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-AFRL/AFOSR-2015-0001

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This announcement remains open until superseded.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. While proposals overall may be submitted at any time, specific topic instructions may recommend proposal submission by specific dates in accordance with (IAW) anticipated funding.

7. **Additional Overview**

The Air Force Office of Scientific Research (AFOSR) manages the basic research investment for the U.S. Air Force. 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 U.S. Air Force 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 U.S. 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 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. Additionally, the office fosters, supports, and conducts research within Air Force, university, and industry laboratories; and ensures transition of research results to support U.S. Air Force 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 two scientific Departments: Engineering and Information Science (RTA) and Physical and Biological Sciences (RTB). The research activities managed within each Department are summarized in this section.

a. Engineering and Complex Systems (RTA1):

The Engineering and Complex Systems team within the Engineering and Information Science Branch leads the discovery and development of the fundamental and integrated science that advances future air and space flight. The broad goal of the division 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. A wide range of fundamental research addressing electronics, fluid dynamics, materials, propulsion, and structural mechanics are brought together in an effort to increase performance and achieve unprecedented operational capability. The division 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 U.S. Air Force.

The central research direction for this team focuses on meeting the basic research challenges related to future air and space flight by leading the discovery and development of fundamental science and engineering in the following research areas:

1) Aerothermodynamics, Dr. Ivett Leyva
2) Dynamic Materials and Interactions, Dr. Jennifer Jordan
3) Energy and Combustion Sciences, Dr. Chiping Li
4) GHz-THz Electronics, Dr. Kenneth Goretta
5) Low Density Materials, Dr. Joycelyn Harrison
6) Multi-Scale Structural Mechanics and Prognosis, Dr. David Stargel
7) Optoelectronics and Photonics, Dr. Gernot S. Pomrenke
8) Space Power and Propulsion, Dr. Mitat A. Birkan
9) Test Science for Test and Evaluation, Dr. Michael Kendra
10) Turbulence and Transition, Dr. Rengasamy Ponnappan

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

1) Aerothermodynamics

Program Description: The Aerothermodynamics portfolio seeks to cover key gaps on the fundamental scientific knowledge of high-speed, high temperature nonequilibrium flows required for enabling future U.S. Air Force capabilities including energy-efficient air and space systems, rapid global and regional response, and thermal/environmental management.

Research supported by this portfolio seeks to discover, characterize and leverage fundamental energy transfer mechanisms within high Mach number flows, shock interactions with boundary layers and other shocks, and flow-structure interactions, through a balanced investment in experimental, numerical and theoretical efforts.

Basic Research Objectives: Proposals are encouraged which leverage recent breakthroughs in other scientific disciplines and foster rapid research advancements. It is encouraged that proposed efforts contain a balanced combination of experiments, computations and theoretical efforts. For any experiments proposed, explain how they capture the most sensitive variables for the problem being studied and how they can be used for validation of numerical models. For any numerical efforts explain which the hardest variables to accurately predict are and how the results will be validated with relevant measurements. Innovative research is sought in all aspects of high Mach number, high temperature, nonequilibrium flows with particular interest in:

- Shock/Boundary Layer, Shock-Shock, and Shock-Separation interactions for both external surfaces, and at the inlet and isolators for scramjets
- Flow-structure interactions at hypervelocity conditions with special emphasis to create a balance between relevant experiments and state-of-the-art computations
- Develop physics-based models for air ro-vibrational-dissociation and ro-vibrational-translational processes that can 1) be incorporated in CFD solvers without incurring orders of magnitude more time to solve a given problem and 2) be validated with experiments
- Characterization and modeling of fundamental processes occurring between nonequilibrium flows and ablative surfaces.

Aerothermodynamics research is critical to the U.S. Air Force's interest in long-range and space operations. The size, weight, and performance of many systems, are strongly influenced by aerothermodynamics. Research areas of interest emphasize the characterization, prediction and control of critical phenomena to provide the scientific foundation for game-changing advancements in aerodynamics, thermal and acoustic management, propulsion, and directed energy.
Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss the current state-of-the-art, how the proposed effort is different from prior and current AFOSR programs in related areas, how the proposed effort would advance the state-of-the-art, and the approximate yearly cost for a 3-5 year effort.

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2) Dynamic Materials and Interactions

Program Description
The objective of the Dynamic Materials and Interactions portfolio is to develop fundamental scientific knowledge of the dynamic chemistry and physics of complex materials, particularly energetic materials. The portfolio focuses on energetic materials science and shock physics of heterogeneous materials. Research supported by this portfolio seeks to discover, characterize, and leverage (1) fundamental chemistry, physics, and materials science associated with energetic materials; and (2) fundamental shock physics and materials science associated with complex, heterogeneous materials. The research will be accomplished through a balanced mixture of experimental, numerical, and theoretical efforts. This is required for revolutionary advancements in future Air Force weapons and propulsion capabilities including increased energy density and survivability in harsh environments.

Basic Research Objectives:
Research proposals are sought in all aspects of the chemistry and physics of energetic materials with particular emphasis placed on chemistry-microstructure relationships and the exploitation of fundamental shock physics in heterogeneous materials. Efforts that leverage recent breakthroughs in other scientific disciplines to foster rapid research advancements are also encouraged. Topics of interest include, but are not limited to, the following:

- Mesoscale experiments, and associated models, to understand initiation in energetic materials;
- Predictive processing-structure-property relationships in energetic materials, including reactive materials by design;
- Detonation physics, particularly the steady state reacting front propagating in energetic materials;
- High strain rate and shock response of polymers, composites, and geologic materials;
- Shock loading and mechanical response of energetic crystals;
- High energy density materials that overcome the CHNO limitations, including scale-up techniques required for gram-scale characterization of materials;
- Bridging length scales in energetic and other heterogeneous materials.

Energetic materials research is critical to the development of next-generation Air Force weapon capabilities. The energy content and sensitivity of these systems are influenced by the energetic materials utilized. Research areas of interest emphasize the characterization, prediction, and control of critical phenomena which will provide the scientific foundation for game-changing advancements in munitions development and propulsion.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss the current state-of-the-art, how the proposed effort would advance it, and the approximate cost for a three to five year effort.

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3) GHz-THz Electronics

Program Description: This program seeks scientific breakthroughs in materials and devices that can lead to game-changing capabilities in RF sensing and amplification, transmit/receive functions, wideband operation, reconfigurability, and novel functionality. The primary frequencies of interest range from GHz to THz.

Basic Research Objectives: The focus of the portfolio is on understanding and exploiting fundamental interactions of electrons and quasiparticles with each other and their host materials in all regions of device operation. Technical challenges include understanding and controlling (1) interactions between particles/quasiparticles and the host lattices, boundaries, and defects, including thermal effects and changes over time that limit lifetime and performance; (2) carrier velocity; (3) dielectric properties and electric field distributions within the dielectrics; and (4) new methods of device operation that do not rely solely on conventional transistors or transport mechanisms such as drift, diffusion, and tunneling. Included are carrier transport and properties in regimes in which transport is not limited by scattering mechanisms. Efficiency, volume, and raw speed matter, but other figures of merit, such as speed or energy of computation, are also of interest. A subarea of interest is two-dimensional materials other than graphene as enablers for high-speed electronics, with focus on bandgap engineering and the unique properties of these materials and heterostructures as basic building blocks for new devices. Research into devices based on materials that perform multiple electronic, magnetic, and optical functions is of interest. It is expected that in order to fully understand the various new phenomena and device configurations, novel techniques to study and control nanoscale structures, defects, and operations must be developed.

Before developing white papers or full proposals, researchers are highly encouraged to contact the Program Officer to discuss the current state-of-the-art, how the proposed effort would advance it, and the approximate cost for a three- to five-year effort.

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4) Energy and Combustion Science

Program Description: This portfolio addresses energy needs for propulsion systems and their supporting sub-systems. The portfolio emphasizes three key attributes: Fundamental, Relevant, and Game-Changing, focusing on establishing fundamental understanding and quantifying rate-controlling processes in Air Force relevant energy processes, leading to game-changing concepts and predictive capabilities in Air Force relevant regimes. Multi-disciplinary collaborations and interactions are strongly desired, and joint experimental, theoretical and numerical efforts are highly appreciated.

Researchers are encouraged to submit white papers (max 4 pages) via email prior to developing full proposals. White papers should describe innovative nature (advancing the state of art) of the proposed efforts, focusing on clearly presenting logics and underlying scientific basis of the proposed approach. Researchers with white papers showing significant fundamental, relevant, and game-changing attributes will be invited to submit full proposals.

Basic Research Objectives: Research proposals are sought in all aspects of Air Force relevant energy storage/conversion research, combustion and otherwise and evaluated according to their strength in fundamental, relevant and game-changing aspects, with the following emphases:

(1) Turbulent Combustion: the primary energy conversion process in most existing propulsion systems such as jet engine, rocket, hypersonic and large UAV systems. It is one of most important processes 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 is on quantifying rate-controlling processes and scales. Proposals will be considered with priority in the following areas:

- Understanding key turbulent combustion phenomena: Including but not limited to: flame structure and propagation, flammability limit, combustion instability, and ignition. Understanding, quantifying and controlling turbulence properties of the underlying flow conditions are essential. Those conditions should be relevant to Air Force propulsion interests, with emphases on highly-turbulent, high-pressure, multiphase and trans-/super-critical conditions relevant to future Air Force propulsion systems.

- Establishing physics-based foundation for predictive turbulence combustion models: based on the first principle and experimental observation/data closely reflecting key features of the underlying phenomena to be modeled, validating and further developing basic model assumptions that are key model building blocks, with a particular emphasis on understanding and quantifying impacts of combustion and fluid processes at sub-grid scales on those at LES resolvable scales, leading to the scientific foundation for developing and validating scientifically and properly constructed sub-grid turbulence combustion models;

- Diagnostics for (1) New game-changing signal generating processes and related basic spectroscopic approaches for key physical and chemical properties in chemically reacting flows; (2) High-frequency, 3-d (volumetric or scanning 2-d) imaging for transient, turbulent flame and flow structures at required temporal and spatial scales. In the both

above (1) and (2), there are strong interests in diagnostics at high pressure multiphase and trans-/super-critical conditions relevant to future Air Force propulsion systems;

- Numerical algorithms and tools for (1) Addressing specific needs in simulations for the turbulent reacting flows due to its complex multi-physics nature and (2) Combined experimental-numerical approaches using simulations directly coupled with experimental data to reduce the simulation uncertainty and to obtain quantitative information which is otherwise not available through experimental measurements alone.

