, the US Air Force Academy, or the Air Force Institute of Technology. A final report is required at the completion of the summer appointment.

Applicants must be U.S. citizens or permanent residents and have an earned Ph.D. in science or engineering. Fellows must be eligible for access to unclassified government information systems; the fellowship award is subject to a successful background review and visit authorization that includes approved access to an Air Force installation and its laboratory facilities.

Fellows are awarded in different categories including both early career investigator and senior investigator. The stipend is based on the category. Each SFFP award is for one summer. The SFFP fellow may reapply for up to two additional summers, for a maximum of three summer awards. Starting in Fiscal Year 2010,

selected fellows may bring a graduate student with them to assist in research on their assignment.

An on-line application is available at: **http://www.asee.org/sffp/**.

The program is currently administered by The American Society for Engineering Education (ASEE):
American Society for Engineering Education
1818 N St, NW Suite 600
Washington DC 20036
http://www.asee.org/sffp

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3. Engineer and Scientist Exchange Program (ESEP)

The Engineer and Scientist Exchange Program (ESEP) is a DoD effort to promote international cooperation in military research, development, and acquisition through the exchange of defense scientists and engineers (S&E). A prerequisite for establishing the program is a formal international agreement, a Memorandum of Understanding (MOU), with each participant nation. Currently, DoD has signed ESEP agreements with Australia, Canada, the Czech Republic, Chile, Egypt, France, Germany, Israel, Italy, Japan, Norway, Poland, Republic of Korea, Singapore, Spain, The Netherlands, and the United Kingdom. The primary goals of ESEP are to:

- Broaden perspectives in research and development techniques and methods.
- Form a cadre of internationally experienced professionals to enhance USAF research and development programs.
- Gain insight into foreign research and development methods, organizational structures, procedures, production, logistics, testing, and management systems.
- Cultivate future international cooperative endeavors.
- Avoid duplication of research efforts among allied nations.

Air Force personnel are selected in a competitive process and are assigned for a 2-year tour. This may be preceded by 6 months of language training. Ad hoc placements (non-competitive) can be initiated by research sites; however, these are funded solely by their originators. Foreign S&E are usually assigned to US DoD organizations for 12 month periods; although assignments can be for shorter or longer duration. Each country bears the cost of supporting its participants in the program. AFOSR/IO is responsible for managing placement of all ESEP exchanges within the USAF, and is the "one face to the customer" for all USAF

ESEP actions. SAF/IAPQ (Armaments Cooperation Division, Deputy Under Secretary of the Air Force, International Affairs), the executive agent, provides policy guidance. The Asian, European and Southern Offices of Aerospace Research and Development (AOARD/EOARD/SOARD) are AFOSR field offices located in Tokyo, London and Santiago. These offices act as overseas program liaison offices for US ESEP personnel working in Asia, Europe and South America.

AFOSR/IO implements all actions for USAF participants once their selection is approved, and for the placement of foreign ESEP participants in Air Force organizations.

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4. Air Force Visiting Scientist Program

The AF Visiting Scientist Program provides outstanding Air Force scientists and engineers the opportunity to conduct full-time, "hands-on" research-related work in a leading United States University or industry laboratory for a period of up to 179 days on a temporary duty (TDY) status funded by AFOSR. The university or industrial laboratory provides a letter of invitation, and makes facilities, equipment, and resources available. The host laboratory must be located in the United States. Typically the researcher is an Air Force scientist or engineer, at least at the GS-13/DR-II level or its military equivalent. The applicant must be currently active in his or her field of expertise, be widely recognized as an expert, and have a strong publication record. The applicant must write a project proposal, preferably not to exceed ten pages, but of sufficient depth and scope for evaluation by scientists at participating organizations. Hands-on laboratory research-related work is an essential program element. At the completion of the TDY, the visiting researcher is required to submit a written report detailing his or her experiences and results of the project. In addition, the visiting researcher may be required to give a seminar presentation at the Air Force Research Laboratory site or at AFOSR and to provide feedback for purposes of program assessment. Upon completion of the assignment the researcher returns to his/her Air Force Research Laboratory site.

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5. Window on Science (WOS) Program

The Window on Science (WOS) program facilitates technical interactions on fundamental research via direct contact between distinguished foreign researchers

and Air Force Research Laboratory scientists and engineers. The WOS program sponsors foreign scientists and engineers to visit Air Force scientists and engineers at USAF sites typically within the United States, but may also include other domestic or overseas locations. Although WOS visits are designed to be short-term in nature, visits to multiple sites are encouraged. In order to present their research to a greater audience, and to further Air Force interests, WOS visitors may also combine visits to Air Force R&D organizations with visits to Army, Navy, other government, university, or industrial facilities. AFOSR's European Office of Aerospace Research and Development (EOARD), London, United Kingdom, manages this program for Europe, Africa, the Middle East, and countries of the former Soviet Union. The Asian Office of Aerospace Research and Development (AOARD), Tokyo, Japan manages this program for the remainder of Asia and the Pacific Rim. The Southern Office of Aerospace Research and Development (SOARD), located in Santiago, Chile manages the WOS program for the Americas, but administers the program from AFOSR/IO located in Arlington, Virginia. Participants in the WOS program will be foreign non-government researchers identified as subject matter experts by AFRL program managers, and whose visit benefits Air Force scientists and engineers. Travelers may be eligible to receive payment for their services; however, base clearance requests for unpaid non-government visitors can also be handled under the WOS program. Visitors will normally present seminars to discuss their work, which may or may not have been funded by the Air Force. The WOS program is not intended as a substitute for research programs, internships, associateships, or personnel exchange programs. The lead-time necessary to arrange a WOS visit is generally three months. A letter report from the traveler is required on completion of the visit.

EOARD/AOARD/SOARD:
http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=8971

6. Windows on the World (WOW) Program

The Windows on the World program provides outstanding Air Force scientists and engineers the opportunity to conduct full-time research at a foreign (non-government) host laboratory, or to perform full-time science and technology assessment activities for a period up to 179 days on temporary duty (TDY) status. The TDY is fully funded by AFOSR. Upon completion of the assignment the researcher returns to his or her Air Force activity. The host laboratory provides facilities, resources, and a letter of invitation. Typically the researcher is an Air Force scientist or engineer, at least at the GM/GS-13/DR-II level or its military equivalent. The researcher must be currently active in his or her field of expertise, be widely recognized as an expert, and have a strong publication record. Some knowledge of the language used by the researcher's host institution is desirable. The applicant must write a research proposal, preferably not to exceed 10 pages, but of sufficient depth and scope, so that it can be evaluated by the scientists at the participating organizations. The proposal must be endorsed by the applicant's Air Force Research Laboratory Technical Directorate Chief Scientist. Non-

laboratory applicants, such as researchers at the Air Force Academy and Air Force Institute of Technology, should pass their proposals through the Chief Scientist of an AFRL Technical Directorate. Proposals that focus tightly on specific research problems or specific science and technology assessment topics will merit greater consideration than those that are of a survey nature. The researcher is required to submit a written report detailing his or her research effort and findings at the completion of the TDY. In addition, the researcher may be required to give a seminar-style presentation at AFOSR and/or the Air Force Research Laboratory site and provide feedback for purposes of program assessment. Lead-time to set up a "Windows" visit is approximately four months. More detailed information is contained in the AFOSR Brochure, “Windows on the World”.

