BROAD AGENCY ANNOUNCEMENT (BAA)

1. **Agency Name**

Air Force Office of Scientific Research
Arlington VA

2. **Funding Opportunity Title**

Research Interests of the Air Force Office of Scientific Research

3. **Announcement Type**

This is the initial announcement.

4. **Funding Opportunity Number**

BAA-AFOSR-2013-0001

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This announcement remains open until superseded.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 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 White papers and proposals that do not contain proprietary information. We expect our research to be fundamental.

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

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

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

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I. Funding Opportunity Description

AFOSR plans, coordinates, and executes the Air Force Research Laboratory's (AFRL) basic research program in response to technical guidance from AFRL and requirements of the Air Force; fosters, supports, and conducts research within Air Force, university, and industry laboratories; and ensures transition of research results to support 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 five scientific Departments: Dynamical Systems and Control (RTA), Quantum and Non-Equilibrium Processes (RTB), Information, Decision and Complex Networks (RTC), Complex Materials and Devices (RTD), and Energy, Power and Propulsion (RTE). The research activities managed within each Department are summarized in this section.

a. Dynamical Systems and Control (RTA):

The Dynamical Systems and Control Department 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 mathematics, materials, fluid dynamics, 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 fosters new scientific discoveries that will ensure future novel innovations for the future U.S. Air Force.

The central research direction for this Department 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) Computational Mathematics, Dr. Fariba Fahroo
2) Dynamics and Control, Dr. Fariba Fahroo
3) Flow Interactions and Control, Dr. Douglas Smith
4) Multi-Scale Structural Mechanics and Prognosis, Dr. David Stargel
5) Optimization and Discrete Mathematics, Dr. Fariba Fahroo
6) Sensory Information Systems, Dr. Patrick Bradshaw
7) Test and Evaluation, Dr. Michael Kendra
8) Turbulence and Transition, Dr. John Schmisseur

Research areas are described in detail in the Sub areas below

1. Computational Mathematics

Program Description: This program seeks to develop innovative mathematical methods and fast, reliable algorithms aimed at making radical advances in computational science. Research in computational mathematics underpins foundational understanding of complex physical phenomena and leads to capabilities for analysis and prediction of phenomena crucial to design and control of future 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. One area of increasing emphasis is simulation of complex systems with dynamic data integration. Issues such as multiscale and multi-modal description of the system, dynamic invocation of appropriate models based on interjection of data into the simulation systems, stable and convergent algorithms which are robust under perturbations from dynamic-data inputs, and Uncertainty Quantification (UQ) analysis for these systems are of importance.

To meet the formidable computational challenges entailed in simulating nonlinear, discontinuous, multi-physics and multi-scale problems of interest to the 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. 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. Research in the Computational Mathematics program also supports the national program in high performance computing.

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2. Dynamics and Control

Program Description: This program emphasizes the interplay of dynamical systems and control theories with the aim of developing innovative synergistic strategies for the design and analysis of controlled systems that enable radically enhanced capabilities, including performance and operational efficiency for future 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; novel approaches and methods where dynamic resources in sensor networks and networks of controllers are adaptively managed through a dynamic feed-back loop symbiotically integrating simulations and models with real-time data-acquisition and control systems; managing adversarial and stability issues for systems in cyberspace; 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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3. Flow Interactions and Control

Program Description: The Flow Interactions and Control portfolio supports basic research into the motion 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 small-scale, unmanned air vehicles.

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 aero-optics, surfaces in actuated motion, flexible and compliant aerodynamic surfaces, vortical flows, and flows with novel geometric configurations. The portfolio maintains an interest in the dynamic interaction between unsteady fluid motion, nonlinear structural deformations, and aerodynamic control effectors for a wide range of flight regimes. Although the portfolio has a strong emphasis in flow control, studies examining underlying flow physics with a path to enabling control of the flow 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 physics.

Prospective researchers are strongly encouraged to submit short (max 6 pages) White papers to the Program Officer prior to developing full proposals. White papers are viewed as a valuable first step in the proposal development and submission process. White papers should briefly describe the proposed effort, illustrate how it will advance the current state-of-the-art, and address the relevance to U.S. Air Force interests. Note, however, that basic research of the variety typically funded by the portfolio may not yet have a clear transition map to an application. The integration of theoretical, numerical, and experimental tools to improve understanding is encouraged. An approximate yearly cost for a three year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals.

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4. 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. An area of particular research interest is the development and validation of new diagnostic techniques capable of measurements at the mesoscale. Experimental techniques capable of simultaneous measurements on multiple length scales (i.e. meso to macro) are also sought.

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

Researchers are highly encouraged to submit short White papers prior to developing full proposals. White papers are encouraged as an initial and valuable step prior to proposal development and submission. White papers should briefly relate the current state-of-the-art, how the proposed effort would advance it, and the approximate yearly cost for a three to five year effort. Researchers with White papers of significant interest will be invited to submit full proposals.

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5. 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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6. Sensory Information Systems

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

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

Another program goal is to deepen the scientific understanding of the sensory and sensorimotor processes that enable agile maneuvering and successful spatial navigation in natural flying organisms. Emphasis is on the discovery of fundamental mechanisms that could be emulated for the control of small, automated air vehicles, yet have no current analogue in engineered systems. Recent efforts have included investigations of information processing in wide field-of-view compound eye optics, receptor systems for linear and circular polarization sensing, and mathematical modeling of invertebrate sensorimotor control of path selection, obstacle avoidance and intercept/avoidance of moving targets. All of these areas link fundamental experimental science with neuromorphic or other mathematical implementations to generate and test hypotheses. Current efforts also include innovations in control science to explain and emulate complex behaviors, such as aerial foraging and swarm cohesion, as possible outcomes of simpler sensory-dominated behaviors with minimal cognitive support. As in the acoustic and psychoacoustic areas described above, applicants are encouraged to develop collaborations with AFRL scientists. However, consistent with AFOSR's basic science mission, all proposals to this program are evaluated for their potential transformative advance in scientific areas, not for their potential to effect technical improvements in current Air Force systems.

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7. 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 Research and Development (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. 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 R&D Centers 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 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 machine
- 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
- 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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8. Turbulence and Transition

Program Description: The objective of the Turbulence and Transition portfolio is to develop the fundamental fluid physics knowledge base required for revolutionary advancements in a broad variety of future U.S. Air Force capabilities including energetically-efficient air and space systems, rapid global and regional response, and thermal/environmental management. Research supported by this portfolio seeks to characterize, model and exploit/control critical fluid dynamic phenomena through a balanced mixture of investments in experimental, numerical and theoretical efforts.

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

- Laminar-turbulent stability, transition and turbulence in high-Mach number boundary layers, especially approaches leading to greater insight into surface heat transfer.
- Characterization and modeling of the impact of realistic surface conditions on transitional and turbulent flows in all speed regimes.
- Innovative experiments and numerical simulations that identify the underlying physics and potential control mechanisms for noise radiated from high-speed hot jets.

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-speed fluid dynamic phenomena which will provide the scientific foundation for game-changing advancements in aerodynamics, environmental (thermal and acoustic) management, propulsion, and directed energy.