(2) Combustion Chemistry: the key element governing the underlying molecular system changes and energy conversion in the combustion process. The research focuses on developing physics-based approaches for identifying rate-controlling reaction pathways and building combustion chemistry models of quantifiable and acceptable uncertainty with reasonable size for the turbulent, reactive flow simulation. Emphasized areas are as follows:

- Physics based (experimental, theoretical and computational) approaches to understand the combustion process of complex molecular systems such as real HC fuels, including jet fuels consisting of many molecular components, focusing on identifying, describing and quantifying key stochastic reaction pathways in those complex combustion chemical reaction systems and developing a new generation of accurate and computational efficient reaction mechanisms based on those key reaction pathways;

- Experimental techniques and diagnostics: (1) Ultra-fast (e.g. using ultra-short pulse laser) and other optical approaches for quantitatively observing histories of species, temperature and properties in key parts of the combustion processes such as those in the initial break-up of fuel molecules crucial to identifying key reaction pathways in the jet fuel combustion (2) Other necessary experiments for identifying reaction pathways and quantifying reaction model parameters;

- Quantifying the uncertainty of research approaches in combustion chemistry and resulting models, especially in the following aspects: (1) Uncertainties due to the empiricism and ad hoc features with the purpose of minimizing such empiricism and ad hoc features, (2) Understanding relationship between the model size and model uncertainty and (3) Uncertainties in combustion chemistry experiments;

- Ab initio constrained approaches for optimization and reduction of combustion chemistry models.

(3) Game-Changing Energy Conversion Processes and Energy Storage Concepts: Here, we are looking for innovative, unconventional fresh approaches to store and convert energy for aviation and other Air Force relevant applications. Potential sub- areas include but not limited to:

- Combustion at extreme time-scales such as detonation and flameless/ mild combustion;

- Innovative thermal-dynamic or energy conversion cycles, particularly for UAVs;

- Non-thermal, reduced-thermal and hybrid energy conversion processes, possibly of non-equilibrium nature, for future propulsion and subsystems.

- Multi-functional energy conversion processes: (1) Understanding/quantification of energy needs and conversion processes in propulsion-supporting subsystems such as resource supply, control, sensing, guidance and navigation as well as information processing and establishing the thermodynamics foundation for those sub-systems and processes and (2) Approaches and algorithms for minimizing the energy consumption of those sub-systems;

- Multi-functional fuels: (1) Endothermic fuels and systems and (2) Aviation fuels and energy systems with favorable source characteristics.

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5) Low Density Materials

Program Description: Reducing the weight of aerospace platforms reduces costs and emissions while increasing payload capacity and performance. The AFOSR Low Density Materials portfolio supports transformative, basic research in materials design and processing to enable weight reductions with concurrent enhancements in performance and function. Such materials can transform the design of future U.S. Air Force aerospace and cyber systems for applications which include airframes, space vehicles, satellites, and load-bearing components and systems. Key scientific areas supported by the program include: materials discovery, processing and characterization; nanotechnology; integrated computational material science and engineering; composite and hybrid materials processing; and interface/phase science.

Among the routes to achieving game-changing improvements in low density materials currently emphasized within the program are 1) materials discovery and processing to increase performance properties of structural materials, e.g., matrix resins and reinforcing fibers and nanoparticulates; 2) multiscale modeling of material degradation mechanisms to improve material life prediction capability and minimize overdesign of load-bearing structures; 3) understanding the impact of nanoscale porosity on mechanical properties; and 4) the creation and interfacial understanding of hybrid structures that combine materials of different classes, scales, and properties to provide synergistic and tailorable performance.

Basic Research Objectives: 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 materials that may engender multifunctionality such as high

strength plus electrical and thermal transport properties and/or adaptivity to enable active aerospace structures is also a keen program interest. Material classes may be polymeric, ceramic, or metallic, possibly combining synthetic and biological species to engender lightweight structural integrity and multifuctionality.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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6) Multi-Scale Structural Mechanics and Prognosis

Program Description: This fundamental basic research program addresses the U.S. 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 U.S. 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.

Basic Research Objectives: 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.

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 contact the Program Officer prior to developing full proposals to briefly discuss 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.

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7) Optoelectronics and Photonics

Program Description: This program supports Air Force requirements for information dominance by increasing capabilities in image and data capture, processing, storage, and transmission for applications in surveillance, communications, computation, target discrimination, and autonomous navigation. 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 with low power, low weight, and small sized components. Five major areas of interest include Integrated Photonics (including Silicon Photonics); Nanophotonics (including Plasmonics, Photonic Crystals, Metamaterials, Metaphotonics and Novel Sensing); Reconfigurable Photonics (including all-optical switching and logic, and optoelectronic computing); Nanofabrication, 3-D Assembly, Modeling and Simulation Tools for Photonics; and Quantum Computing using Optical Approaches.

Basic Research Objective: The major objective is to push the frontiers of optics and explore new fundamental concepts in photonics; understand light-matter interactions at the sub-wavelength and nano-scale; investigate novel optoelectronic materials; improve the fundamental understanding of photonic devices, components, and architectures; and enable discovery and innovation in advancing the frontier of nanophotonics with the associated nanoscience and nanotechnology.

The thrusts in Integrated Photonics 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 technology approaches (such as silicon photonics, tin based Group IV photonics, Graphene and related 2D materials and novel III-V optoelectronics) 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 and 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, quantum plasmonics and quantum Metamaterials, plus novel approaches to ultra-low power optoelectronic devices.

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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8) Space Power and Propulsion

Program Description: Research activities are focused as multi-disciplinary, multi-physics, multi-scale approach to complex problems, and fall into four areas: Coupled Material and Plasma Processes Far From Equilibrium, Nanoenergetics, High Pressure Combustion Dynamics, and Electrospray Physics

Basic Research Objectives: Research in the first area is to significantly advance the state-of-the-art in our ability to understand the fundamental aspects of a coupled plasma/material system in non-equilibrium states, for a variety of potential applications. The typical conditions of interest are characterized by critical phenomena in small spatial and temporal scales which affect the behavior over a much wider range of scales. Detailed understanding and control of non-equilibrium and multiscale effects have the potential to overcome the limitations of traditional plasma in thermodynamic equilibrium, leading to improved system designs; preventing or leveraging dynamic features such as instabilities, coherent structures, and turbulence; and realizing chemical pathways, structural changes or electromagnetic processes for novel devices with unprecedented level of control. Research in second area is the ability to possess smart, functional nano-energetics for propulsion purposes only. There has been tremendous progress in the synthesis and fabrication of nanosized reactive materials. With significant advances in quantum chemistry and molecular dynamics over the last decade, as well as a broader understanding of the properties of nanomaterials, it may now be feasible to design a priori nanostructured reactive materials to perform a given function and then produce them in the laboratory according to the design, in order to avoid simply reacting in an uncontrolled fashion. Smart nanoenergetics may be activated by temperature, pressure, the presence of a particular chemical compound, or external electromagnetic stimuli, such as an electrical field or light. By smart, it may be desirable to initiate a reaction at a particular temperature, to release a particular compound at a particular temperature, to turn on or turn off a reaction, have tailored ignition properties, or to accelerate or slow a reaction with time or location. Research in the third area is to allow the Air Force to capitalize on the higher efficiencies, and increased performance options made possible by taking rocket and other propulsion systems to increasingly extreme pressures. As this necessarily pushes materials and structures to correspondingly extreme limits, it becomes essential to take into consideration the dynamics of combustion processes, because higher pressures lead to increasing coherent dynamic aerothermochemical events that convert thermal energy to thrust in a wider spectrum of time scales. Mathematical and experimental analysis also leads to a "big data" problem. It becomes necessary to combine and dynamically integrate multi-fidelity simulations and experimental probing or monitoring to systematically perform modeling, analytics, stochastic modeling, and dynamic data driven validation for chemical propulsion. Research in fourth area involves charged droplets and molecular ions that are emitted from the meniscus of a conducting liquid due to a strong electric field. A sufficiently strong electrostatic stress can cause either of two behaviors: (1) an aerosol of charged liquid droplets can be extracted from the surface and accelerated away by the field, or (2) single molecular or atomic ions can be ‘field evaporated’ from the liquid into the gas phase and accelerated away by the field. Research is sought to control multiphase liquid electrospray that can be used for nanoenergetic material processing, propulsion, and other applications.

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. Researchers are highly encouraged to consult (**https://community.apan.org/afosr/w/researchareas/default.aspx**), for the latest information.

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9) Test Science for Test and Evaluation (T&E)

Program Description: The T&E program supports basic research which will build the foundation for future revolutionary capabilities that address the identified needs of the T&E Community. As new technologies emerge, the ability to test new capabilities as they are assimilated into applied R&D is a critical part of the development process. The T&E Program sponsors basic research in areas that enable such testing and areas that allow the correct and comprehensive interpretation of test results. Fast and effective Test Science and Test Engineering lead to: improved ability to identify problems, understand causes, and recommend solutions; reduced product development time; improved quality; improved performance; better acquisition program decisions; increased acquisition program flexibility; meeting schedule deadlines; reduce test-and-fix cycle costs; reaching or exceeding performance goals; and superior products. The current T&E Program encompasses five broadly-defined, overlapping thrust areas: Hypersonics, Aeroelasticity and Aerodynamics, Sensors and Electromagnetics, Information and Data Management and Fusion, and Enabling Materials. The Program is closely aligned with many other AFOSR program interests, but with special emphasis on aspects of basic research that lead to revolutionary advances in areas such as metrology and test science.