Point of Contact (POC):
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7. National Defense Science and Engineering Graduate (NDSEG) Fellowship Program

The NDSEG Fellowship Program is a Department of Defense (DoD) fellowship program sponsored by Air Force Office of Scientific Research (AFOSR), Army Research Office (ARO), Office of Naval Research (ONR), and the High Performance Computing Modernization Program (HPCMP). The DoD is committed to increasing the number and quality of our Nation’s scientists and engineers. The actual number of awards varies from year to year, depending upon the available funding. The NDSEG Fellows do not incur any military or other service obligations. NDSEG Fellowships are highly competitive and will be awarded for full-time study and research.

An awardee must be enrolled in a graduate program by Fall 2012; the graduate program must lead toward a Ph.D. Preference will be given to applicants in one, or closely related to one, of the following specialties: Aeronautical and Astronautical Engineering; Biosciences; Chemical Engineering; Chemistry; Civil Engineering; Cognitive, Neural and Behavioral Sciences; Computer and Computational Sciences; Electrical Engineering; Geosciences; Materials Science and Engineering; Mathematics; Mechanical Engineering; Naval Architecture and Ocean Engineering; Oceanography; and Physics.

The NDSEG Fellowship Program is open only to applicants who are citizens or nationals of the United States. Persons who hold permanent resident status are not eligible to apply. NDSEG Fellowships are intended for students at or near the beginning of their graduate study in science or engineering. Applications are encouraged from women, persons with disabilities, and members of ethnic and racial minority groups historically underrepresented in science and engineering

fields, including African American, American Indian and Alaska Native, Native Hawaiian and Pacific Islander, and Hispanic persons.

The duration of an NDSEG Fellowship is thirty-six months cumulative starting in the fall of 2012. NDSEG Fellows may choose as their fellowship institution any accredited U.S. institution of higher education offering doctoral degrees in science or engineering. The availability of funds for the second and third years of each three-year award is contingent upon satisfactory academic progress.

In FY2012 NDSEG fellowships will provide stipends of $30,500, $31,000 and $31,500 in the first, second, and third years, respectively. Additionally, the NDSEG fellowship will pay the fellow's full tuition, required fees (not to include room and board) and minimum health insurance coverage offered through the institution, up to a total value of $1,000. Any excess insurance costs will be the responsibility of the fellow and can be paid using the stipend. The stipends will be prorated monthly based on a twelve-month academic year. If the fellow is not enrolled in an institutionally approved academic study and/or research during the summer months, financial support will not be provided. There are no dependency allowances. Persons with disabilities will be considered for additional allowances to offset special educational expenses.

An on-line application is available at: **http://www.asee.org/ndseg**.

This program is currently administered by the American Society for Engineering Education (ASEE):

NDSEG Fellowship Program c/o American Society for Engineering Education: 1818 N Street, N. W.
Suite 600 Washington, D. C., 20036 (202) 331-3516 Fax: (202) 265-8504 E-mail: **ndseg@asee.org**
http://www.asee.org/ndseg

Mr. Neville Thompson, AFOSR/RSPP, (703) 588-1779
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8. The Awards to Stimulate and Support Undergraduate Research Experiences (ASSURE)

The ASSURE program supports undergraduate research in DoD relevant disciplines and is designed to increase the number of high-quality undergraduate science and engineering majors who ultimately decide to pursue advanced degrees in these fields. A strong U.S. science and engineering workforce is of clear interest to the DoD, as the capability of producing superior technology is essential for future national security.

The ASSURE program aims to provide valuable research opportunities for undergraduates, either through ongoing research programs or through projects specially designed for this purpose. Research projects should allow high quality interaction of students with faculty and/or other research mentors and access to appropriate facilities and professional development opportunities. Active research experience is considered one of the most effective ways to attract and retain talented undergraduates in science and engineering.

ASSURE projects must have a well-defined common focus that enables a research related experience for students. Projects may be based in a single discipline or academic department, or interdisciplinary or multi-department research opportunities with a strong intellectual focus. Each proposal should reflect the unique combination of the proposing institution's interests and capabilities. Applicants are encouraged to involve students in research who might not otherwise have the opportunity, particularly those from institutions where research programs are limited. Thus, a significant fraction of the student participants should come from outside the host institution. In addition, DoD is interested in strengthening institutions with limited research programs and especially encourages proposals that help to enhance the research infrastructure in predominantly undergraduate four-year institutions. Student participants must be citizens or permanent residents of the United States or its possessions.

The DoD ASSURE budget is $4.5 million annually. DoD expected ASSURE budget for new projects is approximately $1.5 million; this funding will be distributed among fifteen to twenty new ASSURE awards. DoD relevance will be considered in making funding decisions. Projects may be carried out during the summer months, during the academic year, or both. Sites may be proposed for durations of one to five years, with a three-year duration being typical.

DoD executes the ASSURE program collaboratively with the National Science Foundation (NSF) through its Research Experiences for Undergraduates (REU) Sites Program. DoD funded ASSURE sites will be selected by DoD scientists and engineers, but will be overseen by NSF as part of the NSF portfolio of REU Sites. There is no separate application for the ASSURE program; ASSURE funding is awarded through the NSF REU Sites Program.

Information about the NSF REU Program can be found at NSF Program Solictation NSF 05-592:
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517. Applications are submitted through NSF Fastlane, **https://www.fastlane.nsf.gov/fastlane.jsp**.

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g. Special Programs:

AFOSR provides support for research and education through the following unique programs: The Small Business Technology Transfer Program (STTR); the Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) Program; and the University Research Initiative (URI) Program. Other support deemed appropriate by AFOSR, such as conferences and workshops, may also be sponsored.

1. Small Business Technology Transfer Program (STTR)

The primary objective of the AF STTR program is to involve small businesses in AF-relevant defense research, and enable them to commercialize their innovative technologies for the advancement of U.S. economic competitiveness. Specifically, the STTR Program is designed to provide an incentive for small companies, academic institutions, and non-profit research institutions, including federally-funded research and development centers (FFRDC), to work together to move emerging technical ideas from the laboratory to the marketplace.

Each STTR proposal must be submitted by a team that includes a small business (as the prime contractor for contracting purposes) and at least one academic or non-profit research institution, which have entered into a Cooperative Research and Development Agreement for the proposed effort. The STTR has two phases: Phase I efforts are up to $100,000 for a period not to exceed one year; and Phase II projects are two year efforts for amounts up to $750,000. More information Regarding the AF STTR can be found at:
http://www.sbirsttrmall.com/TopicPreRelease/Default.aspx.

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2. Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) Program

The objective of the program is to enhance defense-related research and education at covered educational institutions.

AFOSR HBCU/MI program consists of two components:

AFOSR Core Research. Research proposals from HBCU/MI's are reviewed by AFOSR Program Managers to enhance the research and educational capabilities of such institutions and may be funded by the AFOSR Director.

Department of Defense Infrastructure Support Program for Historically Black Colleges and Universities and Minority Institutions. The DoD has been providing grants for research and educational equipment at HBCU/MI. This program is administered by the Army Research Office, in collaboration with the AFOSR. Schools interested in this program should look for the Broad Agency Announcement that is usually published in the Fall of each year in the ARO webpage. The BAA is linked through the AFOSR Web site at **http://www.wpafb.af.mil/AFRL/afosr/**, under "Research Areas"; "Educational, Outreach and Special Programs" at **http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=9304**.

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3. Young Investigator Research Program (YIP)

The Air Force YIP supports scientists and engineers who have received Ph.D. or equivalent degrees in the last five years and show exceptional ability and promise for conducting basic research. The objective of this program is to foster creative basic research in science and engineering; enhance early career development of outstanding young investigators; and increase opportunities for the young investigator to recognize the Air Force mission and related challenges in science and engineering.