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

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b. <u>Quantum and Non-Equilibrium Processes (RTB):</u>

The Quantum and Non-Equilibrium Processes Department lead 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, both 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 U.S. Air Force. Research directions are categorized in three broad areas, and focus on advancing our basic understanding of the physical world:

Fundamental Quantum Processes: This includes exploration and understanding of a wide range of atomic, molecular, and optical phenomena, including strongly coupled electronic phenomena that occurs in complex materials in all physical phases, including but not limited to non-linear optical materials, Metamaterials, cathodes, dielectric and magnetic materials, high energy lasers, semiconductor lasers, and ultra-fast lasers. Additionally, RTB looks to fund research into new classes of quantum phenomena that both creates new knowledge of the physical world and improve the state-of-the-art for devices that perform sensing, information processing, and novel concepts for quantum computing. This area also includes generating and controlling quantum states, such as superposition and entanglement, in photons, ultracold atoms and molecules (e.g. Bose Einstein Condensates), and ultracold plasmas. In addition to research into underlying materials and fundamental physical processes, this area considers how they might be integrated into new classes of devices, seeking breakthroughs in quantum information processing and memory, secure and high speed communication, and fundamental understanding and simulation of materials that are not amenable to conventional computational means (e.g., using cold atoms and optical lattices to model high-temperature superconductors).

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

Optics and Electromagnetics: This area considers all aspects of producing, modifying, and receiving complex electromagnetic and electro optical signals, as well as their propagation through complex media, including adaptive optics and optical imaging. It also covers aspects of the phenomenology of lasers and non-linear optics and the interaction of electromagnetic signals with circuitry. This area not only considers the advancement of physical devices to enable such activities and provide robust operation in the face of interference, but also includes sophisticated mathematics and algorithm development for extracting information from complex and/or sparse signals. This cross-cutting activity impacts such diverse efforts as space object imaging, secure reliable communication, novel electronic warfare schemes, non-destructive test and evaluation, and propagation of directed energy.

The quantum and non-equilibrium physics program includes theoretical and experimental physics from all disciplines, as well as engineering issues such as those found in microwave or photonic systems as well as materials-processing techniques. A main objective of the program is to balance innovative science and U.S. Air Force relevance, being forward looking to anticipate future U.S. Air Force needs while understanding on the current state-of-the-art in the physical sciences. The RTB research portfolios and their program officers are listed here:

1) Atomic and Molecular Physics, Dr. Tatjana Curcic
2) Electromagnetics, Dr. Arje Nachman
3) Laser and Optical Physics, Dr. Howard R. Schlossberg
4) Plasma and Electro-Energetic Physics, Dr. John W. Luginsland
5) Remote Sensing and Imaging Physics, Dr. Kent Miller
6) Space Sciences, Dr. Kent Miller
7) Ultrashort Pulse Laser-Matter Interactions, Dr. Enrique Parra

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

1. 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 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 ultra-cold matter and precision measurement. Specific research topics of interest in this program include, but are not limited to, the following: physics of quantum degenerate atomic and molecular gases; strongly-interacting quantum gases; new phases of matter; non-equilibrium dynamics of cold quantum gases; cold/ultra-cold plasmas; ultra-cold 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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2. Electromagnetics

Program Description: This portfolio supports research in Electromagnetics (EM) to produce conceptual descriptions of electromagnetic properties of novel materials / composites (such as photonic band gap media, negative index media, Parity-Time symmetry media, etc.) and the simulation of their uses in various operational settings.

Basic Research Objectives: 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 pursue 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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3. Laser and Optical Physics

Program Description: The program goal is to advance the science of laser devices and systems, nonlinear optical phenomena and devices, and unique applications of these to solving scientific and technological problems. Novel light sources are also an objective of this program, particularly in regions of the spectrum not otherwise easily available or with characteristics able to again address important scientific and technological issues.

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. Examples of such areas include novel processing techniques for high quality ceramic laser materials with control over spatial distributions of dopants and index of refraction, and processing methods for achieving low loss laser ceramics with non-isotropic, and therefore necessarily aligned, grains. Aligned grain ceramic materials are also of interest as large size, high average power nonlinear optical materials using quasi-phasematching techniques. Recrystallization of large, low loss ceramic laser materials is of high interest. New ideas for high average power fiber lasers are of interest, including new materials, and large mode area structures, novel ways of mitigating nonlinear issues, and studies of coupling multiple fiber lasers which can withstand very high average power. Novel, compact, particularly tunable or wavelength flexible, potentially inexpensive, infrared lasers are of interest for infrared countermeasures or for gas sensing applications. Relatively small novel sources of monochromatic x-rays are also of interest as are innovative imaging with such sources. The Laser and Optical Physics program is interested and will consider any novel and potentially transformational ideas within the broad confines of its title.

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4. 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 and plasma aerodynamics. While the focus of this effort is the generation and collective interaction of electromagnetic fields and plasmas, advances in the enabling technology of compact pulsed power, including innovative dielectric and magnetic materials for high-density energy storage, switching devices, and non-linear transmission lines are also of fundamental interest. Ideas for advancing the state-of-the-art in the following areas are strongly encouraged: highly efficient electron-beam-driven sources of microwave, millimeter-wave, and sub-millimeter coherent radiation (high power microwaves [HPM] and/or vacuum electronics), high-power amplifiers, novel dispersion engineering via Metamaterials and photonic band gap structures, compact pulsed power, particle-field interaction physics, power-efficient methods to generate and maintain significant free-electron densities in ambient air, plasma chemistry at high pressure, and the physics of strongly coupled plasmas. New concepts for the theory, modeling, and simulation of these physical phenomena are also of interest, including combined experimental/theoretical/simulation efforts that verify and validate innovative models.

Basic Research Objectives: A new thrust in this portfolio will be consideration of 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. 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. Innovative science that combines plasma and electro-energetic physics with the high-energy density associated with nuclear forces (e.g. nuclear batteries where radiation produces currents in semiconductors and propulsion plasmas sustained via fusion) will be considered. Nuclear fission or fusion for large-scale energy production is not of prime interest to this portfolio.

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

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5. 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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6. Space Sciences

Program Description: The AFOSR Space Sciences program supports basic research on the solar-terrestrial environment extending from the Sun through Earth's magnetosphere and radiation belts to the mesosphere and lower thermosphere region. This geospace system is subject to solar radiation, particles, and eruptive events, variable interplanetary magnetic fields, and cosmic rays. Perturbations to the system can disrupt the detection and tracking of aircraft, missiles, satellites, and other targets; distort communications and navigation signals; interfere with global command, control, and surveillance operations; and negatively impact the performance and longevity of 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 strongly encouraged to submit short White papers (three pages max) prior to developing full proposals. White papers should briefly describe the proposed effort and how it will advance the current state-of-the-art. It should include a list of any collaborators and an approximate yearly cost for the effort.

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7. Ultrashort Pulse Laser-Matter Interactions

Program Description: The objective of this program is to explore and understand the broad range of physical phenomena accessible via the interaction of Ultrashort pulse laser sources with matter in order to further capabilities of interest to the U.S. Air Force, including directed energy, remote sensing, communications, diagnostics, and materials processing. The program aims to understand and control light sources exhibiting extreme temporal, bandwidth and peak power characteristics.

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

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

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

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

High quality efforts from single individual investigators or collaborative, multi-investigator teams will be considered. Prior to submitting a basic research proposal, interested parties are highly encouraged to contact the AFOSR Program Officer to discuss the proposed research project. If interested, the Program Officer will request a White paper on the proposed effort. Researchers with White papers of significant interest will subsequently be invited to submit full proposals. Research efforts requesting consideration for FY14 funds should plan to have White papers submitted by April 1, 2013 and full proposals by June 1, 2013.

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c. Information, Decision and Complex Networks (RTC):

The Information, Decision, and Complex Networks Department is designed to support many U.S. Air Force priority areas including space situational awareness, autonomy, and cyber. The programs in the Department include Complex Networks, Computational and Machine Intelligence, Dynamic Data Driven Application Systems, Foundations of Information Systems, Information Operations and Security, Mathematical and Computational Cognition, Science of Information Computation and Fusion, Sensing Surveillance and Navigation, Systems and Software, and Trust and Influence.