Basic Research Objectives: The T&E Program is closely engaged with technical experts at Air Force Developmental Test and Evaluation organizations located at Edwards, Arnold, and Eglin Air Force Bases, who help advise the program on basic research objectives. Basic research in areas that advance the science of testing is broadly defined and spans mathematics as well as most disciplines in engineering and the physical sciences. Areas include:

- Novel measurement techniques, materials, and instruments that enable accurate, rapid, and reliable test data collection of physical, chemical, mechanical, and flow parameters in extreme environments, such as those encountered during transonic flight, hypersonic flight, and the terminal portion of weapons engagement
- Accurate, fast, robust, integratable models of the aforementioned that reduce requirements to test or help provide greater understanding of test results
- Advanced algorithms and computational techniques that are applicable to new generations of computers, including massively parallel, quantum, and neuromorphic machines
- Advanced algorithms and test techniques that allow rapid and accurate assessment of devices and software to cyber vulnerability
- New processes and devices that increase bandwidth utilization and allow rapid, secure transfer of test data to control facilities during test, with special emphasis on telemetry
- Advanced mathematical techniques that improve design of experiment or facilitate confident comparison of similar but disparate tests
- Advanced models of test equipment and processes that improve test reliability and efficiency
- New or advanced technologies that enable the test process

- Basic research in other T&E technical areas that advances the science of test and contributes to the development of knowledge, skills, and abilities of the established or emerging AF T&E workforce.

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10) Turbulence and Transition

Program Description: The Turbulence and Transition portfolio supports basic research and development of the fundamental fluid flow-physics knowledge-base required for revolutionary advancements in a broad variety of future U.S. Air Force capabilities. These include aerodynamically-efficient aerospace systems, rapid global and regional response, and management of hypersonic and high-temperature environments. Research supported by this portfolio seeks to characterize, model, exploit and control critical fluid dynamic phenomena associated with external/internal wall-bounded flows through integrated approaches comprised of experimental, numerical and theoretical efforts.

Basic Research Objectives: Innovative research is sought in all aspects of turbulent and transitional flows with particular interest in efforts that explore the dynamics within high-Mach number viscous flows. Topics of interest include, but are not limited to, the following:

- Turbulence studies – structure and growth, unsteady flow field characterization, effects of micro/macro particles in free stream, wall roughness, curvature, angle of attack, etc.
- Receptivity – initial value versus Eigen value approaches for transition prediction, laminar-turbulent stability, transition and turbulence in high-Mach number boundary layers, especially approaches leading to greater insight into surface heat transfer.
- Multimode transition and flow field – analysis and effects on transition prediction.
- Diagnostics for the flow field – advanced sensing methods/ approaches and tools to measure both the shock layer and the free stream disturbances.

The behavior of viscous flows impacts the performance of all aerodynamic, propulsion, and environmental management systems and frequently determines the environment experienced by the system structure. The development of accurate methods for predicting the behavior of transitional and turbulent flows across a wide range of flow conditions will facilitate the design of future systems with optimized performance and energy-efficiency. Research areas of interest emphasize the characterization, prediction and control of high-Mach number fluid dynamic phenomena which will provide the scientific foundation for game-changing advancements in aerodynamics, environmental (thermal and acoustic) management, propulsion, and directed energy science areas.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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b. Information and Networks (RTA2)

The Information and Networks Team within the Engineering and Information Science Branch is organized to support many U.S. Air Force priority areas including autonomy, space situational awareness, and cyber security. The research programs within this team lead the discovery and development of foundational issues in mathematical, information and network oriented sciences. They are organized along three themes: *Information*, *Decision Making*, and *Networks*. The information theme addresses the critical challenges faced by the U.S. Air Force which lie at the intersection of the ability to collect, mathematically analyze, and disseminate large quantities of information in a time critical fashion with assurances of operation and security. Closely aligned with the mathematical analysis of information is the need for autonomous decision making. Research in this theme focuses on the discovery of mathematical laws, foundational scientific principles, and new, reliable and robust algorithms, which underlie intelligent, mixed human-machine decision-making to achieve accurate real-time projection of expertise and knowledge into and out of the battle space. Information analysis and decision making rarely occur in the context of a single source. The networks theme addresses critical issues involving how the organization and interaction among large collections of information providers and consumers contributes to an understanding of the dynamics of complex information systems.

The RTA2 research portfolios and their program officers are listed here:

1) Complex Networks, Dr. James Lawton
2) Computational Cognition and Machine Intelligence, Dr. James Lawton
3) Computational Mathematics, Dr. Jean-Luc Cambier
4) Dynamics and Control, To Be Determined
5) Dynamic Data Driven Applications Systems (DDDAS), Dr. Frederica Darema
6) Information Operations and Cybersecurity, Dr. Tristan Nguyen
7) Optimization and Discrete Mathematics, To Be Determined
8) Science of Information, Computation and Fusion, Dr. Doug Riecken
9) Systems and Software, Dr. Kathleen Kaplan
10) Trust and Influence, Dr. Benjamin Knott

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

1) 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 U.S. Air Force 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, and quantum information theory. Advances in these mathematical methods will then enable specific ways to model, characterize, design, and manage U.S. 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 U.S. Air Force networking, communications, and architectural design problems but may be drawn from techniques in network analysis from a broad set of disciplines including quantum information systems, materials science and statistical mechanics, molecular and systems biology, 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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2) Computational Cognition and Machine Intelligence

Program Description: This program supports innovative basic research on the fundamental principles and methodologies needed to enable intelligent machine behavior in support of autonomous and mixed-initiative (i.e., human-agent teaming) systems. The overall vision of this program is that future computational systems will achieve high levels of performance, adaptation, flexibility, self-repair, and other forms of intelligent behavior in the complex, uncertain, adversarial, and highly dynamic environments faced by the U.S. Air Force. This program covers the full spectrum of computational and machine intelligence, from cognitively plausible reasoning processes that are responsible for human performance in complex problem-solving and decision-making tasks, to non-cognitive computational models of intelligence necessary to create robust intelligent autonomous systems. In the midst of this spectrum are the technologies needed to seamlessly incorporate intelligent computational systems into mixed human-agent teams. The program is divided into three sub-areas that span the full spectrum of computational and machine intelligence. They are: Computational Cognition, Robust Decision Making and Machine Intelligence.

The Computational Cognition sub-area supports innovative basic research on high-order cognitive processes that are responsible for good human performance in complex problem solving and decision making tasks – we only want to model the things people excel at. The sub-area also seeks to support research on building computational systems that derive from and/or integrate cognitive and biological models of human and animal intelligence. The overall objective is to understand and exploit these processes to create computational models that perform as well as or better than the reasoning systems they emulate. 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

The Robust Decision Making sub-area is concerned with the need for mixed human-machine decision making, which appears at all levels of U.S. Air Force operations and pervades every stage of U.S. Air Force missions. To that end, 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. Basic research is needed to produce cognitive systems that are capable of communicating with humans in a natural manner, that build 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 a collaborative manner, achieving comprehensive situation awareness and anticipatory command and control.

The Machine Intelligence sub-area supports innovative basic research on fundamental principles and methodologies of computational intelligence necessary to create robust intelligent autonomous systems. These methodologies are likely to be non-cognitive, taking full advantage of the strengths embodied in mathematical and computational systems, such as the ability of quickly manage vast amounts of data. Robustness in this context is 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 program encourages 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., especially when the research pertains to common issues and when collaboration is likely to generate bidirectional benefits. This program is aggressive, accepts risk, and seeks to be a pathfinder for U.S. Air Force research in this area. Proposals that may lead to breakthroughs or highly disruptive results are especially encouraged.

Basic Research Objectives: The Computational Cognition sub-area seeks basic research to elucidate core computational approaches that pertain to understanding of the mind and brain (human or animal), as well as cognitively plausible mechanisms inspired by human (or animal) reasoning. 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 work that (1) creates cognitively plausible computational frameworks that (semi-)autonomously integrates model development, evaluation, selection, and revision; and (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.

The Robust Decision Making sub-area seeks basic research in the areas of (1) Data collection, processing, and exploitation technologies, including mechanisms to help focus attention, analyze and summarize an overload of information, and support inferences in tasks like recognition and identification; (2) Command and Control (C2) technologies, where there is a need for predicting adversarial behavior, sorting the mixture of human and machine responsibilities, and robust planning and scheduling in dynamic environments; and (3) Situation Awareness technologies, where there is a need for a human-system interface that understands human limitations, prioritizes information presentation, and helps achieves symbiosis between human and machine systems in delegating and coordinating responsibilities. In sum, new empirical and theoretical research is needed that provides a deeper understanding of the cognitive requirements of 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.

The Machine Intelligence sub-area encourages research on building computational systems that enable intelligent behavior based on less-strict cognitive or purely mathematical approaches. The investigative methodology may be theoretical, computational, or experimental, or a combination of thereof. Proposals that lead 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.

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3) 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 U.S. 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 U.S. 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 and biological sciences.

To meet the formidable computational challenges entailed in simulating nonlinear, discontinuous, multi-physics and multi-scale problems of interest to the U.S. 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 (UQ). The active areas of interest in UQ include development of high accuracy stochastic numerical methods, stochastic model reduction and long term time 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.

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4) 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 U.S. 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; and applying control concepts motivated by studies of biological systems. In general, interest in the control of large 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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5) 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 and which can benefit from DDDAS transformative advances, include areas driven by the AF Technology Horizons, Energy Horizons, and Global Horizons reports, such as: 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. DDDAS provides new approaches for combining computational, theoretical, and instrumentation data sets for high interactive testing of multiple physical and engineering hypotheses.

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

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6) Information Operations and Cybersecurity

Program Description: Securing cyberspace, defending against and preventing cyber attacks are not new but have become increasingly pressing in the light of technological advancements. Software and protocols are only becoming more complex to meet application demands. More flexible computing environments such as distributed systems need new ways of thinking to ensure secure end-to-end functionalities even though components are only known to be individually secure. The emergence of nano-scale and quantum computing with various physical realizations and different architectures further compound technological challenges for cybersecurity.