Individual awards will be made to U.S. institutions of higher education, industrial laboratories or non-profit research organizations where the principal investigator is a U.S. citizen, national or permanent resident; employed on a full-time basis and hold a regular position. Researchers working at the Federally Funded Research and Development Centers and DoD Laboratories will not be considered for the YIP competition. Each award will be funded at the $120K level for three years. Exceptional proposals will be considered individually for higher funding levels and longer duration. When there is an open YIP BAA, specific information about YIP proposal preparation and submission can be found at AFOSR's Web site: **http://www.wpafb.af.mil/AFRL/afosr/** under 'Other Links"; "List of Broad Agency Announcements". Click the 'AFOSR BAAs' button. When AFOSR has an open Young Investigator Research Program BAA it will be listed.

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h. University Research Initiative (URI) Programs

The URI programs are executed under the policy guidance of the Office of the Deputy Under Secretary of Defense for Laboratories and Basic Research, to enhance universities' capabilities to perform basic science and engineering

research and related education in science and engineering areas critical to national defense. The URI programs include: the Defense Research Instrumentation Program (DURIP); the Multidisciplinary Research Program of the University Research Initiative (MURI); and the Presidential Early Career Awards for Scientists and Engineers. A short description of each program is listed below. Specific information on each URI program Broad Agency Announcement can be found on the AFOSR Web site at **http://www.wpafb.af.mil/AFRL/afosr/**, under "Research"; "Educational, Outreach and Special Programs" at **http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=8972**

1. Defense University Research Instrumentation Program (DURIP)

This program is administered through the Air Force Office of Scientific Research, the Army Research Office, and the Office of Naval Research. The DURIP program is for the acquisition of major equipment to augment current or develop new research capabilities to support research in the technical areas of interest to the DoD. The competition is open only to U.S. institutions of higher education, with degree granting programs in science, math, and/or engineering. Proposals to purchase instrumentation may request $50,000 to $1,000,000. Awards are typically one year in length. The latest DURIP BAA can be found at **http://www.wpafb.af.mil/AFRL/afosr/**, under "Other Links"; "List of Broad Agency Announcements"; "Broad Agency Announcements – Current" or "Broad Agency Announcements – Archive" as applicable.

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2. Multidisciplinary Research Program of the University Research Initiative (MURI)

MURI supports basic research in the science and engineering areas intersecting more than one traditional discipline. The program is focused on multidisciplinary team efforts to address issues of critical concern to the DoD and the AF. The goal of this program is to advance defense research, accelerate technology transition, and educate scientists and engineers in the interdisciplinary areas important to national defense.

MURI is a DoD-wide program which complements other DoD programs that support university research through the single-investigator awards. The awards are typically for a period of three years with two additional years as options. New awards can be funded up to $1.5M per year, with the actual amount contingent upon the availability of funds, the specific topic and the scope of the proposed work. All the award selections result from a merit based competition of the proposals. Proposal submission is a two-stage process including White papers and full proposals. Details of the proposal submission process and the specific MURI topics under the solicitation can be found in the most recent MURI announcement at **http://www.wpafb.af.mil/AFRL/afosr/,** under "Other Links"; "List of Broad Agency Announcements"; "Broad Agency Announcements – Current" or "Broad Agency Announcements – Archive" as applicable.

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3. Presidential Early Career Award in Science & Engineering (PECASE)

The National Science & Technology Council (NTSC) sponsors PECASE awards to recognize outstanding young scientists and engineers at the outset of their careers. The PECASE embodies the high priority placed by the President on maintaining the leadership position of the US in science by producing outstanding scientists and engineers and nurturing their continued development. The Awards will identify a cadre of outstanding scientists and engineers who will broadly advance science and the missions important to the participating agencies.

The PECASE recognize some of the nation's finest scientists and engineers who, while early in their research careers, show exceptional potential for leadership at the frontiers of scientific knowledge during the 21st century. The Awards foster innovative and far-reaching developments in science and technology, increase awareness of careers in science and engineering, give recognition to the scientific missions of participating agencies, enhance connections between fundamental research and national goals, and highlight the importance of science and technology for the nation's future. The Awards are conferred annually at the White House following recommendations from participating agencies.

To be eligible for the PECASE, an individual must be a US citizen, national, or permanent resident with no more than five years from receipt of the doctorate degree. Each award will be $200K per year for five years. AFOSR awardees will be selected from among highly qualified institute of higher education principal investigators to the AFOSR or former National Defense Science and Engineering Graduate (NDSEG) fellowship recipients. Candidates must hold tenure-track positions at U.S. universities. An individual wishing to apply for the program must be nominated by an AFOSR program manager and have a proposal that addresses Air Force research interests as described in the current AFOSR Broad Agency Announcement (BAA).

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i. Conferences and Workshops

The Air Force Office of Scientific Research (AFOSR) understands that it is essential for the scientific community to maintain clear lines of communication for thorough and well-reasoned research to be accomplished. Conferences and workshops have proven to be extremely valuable tools for AFOSR. They allow our technical managers the opportunity to receive current information in their respective disciplines. They also allow AFOSR the opportunity to inform the research community of the current thrust of AFOSR's programs. Conferences and workshops constitute key forums for research and technology interchange. AFOSR accepts proposals from all recognized scientific, technical, or professional organizations that qualify for federal tax-exempt status. AFOSR's financial support through appropriate financing vehicles for conferences and workshops is dependent on the availability of funds, program manager's discretion, and certain other restrictions including:

- AFOSR support for a workshop or conference is not to be considered as an endorsement of any co-sponsoring organization, profit or non-profit.
- The subject matter of the conference or workshop is scientific, technical, or involves professional issues that are relevant to AFOSR's mission of managing the Air Force basic research program.
- The purpose of our support is to transfer federally developed technology to the private sector or to stimulate wider interest and inquiry into the relevant scientific, technical, or professional issues relevant to AFOSR's mission of managing the Air Force basic research program. Proposals for conference or workshop support should be submitted a minimum of six months prior to the date of the conference. Proposals should include the following:

j. Technical Information:

- Summary indicating the objective(s) of the conference/workshop
- Topic(s) to be covered and how they are relevant to AFOSR's mission of managing the Air Force basic research program
- Title, location, and date(s) of the conference/workshop
- Explanation of how the conference/workshop will relate to the research interests of AFOSR identified in Section III of the Broad Agency Announcement (BAA)
- Chairperson or principal investigator and his/her biographical information
- List of proposed participants and method (or copies) of announcement or invitation
- A note on whether foreign nationals will be present

k. Evaluation Criteria For Conference Support:

Anticipated use of funds requested from AFOSR proposals for conferences and workshops will be evaluated using the following criteria. All factors are of equal importance to each other:

- Technical merits of the proposed research and development.
- Potential relationship of the proposed research and development to the Department of Defense.
- The qualifications of the principal investigator(s) or conference chair(s).
- Overall realism and reasonableness of cost including proposed cost sharing when applicable and availability of funds.

l. Cost Information (In addition to information required on SF 424 (R&R) Budget forms):

- Total project costs by major cost elements
- Anticipated sources of conference/workshop income and amount from each source
- Proposals should break down how AFOSR funds will be spent in sufficient detail for AFOSR personnel to determine whether costs are allowable

If you have questions concerning the scientific aspects of a potential proposal to AFOSR for conference or workshop support, please contact the program manager listed in Section I of the BAA responsible for the particular scientific area of the conference/workshop.