Information: Critical challenges for the U.S. Air Force moving forward 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 from the infrastructure to the mission levels of the systems. The Science of Information, Computation and Fusion Program enables the ability to collect, disseminate and integrate information in such a way as to mathematically characterize and assess the most appropriate information for a range of mission critical tasks. The Sensing Surveillance and Navigation Program develop algorithms to collect and decompose critical sensing information and enables techniques that interface between the physical domains such as Electromagnetics and methods in navigation and geo-location. The Dynamic Data Driven Applications Program enables analysis of the interplay between physical systems such as fluid dynamical systems and software systems and architectures as in the case of aircraft flight systems. The Information Operations and Security Program looks at fundamental issues for assessing systems in terms of secure operations and mission assurance and the Systems and Software Program assesses these systems from a verification and validation standpoint to guarantee operations under a variety resource constraints.

Decision Making: This thrust 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. The Computational and Machine Intelligence as well as the Mathematical and Computational Cognition Programs focus on machine and human cognition and learning. The objective is to maximize the ability of machines to conduct higher level cognitive activities with quantifiable risk and accurate models of human decision makers. The Trust and Influence Program seeks to model and measure the way collections of individuals make decisions and are influenced both in small groups and culturally.

Complex Networks: Complex Networks consists of the Complex Networks Program and the Foundations of Information Systems Programs. Complex Networks is designed to mathematically represent networks of all kinds including communications and computation at all levels including content, protocol, and architecture. This mathematically unified representation is meant to measure, represent, resource, and secure critical infrastructures for U.S. Air Force and Department of Defense (DoD) applications. Additionally, the Foundations of Information Program is designed to use measurements and representations from the Complex Networks Program to verify and validate critical infrastructure performance.

1) Complex Networks, Dr. Robert Bonneau
2) Computational and Machine Intelligence, Dr. Jay Myung
3) Dynamic Data Driven Applications Systems (DDDAS), Dr. Frederica Darema
4) Foundations of Information Systems, Dr. Robert Bonneau
5) Information Operations and Security, Dr. Robert L. Herklotz
6) Mathematical and Computational Cognition, Dr. Jay Myung
7) Robust Decision Making in Human-System Interface, Dr. Jay Myung
8) Science of Information, Computation and Fusion, Dr. Tristan Nguyen
9) Sensing, Surveillance, Navigation, Dr. Tristan Nguyen
10) Systems and Software, Dr. Robert Bonneau
11) Trust and Influence, Dr. Joseph Lyons

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 and Machine Intelligence

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

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

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3. 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: <u>Applications modeling</u>: In DDDAS an application/simulation must be able to accept data at execution time and be dynamically steered by such dynamic data inputs. This requires research advances in application models that: describe the application system at different levels of detail and modalities; are able to dynamically invoke appropriate models as needed by the dynamically injected data into the application; and include interfaces of applications to measurements and other data systems. DDDAS will, for example, engender an integration of large scale simulation with traditional controls systems methods, thus provide an impetus of new directions to traditional controls methods. Advances in Mathematical and Statistical Algorithms include creating algorithms with stable and robust convergence properties under perturbations induced by dynamic data inputs: algorithmic stability under dynamic data injection/streaming; algorithmic tolerance to data perturbations; multiple scales and model reduction; enhanced asynchronous algorithms with stable convergence properties; multimodal, multiscale modeling and uncertainty quantification, and in cases where the multiple scales or modalities are invoked dynamically and there is need for fast methods of uncertainty quantification and uncertainty propagation across dynamically invoked models. Such aspects push to new levels of challenges the traditional computational math approaches. Application Measurement Systems and Methods include improvements and innovations in instrumentation platforms, and improvements in the means and methods for collecting data, focusing in a region of relevant measurements, controlling sampling rates, multiplexing, multisource information fusion, and determining the architecture of heterogeneous and distributed sensor networks and/or networks of embedded controllers. The advances here will create new instrumentation and control capabilities. Advances in Systems Software runtime support and infrastructures to support the execution of applications whose computational systems resource requirements are dynamically dependent on dynamic data inputs, and include: dynamic selection at runtime of application components embodying algorithms suitable for the kinds of solution approaches depending on the streamed data, and depending on the underlying resources, dynamic workflow driven systems, coupling domain specific workflow for interoperation with computational software, general execution workflow, software engineering techniques. The systems software environments required are those that can support execution in dynamically integrated platforms ranging from the high-end to the real-time data acquisition and control - cross-systems integrated. Software Infrastructures and other systems software (OS, data-management systems and other middleware) services to address the “real time” coupling of data and computations across a wide area heterogeneous dynamic resources and associated adaptations while ensuring application correctness and consistency, and satisfying time and policy constraints. Specific features include the ability to process large volume, high rate data from different sources including sensor systems, archives, other computations, instruments, etc.; interfaces to physical devices (including sensor systems and actuators), and dynamic data management requirements.

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

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

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4. Foundations of Information Systems

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

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

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5. Information Operations and Security

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

Basic Research Objectives: The development of a Science of Cyber Security is the major thrust of this program. The development of the mathematical foundations of system software, hardware, human users and attackers, and network architectures with respect to cyber security (implemented in policy), including key metrics, abstractions, and analytical tools is a critical issue. Security policy research is of high interest to this program. Formal modeling and understanding of the human users and attackers in these systems is of high interest. Developing the theory and methods to operate securely on distributed and cloud systems and systems that may not be secure is of high interest. New approaches for cyber forensics, active response, moving target, fight through and recovery related to cyber-attack is of high interest. Attack attribution is of particular interest. Basic research that predicts and anticipates the nature of future information system attacks is of high interest. Research that leads to methods to discover malicious code already imbedded in software or hardware is a high priority. The theory and modeling of covert and side channels is of high interest.

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6. Mathematical and Computational Cognition

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

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

In relating formal models to human cognition and performance, research projects should not only ascertain their descriptive validity but also their predictive validity. To this end, the program welcomes the work that (1) creates a statistical and machine learning framework that semi-autonomously integrates model development, evaluation, selection, and revision; (2) bridges the gap between the fields of cognitive modeling and artificial general intelligence by simultaneously emphasizing important improvements to functionality and also explanatory evaluation against specific empirical results. The program also encourages the development and application of novel and innovative mathematical and neurocomputational approaches to tackle the fundamental mechanisms of the brain, that is, how cognitive behavior emerges from the complex interactions of individual neurobiological systems and neuronal circuits. Cross-disciplinary teams with cognitive scientists in collaboration with mathematicians, statisticians, computer scientists and engineers, operation and management science researchers, information scientists, econometricians and game theoreticians, etc., are encouraged, especially when the research pertains to common issues and when collaboration is likely to generate bidirectional benefits.

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7. Robust Decision Making in Human-System Interface

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

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

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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. 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 Battlespace. “Signals Communication” is a sub-area referring to the conveyance of information physically through a channel. Surveillance images are of special importance in targeting, damage assessment and resource location. Signals are either naturally or deliberately transmitted, propagated as electromagnetic waves or other media, and recaptured at the receiving sensor. Modern radar, infrared, and electro-optical sensing systems produce large quantities of raw signaling that exhibit hidden correlations, are distorted by noise, but still retain features tied to their particular physical origin. Statistical research that treats spatial and temporal dependencies in such data is necessary to exploit its usable information.

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 audio, video, and multi-spectral data. New combinations of known methods of asset location and navigation are being sought, based on analysis and high-performance computation that bring a force-multiplier effect to command/control capabilities. Continued upgrade and reliance on Global Positioning System makes it critical to achieve GPS-quality positioning in situations where GPS by itself is not sufficient. Ongoing research in Inertial and non-Inertial navigation methods (including optical flow and use of signals of opportunity) will bring location precision and reliability to a superlative level. Continuous improvement in its repertoire of signal processing and statistical tools will enable the U.S. Air Force to maintain its lead in Battlespace awareness through navigation and surveillance. Communications are what hold together the networked Infosphere and cost-effective systems innovations that enable phenomenal air power projection.