Although engineering practices continue to provide short-term and temporary relieves to these pressing needs, new scientific ideas are required to address the inherent insecurity in cyberspace. Many fundamental concepts are still eluding precise formulation and awaiting rigorous responses. The goal of this Basic Research program is to explore novel, promising ideas and methodologies that can establish a firm scientific foundation for cybersecurity and potentially tackle the difficult technical hurdles put forth in the previous paragraph.

Basic Research Objectives: Mathematical formalisms and logical constructs will likely continue to play a central role in the development of a Science of Cybersecurity. Recent developments and advances in formal semantics, type theory, modern cryptography, interactive and automated theorem proving, logics, programming languages, constructive mathematics, game theory, etc. are expected to provide valuable insights into the modeling, expressing, analyzing, verifying, and reasoning tasks of security policies or goals in terms of their formal properties.

Research areas of interest include, but are not limited to: composition of security properties and protocols in view of distributed interactive systems; primitives for various security mechanisms that can support compositionality; abstract formulations that can unify key security properties of hardware and software aspects; information flow security and noninterference in dynamic and distributed settings; rigorous techniques to enable persistent and secure operations on unsecure systems; new formulations of invariants associated with security properties that can readily be computed and interpreted; rigorous formulation and construction of obfuscation techniques for software programs or hardware architecture designs to enhance security. Many of these research topics are not restricted only to digital technologies.

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7) 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 U.S. 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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8) Science of Information, Computation and Fusion

Program Description: The U.S. 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.

In order to understand and interpret information contained in various data sources, it is necessary to extract relevant pieces of information from these datasets and to make inferences based on prior knowledge. The discovery of relevant pieces of information is primarily a data-driven process that is correlational in nature and, hence, offers point solutions. This bottom-up processing direction needs conceptually-driven reasoning to integrate or fuse the previously extracted snippets of information by leveraging domain knowledge. Furthermore, the top-down process can offer causal explanation or causal inference, generate new hypotheses, verify or test hypotheses in light of observed datasets. Between the data-driven and conceptually-driven ends,

there may reside different levels of abstraction in which information is partially extracted and aggregated based on the nature of applications.

Basic Research Objectives: With the rationale and guiding principles outlined in the above paragraph, this program seeks fundamental research that potentially leads to scientific advancements in informatics and computation which can support processing and making sense of disparate information sources. After all, information processing can formally and fundamentally be described as computing and reasoning on various data structures. Successes in addressing the research sub-areas stated below would give the U.S. Air Force new capabilities to: (1) shift emphasis from sensing to information; (2) understand the underpinning of autonomy; (3) relieve human's cognitive overload in dealing with the data deluge problem; (4) enhance human-machine interface in information processing.

To accomplish the research objectives, this program focuses on, but is not limited to, new techniques in mathematics, computer science, statistics and logic which have potentials to: (1) cope with various disparate and complex data types; (2) construct expressive data structures for reasoning and computation; (3) bridge correlational with causal discovery; (4) determine solutions or obstructions to the local-to-global data-fusion problem; (5) mechanize reasoning and computing in the same computational environment; (6) yield provably efficient procedures to enable or facilitate data analytics; (7) deal with high-dimensional and massive datasets with provably guaranteed performance.

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9) Systems and Software

Program Description: The AF's mission is to "fly, fight, and win in air, space, and cyberspace." In order to accomplish its mission, the AF invests in Systems & Software, which is the keystone of all advanced technology. The Systems & Software program actively searches for ideas with respect to two submissions: 1) Improving current AF systems, and; 2) Introducing cutting-edge research to expand the field of knowledge. Improving current AF systems is needed; the AF's use of legacy systems is well known, along with the detrimental issues of legacy system use. There are many AF systems which have extremely long life cycles (such as combat system software). In order to ensure that these legacy systems are up-to-date, new systems infrastructures are investigated. Additionally, new areas of Systems & Software are encouraged to ensure that the AF continues to be on the cutting-edge of technology; novel areas include entirely new directions that will have significant impact in the future. Overall examples of areas include operating systems, compilers, virtual memory, multi-core platforms, etc. AFOSR is looking for research that will drastically improve current AF systems and help to develop new S&T for the benefit of the nation.

Basic Research Objectives: As stated above, Systems & Software addresses two issues – both the new and the old: 1) New Technology Research (such as, but not limiting to, multi-core and many-core systems), and; 2) Legacy System Research (concerning existing AF systems such as, but not limiting to, operating systems, software, etc.). Since Systems & Software direction is continually changing, i.e., technology life-span of approximately 3 years or less, specific subareas are not specifically stated within this BAA; instead, due to the topical nature of the field, the specific area of research is open to the proposer, as long as the research addresses either issue – New Technology Research or Legacy System Research – in Systems & Software. Any new ideas of either of the two issues are welcomed.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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10) Trust and Influence

Program Description: The Trust and Influence program is motivated by recent technological advances in the area of unmanned and autonomous systems, and the strategic environment that the U.S. Air Force is expected to face in the future; a significant departure from that which has dominated most of its history. The Air Force is facing a broader range of threats that are less predictable, with many conflicts occurring in failed or failing states that include radical extremists and a wide range of non-state actors. Moreover, the rapid advances and proliferation of advanced autonomous systems are expected to fundamentally change the way the Air Force operates. To address these challenges, the Trust and Influence program invests in the development of the theoretical and empirical foundations of reliance and contemporary influence. Specifically, we are concerned with investigating the mechanisms by which humans establish, maintain, and repair trust in other agents, both human and machine. The science of influence or persuasion will expand our understanding for how we might shape the behaviors, attitudes and beliefs of others. The resulting portfolio directly enhances the Air Force's technology development programs, and will impact policies and operations related to national security. Trust and Influence invests in the discovery of the foundational concepts of effective influence, deterrence, trust-building, trust calibration, and counter-terrorism operations. Multi-disciplinary approaches are encouraged, to include cognitive science, neuroscience, anthropology, sociology, linguistics, economics, computer science and mathematics. Research designs that incorporate laboratory studies, modeling or field research leading to transformative novel theories are also encouraged.

Basic Research Objectives: The basic research interests under this program can be defined broadly by three areas: trust in autonomous systems, cross-cultural trust, and socio-digital influence. In the area of *trust in autonomous systems* there is particular interest in (1) empirical studies to examine drivers of trust between humans and intelligent, autonomous or robotic

agents, (2) laboratory and field studies to examine the impact of socially-designed cues or physical features such as appearance, voice, personality, and other social elements on human trust and system performance, (3) development of trust metrics and other relevant constructs in human-machine teaming with a particular focus on real-time and dynamic assessment, and (4) modeling of human-machine teaming that supports adaptive and continuous improvement of joint performance in complex environments. In the area of *cross-cultural trust*, there is interest in (1) developing theories of interpersonal and organization trust that account for various cultural constructs and characteristics, (2) revealing the antecedents of trust in cross-cultural interactions, and (3) cultural differences in complex human-machine interaction. In the area of *socio-digital influence* there is a need for (1) laboratory and field studies to reveal sources of influence and persuasion in social media and across different cultural groups, (2) social, cognitive, and neural mechanisms of influence and persuasion (3) modeling and measuring the relationship between online and real-world behaviors, (4) empirical studies to discover new theories of influence as it pertains to the cyber domain, and (5)understanding the behavioral effects of influence tactics such as foreign policies or developmental activities.

Researchers are encouraged to contact the Program Officer prior to developing full proposals to discuss alignment of the researchers' ideas with program goals, their proposed methods and scope of the proposed effort.

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c. Physical Sciences (RTB1)

The Physical Sciences Team leads the discovery and transition of foundational physical science to enable air, space, and cyber power. Research in physics generates the fundamental knowledge needed to advance U.S. Air Force operations, from the perspective of sensing, characterizing, and managing the operational environment as well as developing advanced devices that exploit novel physical principles to bring new capabilities to the warfighter. Research directions are categorized in the following four broad areas, with the focus on advancing our basic understanding of the physical world: (1) quantum matter and devices; (2) plasma and high-energy density physics; (3) optics and electromagnetics; and (4) aerospace materials and flow physics.

The Physical Sciences Team research portfolios and their program officers are listed here:

1) Aerospace Materials for Extreme Environments, Dr. Ali Sayir
2) Atomic and Molecular Physics, Dr. Tatjana Curcic
3) Electromagnetics, Dr. Arje Nachman

4) Flow Interactions and Control, Dr. Douglas Smith
5) Laser and Optical Physics, Dr. John Luginsland
6) Plasma and Electro-Energetic Physics, Dr. Jason Marshall
7) Quantum Electronic Solids, Dr. Harold Weinstock
8) Remote Sensing and Imaging Physics, Dr. Julie Moses
9) Sensing, Surveillance and Navigation, Dr. Arje Nachman
10) Space Science, Dr. Kent Miller
11) Ultrashort Pulse Laser-Matter Interactions, Dr. Enrique Parra

Research of interest to these sub areas is described in detail below:

1) Aerospace Materials for Extreme Environments

Program Description: The objective of basic research in Aerospace Materials for Extreme Environments is to provide the fundamental knowledge required to enable revolutionary advances in future U.S. Air Force technologies through the discovery and characterization of materials for extreme temperatures (exceeding 1000°C), other extreme environments of stress-, magnetic-, electric-, microwave-, and ultrasound fields. Interest domain includes the fundamental science of single crystals, heterogeneous structures, interface of phases and grain boundaries. Materials of interest are ceramics, metals, hybrid systems including inorganic composites that exhibit superior structural, functional and/or multifunctional performance.

Basic Research Objectives: The function within a specific time domain of interest profoundly important and response characteristics defines the material more importantly than generalized properties. The following research concentrations are selected to highlight the aforementioned philosophy about function, environment and state of the materials that could create disruptive source of transformations.