II. Award Information

1. In Fiscal Year 2011, AFOSR managed funding support for approximately 2,500 grants, cooperative agreements, and contracts to about 400 academic institutions, non-profit organizations and industrial firms. This included grants, cooperative agreements and contracts to academic institutions, non-profit organizations, and industry. Approximately $350M is available for support of actions awarded through this BAA process. Research proposals in the range of $200-400K per year are encouraged. Awards may be proposed for up to five years. Awards may start any time during the fiscal year.

2. The Government anticipates the award of grants, cooperative agreements or contracts under this BAA.

III. Eligibility Information

All responsible, potential applicants from academia and industry are eligible to submit proposals. AFOSR particularly encourages proposals from small businesses; however, no portion of this BAA is set aside for a specific group. Proposals from Federal Agencies, including subcontracting/subrecipient efforts will not be evaluated under this BAA. Federal agencies should contact the primary POCs listed under each technical area to discuss funding through the internal Government procedures.

IV. Application and Submission Information

1. Address to Request Announcement Package – This announcement may be accessed from the Internet at the Grants.gov web site (**http://www.grants.gov**). See 'For Electronic Submission' below. A copy of this BAA is also posted on FedBizOpps.gov (www.fbo.gov).

2. Marking of Proposals – As previously stated, AFOSR is seeking White papers and proposals that do not contain proprietary information. If proprietary information is submitted, AFOSR will make every effort to protect the confidentiality of the proposal and any evaluations. However, under the Freedom of Information Act (FOIA) requirements, such information (or portions thereof) may potentially be subject to release. If protection is desired for proprietary or confidential information, the proposer must mark the proposal with a protective legend found in FAR 52.215-1(e), Instructions to Offerors – Competitive Acquisition (Jan 2004), (modified to permit release to outside –Non-government evaluators and support contractors retained by AFOSR. See Section V). **It is the offerors responsibility to notify AFOSR of proposals containing proprietary information and to identify the relevant portions of their proposals that require protection. The entire proposal (or portions thereof) without protective markings or otherwise identified as requiring protection will be consided to be furnished voluntarily to AFOSR without restriction and will be treated as such for all purposes**. Since the Government anticipates the award of either grants, cooperative agreements, or contracts, this statement is applicable to proposals for all three of these potential instruments.

3. Content and Form of Application Submission –

a. White paper. Before submitting a research proposal, you may wish to further explore proposal opportunities. You can do this by contacting the appropriate AFOSR program manager who can provide greater detail about a particular opportunity; the program manager may then ask for a White paper. However, in your conversations with a Government official, be aware that only warranted contracting and grants officers are authorized to commit the Government.

If you prefer, or the program manager requests, you may submit a White paper, which should briefly describe the proposed research project's (1)

objective, (2) general approach, and (3) impact on Department of Defense (DoD) and civilian technology. The White paper may also contain any unique capabilities or experience you may have (e.g., collaborative research activities involving Air Force, DoD, or other Federal laboratory.) The Program Manager may have additional guidelines regarding form, content and length of preliminary proposals so pay particular attention to the requirements included under each topic area. For additional information regarding White papers, please see the AFRL BAA Guide for Industry at **http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=6790**.

White paper Format

- Paper Size – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – single or double spaced
- Font – Times New Roman, 10 or 12 point
- Copies –as discussed with the Program Manager
- Content – as described above
-Length – as indicated in specific topic areas

b. Full Proposals. The proposal may be submitted either electronically or in hard copy form, but not both. All proposers must include the SF 424 (R&R) form as the cover page. Unnecessarily elaborate brochures, reprints or presentations beyond those sufficient to present a complete and effective proposal are not desired. To convert attachments into PDF format, Grants.gov provides a list of PDF file converters at **http://www.grants.gov/help/download_software.jsp**

Full Proposal Format

- Paper Size – 8.5 x 11 inch paper
- Margins – 1 inch
- Spacing – single or double spaced
- Font – Times New Roman, 10 or 12 point
- Page Limitation – None, although unnecessarily elaborate proposals are not desirable.
- Attachments – submit in **PDF** format (Adobe Portable Document Format)
- Copies for hardcopy submissions – (one original, number of copies as discussed with the Program Manager)
- Content – as described below

(1) Advance Preparation For Electronic Submission - Electronic proposals must be submitted through Grants.gov. There are several one-

time actions your organization must have completed before it will be able to submit applications through Grants.gov. Well before the submission deadline, you should verify that the persons authorized to submit proposals for your organization have completed those actions. If not, it may take them up to 21 days to complete the actions before they will be able to submit applications.

The process your organization must complete includes obtaining a Dun and Bradstreet Data Universal Numbering System (DUNS) number, registering with the Central Contract Registry (CCR), registering with the credential provider, and registering with Grants.gov. (Designating an E-Business Point of Contact (EBiz POC) and obtaining a special password called MPIN are important steps in the CCR registration process.) Go to **http://www.grants.gov/applicants/get_registered.jsp**. Use the Grants.gov Organization Registration Checklist at **http://www.grants.gov/assets/Organization_Steps_Complete_Registration.pdf** to guide you through the process. To submit a proposal to through Grants.gov, applicants will need to download Adobe Reader. This small, free program will allow you to access, complete, and submit applications electronically and securely. To download a free version of the software, visit the following web site: **http://www.grants.gov/help/download_software.jsp**. Consult Grants.gov to ensure you have the required version of Adobe Reader installed. Should you have questions relating to the registration process, system requirements, how an application form works, the submittal process or Adobe Reader forms, call Grants.gov at 1-800-518-4726 or **support@grants.gov** for updated information.

(2) Submitting the Application

(a) For Electronic Submission – Application forms and instructions are available at Grants.gov. To access these materials, go to **http://www.grants.gov**, select “Apply for Grants”, and then follow the instructions. In the Grants.gov search function, enter the funding opportunity number for this announcement (BAA-AFOSR-2012-0001). You can also search for the CFDA Number 12.800, Air Force Defense Research Sciences Program. On the Selected Grant Applications for Download page, click on 'download' under the heading 'Instructions and Applications' to download the application package.

The funding opportunity will be listed multiple times. The funding opportunity number is identical for each listing. Select the Competition ID and Competition Title for the directorate specific to your area of interest to download the instructions and application.

If you are unsure which directorate and program manager is appropriate for your specific area of interest, select the Competition ID and Competition Title “Other” to download.

Due to high traffic volume, applicants are highly encouraged to submit applications early. Waiting until the due date and time may result in applications being late. Common closing dates include the first, fifteenth and last day of any month. Potential applicants are reminded to plan accordingly. Also, please check Grants.gov prior to submission for any notices posted on Grants.gov offering alternate submission options as a result of system saturation. **Note: All attachments to all forms must be submitted in PDF format (Adobe Portable Document Format).** Grants.gov provides links to PDF file converters at this site: **http://www.grants.gov/help/download_software.jsp**.

(b) For Hard Copy Submission – For hard copy submission, the original proposal and copies must be delivered to the attention of the program manager at the Air Force Office of Scientific Research at the following address:

AFOSR (Attn: Name of Program Manager)
Air Force Office of Scientific Research
875 North Randolph Street, Suite 325 Room 3112
Arlington VA 22203-1768

In case of difficulties in determining the appropriate AFOSR addressee, proposals may be submitted to:

AFOSR/PKC
875 Randolph Street, Suite 325 Room 3112
Arlington VA 22203-1768

(c) SF 424 Research and Related (R&R) - The SF 424 (R&R) form must be used as the cover page for all electronic and hard copy proposals. No other sheets of paper may precede the SF 424 (R&R) for a hard copy proposal. A signed copy of the SF 424 (R&R) should be submitted with all hardcopy proposals. Complete all the required fields in accordance with the "pop-up" instructions on the form and the following instructions for the specified fields. To see the instructions, roll your mouse over the field to be filled out. You will see additional information about that field. For example on the SF424 (R&R) the Phone Number field says 'PHONE NUMBER (Contact Person): Enter the daytime phone number for the person to contact on matters relating to this application. This field is required.' Mandatory fields will have an asterisk marking the field and will appear yellow on most computers. In Grants.gov, some fields will self populate based on the BAA selected. Please fill out the SF 424 (R&R) first, as some fields on the SF 424 are used to auto populate fields in other forms. The completion of most fields is self-explanatory except for the following special instructions:

- **Field 2**: The Applicant Identifier may be left blank.