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10. Systems and Software

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

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

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11. Trust and Influence

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

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

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d. <u>Complex Materials and Devices (RTD):</u>

The Complex Materials and Devices Department leads the discovery and development of the fundamental and integrated science that provides novel options that increase operational flexibility and performance of systems and environments of relevance to the U.S. Air Force. A key emphasis is the establishment of the foundations necessary to advance the integration or convergence of the scientific disciplines critical to maintaining technological superiority. The Department carries out its ambitious mission through leadership of an international, highly diverse, and multidisciplinary research community to find, support and fosters new scientific discoveries that will ensure future novel innovations to transform the U.S. Air Force of the future.

This Department focuses on meeting the basic research challenges by leading the discovery and development of fundamental science and engineering across three integrated research focus areas:

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

Complex Electronics and Fundamental Quantum Processes: This includes exploration and understanding of a wide range of complex engineered materials and devices, including non-linear optical materials, optoelectronics, Metamaterials, cathodes, dielectric and magnetic materials, new classes of high temperature superconductors, quantum dots, quantum wells, and Graphene. In addition to research into underlying materials and fundamental physical processes, this area considers how they might be integrated into new classes of devices and a fundamental understanding of materials that are not amenable to conventional computational means (e.g., using optical lattices to model high-temperature superconductors).

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

The program descriptions that follow address specific sub-areas of interest as well as explore novel ideas to bridge disciplines across the research scoped through the three broad areas above. Many critical research activities fostered under the programs discussed here are multidisciplinary and involve support from the other scientific Departments within AFOSR. Research at the interfaces across disciplines often provides insights necessary for and leading to new technological advances. Creativity is highly encouraged in proposing novel scientific approaches for our consideration.

1) Adaptive Multimode Sensing, Dr. James Hwang
2) Aerospace Materials for Extreme Environments, Dr. Ali Sayir
3) GHz-THz Electronics, Dr. James Hwang
4) Low Density Materials, Dr. Joycelyn Harrison
5) Mechanics of Multifunctional Materials and Microsystems, Dr. Byung-lip Lee
6) Natural Materials and Systems, Dr. Hugh C. De Long
7) Optoelectronics and Photonics, Dr. Gernot S. Pomrenke
8) Organic Materials Chemistry, Dr. Charles Lee
9) Quantum Electronic Solids, Dr. Harold Weinstock

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

1. Adaptive Multimode Sensing

Program Description: This program seeks to discover and exploit scientific breakthroughs in natural and artificial (Meta) solid-state electronic and photonic materials, micro/nanostructures, novel device physics concepts, and sensing and data exploitation schemes potentially enabling for future transformational capabilities in adaptive combinatorial multimodal sensing methods. Breakthrough novel EO/IR sensor designs and methods are essential for meeting envisioned long-term game-changing U.S. Air Force Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) capability needs. Future U.S. Air Force universal situational awareness needs include near real-time detection, tracking, and identification of low-contrast and complex targets in broad areas and highly-cluttered dynamic environments, integrated with near real-time communication of resultant actionable data to battlefield commanders. Resulting near instantaneous sensor-to-shooter capability will require remote and autonomous real-time-closed-loop-controlled target spectra sensing, data fusion and processing, knowledge objective exploitation, and communications.

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

One can envision a hypothetical imaging focal plane array possessing individually addressable pixels of one construct or another, and each pixel having tunable wavelength, polarization, and phase set-and-read capability, i.e., a multimodal-sensor-in-a-pixel. Then in principal one could find the optimum minimum number of pixels and pixel modalities needed to achieve a specified knowledge objective as governed by closed-loop decision and exploitation algorithms. However, a fully adaptive and integrated multimodal sensing (AIMS) capability, along with complimentary closed-loop sensor-mode decision and control algorithms do not yet exist. Today, a majority of military ISR platforms are single-mode and independently operated, forwarding data via their own specialized (stove-piped) ground processing channels with poor interoperability. Many ISR assets generate enormous volumes of data that greatly bottleneck communications bandwidth (e.g., Gbps-Pbps versus Mbps) and completely overwhelm ground C2 man-in-loop exploitation and recognition capabilities. In fact in many cases the vast majority of collected and transmitted ISR data is deemed redundant and/or useless. Herein lies a crucial breakthrough opportunity for PDS, whereby one senses, processes, exploits, and communicates only the most decision-relevant target/scene spectra data. However, very significant and substantial basic and applied research challenges presently confront the realization of PDS. These challenges span multidisciplinary topics in electronics and photonics, novel solid-state materials sciences, novel electromagnetic spectra, micro/nanostructures interactions and phenomenology, innovative compact mixed-mode device constructs and physics, and breakthrough closed-loop decision and exploitation algorithms.

Basic Research Objectives: Fundamental solid-state materials science and device physics challenges facing many envisioned multimodal sensing concepts are primarily driven by three factors: 1) incompatible electronic and optical interactions at complex device heterointerfaces, where lattice-mismatched layers produce a plethora of deleterious structural and electrical defect states that enhance photo-carrier generation and, more importantly, recombination, 2) interface electronic band-discontinuities yield deleterious potential barriers that retard carrier transport, and 3) paramount challenge associated with non-demolition interrogation of mixed-mode spectra, preserving electromagnetic wave properties under test. For example, methods are needed to determine the number of photons in some range $\Delta\lambda$, while preserving the photon (or a large fraction of them) properties long enough to query their polarization state.

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

Additionally, novel multimodal sensor device constructs, concepts and methods are desired for achieving co-bore sighted multimodal spectra imaging in a staring format, as well as non-image detection and spectral discrimination techniques. Novel concepts are sought for tunable/reconfigurable pixel/detector element approaches offering multiple modes in one or more UV-LWIR bands, same-pixel multicolor (4+ wavelength bands) designs with suitable pixel-to-readout interconnect schemes, and biologically inspired multimodal detection processes and devices. Possible sensor structures include, but are not limited to, integrated monolithic/hybrid approaches utilizing homogeneous/heterogeneous material layers and structures, multi-dimensional quantum and nanobased structures, and any combination thereof, with a requirement that novel sensor device concepts should have a reasonable expectation of yielding external quantum efficiencies in excess of 50%.

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2. 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 high temperature materials (nominally temperatures above 1000°C) including: ceramics, metals, hybrid systems including composites that exhibit superior structural, functional and/or multifunctional performance. Interest domain includes the fundamental science at the interface of phases of heterogeneous structures, nanotechnology and mesotechnology efforts are focused on new architectures using crystal chemistry principles to create pathways to synthesize transparent ceramics, fiber materials, three dimensional power structures and heterogeneous materials.

Basic Research Objectives: While the focus of this basic research is the design, creation, and employment of nontraditional approaches on synthesis of novel materials and nanostructures, for example, by using electric fields, lasers, microwave and other external field approaches that take into account of geometric or topological descriptors to characterize similarity and scaling between stimuli under the multi-dimensional external fields to secure revolutionary advances. 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 loads) under high energy density non-equilibrium extremities. This program also embraces materials that are far from the thermodynamic equilibrium domain (bulk metallic glasses, highly doped polycrystalline materials and supersaturated structures etc.). Realization of these multi-component systems that are far from equilibrium may also require new approaches to how computation itself is modeled or even an entirely new understanding of computation. Often the modeling approaches make casual inference about the microstructural features and basic research methodologies and metrics are needed. The aim is to explore the possibility for the quantification of microstructure through reliable and accurate descriptions of grain and particle shapes, and identifying sample distributions of shape descriptors to generate and predict structures which might revolutionize the design and performance.