- **Predictive Materials Science:** Simulation-based materials design has the potential to dramatically reduce the need for expensive down-stream characterization and testing. Currently, we don't even have a good grasp of how combining materials into particular compounds gives them certain properties, or how these properties give materials functional qualities. Often the modeling approaches make casual inference about the microstructural features. 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. The quality of computerized representation of microstructures and models will be measured by its (a) geometric accuracy, or faithfulness to the physical landscape, (b) complexity, (c) structure accuracy and controllability (function), and (d) amenability to processing and high level understanding. In order to satisfy this objective, the approaches may require development of an accurate methodology for the quantification of 3-Dimensional shapes in both experimental and theoretical microstructures in heterogeneous systems, and to establish a pathway for an accurate comparison tools (and metric).

- **Materials Response Far from Equilibrium**: The transformative breakthrough has not originated from the investigations of materials in equilibrium state but in contrary at the margins of the disciplines. In this context, this program embraces materials that are far from the thermodynamic equilibrium domain; bulk metallic glasses, highly doped polycrystalline laser materials, adaptive oxides, multiferroics, supersaturated-, frustrated structures (quasi-two-dimensional electron gas of layered structures). The aim is to link an effective property to relevant local fields weighted with certain correlation functions that statistically exemplify the structure and demonstrate clear scientific pathway to create new materials with specific tailorable properties. This subtopic area require elucidation of complex interplay between (first order) phase transitions for electronic/magnetic phase separation and untangle the interdependence between structural, electronic, photonic and magnetic effects. Realization of the 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.

- **Combined External Fields**: This portfolio stresses a fundamental understanding of external fields and energy through the materials microstructure at a variety of time scales and in a variety of conditions. This area includes a wide range of activities that require understanding and managing the non-linear response of materials to combined loads (i.e., thermal, acoustic, chemistry, shear or pressure fields) under high energy density non-equilibrium extremities. One example of this this objective is the interest to expand the scientific understanding of high electrical field applications through the incorporation of the new mathematical enterprises that captures the dynamic relationship between structure and properties across the space and time scales that exist at the hetero-interface. Another example is 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 thermal conduction, convection, and radiation physics. As a whole, this subtopic also aims to expand the scientific base for understanding the formation, control, and mitigation of structures in external fields and use this scientific base to design and build materials far from equilibrium as well as thermodynamically stable structures.

It is important to consider cross-disciplinary teams with material scientist and engineers in collaboration with mathematicians, statisticians, and physicist, and chemist, etc., are encouraged. While single investigator and multidisciplinary team proposals also are encouraged and will be considered on a case by case basis.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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2) Atomic and Molecular Physics

Program Description: This program encompasses fundamental experimental and theoretical Atomic and Molecular physics research that is primarily focused on studies of cold and ultra-cold 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 U.S. Air Force, including precision navigation, timekeeping, remote sensing, secure communication, metrology, and novel materials for the U.S. Air Force needs in the future.

Basic Research Objectives: 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 quantum 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.

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) Electromagnetics

Program Description: This portfolio supports research in Electromagnetics (EM) whose objective is the interrogation (modeling/simulation) of linear/nonlinear Maxwell's equations.

Basic Research Objectives: Basic research 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 is encouraged. Basic research in inverse scattering theory in order to promulgate new methods which recognize and track targets or upgrade efforts to pursue Nondestructive Evaluation is encouraged. Efforts to identify suitable wideband radar waveforms to penetrate foliage, clouds, buildings, the ionosphere, or other dispersive/random/turbulent

media as well as to design transmitters to produce such waveforms are 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 encouraged. In the area of nonlinear Maxwell's equations, commonly called nonlinear optics, research 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 (particularly the modeling/simulation of nonequilibrium carrier dynamics within semiconductor lasers) 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 portfolios within AFOSR. 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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4) Flow Interactions and Control

Program Description: The Flow Interactions and Control portfolio supports basic research into the dynamics and control of aerodynamic shear flows, including the interactions of these flows with rigid and flexible surfaces. The portfolio is interested in aerodynamic interactions arising in both internal and external flows and extending over a wide range of Reynolds numbers. 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. Research in this portfolio is motivated, in part, by the unique fluid-structure interactions that are found in nature, in vortex and shear layer flows, and on novel aerodynamic configurations.

Basic Research Objectives: 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 surfaces in actuated motion, rigid and flexible aerodynamic surfaces, vortical flows, and flows with novel geometric configurations. Note however that basic research of the variety typically funded by the portfolio may not yet have a clear transition path to an application. The portfolio maintains an interest in the dynamic interaction between unsteady fluid motion, nonlinear structural deformations, and aerodynamic control effectors for a wide range of flight regimes. Although the portfolio places a strong emphasis on flow control, studies examining fundamental flow physics with a path to enabling

control of the flow are also of interest. 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 dynamics. The integration of theoretical, numerical, and experimental tools to improve understanding is encouraged.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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5) Laser and Optical Physics

Program Description: The program goal is to advance the science of laser devices, beam control and propagation systems, laser matter interaction, nonlinear optical phenomena and devices, and unique applications of these to solving scientific and technological problems of interest to the Air Force. Novel light sources are also an objective of this program, particularly in regions of the spectrum otherwise not easily accessible. Theoretical, computational, and experimental research is encouraged.

Basic Research Objectives: This U.S. 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 and standoff sensing, while supporting fundamental science in novel lasing processes in solids, liquids, gases, and plasma. Research that enhances the power, energy, and waveform stability of lasers across the wavelength spectrum is especially encouraged. Examples include novel processing techniques for high quality solid-state laser materials with control over spatial distributions of dopants and index of refraction, and processing methods for achieving low loss lasers. New ideas for high average power fiber lasers are of interest, including new materials, and large mode area structures, novel ways of mitigating nonlinear instabilities, and studies of coupling multiple fiber lasers which can withstand very high average power. Novel, compact, particularly tunable or wavelength flexible, infrared lasers are of interest for countermeasures and sensing applications. Compact novel sources of monochromatic x-rays and gamma rays are also of interest as are innovative imaging with such sources. Fundamental advances in optics that promotes long range propagation through complex media, including aero-optics and innovative control research, are of interest to the portfolio. More broadly, the Laser and Optical Physics program will consider any novel and potentially transformational ideas, and is especially interested in inter-disciplinary research, within the broad confines of its portfolio title. With this in mind, researchers should also consult the programs in Ultrashort Pulse Laser-Matter Interactions, Plasma and Electro-Energetic Physics, and Remote Sensing and Imaging Physics described in this Broad Area Announcement. New concepts for the computational modeling of light and laser devices, including thermal effects, are also of

interest. Combined theory, simulation, and experimental efforts designed to verify and validate innovative models are welcome.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss the current state-of-the-art, how the proposed effort would advance it, and the approximate yearly cost. Collaborative efforts with the researchers at the Air Force Research Laboratory are encouraged, but not required.

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6) Plasma and Electro-Energetic Physics

Program Description: 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. 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. This portfolio will also consider research increasing the scientific understanding required to predict heat transfer across a broad range of temporal and spatial scales, both in plasmas, in the connection of plasma to energy supplying electrodes, and in advanced materials facing the extreme environments associated with energy dense materials.

Basic Research Objectives: Ideas for advancing the state-of-the-art in the following areas are strongly encouraged: highly efficient electron-beam-driven sources of high-frequency microwave, millimeter-wave, and sub-millimeter coherent radiation (high power microwaves [HPM] and/or vacuum electronics), high-power amplifiers, novel dispersion engineering via metamaterials and photonic band gap structures, novel sources of relativistic particle beams, laser plasma/matter interaction, 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. 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, and thermal conductivity in hybrid materials, including the role of radiative processes. Proposals addressing new ideas and directions related to understanding of thermal transport and phonon-assisted devices are highly encouraged, especially as they relate to operation in hostile environments consistent with high energy density physics. Researchers should also consult the program in Aerospace Materials for Extreme Environments as described in this Broad Agency Announcement to find the best match for research concerning thermal

physics. 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. Additionally, laser plasma/matter interaction, while of interest to this portfolio, is generally limited to the non-equilibrium physics of plasmas; other concepts related to laser-matter interactions should consult the Ultrashort Pulse Laser-Matter Interactions or Laser and Optical Physics programs as described in this Broad Agency Announcement. 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.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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. Collaborative efforts with the researchers at the Air Force Research Laboratory are encouraged, but not required.

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7) Quantum Electronic Solids

Program Description: 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, nanotubes and other forms of carbon 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 U.S. Air Force electronic systems.

Basic Research Objectives: The superconductivity portion of this program is almost entirely devoted to a search for new classes of superconducting materials that either have higher transition temperatures, higher critical magnetic fields 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 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 in the near future. 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 U.S. Air Force applications.

The metamaterials portion of this program is devoted to the production of 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 relatively new area of interest involves thin-film, oxide-based materials that are critical for the development of devices with 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 that can be synthesized in unusual nanostructured geometries that 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.

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8) Remote Sensing and Imaging Physics

Program Description: 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. 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.

Basic Research Objectives: Research goals include, but are not limited to:

- Theoretical foundations of remote sensing and imaging.
- 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.
- 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 Program Officer is Dr. Arje Nachman.)
- Innovative methods of remote target location, characterization, and tracking, as well as non-imaging methods of target identification.
- Understanding and predicting dynamics of space objects as it relates to space object identification and space situational awareness.
- 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.
- Remote sensing signatures and backgrounds of both ground-based and space-based observations.
- The interaction of U.S. 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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9) Sensing, Surveillance and Navigation

Program Description: This research activity is concerned with the systematic analysis and interpretation of variable quantities that represent critical working knowledge and understanding of the changing battle-space. Sensor/Surveillance images are of special importance in targeting, damage assessment and resource location. Signals are either naturally or deliberately transmitted, propagated as electromagnetic waves, and recaptured at the receiving sensor. Modern radar, infrared, and electro-optical sensing systems produce large quantities of raw signals 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.

Basic Research Objectives: 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 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 U.S. Air Force to maintain its lead in battle-space 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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10) Space Science

Program Description: The AFOSR Space Science 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 U.S. 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 represents 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.