- **Field 3**: The Date Received by State and the State Application Identified are not applicable to research.

- **Field 7**: Complete as indicated. If Small Business is selected, please note if the organization is Woman-owned and/or Socially and Economically Disadvantaged. If the organization is a Minority Institution, select "Other" and under “Other (Specify)” note that you are a Minority Institution (MI).

- **Field 9**: List Air Force Office of Scientific Research as the reviewing agency. This field is pre-populated in Grants.gov.

- **Field 16**: Choose ‘No’. Check 'Program is Not Covered By Executive Order 12372'.

- **Attachments: All attachments to all Grants.gov forms must be submitted in PDF format** (Adobe Portable Document Format). To convert attachments into PDF format, Grants.gov provides a list of PDF file converters at **http://www.grants.gov/help/download_software.jsp**

A signed copy of the SF 424 (R&R) should be submitted with all hardcopy proposals.

(d) Certification: All awards require some form of certifications of compliance with national policy requirements.

For assistance awards, i.e., grants and cooperative agreements, proposers using the SF 424 (R&R) are providing the certification required by 32 CFR Part 28 regarding lobbying. (The full text of this certification may be found at http://www.wpafb.af.mil/shared/media/document/AFD-070817-127.pdf). If you have lobbying activities to disclose, you must complete the optional form **SF-LLL**, Standard Form – LLL, ‘Disclosure of Lobbying Activities’ in the down-loaded forms package.

If it is determined a contract is the appropriate vehicle, AFOSR will request additional documentation from prospective awardees. For contract awards, prospective contractors shall complete electronic annual representations and certifications at **http://www.bpn.gov/orca**. The representations and certifications shall be submitted to ORCA as necessary, but updated at least annually, to ensure they are current, accurate, and complete. These representations and certifications are effective until one year from date of submission or update to ORCA. In addition to the ORCA representations and certifications, prospective contractors shall complete the AFOSR Contract Certification which can be located at **http://www.wpafb.af.mil/shared/media/document/AFD-070820-024.doc**.

(e) Research and Related (R&R) Other Forms: The following other forms must be used for all electronic and hard copy proposals: R&R Senior/Key Person Profile form, R&R Project/Performance Site Locations form, R&R Other Project Information form and the R&R Budget form. The **R&R Subaward Budget Attachment Form** is required when subawardees are involved in the effort. Primes should ensure that subrecipients' cost information reflects the same level of detail as the primes' cost information. The format should follow the Prime's submission as well. See section IV. 3. (j.) R&R Budget Form for detail on submission of the Prime's budget information. The **SF-LLL form** is required when applicants have lobbying activities to disclose. PDF copies of all forms may be obtained at the Grants.gov website.

(f) R&R Senior/Key Person Profile Form – Complete the R&R Senior/Key Person Profile Form for those key persons who will be performing the research. The principal purpose and routine use of the requested information are for evaluation of the qualifications of those persons who will perform the proposed research. For the principal investigator and each of the senior staff, provide a short biographical sketch and a list of significant publications (vitae) and attach it to the R&R Senior/Key Person Profile Form.

(g) R&R Project/Performance Site Locations Form – Complete all information as requested.

(h) R&R Other Project Information Form - Human Subject/Animal Use and Environmental Compliance.

Human Subject Use. Each proposal must address human subject involvement in the research by addressing Field 1 and 1a of the R&R Other Project Information Form. If Field 1 indicates "Yes", the Air Force must receive a completed OMB No. 0990-0263 form before a contract, grant, or cooperative agreement may be awarded to support research involving the use of human subjects. Attach the document to the R&R Other Project Information Form. If using Grants.gov, a completed OMB No. 0990-0263 form shall be attached in field 12 of the R&R Other Project Information Form. Refer any questions regarding human subjects to Stephanie Bruce of the AFOSR Directorate of Mathematics, Information and Life Sciences at stephanie.bruce@afosr.af.mil.

Animal Use. Each proposal must address animal use protocols by addressing Field 2 and 2a of the R&R Other Project Information Form. If selected for award, additional documentation in accordance with Air Force standards will be required. Additional proposal guidance may be found at the AFOSR web site **http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=9388**. Refer any questions regarding animal subjects to Stephanie Bruce of the AFOSR Directorate of Mathematics, Information and Life Sciences at stephanie.bruce @afosr.af.mil.

Environmental Compliance. Federal agencies making contract, grant, or cooperative agreement awards and recipients of such awards must comply with various environmental requirements. The National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. Sections 4321-4370 (a), requires that agencies consider the environmental impact of "major Federal actions" prior to any final agency decision. With respect to those awards which constitute "major Federal actions," as defined in 40 CFR 1508.18, federal agencies may be required to comply with NEPA and prepare an environmental impact statement (EIS) even if the agency does no more than provide grant funds to the recipient. Questions regarding NEPA compliance should be referred to the applicable AFOSR Program Manager. Most research efforts funded by AFOSR will, however, qualify for a categorical exclusion from the need to prepare an EIS. Air Force instructions/regulations provide for a categorical exclusion for basic and applied scientific research usually confined to the laboratory, if the research complies with all other applicable safety, environmental and natural resource conservation laws. Each proposal shall address environmental impact by filling in fields 4a through 4d of the R&R Other Project Information Form. This information will be used by AFOSR to make a determination if the proposed research effort qualifies for categorical exclusion.

Abstract - Include a concise (not to exceed 300 words) abstract that describes the research objective, technical approaches, anticipated outcome and impact of the specific research. In the header of the abstract include the program manager's name and directorate who should receive the proposal for consideration and evaluation. Attach the Abstract to the R&R Other Project Information form in field 7.

(i) R&R Other Project Information Form - Project Narrative Instructions

Project Narrative – Describe clearly the research including the objective and approach to be performed keeping in mind the evaluation criteria listed in Section V of this announcement. Also briefly indicate whether the intended research will result in environmental impacts outside the laboratory, and how the proposer will ensure compliance with environmental statutes and regulations. Attach the proposal narrative to R&R Other Project Information form in field 8.

Project Narrative - Statement of Objectives – Describe the actual research to be completed, including goals and objectives, on one-page titled Statement of Objectives. This statement of objectives may be incorporated into the award instead of incorporating the entire technical proposal. Active verbs should be used in this statement (for example, "conduct" research into a topic, "investigate" a problem, "determine" to test a hypothesis). It should not contain proprietary information.

Project Narrative - Research Effort – Describe in detail the research to be performed. State the objectives and approach and their relationship and

comparable objectives in progress elsewhere. Additionally, state knowledge in the field and include a bibliography and a list of literature citations. Discuss the nature of the expected results. The adequacy of this information will influence the overall evaluation. Proposals for renewal of existing support must include a description of progress if the proposed objectives are related.