A specific thrust area of interest 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 conduction, convection, and radiation physics. This portfolio is seeking to establish the scientific foundations that will enable a sophisticated level of control of heat transfer via interfacial phenomena in materials. Ideas relating to interactions among the vibrations of the atoms (phonons), excitations of the valence electrons (electrons and holes), and electromagnetic fields (photons) are interest to this program, and scientific concepts that combines their interactions with the interface that engender a rich basic science of heat transport and offer exciting potential for discovery of new physical phenomena will be considered.

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, especially when collaboration is likely to generate multidimensional benefits. 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 submit short (max 2 pages) White papers by email prior to developing full proposals. White papers should briefly describe the proposed effort and describe how it will advance the current state-of-the-art; an approximate yearly cost for a three to five year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals.

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3. GHz-THz Electronics

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

Basic Research Objectives:
I) THz Electronics: These include devices that are mainly based on covalent-bond semiconductors such as C, Si, Ge, GaAs, InP, GaN, and related compounds. The main challenges are in perfecting crystals, interfaces, transports and hetero-structures, as well as scaling to nanometer dimensions for THz operations, while maintaining adequate device characteristics such as on/off current ratio, sub-threshold turn-on slope, and breakdown voltage. Particular emphasis will be placed on approaches that can lead to room-temperature compact and high-power THz sources that can be tuned and modulated over wide bandwidth.

II) Novel GHz Electronics: These include devices that are mainly based on ionic-bond semiconductors such as complex oxides of transition metals, with less overlapped electron orbital's and much higher bandgaps or dielectric constants that may relax the requirement on crystalline perfectness while delivering much higher power than covalent-bond semiconductors can. The main challenges are in understanding different mechanisms for higher-quality, larger-area, and lower-cost growth on flexible substrates, as well as in understanding composition control, doping mechanism, correlated transport, metal-insulator transition, and topological insulating properties, especially in p-n and other hetero-junctions. Scaling to advance operation speed from the GHz range toward the THz range will also be explored.

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

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4. Low Density Materials

Program Description: The Low Density Materials portfolio supports transformative, basic research in materials design and processing to enable radical reductions in system weight with concurrent enhancements in performance and function. Such materials can transform the design of future U.S. Air Force aerospace and cyber systems for applications which include airframes, satellites, and adaptive vehicles. Among the routes to achieving game-changing improvements in low density materials currently emphasized within the program are understanding the impact of nanoscale porosity on aerospace structures and the creation of hierarchical architectures that combine materials of different classes, scales, and properties to provide synergistic and tailorable performance.

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 radical improvements in stimuli-responsive materials that can be used to couple structure and function in aerospace platforms is also a keen program interest. Material classes may be polymeric, ceramic, and metallic, possibly combining synthetic and biological species to engender lightweight structural integrity and multifuctionality.

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

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5. Mechanics of Multifunctional Materials and Microsystems

Program Description: The main goals of this program are to establish safer, more maneuverable aerospace vehicles and platforms with unprecedented performance characteristics; and to bridge the gap between the viewpoints from materials science on one side and structural engineering on the other in forming a science base for the materials development and integration criteria.

Basic Research Objectives: Specifically, the program seeks to establish the fundamental understanding required to design and manufacture new aerospace materials and microsystems for multifunctional structures and to predict their performance and integrity based on mechanics principles. The 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 sense, diagnose and respond for adjustment with minimum external intervention, (b) “adaptive” structures allowing reconfiguration or readjustment of functionality, shape and mechanical properties on demand, and (c) structural integration of energy harvesting/storage capabilities for “self-sustaining” system. This program thus focuses on the developing new design criteria involving mechanics, physics, chemistry, biology, and information science to model and characterize the integration and performance of multifunctional materials and microsystems at multiple scales from atoms to continuum. Projected 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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6. Natural Materials and Systems

Program Description: The goals of this multidisciplinary program are to study, use, mimic, or alter how living systems accomplish their natural functions 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 (non-medical only) area is focused on synthesis of novel materials and nanostructures using organisms as material factories. The program also focuses on understanding the structure and properties of the synthetic materials. 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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7. Optoelectronics and Photonics

Program Description: This program supports U.S. Air Force requirements for information dominance by increasing capabilities in image capture; processing, storage, and transmission for surveillance, communications and computation; target discrimination; and autonomous navigation. In addition, high bandwidth interconnects enhance performance of distributed processor computations that provide real-time simulation, visualization, and battle management environments. Further important considerations for this program are the airborne and space environment in which there is a need to record, read, and change digital data at extremely high speeds. Five major areas of interest include Integrated Photonics (including Optical Components, Optical Buffer, Silicon Photonics; Nanophotonics (including Plasmonics, Photonic Crystals, Metamaterials, Metaphotonics and Novel Sensing); Reconfigurable Photonics (including 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 explore new fundamental concepts in photonics; understand light-matter interactions at the nanoscale; 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 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. 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, polymers with controlled dielectric permittivity and magnetic permeability including negative index materials, and novel properties polymers modified with nanostructures. Applications of polymers in extreme environments, including space operation environments, are of interests. Material concepts for power management, 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, electrooptic polymers, liquid crystals, photorefractive polymers and magneto-optical polymers. Examples of electronic properties of interest include conductivity, charge mobility, 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. Potential proposers are encouraged to submit a one-page White paper by email outlining the proposed research for FY14 considerations before 15 May, 2013. The White paper should outline the research concept and approach, state the novelty of the research idea, and include a one-sentence proposed budget for the effort.

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9. 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, and on pure and doped nanotubes, with low power dissipation and the ability to provide denser non-volatile memory, logic and/or sensing elements that have the potential to impact future U.S. Air Force electronic systems.

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

The Metamaterials portion of this program is devoted to the production of 2-D and 3-D Metamaterials that operate over a wide swath of the electromagnetic spectrum, from microwaves, to IR and the visible. The long-term goal is to produce materials that improve the efficiency and selectivity of, and reduce the size of communications system components such as antennas, filters and lenses. Another important aspect is to study the ability to create sub-wavelength, near-field (and possibly far-field) imaging. These desired properties could lead to denser information storage and retrieval.

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

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

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e. Energy, Power and Propulsion (RTE):

The Energy, Power and Propulsion Department lead the discovery and development of innovative fundamental science addressing a broad spectrum of energy-related issues. The overarching goal of the department is to discover and exploit the critical knowledge and capabilities that will shape the development of energetically-efficient future U.S. Air Force systems. In pursuit of this goal, the Department proactively directs an international, highly diverse and multidisciplinary research community to find, support and foster new scientific knowledge that will provide the foundation for unprecedented energy efficiency in future systems.

The research supported by the Energy, Power and Propulsion Department spans a considerable set of topics ranging from biological systems to space propulsion, with the following research emphasis areas shared by many of the contributing portfolios:

Discovery and Development of Energy Sources: Research in this area emphasizes the identification and characterization of key fundamental phenomena that will provide the scientific foundation for revolutionary advancements in energy sources and conversion processes. A broad spectrum of research topics contribute to progress in this area, including, but not limited to: biologically-derived energy sources; innovative chemical formulations and synthesis; combustion enhancement; and scientific foundations for revolutionary propulsion concepts.

Fundamental Mechanisms of Energy Transfer: Research in this area emphasizes the identification, characterization and modeling of energy transfer between various energetic modes in a heterogeneous environment and across media boundaries. Representative topics of interest include, but are not limited to: phonon dynamics in heterogeneous media; transfer of energy between kinetic, internal and chemical states in gasses; biological interactions between living and non-living systems, and interactions between nonequilibrium environments and reactive surface boundaries.

Within the Department special emphasis is placed on the identification and development of multidisciplinary research opportunities where advancements and insight originating in one discipline may inspire and drive innovative progress in another.