Basic Research Objectives: Research goals include, but are not limited to:

- 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 highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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11) Ultrashort Pulse Laser-Matter Interactions

Program Description: The Ultrashort Pulse Laser-Matter Interactions program is focused on the most fundamental process in nature, the interaction of light with the basic constituents of matter. The objective of the program is to explore and understand the broad range of physical phenomena accessible via the interaction of ultrashort pulse (USP) laser sources with matter in order to further capabilities of interest to the U.S. Air Force, including directed energy, remote sensing, communications, diagnostics, and materials processing. The portfolio explores research opportunities accessible by means of the three key distinctive features of USP laser pulses: high peak power, large spectral bandwidth and ultrashort temporal duration.

Basic Research Objectives: The Ultrashort Pulse Laser-Matter Interactions program seeks innovative science concepts in the research focus areas of high-field laser physics, frequency combs and attosecond science described below:

- **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.

- **Optical frequency combs:** The large coherent spectral bandwidths intrinsic to USP lasers make them especially suitable for applications requiring high temporal and spectral precision such as telecommunications, optical clocks, time and frequency transfer, precision spectroscopy 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.

- **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. This highly exploratory thrust of the program is interested in developing research aimed at resolving attosecond electron dynamics in complex systems of interest to DOD (i.e. such as solid-state semiconductor, magnetic, and plasmonic systems). If successful, such understanding would have a broad and direct impact on future materials research, moving us closer to designing materials with carefully engineered electronic properties. 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.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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d. Chemistry and Biological Sciences (RTB2)

The Chemistry and Biological Sciences Team is responsible for research activities in chemistry and biological sciences. A wide range of fundamental chemistry, biology, mechanics, and biophysics research is supported to provide the Air Force with novel options to increase performance and operational flexibility. Research carried out within this team will help usher in revolutionary new technologies that will fundamentally change the way future Air Force weapon systems are designed and implemented. This research effort will endeavor to identify chemical and biological mechanisms, structures, and systems with the potential to inspire future technology in all Air Force systems. Understanding these mechanisms, structures and systems at a fundamental level will accelerate advances in energy technology, control of complex systems, sensors and sensory systems, and materials engineering. The focus is on complex materials, microsystems and structures and well as systems of a biological natural by incorporating hierarchical design of mechanical and functional properties from the nanoscale through the mesoscale, ultimately leading to controlled well-understood chemistry/biochemistry, and material or structural behavior capable of dynamic functionality and/or performance characteristics to enhance mission versatility. In addition to research into underlying materials/biomaterials and fundamental physical/biophysical processes, this area considers how they might be integrated into new classes of devices and pursues a fundamental understanding of materials that are not amenable to conventional computational means. Finally, the energy extraction and storage efforts addresses the characterization, synthesis, and utilization of fundamental energy sources, ranging from novel molecular configurations to photoelectric stimulated mitochondria and solid rocket motor propellants infused with performance improving nanoenergetic particles.

The Chemistry and Biological Sciences Team research portfolios and their program officers are listed here:

1) Biophysics, Dr. Hugh De Long and Dr. William P. Roach
2) Human Performance and Biosystems, Dr. Patrick O. Bradshaw
3) Mechanics of Multifunctional Materials and Microsystems, Dr Byung-Lip Lee
4) Molecular Dynamics and Theoretical Chemistry, Dr. Michael R. Berman
5) Natural Materials, Systems, and Extremophiles, Dr. Hugh C. De Long
6) Organic Materials Chemistry, Dr. Charles Y. Lee

Research of interest to these sub areas is described in detail below:

1) Biophysics

Program Description: This program encompasses fundamental experimental and theoretical Biophysics research that is primarily focused on studies of bio-molecular and atomic imaging

below the diffraction limit, bioelectricity, electromagnetic stimulation, and quantum biology. We are concerned then, with the study of physical biology with the aim of answering fundamental and basic physics questions through the application of the principles and methods of physical sciences to achieve novel and innovative solutions in biology and physics. The relatively recent emergence of biophysics as a scientific discipline may be attributed to the spectacular success of biophysical tools born out of a physics understanding that have allowed us to unravel the complex molecular structures found in DNA and RNA. More recently areas of interest in Biophysics include, but are not limited to bio-molecular imaging below the diffraction limit, bioelectricity, electromagnetic stimulation and quantum biology. These research areas support technological advances in application areas of interest to the United States Air Force including biologically inspired new innovative and novel materials, human performance, and enhanced computational development for future Air Force needs.

Basic Research Objectives: We are initiating a new, multidiscipline collaborative basic research effort that meets scientifically meritorious rigor in the area of Biophysics. We seek to directly or indirectly support the efforts of the Air Force Research Laboratories ongoing in house research in Biophysics and Human Performance. We seek to explore new areas in applied mathematics, physics, and biology by working in the sub-areas of bio-molecular imaging below the diffraction limit, bioelectricity, electromagnetic stimulation, quantum biology and mechanisms of sensory systems.
As examples, nano-pores have been shown to form in the plasma membranes of mammalian cells upon exposure to nanosecond pulsed electric fields with complete functional recovery. High-speed imaging is now a reality yet its goal of working below the diffraction limit to allow for a more rapid signaling acquisition process while illuminating the mechanisms of action from the cellular membrane to the interior structures of the cell has yet to be realized. Bioelectronics, no longer limited to solid-state device faux-integration with biological systems, can now create bio-analog circuitry. Recent work has found that rapid change in temperature from the IR laser stimulation reversibly alters the electrical capacitance of the plasma membranes of a cell and depolarization of the membrane can results in real measurable action potentials. This capacitance is established by the spatial distributions of ions near the plasma membrane surface and underlies the mechanism responsible for the voltage waves in the Soliton theory of action potentials. Finally, 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 in natural acoustic, visual, and sensorimotor systems.

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2) 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 direct methods used to augment human performance. The primary goal for this program is to gain a better understanding of the biophysical, biochemical, and physiological mechanisms responsible for the behavioral, genetic, cellular, tissue and systems changes resulting from various forms of bio-stimulation. Additionally, a sensory systems focus has been added to this program and the emphasis is on developing 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: This program is interested in defining the mechanisms (biological, cognitive, genetic, neural, physiological, etc.) associated with enhancing human capabilities as well as understanding the associated biomarkers, bio-circuits, bioelectric and connection 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 Biosystems. We are also interested in understanding the variables of fatigue and toxicology as they relate to performance decrement in the aviation environment i.e. exploring the bio-circuitry, biochemical and molecular pathways and processes that generate signals associated with fatigue or performance changes. We wish to define and understand the biomarkers and genetic changes associated with human performance 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. Proposals aimed at understanding synthetic biological processes as they relate to energy production in Biosystems will be accepted. We have a specific interest in understanding organelles, cells, tissues or systems perturbed with Acoustic, Photo, Electric or Magnetic energy.

For the sensory systems portion of the portfolio a goal is to pursue new capabilities in acoustic analysis, 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. 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.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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.

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3) Mechanics of Multifunctional Materials and Microsystems

Program Description: The main goals of this program are (a) to promote the utilization of newly emerging materials, nano-devices and microsystems in multifunctional design of advanced structures for higher system efficiency, (b) to bridge the gap between the viewpoints from materials science on one side and structural engineering on the other in forming a scientific basis for the materials development and integration criteria, and thereby (c) to establish safer, more maneuverable aerospace vehicles and platforms with unprecedented performance characteristics.

Basic Research Objectives: Specifically, the program seeks to establish the fundamental understanding required to design and manufacture new aerospace materials, nano-devices and microsystems for multifunctional structures and to predict their performance and integrity based on mechanics principles. The multifuctionality 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 multifuctionality, the concepts of particular interest are: (a) "autonomic" structures which can 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 power harvesting/storage/transmission capabilities for "self-sustaining" system. This program thus focuses on the development of 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 U.S. 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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4) Molecular Dynamics and Theoretical Chemistry

Molecular Dynamics

Program Description: This program seeks a molecular-level description of reaction mechanisms and energy transfer processes related to the efficient storage and utilization of energy. The program supports cutting-edge experimental and joint theory-experiment studies that address key, fundamental questions in these areas. There are four major focus areas in the program: Catalytic Reactivity and Mechanisms; Novel Energetic Material Concepts; Dynamics of Energy Transfer and Transport; and Chemistry in Extreme Environments.

Basic Research Objectives: The molecular dynamics program seeks to understand, predict, and control the reactivity and flow of energy in molecules in many areas of interest to the U.S. Air Force. Thus, the program encourages novel and fundamental studies aimed at developing basic understanding and predictive capabilities for chemical reactivity, bonding, and energy transfer processes. Some of the program's current interests focus on molecular clusters and nanoscale systems in catalysis, and as building blocks for creating novel materials. Understanding the catalytic mechanisms needed to produce storable fuels from sustainable inputs and to improve propulsion processes are also topics of interest, as are novel properties and dynamics of ionic liquids. Work in this program 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, plasma-surface interactions, 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. The program is also interested in utilizing plasmonics, and laser excitation to control reactivity.

Theoretical Chemistry

Program Description: The theoretical chemistry program supports research to develop new methods that can be utilized as predictive tools for designing new materials and improving processes important to the U.S. Air Force. These new methods can be applied to areas such as 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 or catalysts for their formation, investigate the interactions that control or limit the stability of these systems, and help guide synthesis by identifying the most promising synthetic reaction pathways and predicting the effects of condensed media on synthesis.

Basic Research Objectives: The program seeks new methods in quantum chemistry to improve electronic structure calculations to efficiently treat increasing larger systems with chemical accuracy. These calculations will be used, for example, to guide the development of new catalysts and materials of interest. New approaches to treating solvation and condensed phase effects will also be considered. New methods are sought to model reactivity and energy transfer in molecular systems. 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 U.S. Air Force systems. Interest in molecular clusters, 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 reaction dynamics that span multiple time and length scales.