Project Narrative – **Principal Investigator (PI) Time.** PI time is required. List the estimate of time the principal investigator and other senior professional personnel will devote to the research. This shall include information pertaining to other commitments of time, such as sabbatical or extended leave; and proportion of time to be devoted to this research and to other research. Awards may be terminated when the principal investigator severs connections with the organization or is unable to continue active participation in the research. State the number of graduate students for whom each senior staff member is responsible. If the principal investigator or other key personnel are currently engaged in research under other auspices, or expect to receive support from other agencies for research during the time proposed for AFOSR support, state the title of the other research, the proportion of time to be devoted to it, the amount of support, name of agency, dates, etc. Send any changes in this information as soon as they are known. Submit a short abstract (including title, objectives, and approach) of that research and a copy of the budget for both present and pending research projects.

Project Narrative – **Facilities**. Describe facilities available for performing the proposed research and any additional facilities or equipment the organization proposes to acquire at its own expense. Indicate government-owned facilities or equipment already possessed that will be used. Reference the facilities contract number or, in the absence of a facilities contract, the specific facilities or equipment and the number of the award under which they are accountable.

Project Narrative – **Special Test Equipment.** List special test equipment or other property required to perform the proposed research. Segregate items to be acquired with award funds from those to be furnished by the Government. When possible and practicable, give a description or title and estimated cost of each item. When information on individual items is unknown or not available, group the items by class and estimate the values. In addition, state why it is necessary to acquire the property with award funds.

Project Narrative – **Equipment.** Justify the need for each equipment item. Additional facilities and equipment will not be provided unless the research cannot be completed by any other practical means. Include the proposed life expectancy of the equipment and whether it will be integrated with a larger assemblage or apparatus. If so, state who owns the existing apparatus.

Project Narrative – **High Performance Computing Availability.** Researchers that are supported under an AFOSR grant or contract, and meet certain restrictions, are eligible to apply for special accounts and participation in

a full-spectrum of activities within the DOD high performance computing modernization program. This program provides, at no cost to the user, access to a range of state-of-the-art high performance computing assets and training opportunities that will allow the user to fully exploit these assets. Details of the capabilities of the program can be found at the following Internet address: **http://www.hpcmo.hpc.mil**. Researchers needing high performance cycles should address the utilization of this program to meet their required needs. AFOSR program managers will facilitate the establishment of accounts awarded.

(j) R&R Budget Form - Estimate the total research project cost. Categorize funds by year and provide separate annual budgets for projects lasting more than one year. In addition to the Research & Related Budget forms available on Grants.gov, the budget proposal should include a budget justification for each year, clearly explaining the need for each item. Applicants who enter a fee on Part J of the budget will not be eligible to receive a grant or cooperative agreement. Attach the budget justification to Section K of the R&R Budget form.

4. Other Submission Requirements

Proposals submitted in whole or in part by electronic media (computer disk or tape, facsimile machine, electronic mail, etc.) ***will not be accepted*** (unless the full proposal is submitted electronically through Grants.gov).

5. Application Receipt Notices.

a. For Electronic Submission - The applicant's approved account holder for Grants.gov will receive a confirmation page upon completing the submission to Grants.gov. This confirmation page is a record of the time and date stamp that is used to determine whether the proposal was submitted by the deadline. After an institution submits an application, Grants.gov generates a submission receipt via email and also sets the application status to "Received". This receipt verifies the Application has been successfully delivered to the Grants.gov system. Next, Grants.gov verifies the submission is valid by ensuring it does not contain viruses, the opportunity is still open, and the applicant login and applicant DUNS number match. If the submission is valid, Grants.gov generates a submission validation receipt via email and sets the application status to "Validated". If the application is not validated, the application status is set to "Rejected". The system sends a rejection email notification to the institution and the institution must resubmit the application package. Applicants can track the status of their application by logging in to Grants.gov.

b. For Hard Copy Submission – An applicant that submits a hard copy proposal to AFOSR will receive an email from the agency approximately ten days after the

proposal due date to acknowledge receipt of the proposal and provide the agency's assigned tracking number. The email is sent to the authorized representative for the applicant institution.

6. Submission Due Dates and Times. This is an open-ended BAA, thus, this announcement will remain open until replaced by a successor BAA. Proposals may be submitted at any time during that period. For topic specific restrictions, see topic descriptions above. For additional information regarding the BAA process please refer to the AFRL BAA Guide for Industry at **http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=6790**.

7. Indirect Cost Limitation for Basic Research Awards Notices:

The DoD Appropriations Acts of 2011 and 2012 did not carry forward the Indirect Cost Limitation for Basic Research Awards as originally set forth in Section 8115 of the Department of Defense Appropriations Act, 2008 (P.L. 110-116) and subsequently included in the 2009 and 2010 Appropriation Acts which limited payments of negotiated indirect cost rates on contracts, grants, and cooperative agreements (or similar arrangements) to not more than 35 percent of the total cost of the instrument. However, efforts using FY2008 funds after 14 Nov 2007, FY2009 and FY2010 appropriations remain subject to the 35 percent restriction on indirect cost reimbursement. Records in the contractor's or recipient's financial management system must be able to identify the sources and applications of funding adequately to demonstrate compliance with the limitation.

V. Application Review Information

AFOSR's overriding purpose in supporting this research is to advance the state of the art in areas related to the technical problems the Air Force encounters in developing and maintaining a superior Air Force; lowering the cost and improving the performance, maintainability, and supportability of Air Force weapon systems; and creating and preventing technological surprise.

Proposals submitted under this BAA are evaluated through a peer or scientific review process. If selected for contract award, evaluation will be on a competitive basis according to Public Law 98-369, Competition in Contracting Act of 1984, 10 USC 2361, and 10 USC 2374. If selected for grant/assistance instrument award, evaluation will use merit-based competitive procedures according to DoDGARS citation of 32 C.F.R Sec 22.315. Proposals may be evaluated by program managers at EOARD/AOARD and the appropriate AFRL Technology Directorates, other military services, DoD agencies, civilian agencies and non-Government sources. Non-Government sources can include academia, nonprofit institutions, and support contractor personnel. Non-Government evaluators are authorized

access only to those portions of the proposal data and discussions that are necessary to enable them to perform their respective duties. Non-Government evaluators are also required to sign nondisclosure agreements which prohibit them from disclosing proprietary information submitted by contractors. **However as previously stated in Section IV para 2, AFOSR is seeking White papers and proposals that do not contain proprietary information. If proprietary information is submitted it is the offerors responsibility to mark the relevant portions of their proposal as specified in Section IV para 2.**

Employees of commercial firms under contract to the Government may be used to administratively process proposals and may gain access to proprietary information contained in proposals and/or post award documentation. These support contracts include nondisclosure agreements prohibiting their contractor employees from disclosing any information submitted by other contractors.

Proposals submitted for Special Programs listed in Section I shall be evaluated under criteria as specified in their description. Subject to funding availability, all other proposals will be evaluated under the following two primary criteria, of equal importance, as follows:

1. Technical merits of the proposed research and development; and
2. Potential relationship of the proposed research and development to Department of Defense missions.

Other evaluation criteria used in the technical reviews, which are of lesser importance than the primary criteria and of equal importance to each other, are:

1. The likelihood of the proposed effort to develop new research capabilities and broaden the research base in support of U.S. national defense.
2. The proposer's capabilities integral to achieving USAF objectives. This includes principal investigator's, team leader's, or key personnel's qualifications, related experience, facilities, or techniques or a combination of these factors integral to achieving USAF objectives.
3. Overall realism and reasonableness of proposed costs.

Additional administrative information regarding submission of applications is contained in Section VIII below. The technical and cost information will be analyzed simultaneously during the evaluation process.

For conference support, please see the evaluation criteria listed under the heading of "Conferences and Workshops" under Section I of this announcement.