1) Aerothermodynamics, Dr. John Schmisseur
2) Energy Conversion and Combustion Sciences, Dr. Chiping Li
3) Human Performance and Biosystems, Dr. Patrick O. Bradshaw
4) Molecular Dynamics and Theoretical Chemistry, Dr. Michael Berman
5) Space Power and Propulsion, Dr. Mitat A. Birkan

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

1. Aerothermodynamics

Program Description: The objective of the Aerothermodynamics portfolio is to develop the fundamental scientific knowledge of high-speed, nonequilibrium flows required for revolutionary advancements in a broad variety of future U.S. Air Force capabilities including energetically-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 the high-speed flow and at gas-surface interfaces through a balanced mixture of investments in experimental, numerical and theoretical efforts.

Basic Research Objectives: Innovative research is sought in all aspects of high-speed nonequilibrium flows with particular interest in efforts that explore the dynamics and mechanisms for energy transfer between the kinetic, internal and chemical modes of the gas. 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:

- Characterization and modeling of the coupled dynamics, thermodynamics and chemistry of nonequilibrium flows, driven by rate-dependent fundamental processes.
- Innovative insight into the control and exploitation of energy transfer within the flowfield is of particular interest. (Note: Combustion processes are addressed by other portfolios and are not within the scope of interest.)
- Shock/Boundary Layer and Shock-Shock Interactions
- Characterization and modeling of fundamental processes occurring between nonequilibrium flows and reactive surfaces.

Aerothermodynamic 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 Aerothermodynamic considerations. Research areas of interest emphasize the characterization, prediction and control of critical phenomena which will provide the scientific foundation for game-changing advancements in aerodynamics, environmental (thermal and acoustic) management, propulsion, and directed energy.

Researchers are strongly encouraged to submit short (max 6 pages) White papers to initiate discussion of a potential proposal topic prior to developing full proposals. White papers should briefly describe the proposed effort and illustrate how it will advance the current state-of-the-art;

an approximate yearly cost for a three year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals.

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2. Energy Conversion and Combustion Sciences

Program Description: This portfolio focuses on fundamental understanding of key multi-physics and multi-scale phenomena in conversion of chemical energy to mechanical energy, combustion or otherwise, for U.S. Air Force propulsion interests. The research emphasis is on identification and quantification of rate-controlling processes and critical scales in key phenomena in the energy conversion processes, leading to game-changing energy-conversion concepts and modeling/ simulation capabilities. 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 effort and should focus on clearly presenting logics of the proposed approach. Researchers with White papers of significant interest will be invited to submit full proposals.

Basic Research Objectives: Research proposals are sought in all aspects of energy conversion and combustion sciences with the following emphases:

(1) **Turbulent Combustion** is the central process in converting chemical energy to mechanical energy in most Air-Force propulsion systems. It is one of most important factors in determining operability, performance, size and weight of such systems. It is also one of least understood areas in basic combustion research with, in general, rather large model/prediction uncertainties. In this area, the research focus is on key combustion phenomena and characteristics, including but not limited to: flame propagation, flammability limit and combustion instability, at multi-phase conditions applicable to U.S. Air Force propulsion systems. Proposals will be considered with priority for understanding and quantifying interactions among different scales of multi-physics phenomena in turbulent combustion process with the following emphases:

- Quantifying rate-controlling processes and scales that govern the above mentioned key combustion phenomena and their interactions;
- Validating as directly as possible and further developing basic model assumptions used in the numerical simulation for turbulence combustion with the particular focus 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 building and validating sub-grid turbulent combustion models.

- In such proposed efforts, understanding, quantifying and controlling turbulence properties at corresponding flow conditions will be essential. Those conditions should be relevant to U.S. Air Force propulsion interests.

(2) **Combustion Chemistry** is another key element in the energy converging process, governing the fuel decomposition and subsequent energy release. The research focus is to develop physics-based approaches, based on rate-controlling reaction pathways, for generating combustion chemistry models of quantifiable and acceptable uncertainty with reasonable size for the turbulent, reactive flow simulations. Emphasized areas are as follows:

- The first principle based, theoretical and computational approaches for identifying key reaction pathways;
- Ab initio constrained methods for optimizing combustion chemistry models;
- Quantifying the uncertainty of research approaches in combustion chemistry and understanding relationship between the model size and model uncertainty.

(3) **Mathematical Methods and Computational Algorithms for Combustion Modeling**: Research efforts are closely coupled to portfolios in mathematical and computational areas of common interests, with the following emphases:

- Theoretical and computational approaches to study stochastic pathways in complex combustion chemical reaction systems;
- Capability to analyze large-scale datasets from experiments or simulations to extract key physics in combustion process;
- Combined experimental-numerical approaches using simulations directly coupled/ fused with experimental data to reduce the simulation uncertainty and to obtain quantitative information which is otherwise not available through experimental measurements alone.
- Approaches using numerical simulations as experimental tools (numerical experiments), with help of theoretical combustion research, to qualitatively explore key combustion phenomena and to reduce reliance on expensive ground and flight tests in the development U.S. Air Force propulsion systems;

(4) **Combustion Diagnostics** is crucial to observe the nature as it happens and to gather data for understanding key phenomena in the energy conversion process. Innovative efforts in this area will be continuously supported with the following focuses:

- Ultra-fast approaches (e.g. using ultra-short pulse laser) for observing ultra-fast events such as those in initial break-up of fuel molecules crucial to identifying key reaction pathways;
- High-frequency, three-dimensional (volumetric or scanning two-dimensional) imaging approaches for transient, turbulent flame and flow structures at required temporal and spatial scales;
- New game-changing signal generating processes and related basic spectroscopic approaches for key properties in chemically reacting flows.

(5) **Game-Changing Energy Conversion Concepts**: Proposals are solicited for concepts of unconventional combustion processes and other approaches for converting chemical energy to mechanical energy for the U.S. Air Force propulsion applications. Potential areas include but not limited to:

- Flameless or mild combustion;
- Fast and strong combustion process such as rotational detonation and steady-state detonation;
- Direct conversion from chemical energy to mechanical energy without (or minimizing) combustion or similar thermal processes;
- Alternative fuel of superior physical and combustion/energy-conversion properties with favorable source-characteristics.

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3. 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, tissue, cellular and genetic effects resulting from various forms of bio-stimulation. Recently, extremophiles has been added to this program.

Basic Research Objectives: This program is interested in defining the mechanisms (cognitive, neural, genetic, physiological, biological 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. The mechanism associated with the effects of photo-electro-magnetic stimulation as they relate to performance change is of interest to us. We wish to define and understand the biomarkers and genetic changes associated with human performance decrement after the administration of toxicological agents, specific interest in toxicology mechanisms that may or may not exhibit toxic effects at a minimal dose level and toxicological effects of flight line equipment). Proposals aimed at the understanding of synthetic biological process as they relate to energy production in Biosystems (specifically enzymatic and microbial fuel cells as well as photosynthesis) will be accepted.

The extremophiles area is focused on discovering and understanding basic natural mechanisms used by organisms that could be used to either harden or repair soft material-based devices. This will enable the U.S. Air Force to employ biological systems with optimum performance and extended lifetimes. As protein and nucleic acid molecules are increasingly used as catalysts, sensors, and as materials, it will be necessary to understand how we can utilize these molecules in extreme environments, with the ability to regulate the desired function as conditions change, and to store the device for prolonged periods of time. Areas of interest include: the mechanisms for survival and protein stability in extremophilic archaea, and enzymatic engineering for faster catalysis in materials identification or degradation.

Researchers are encouraged to submit White papers (3-4 pages) via email prior to developing full proposals. White papers should describe how the proposed effort will advance the current state-of-the-art, the uniqueness of the idea and include an approximate budget for a three to five year effort. Researchers with new and unique White papers will be invited to submit full proposals.