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5) Natural Materials, Systems, and Extremophiles

Program Description: The goals of this multidisciplinary program are to study, use, mimic, or alter how living systems accomplish their natural functions or to take those biomaterials and systems and use them in new ways such as seen with bionanotechnology. Nature has used evolution to build materials and sensors that outperform current sensors such as a spider's haircells that can detect air flow at low levels even in a noisy background. Nature is very good at solving the problem of working in a noisy environment. 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 three general areas: biomimetics, biomaterials (non-medical only), and biotic/abiotic interfaces.

Basic Research Objectives: Biomimetics 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.

The biomaterials area (doesn't include any medical materials work) 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. We are also interested in organisms that disrupt or deny a material's function or existence in some way.

The biointerfacial sciences 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).

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6) Organic Materials Chemistry

Program Description: The goal of this research area is to achieve unusual properties and behaviors from polymeric and organic materials and their inorganic hybrids through a better understanding of their chemistry, physics and processing conditions. This understanding will lead to development of advanced organic and polymeric materials for future U.S. Air Force applications. This program's approach is to study the chemistry and physics of these materials through synthesis, processing control, characterization and establishment of the structure properties relationship of these materials. There are no restrictions on the types of properties to be investigated but heavy emphases will be placed on unusual, unconventional and novel properties. Research concepts that are novel, high risk with potential high payoff are encouraged. Both functional properties and properties pertinent to structural applications will be considered. Materials with these properties will provide capabilities for future Air Force systems to achieving global awareness, global mobility, and space operations.

Basic Research Objectives: Proposals with innovative material concepts that will extend our understanding of the structure-property relationship of these materials, discover previously unknown properties and/or 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, 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, power generation and

storage applications 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, third order nonlinear optical materials, electro-optic polymers, liquid crystals, photorefractive polymers and magneto-optical polymers. Examples of electronic properties of interest include conductivity, charge mobility, stretchable electronic materials, electro-pumped lasing and solar energy harvesting. 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 (thermoelectric), or vice versa, (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 achieve material properties that are difficult to attain through conventional means are encouraged. Concepts of excited state engineering to control the flow of energy within a material or molecule are of interest. Concepts of single molecules that combined different moieties with various functionalities to perform as complex function as in a rudimentary electronic or photonic circuit for novel applications are welcome.

Researchers are highly encouraged to contact the Program Officer prior to developing full proposals to briefly discuss 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. White paper inquiries should be submitted before May 15, 2015 for FY 16 considerations.

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e. Other Innovative Research Concepts:

Program Description: AFOSR is always looking for new basic 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. Pre-coordination with the point of contact listed below is strongly encouraged before submitting a proposal.

Basic Research Objective(s): 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 U.S. Air Force 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 U.S. Air Force mission.

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f. Conferences and Workshops:

The Air Force supports conferences and workshops (as defined in the DoD Travel Regulations) in special areas of science that bring experts together to discuss recent research or educational findings or to expose other researchers or advanced graduate students to new research and educational techniques.

Conferences and workshops constitute key forums for research and technology interchange. AFOSR's financial support through grants for conferences and workshops is dependent on the availability of funds, Program Officer's discretion, and certain other restrictions including:

- AFOSR support for a workshop or conference is not to be considered as an endorsement of any 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 U.S. 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 U.S. Air Force basic research program. Proposals for conference or workshop support are encouraged to be submitted a minimum of six months prior to the date of the conference. Proposals should include the following:

  Technical Information:

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

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

1) Total project costs by major cost elements
2) Anticipated sources of conference/workshop income and amount from each source
3) Proposals should break down how AFOSR funds will be spent in sufficient detail for AFOSR personnel to determine whether costs are allowable. See Part 200 of the Code of Federal Regulations (CFR) Section 200.420 – 200.475 for a listing of allowable and unallowable costs; **http://www.ecfr.gov/cgi-bin/text-idx?SID=36766b4d82ebca47caae047cb4606343&node=2:1.1.2.1.1&rgn=div5**

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:

1. Technical merits of the proposed research and development.
2. Potential relationship of the proposed research and development to the Department of Defense.
3. The qualifications of the principal investigator(s) or conference chair(s).

Once selected for possible award, price will be analyzed for Cost Realism and Price Reasonableness. Cost/Price is considered, but not an evaluation criteria

Eligibility

Notwithstanding the above, the Department of Defense (DOD) has imposed certain restrictions on the Air Force's co-sponsorship of scientific and technical conferences and workshops. Specifically, DOD Instruction 5410.20 prohibits co-sponsorship of conferences and workshops with commercial concerns. Scientific, technical, or professional organizations which qualify for US federal tax exempt status may receive conference and workshop grants.

Applicants for support of conferences or workshops must be able to demonstrate US tax exempt status. Acceptable documentation includes registering as "tax exempt" in the System for Award Management (SAM.gov) or following the instructions at http://www.irs.gov/uac/Form-W-8EXP,-Certificate-of-Foreign-Government-or-Other-Foreign-Organization-for-United-States-Tax-Withholding.

In cases where the grant applicant is a third party, i.e., the grant applicant is not the conference sponsor, but is applying for funding on behalf of the sponsor, the actual conference sponsor will also need to meet the eligibility requirements of this BAA.

Participant Support

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

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

II. Award Information

1. In Fiscal Year 2014, AFOSR managed funding support for approximately 1,600 grants, cooperative agreements, and contracts to about 470 academic institutions, non-profit organizations and industrial firms. This included grants, cooperative agreements and contracts to academic institutions, non-profit organizations and industry. About $260M is anticipated to be available for support of actions awarded through this BAA process; subject to availability of funds. 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 (but see additional eligibility requirements for conferences and workshops under Section I. f). 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 proposals that do not contain proprietary information. AFOSR will make every effort to protect the confidentiality of any proprietary information submitted as long as it is properly marked. 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) (but see also Section V of this announcement regarding Non-government evaluators and support contractors retained by AFOSR). **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 considered to be furnished voluntarily to AFOSR without**

restriction and will be treated as such for all purposes. Since the Government anticipates the award of grants, cooperative agreements, or contracts, this statement is applicable to proposals submitted for all three of these potential instruments.

3. Content and Form of Application Submission –

a. Prior to proposal submission.

Applicants are encouraged to contact the Program Officer for the subject area to discuss the proposed research effort, particularly the current state of related research, the potential of the effort to advance the state of the art, and anticipated budget. The Program Officer may ask for additional information at that time.

However, in your conversations with a Government official, be aware that only warranted contracting and grants officers are authorized to commit the Government.

b. Proposals. The proposal may be submitted either electronically through Grants.gov or in hard copy form, but not both. Proposers submitting in hard copy format are strongly encouraged to follow-up by email with the AFOSR program officer to validate that the proposal has been received. 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**

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 Officer)
- 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 System for Award Management (SAM), 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 SAM registration process.) Go to **http://www.grants.gov/web/grants/applicants/organization-registration.html** and use the Grants.gov Organization Registration Checklist to guide you through the process.

To submit a proposal 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 ensure you have the required version of Adobe Reader installed or to download a free version of the software, visit the following web site: **http://www.grants.gov/web/grants/support/technical-support/software/adobe-reader-compatibility.html**. 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" under "Applicants," and then follow the instructions. Or in the Grants.gov search function, enter the funding opportunity number for this announcement (BAA-AFRL/AFOSR-2015-0001). You can also search for the CFDA Number 12.800, Air Force Defense Research Sciences Program. On the "View Grant Opportunity" page, click on the "Application Package" tab 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 Department specific to your area of interest to download the instructions and application.

If you are unsure which Department and Program Officer 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. 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/web/grants/support/technical-support/software/pdf-conversion-software.html**.

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

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

Proposals being sent to AOARD must be delivered to the attention of the Program Officer at the at the following address:

AFOSR/AOARD (Attn: Name of Program Officer)
7-23-17, Roppongi, Minato-Ku
Tokyo 106-0032 Japan

Proposals being sent to EOARD must be delivered to the attention of the Program Officer at the at the following address:

AFOSR/EOARD (Attn: Name of Program Officer)
86 Blenheim Crescent
Ruislip, Middlesex, United Kingdom HA4 7HB

Proposals being sent to SOARD must be delivered to the attention of the Program Officer at the at the following address:

AFOSR/SOARD (Attn: Name of Program Officer)
US Embassy- Santiago
Av. Andrés Bello 2800, Las Condes
Santiago, Chile

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

AFOSR (Attn: Dr. Van Blackwood)
Air Force Office of Scientific Research
875 North Randolph Street, Suite 325 Room 3112
Arlington VA 22203-1768

Applicants should send hard copy submissions through a delivery method that allows the sender to confirm receipt. Additionally, the applicant should contact the Program Officer to confirm receipt. Proposals ***shall not*** be submitted by email.

(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 field's 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'.

- **Field 17:** Select "I Agree" to:

Provide the certification regarding lobbying that is required by law (13 USC 1352, as implemented by the DoD at 32 CFR Part 28). The full text of this certification may be found at http://www.wpafb.af.mil/shared/media/document/AFD-070817-127.pdf or a copy will be provided upon request.

Certify that the statements in the proposal and the associated representations on tax delinquency and felony convictions are true, complete and accurate to the best of your knowledge.

- **Field 18:** Attach the representations on tax delinquency and felony convictions (The representations page is provided with for the full

announcement of the funding opportunity under Other Supporting Documents and available for download at grants.gov). Also attach the SF-LLL or other explanatory documentation if there is lobbying that must be disclosed under 13 USC 1352, as implemented by the DoD at 32 CFR Part 28.

- **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/web/grants/support/technical-support/software/pdf-conversion-software.html**.

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

(d) 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. (i.) 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.

(e) 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.

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

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

Human Subject Research Requirements - Each proposal must address prospective human subject involvement by addressing Field 1 and 1a of the R&R Other Project Information Form. If selected for award, additional documentation in accordance with U.S. Air Force standards is required. All inquiries for proposals to AFOSR

regarding human subject research requirements should go to the AFOSR Research Protections Office at AFOSRHARPO@us.af.mil.