Proposals may be submitted for one or more topics or for a specific portion of one topic. A proposer may submit separate proposals on different topics or different proposals on the same topic. The U.S. Government does not guarantee an award

in each topic area. Further, be advised that as funds are limited, otherwise meritorious proposals may not be funded. Therefore, it is important that proposals show strength in as many of the evaluation area as practicable for maximum competitiveness.

VI. Award Administration Information

1. Award Notices.

Should your proposal be selected for award, the principal investigator will receive a letter from the Technical Directorate stating this information. This is not an authorization to begin work. Your business office will be contacted by the grant or contracting officer to negotiate the terms of your award.

2. Reporting Requirements.

Grants and cooperative agreements typically require annual and final technical reports, financial reports, and final patent reports. Contracts typically require annual and final technical and patent reports. Copies of publications and presentations should be submitted.

Additional deliverables may be required based on the research being conducted.

3. Additional information for offerors seeking contract awards.

a. 5352.245-9005 Elimination of Competitive Advantage in the Use of Government Property.

ELIMINATION OF COMPETITIVE ADVANTAGE IN THE USE OF GOVERNMENT PROPERTY (AFMC) (OCT 2008)

(a) Unless otherwise specified in this solicitation or attachments, the Government does not plan to furnish any facilities, special tooling, special test equipment or other Government property for use in the performance of the contract resulting from this solicitation.

(b) The Government may, however, authorize such use in accordance with **FAR 45.3**, Providing Government Property to Contractors. To use existing Government property in the performance of this proposed contract, a copy of the cognizant Contracting Officer's written concurrence with such use must be furnished to the Government as a part of the response to this solicitation. Your proposal must include a listing of Government property you desire to use in the performance of the proposed contract, including the following information for each item: nomenclature, date of purchase, acquisition value, number of

months of contemplated use (identify first, last, and all intervening months), rental fee, if applicable, and the copy of the Contracting Officer's written concurrence for such use.

(c) In the event that permission for such use of Government property is not authorized and the Contractor must furnish the property to perform the contract, identify the total cost impact, if any, to the proposed price.

(d) An evaluation factor as set forth in **FAR 45.202**, Evaluation Procedures, will be used to eliminate any competitive advantage from the use of such property unless the Contracting Officer determines that the use of an evaluation factor would not affect the choice of Contractor.

(End of provision)

b. Occupational Safety and Health Administration's (OSHA) Voluntary Protection program (VPP).

1. AFOSR is in the process of pursuing recognition under the Occupational Safety and Health Administration's (OSHA) Voluntary Protection program (VPP). Include the OSHA website in the solicitation and request offerors use it to familiarize themselves with the VPP program.

2. Contractors are required to provide 3 years of TCIR/DART data with their proposal for Government evaluation.

3. Contractors will be required to provide their Safety Plans within 10 days of award.

c. 252.227-7017 Identification and Assertion of Use, Release, or Disclosure Restrictions.

As prescribed in 227.7103-3(b), 227.7104(e)(2), or 227.7203-3(a), use the following provision:

IDENTIFICATION AND ASSERTION OF USE, RELEASE, OR DISCLOSURE RESTRICTIONS (JUN 1995)

(a) The terms used in this provision are defined in following clause or clauses contained in this solicitation—

(1) If a successful offeror will be required to deliver technical data, the Rights in Technical Data--Noncommercial Items clause, or, if this solicitation contemplates a contract under the Small Business Innovative Research Program, the Rights in Noncommercial Technical Data and Computer Software--Small Business Innovative Research (SBIR) Program clause.

(2) If a successful offeror will not be required to deliver technical data, the Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation clause, or, if this solicitation contemplates a contract under the Small Business Innovative Research Program, the Rights in Noncommercial

Technical Data and Computer Software--Small Business Innovative Research (SBIR) Program clause.

(b) The identification and assertion requirements in this provision apply only to technical data, including computer software documentation, or computer software to be delivered with other than unlimited rights. For contracts to be awarded under the Small Business Innovative Research Program, the notification and identification requirements do not apply to technical data or computer software that will be generated under the resulting contract. Notification and identification is not required for restrictions based solely on copyright.

(c) Offers submitted in response to this solicitation shall identify, to the extent known at the time an offer is submitted to the Government, the technical data or computer software that the Offeror, its subcontractors or suppliers, or potential subcontractors or suppliers, assert should be furnished to the Government with restrictions on use, release, or disclosure.

(d) The Offeror's assertions, including the assertions of its subcontractors or suppliers or potential subcontractors or suppliers, shall be submitted as an attachment to its offer in the following format, dated and signed by an official authorized to contractually obligate the Offeror:

Identification and Assertion of Restrictions on the Government's Use, Release, or Disclosure of Technical Data or Computer Software.

The Offeror asserts for itself, or the persons identified below, that the Government's rights to use, release, or disclose the following technical data or computer software should be restricted:

Technical Data or			
Computer Software			Name of Person
to be Furnished	Basis for	Asserted Rights	Asserting
With Restrictions*	Assertion**	Category***	Restrictions****
(LIST)*****	(LIST)	(LIST)	(LIST)

*For technical data (other than computer software documentation) pertaining to items, components, or processes developed at private expense, identify both the deliverable technical data and each such item, component, or process. For computer software or computer software documentation identify the software or documentation.

**Generally, development at private expense, either exclusively or partially, is the only basis for asserting restrictions. For technical data, other than computer software documentation, development refers to development of the item,

component, or process to which the data pertain. The Government's rights in computer software documentation generally may not be restricted. For computer software, development refers to the software. Indicate whether development was accomplished exclusively or partially at private expense. If development was not accomplished at private expense, or for computer software documentation, enter the specific basis for asserting restrictions.

***Enter asserted rights category (e.g., government purpose license rights from a prior contract, rights in SBIR data generated under another contract, limited, restricted, or government purpose rights under this or a prior contract, or specially negotiated licenses).

****Corporation, individual, or other person, as appropriate.

*****Enter “none” when all data or software will be submitted without restrictions.

Date _____

Printed Name and Title _____

_____

Signature _____

(End of identification and assertion)

(e) An Offeror's failure to submit, complete, or sign the notification and identification required by paragraph (d) of this provision with its offer may render the offer ineligible for award.

(f) If the Offeror is awarded a contract, the assertions identified in paragraph (d) of this provision shall be listed in an attachment to that contract. Upon request by the Contracting Officer, the Offeror shall provide sufficient information to enable the Contracting Officer to evaluate any listed assertion.

(End of provision)

VII. Agency Contacts

Should you have questions about a technical research area, contact the program manager listed for the research topic areas listed in Section I. Should you have questions about the BAA or procedures for submission of a proposal, please email **afosr.baa@afosr.af.mil**.

** Important Notice Regarding Questions of a Business Nature **
All questions shall be submitted in writing by electronic mail.

Questions presented by telephone call, fax message, or other means will not be responded to.

VIII. Additional Information

1. The cost of proposal preparation in response to this Announcement is not considered an allowable direct charge to any resulting award. Such cost is, however, an allowable expense to the normal bid and proposal indirect cost specified in FAR 31.205-18, or OMB Circular A-21, Cost Principles for Educational Institutions or OMB Circular A-122, Cost Principles for Nonprofit Organizations.

2. Every effort will be made to protect the confidentiality of the proposal and any evaluations. The proposer must mark the proposal with a protective legend in accordance with FAR 52.215-1(e), Instructions to Offerors – Competitive Acquisition (Jan 2004), if protection is desired for proprietary or confidential information.