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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: Nanostructures and Catalysis; Energetic Materials; Atmospheric and Space Chemistry; and Lasers and Diagnostics.

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 plasmas, plasmonics, and laser excitation to control electron energy 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. Space Power and Propulsion

Program Description: Research activities are focused as multi-disciplinary, multi-physics, multi-scale approach to complex space propulsion problems, and fall into three areas: non-chemical launch and in-space propulsion, chemical propulsion, and plume contamination resulting from both chemical and non-chemical propulsion.

Basic Research Objectives: Research in the first area is directed primarily at advanced space propulsion, and is stimulated by the need to transfer payloads between orbits, station-keeping, and pointing, including macro- and nano-satellite propulsion. It includes studies of the sources of physical (non-chemical) energy and the mechanisms of release. Emphasis is on understanding electrically conductive flowing propellants (plasmas or charged particles) that serve to convert beamed or electrical energy into kinetic form.

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

All fundamental research ideas relating to space propulsion and power are of interest to this program in addition to the examples given above, but researchers should also consult the programs in Plasma and Electro-Energetic Physics, Aerospace Materials for Extreme Environments, Theoretical Chemistry and Molecular Dynamics, Thermal Sciences, Computational Mathematics, and other programs as described in this Broad Area Announcement to find the best match for the research in question. Joint innovative science projects may develop in the areas such as: (1) design and testing of compact, highly efficient and robust chemical or electric propulsion systems with minimal power conditioning requirements; (2) thermal management, sensing, self-healing, and other fundamental concepts to increase efficiency, and lifetime of space structures; (3) innovative processes that transform structural material into high energy density propellant (e.g. phase change, or even biological process); (4) novel energetic materials; and (5) development of modeling and simulation capabilities at all relevant scales, including a general mathematical framework for stochastic modeling of such systems, and facilitate the extraction of dominant causal relationships from large data sets. Researchers are highly encouraged to consult (**https://community.apan.org/afosr/w/researchareas/7459.space-power-and propulsion.aspx**), for the latest information

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f. Basic Research Initiatives (BRIs):

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

1) 2D Materials and Devices beyond Graphene
2) Bio-Sensing of Magnetic Fields
3) Development and Verification of Effective First Principles Modeling (Maxwell-Bloch Equations) of Semiconductor Lasers under Non Equilibrium Operating Conditions

4) Laser-matter Interactions in the Relativistic Optics Regime
5) Lasers Physics for Scaling of Single Fibers to High Beam Quality and High-power
6) Metal Dielectric Interface - Charge Transfer in Heterogeneous Media under Extreme Environments
7) Nanoscale Building Blocks for Novel Materials
8) Perceptual and Social Cues in Human-like Robotic Interactions
9) Plasma – Surface Interactions in Reactive Environments
10) Socio-Digital Influence
11) Theory-based Engineering of Biomolecular Circuits in Living Cells
12) Understanding the Interaction of Coronal Mass Ejections with the Solar-Terrestrial Environment
13) Understanding the Psychological/Behavioral Effects of Advanced Weaponry

U.S. Air Force Program Officers are listed by Sub areas below.

1. 2D Materials and Devices beyond Graphene

Background: Following the isolation of Graphene, a treasure trove of 2D layers have been successfully prepared, whose properties range from insulating (2D BN) to semiconducting (2D MoS2), with direct or indirect band-gap depending on the exact number of atomic layers. These new 2D materials not only complement Graphene, which is basically a conductor, but also, being 2D in nature without dangling bonds, minimally strain or otherwise perturb each other. Following the successful exploitation of thin- film hetero-structures over the past four decades, hetero-structures made of different 2D materials may enable a wide range of unique devices with unprecedented performance characteristics for electronic, photonic, sensing, structural, thermal and energy applications. For example, high-speed transistors that consume little power, optical detectors of extremely low noise, and structural layers with extremely high thermoelectric coefficients may be fabricated on flexible substrates. Multi-function devices for spintronics and quantum computing are also envisioned. However, although limited success for growing 2D BN on Graphene has been demonstrated, the weak van der Waals interaction between 2D layers makes it very challenging to grow one 2D material on top of another. It will take many years to develop growth techniques, whether van der Waals epitaxy or other techniques, for large-area 2D hetero-structures typically required for device fabrication on the commercial scale. In addition, there is little knowledge about properties derived from predictive modeling capabilities of 2D hetero-structures. Many of these challenges were discussed in a recent NSF/AFOSR workshop of the same name as this initiative (**http://nsf2dworkshop.rice.edu/**).

Objective(s): Grow, characterize and understand hetero-structures of different 2D materials with unique electronic, photonic, thermal and structural characteristics. Design, fabricate and explore devices based on such 2D hetero-structures.

Research Concentration Area(s):

- Innovative growth techniques for uniform and reproducible assembly of 2D hetero-structures with precise control of purity and stoichiometry

- Advanced characterization techniques and structure-property correlation for 2D materials and interfaces
- Theoretical tools for predictive modeling/simulation of properties of 2D materials and their interactions with the environment and other 2D materials including edge and interface effects
- Demonstration of 2D hetero-structure devices with unique performance characteristics

Resources: Under this initiative, several large teams and several small teams are anticipated to be funded for 3-5 years. Large teams may include 4-7 faculty members or equivalents for comprehensive investigation of material growth, characterization, modeling, and device demonstration with a budget on the order of $1 million per year. Small teams may include 1-3 faculty members or equivalents with a narrow focus such as hetero-structure growth, transport study, contact formation, or edge/interface effect with a budget of approximately $300,000 per year. For both large and small teams, international collaboration is encouraged, but not required. Before submitting a full proposal, potential proposer is highly recommended to email a White paper to one of the research topic chiefs listed below. The White paper should not exceed three pages. Additional sections on curriculum vitae, current and pending supports, facilities and equipment, and estimated budgets can be attached to the White paper and will not be counted against the page limit. AFOSR and NSF are collaborating on this initiative. Additional funding and requirements may be announced by NSF later.

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2. Bio-Sensing of Magnetic Fields

Background: A natural magnetoreceptor must be sensitive to the Earth's very low magnetic field strength. Despite compelling evidence that many animal species, from insect to migratory birds, show behavioral sensitivity to Earth-strength magnetic fields, a conclusive description of the underlying receptor mechanism is still missing. Since classical chemical reactions are unaffected at this level, a quantum-level process may be required. A current idea, known as the "radical pair hypothesis," proposes that electron transfer reactions in certain photolyase-derived retinal proteins, cryptochromes, form radical pairs with correlated spin dynamics susceptible to low-strength magnetic fields, hence acting as a non-linear biochemical interferometer. Exactly how this highly transient quantum-level effect could be sustained and converted to a neural signal has not yet been elucidated. A second proposed mechanism is based on biogenic magnetite, which has been isolated from a variety of animals in two forms, single-domain crystals with a fixed magnetic axis, and superparamagnetic crystals, which track the direction of a weak external field. While the radical-pair mechanism is tied to photoreception, and requires a certain level of luminance, the magnetite-based would operate in complete darkness.

Objective(s): This BRI initiates a basic research program to understand biological magnetic field sensation. These research projects will (a) address the bio-sensory basis for long-range navigation by orientation to the geo-magnetic field, (b) elucidate possible quantum-level physical mechanisms for magnetic field sensation tied, e.g., to cryptochromes, and (c) provide a scientific foundation for the effects of static and pulsed magnetic fields on the cellular and molecular level of neural processing.