Animal Subject and rDNA Research Requirements - Each proposal must address prospective animal subject and/or rDNA involvement by addressing Field 2 and 2a of the R&R Other Project Information Form. If selected for award, additional documentation in accordance with U.S. Air Force standards is required. All inquiries for proposals to AFOSR regarding animal subjects or rDNA research requirements should go to the AFOSR Research Protections Office at AFOSRHARPO@us.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 Officer. Most research efforts funded by AFOSR will, however, qualify for a categorical exclusion from the need to prepare an EIS. U.S. 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.

Data Management Plan - All proposals must include a supplementary document of no more than two pages labeled "Data Management Plan." The plan should address data management issues such as:

1) The types of data, software, and other materials to be produced in the course of the project, with notation marking those that are publicly releasable;
2) How the data will be acquired;
3) Time and location of data acquisition if they are scientifically pertinent;
4) How the data will be processed;
5) The file formats and the naming conventions that will be used;
6) A description of the quality assurance and quality control measures during collection, analysis, and processing;
7) If existing data are to be used, a description of their origins;
8) A description of the standards to be used for data and metadata format and content;
9) Plans and justifications for archiving the data;

10) Appropriate timeframe for preservation; and
11) If for legitimate reasons the data cannot be preserved, the plan will include a justification citing such reasons.

Attach the Data Management Plan to the R&R Other Project Information form in field 12, Other Attachments.

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 terms that the public may understand. In the header of the abstract include the Program Officer's name and Department who should receive the proposal for consideration and evaluation. This abstract ***must be marked that it is publicly releasable***. Attach the Abstract to the R&R Other Project Information form in field 7.

(h) 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 Officers will facilitate the establishment of accounts awarded.

(i) 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. (See Title 2 Code of Federal Regulations (CFR) Sections 200.420 – 200.475 for a listing of allowable and unallowable costs under Federal awards;

http://www.ecfr.gov/cgi-bin/text-idx?SID=f0280ad0f23f40698315bf28acca3dae&tpl=/ecfrbrowse/Title02/2cfr200_main_02.tpl
Applicants who enter a fee on Part J of the budget will not be eligible to receive a grant or cooperative agreement.

In addition to the Research and 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. For example, travel should be itemized (quantity of trips/personnel, destination, duration, and purpose, as well as basis for calculating costs such as airlines and hotels). Materials, supplies and equipment should also be itemized with the basis for costs provided. List all material/equipment by type and kind with associated costs and indicate if the costs are based on vendor quotes, historical data and/or engineering estimates; provide copies of vendor quotes and/or catalog pricing data. Attach the budget justification to Section K of the R&R Budget form.
If a current rate agreement is used to propose indirect cost rates and/or fringe benefit rates, attach a copy of the agreement to Section K of the R&R Budget form as well.

(j) Certifications –

Representations on tax delinquency and felony convictions Check either "is" or "is not" for each of the two representations, as appropriate for the proposing institution, and attach the representations page to field 18 of the SF-424. The representations page is provided with for the full announcement of the funding opportunity under Other Supporting Documents and available for download at grants.gov.

SF-LLL Form "Disclosure Form to Report Lobbying" -- If your organization has lobbying activities that you are required to disclose under 31 USC 1352, as implemented by the DoD at 32 CFR part 28, you also must complete and attach the SF-LLL form in the downloaded Adobe forms package at Grants.gov.

Online Representations and Certifications If it is determined that 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 in the System for Award Management (SAM) at **http://www.sam.gov**. The representations and certifications shall be submitted to SAM 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 SAM. In addition to the SAM representations and certifications, prospective contractors shall complete the AFOSR Contract Certification which will be supplied upon request.

4. Other Submission Requirements –

The only acceptable electronic submission method is through Grants.gov. Proposals submitted in whole or in part by other electronic methods (computer disk or tape, facsimile machine, electronic mail, etc.) ***will not be accepted***.

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 should contact the Program Officer to verify receipt.

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 additional information regarding the BAA process please refer to the AFRL BAA Guide for Industry at **http://www.wpafb.af.mil/shared/media/document/AFD-120614-075.pdf**.

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 U.S. Air Force encounters in developing and maintaining a superior U.S. Air Force; lowering the cost and improving the performance, maintainability, and supportability of U.S. 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 a contract award is contemplated, evaluation will be on a competitive basis according to Public Law 98-369, Competition in Contracting Act of 1984 (41 USC 253), 10 USC 2361, and 10 USC 2374. If a grant/assistance instrument award is contemplated, evaluation will use merit-based competitive procedures according to 2 CFR §200.319, Competition. Proposals may be evaluated by Program Officers at EOARD/AOARD and the appropriate AFRL Technology Departments, 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. Government and non-Government evaluators are also required to sign nondisclosure agreements which prohibit them from disclosing proprietary information submitted by applicants in a proposal. **However as previously stated in Section IV para 2, AFOSR is seeking proposals that do not contain proprietary information. If proprietary information is submitted it is the offeror's responsibility to mark the relevant portions of any submissions as specified in Section IV paragraph 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 applicants.

Proposals submitted for Conference Support and Workshops listed in Section I shall be evaluated only under criteria as specified in its 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.

A third evaluation criterion used in the technical reviews, which is of lesser importance than the primary criteria is:

3. The proposer's capabilities integral to achieving U.S. Air Force 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 U.S. Air Force objectives, and the potential risk of this effort to the U.S. Air Force.

Once selected for possible award, price will be analyzed for Cost Realism and Price Reasonableness. Cost/Price is considered, but not an evaluation criteria.

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

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 an email notification from AFOSR 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

Deliverables: Grants and cooperative agreements typically require annual and final performance reports, final financial reports, and final invention reports. Contracts typically require annual and final technical and invention reports.

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

3. Additional information for offerors seeking contract awards

a. 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 (JAN 2011)

(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 Innovation Research Program, the Rights in Noncommercial Technical Data and Computer Software--Small Business Innovation 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 Innovation Research Program, the Rights in Noncommercial Technical Data and Computer Software--Small Business Innovation Research (SBIR) Program clause.

(b) The identification and assertion requirements in this provision apply only to technical data, including computer software documents, or computer software to be delivered with other than unlimited rights. For contracts to be awarded under the Small Business Innovation Research Program, the notification 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)

b. See also the following clauses recently added to Defense Federal Acquisition Regulation Supplement (DFARS):

252.227-7013 RIGHTS IN TECHNICAL DATA—NONCOMMERCIAL ITEMS (FEB 2014)

252.244-7001 CONTRACTOR PURCHASING SYSTEM ADMINISTRATION (MAY 2014)

252.209-7004 SUBCONTRACTING WITH FIRMS THAT ARE OWNED OR CONTROLLED BY THE GOVERNMENT OF A COUNTRY THAT IS A STATE SPONSOR OF TERRORISM (DEC 2014)

252.204-7007 ALTERNATE A, ANNUAL REPRESENTATIONS AND CERTIFICATIONS (JAN 2015)

252.209-7992 REPRESENTTION BY CORPORATIONS REGARDING AN UNPAID DELINQUENT TAX LIABILITY OR A FELONY CONVITION UNDER ANY FEDERAL LAW – FISCAL YEAR 2015 APPROPRIATIONS (JAN 2015)

252.235-7011 FINAL SCIENTIFIC OR TECHNICAL REPORT (JAN 2015)

252.203-7998 PROHIBITION ON CONTRACTING WITH ENTITIES THAT REQUIRE CERTAIN INTERNAL CONFIDENTIALITY AGREEMENTS--REPRESENTATION (FEB 2015)

252.203-7999 PROHIBITION ON CONTRACTING WITH ENTITIES THAT REQUIRE CERTAIN INTERNAL CONFIDENTIALITY AGREEMENTS (FEB 2015)

252.239-7999 CLOUD COMPUTING SERVICES (DEVIATION) (FEB 2015)

VII. Agency Contacts

Should you have questions about a technical research area, contact the Program Officer 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@us.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. Please be aware that since December 2014 all AFOSR grants have been governed by the guidance in 2 Code of Federal Regulations (CFR) part 200, "Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards" as modified and supplemented by the Department of Defense's (DoD) interim implementation of Guidance in 2 CFR part 200" (79 FR 76047, December 19, 2014) all of which are incorporated by reference in AFOSR's grants. Provisions of Chapter 1, Subchapter C of Title 32, CFR, "DoD Grant and

Agreement Regulations" other than parts 32 and 33 continue to be in effect and are incorporated in AFOSR grants by reference, with applicability as stated in those provisions. The DoD anticipates issuing Terms and Conditions for all grants, which AFOSR will incorporate by reference at a later date.

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 2 CFR §200.460, Proposal Costs.

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-AFRL/AFOSR-2015-0001.

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. SAM Registration

Prospective awardee shall be registered in the SAM 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 **https://www.sam.gov**.

Awardees must:

(a) Be registered in the System for Award Management (SAM) prior to submitting an application or proposal;

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

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

10. 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 Officer, 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.gehrs@us.af.mil.

Concerns, issues, disagreements, and recommendations that cannot be resolved at the MAJCOM/DRU or AFISRA level, may be brought by the concerned party for further consideration to the U.S. Air Force ombudsman, Associate Deputy Assistant Secretary (ADAS) (Contracting), SAF/AQC, 1060 Air Force Pentagon, Washington DC 20330-1060, phone number (571) 256-2397, facsimile number (571) 256-2431.

(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.

11. Grant Payment Process

(a) All Grantees are expected to access the Invoicing, Receipt, Acceptance and Property Transfer system (iRAPT), part of the Wide Area Workflow eBusiness Suite (WAWF), and complete iRAPT'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.

(b) 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 and hyperlinks to instructions for "Vendors Getting Started" at the bottom of the page under "Getting Started Help."

Please note that each Grantee must be registered in SAM 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 iRAPT 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.

(c) 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.

12. 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 requires 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 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 Officer.

13. For additional programs and specific funding opportunities, please visit the AFOSR website at: http://www.wpafb.af.mil/afrl/afosr/