3. Offerors are advised that employees of commercial firms under contract to the Government may be used to administratively process proposals. These support contracts include nondisclosure agreements prohibiting their contractor employees from disclosing any information submitted by other contractors.

4. Only contracting or grants officers are legally authorized to bind the government.

5. AFOSR documents are available on the AFOSR website at **http://www.wpafb.af.mil/AFRL/afosr/**.

6. Responses should reference Broad Agency Announcement BAA-AFOSR-2012-0001.

7. AFOSR expects the performance of research funded by this announcement to be fundamental. DoD Directive 5230.24 and DoD Instruction 5230.27 define contracted fundamental research in a DoD context as follows:

   "Contracted Fundamental Research. Includes [research performed under] grants and contracts that are (a) funded by budget Category 6.1 ("Research"), whether performed by universities or industry or (b) funded by budget Category 6.2 ("Exploratory Development") and performed on-campus at a university. The research shall not be considered fundamental in those rare and exceptional circumstances where the 6.2-funded effort presents a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense, and where agreement on restrictions have been recorded in the contract or grant."

8. Federal Awardee Performance and Integrity Information System (FAPIIS)

There is a Government-wide policy on the use of the Federal Awardee Performance and Integrity Information System (FAPIIS) in the award of contracts and grants that may affect the agencies' processes for judging proposed recipients to be qualified to receive contracts and financial assistance awards. The policy implements requirements of section 872 of the Duncan Hunter National Defense Authorization Act for fiscal year 2009 (Public law 110-417). For additional background information, see the Supplementary Information section in OMB's proposal of the policy for comment, which appeared in the Federal Register on February 18, 2010 [FR 7316]. Note that the particulars of the proposed guidance and specifics of its application to grants may change when OMB issues the final guidance.

9. CCR Registration

Prospective awardee shall be registered in the CCR database prior to award, during performance, and through final payment of any award resulting from this announcement. Offerors may obtain information on registration and annual confirmation requirements via the Internet at http"//www.ccr.gov or by calling 1-888—227-2423, or 269-961-5757 CR Registration.

Awardees must:

(1) Be registered in the Central Contractor Registration (CCR) prior to submitting an application or proposal;

(2) Maintain an active CCR registration with current information at all times during which it has an ative Federal award or an application or proposal under consideration by an agency; and

(3) Provide its DUNS number in each application or proposal it submits to the agency.

10. Reporting Subawards and Executive Compensation.

Reporting of first-tier subawards.

Applicability. Unless you are exempt (in the previous tax year, you had gross income, from all sources, under $300,000) you must report each action that obligates $25,000 or more in Federal funds that does not include Recovery funds (as defined in section 1512(a)(2) of the American Recovery and Reinvestment Act of 2009, Pub. L. 111–5) for a subaward to **http://www.fsrs.gov**.

11. OMBUDSMAN

(a) An ombudsman has been appointed to hear and facilitate the resolution of concerns from offerors, potential offerors, and others for this acquisition. When requested, the ombudsman will maintain strict confidentiality as to the source of

the concern. The existence of the ombudsman does not affect the authority of the program manager, contracting officer, or source selection official. Further, the ombudsman does not participate in the evaluation of proposals, the source selection process, or the adjudication of protests or formal contract disputes. The ombudsman may refer the party to another official who can resolve the concern.

(b) Before consulting with an ombudsman, interested parties must first address their concerns, issues, disagreements, and/or recommendations to the contracting officer for resolution. Consulting an ombudsman does not alter or postpone the timelines for any other processes (e.g., agency level bid protests, GAO bid protests, requests for debriefings, employee-employer actions, contests of OMB Circular A-76 competition performance decisions).

(c) If resolution cannot be made by the contracting officer, concerned parties may contact the Center/MAJCOM or AFISRA ombudsmen,

Ombudsman: Ms. Barbara G. Gehrs HQ AFRL/PK, Wright-Patterson AFB OH. telephone: (937) 904-4407

Email: Barbara G. Gehrs@afrl.af.mil. Concerns, issues, disagreements, and recommendations that cannot be resolved at the MAJCOM/DRU or ARISRA level, may be brought by the concerned party for further consideration to the Air Force ombudsman, Associate Deputy Assistant Secretary (ADAS) (Contracting), SAF/AQC, 1060 Air Force Pentagon, Washington DC 20330-1060, phone number (703) 588-7004, facsimile number (703) 588-1067.

(d) The ombudsman has no authority to render a decision that binds the agency.

(e) Do not contact the ombudsman to request copies of the solicitation, verify offer due date, or clarify technical requirements. Such inquiries shall be directed to the Contracting Officer.

12. Grant Payment Process

(1) Effective 1 November 2011, the Air Force Office of Scientific Research no longer sets up automatic payments for Grants to educational and nonprofit recipients. Therefore, all Grantees must access Wide Area Workflow (WAWF) and complete WAWF's Standard Form (SF) 270, Request for Advance or Reimbursement, for payment. Grantees should submit SF 270s as expenses occur; however, Grantees should have no more than one month cash on hand at any given time.

(2) Each Grantee must register with WAWF at https://wawf.eb.mil. To begin the registration process, click on the accept button at the bottom of the page. WAWF will display the login page with a block for new users with hyperlinks to instructions for "Pre-registration for Vendors" and the actual registration link.

Please note that each Grantee must be registered in CCR and have an Electronic Business Point of Contact set up to approve new registrations within their Institution. Each Grantee will also need to set up a Group Administrator (GAM) to register their CAGE Code and DUNS number, in addition to setting up an organizational email address for email notification from WAWF advising on the status of vouchers submitted for payment. The Grantee will also need to contact the WAWF Help Desk to register their CAGE code within the WAWF system. WAWF Help Desk information is available at the WAWF web site.

(3) If you encounter any problems with your WAWF registration please click on "Vendor Customer Support" in the blue bar at the bottom of the login page. This link will provide phone numbers and an email address to the WAWF Help Desk.

(4) Please direct questions regarding changes in the invoicing process to Dorothy Howe at 703-588-8618 or Dorothy.Howe@afosr.af.mil. Please direct all WAWF questions to Vendor Customer Support.

13. Prohibition Against Contracting with Corporations that have an Unpaid Delinquent Tax liability or Felony Conviction under Federal Law

Offerors should be aware that: OUSD (AT&L) DPAP Memo, Class Deviation, 23 Jan 12 **http://www.acq.osd.mil/dpap/policy/policyvalult/USA0077336-11-DPAP.pdf** precludes Contracting Officers from awarding FY12 funds to any corporation that has an unpaid delinquent tax liability or felony conviction under Federal law. This requirement, applicable to contracts and requiring a certificate from offerors, has not yet been implemented for grants. However, because Public law 112-74 does include grants, it is anticipated that OMB guidance for grant implementation will occur during the period this BAA is active.

14. AFOSR Policy on No Cost Extensions (NCE's)

AFOSR grants NCE's only in situations in which the extension is truly warranted and properly documented. AFOSR Agency Specific Requirements, 1 July 2008, which are incorporated into every AFOSR grant by reference, require prior written approval "to extend the period of performance, without additional funds, beyond the expiration date of the grant." For an extension to be granted, Articles 2 and 15 of the AFOSR Specific Requirements indicate recipients are to provide notice "in writing and with the supporting reasons and revised expiration date at least thirty (30) days prior to the expiration of the award." In no event will the period of performance be extended merely for the purpose of using unobligated balances. Institutions should make every effort to insure work is completed on time. If an institution deems an NCE is truly warranted, it should submit its request for an extension and supporting reasons to the relevant Program Manager.