Research Concentration Area(s):
(1) Long-range navigation: Understanding the key factors underlying the geo-magnetic field compass, especially its bio-sensory basis using novel, robust, and reproducible experimental approaches. Possible research includes, but is not limited to behavioral and neurophysiological experiments on genetically modified organisms.
(2) Spin chemical receptor mechanism: Determining the functional role of molecules of the cryptochrome family for the transduction process of magnetic field sensing. Explore possible contributing quantum-level physical mechanisms, and the signaling pathway.
(3) Magnetic effects on neural processing: Establishing the scientific foundation for current AFRL explorations of effects of strong magnetic fields on neural processing. Understanding the cellular and molecular neuronal processes following exposure to static and pulsed magnetic fields

Resources: This BRI particularly invites multi-disciplinary teams. The submission of concise (3 page) White papers prior to developing full proposals is highly recommended. White papers should briefly describe the current state of related research, the potential of the proposed effort to advance it, and include a yearly budget estimate for a three to five year effort.

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3. Development and Verification of Effective First Principles Modeling (Maxwell-Bloch Semiconductor Equations) of Semiconductor Lasers under Non-equilibrium Operating Conditions

Background: The current state-of-the-art in modeling and consequently understanding the physics of semiconductor active structures derives from ad-hoc parameterized models that rely on experimental input to fit multiple parameters and completely lacks any predictive capability so that any device realization requires a long and expensive trial-and-error scheme. Part of this failure can be ascribed to an insufficient understanding of the fundamental principles governing the semiconductor gain medium operating under extreme non-equilibrium conditions. Effective Maxwell-Bloch Semiconductor equations are the essential basic science in describing many-body and plasma-dynamic effects in highly excited semiconductors, such as the operating electron-hole plasma in semiconductor lasers.

Objective(s): The objective of this BRI is to support theory and measurements that are highly sensitive to detailed gain and index dynamics and should therefore provide verification or otherwise of the effective Maxwell-Bloch Semiconductor (M-BS) Equations as representations of the dynamic gain and index dependence on carrier density and photon energy. It is the case that ultrafast many-body interactions on femtosecond timescales between electrons, holes, and phonons dictate the performance of ultra-short semiconductor laser pulses. Indeed the ultra-short pulses generated in semiconductor active media exhibit very strong pulse distortions which can likely be ascribed to strong nonlinear interactions due to those highly non-equilibrium carrier distributions resulting from ultrafast carrier-carrier and carrier-phonon scattering in both semiconductor gain and saturable absorber elements in the cavity. Also the Continuous Wave operation of semiconductor lasers, especially at high electrical/optical pumping, can likely be ascribed to strong nonlinear interactions due to highly non-equilibrium injection. While the many-body equation hierarchy is now well established, modelers have relied thus far on some quasi-equilibrium approximations where the nonlinear optical response is linearized about some reference carrier density or temperature. The latter approximation suffices to address a broad range of problems relating to the design of semiconductor laser structures but fails under conditions where the physical system is subjected to extreme conditions such as very high pump levels (strong departure from Fermi-Dirac distributions). Understanding the physics of these extreme conditions is a compelling and exciting scientific goal. In addition, because the M-BS equations make predictions that haven't been measured yet, some key ideas in many-body problems may be disproven.

Research Concentration Area(s): Many-body microscopic interactions of electron and whole plasmas and their coupling to lattice phonons (especially under strong non-equilibrium conditions such as substantial departure from Fermi-Dirac distributions). Inclusion of large separations of physical time scales requiring the development of sophisticated mathematical approaches. Confirmation of theoretical predictions in dynamic-state and pulsed-laser systems in laboratory settings leading toward a comprehensive understanding and a new mathematical foundation for semiconductor laser physics

By fully implementing a first-principles approach it will not only become possible to fast-track novel devices but also to establish semiconductor laser analysis and modeling as a new scientific discipline with truly predictive capabilities.

Resources: Approximately $1.1M is available annually to support 3 year efforts awarded through this topic. Efforts from collaborative, multi-investigator teams are highly encouraged. Prior to submitting a basic research proposal, interested parties should contact the AFOSR Program Officers below to discuss the proposed research project. The awards are expected to have a start date of 1 August 2013 with the 1st period being 14 months and the next 2 periods running 12 months each so formal proposal should be submitted in Spring 2013.

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4. Laser-matter Interactions in the Relativistic Optics Regime

Background: Since the first demonstration of the laser in 1960, there has been a remarkable increase in the peak power available from pulsed lasers. Techniques for the generation and amplification of laser pulses, such as Q-switching (1962), mode-locking (1964) and chirped pulse amplification (CPA) (1985), have enabled laser peak powers to increase by 12 orders of magnitude from the kilowatt level, available from the first pulsed ruby lasers, to the Petawatt (PW = 10^15 W), first demonstrated in the late 1990s at the Lawrence Livermore National Laboratory.

The ability to achieve record ultrahigh peak powers has provided scientists research opportunities to explore the fundamental interactions of extreme light fields with matter. Laser produced plasmas easily generate secondary forms of radiation such as coherent extreme ultraviolet, x-rays and protons. In the relativistic optics regime, the ionized electrons quiver with relativistic speeds, giving rise to effects such as laser wakefield acceleration where electrons are accelerated to gigaelectronvolt (GeV) energies over centimeters distances; a 10,000x length reduction relative to conventional accelerators. At even higher intensities, not previously available, protons can also respond relativistically possibly resulting in radiation sources with novel and extreme characteristics. It is theorized that at the very highest intensities, we can approach and see evidence of nonlinear quantum electrodynamics (QED) interactions (e.g. Schwinger electron-positron pair production from vacuum is expected to be observable at intensities I~10^27 W/cm^2).

In contrast to the LLNL Petawatt, which was a large scale laser user facility, table-top CPA laser science and technology has advanced at a similar pace resulting in laser systems with significantly shorter pulse durations, high repetition rates and much increased focused laser intensity. The last two decades alone has experienced a remarkable six order of magnitude increase in the achieved focused intensity of table-top CPA lasers to a record intensity of 2x10^22 W/cm^2. Table-top lasers at a myriad of academic and national labs worldwide routinely generate peak powers well above 10 terawatts (TW) and, in some cases, above 100 TW. In what is becoming a potential paradigm shift, petawatt-scale science is moving from a few large scale (i.e. building sized) national facilities operating at very low repetition rates (i.e. few laser shots per day) to compact (i.e. few table-tops) university-scale laboratories operating a much high rep rates (i.e. a laser shot every few seconds). In addition, CPA technology to go well beyond 1 PW and to increase the average power of PW-class lasers exists and is maturing rapidly; evidenced by several projects to build 10 PW-class lasers (e.g. Extreme Light Infrastructure).

Objective(s): The extraordinary increase in achieved focused laser intensity provides access to a wide range of underlying physical regimes that span from nonlinear optics to relativistic plasma physics and approach nonlinear QED interactions. The recent proliferation of Petawatt-class lasers at university scale laboratories opens up a number of exciting and unprecedented research opportunities for the investigation and application of laser-matter interactions at the highest intensity level. The objective of this initiative is to explore and understand the rich variety of physical processes and potential new physics involved in the interactions of extreme light fields with matter in the relativistic optics regime.

Research Concentration Area(s): This initiative seeks to address research areas which include, but are not limited to, the following:

- Fundamental studies of atomic/molecular physics in the strongest fields ever created (i.e. >10^22 W/cm^2).
- Novel concepts for laser acceleration of ions (e.g. protons and heavy ions) to include, but not be limited to, new acceleration mechanisms, novel microstructured targets and optimal regimes of operation exhibiting high flux and narrow energy spread.
- Novel approaches for laser-driven electron acceleration to include, but not be limited to, pathways towards 10 GeV energy electrons, increased electron bunch charge with monochromatic energy spread and vacuum-based (vs. plasma-based) acceleration concepts.
- Laser-based, high-energy particle, X-ray and γ-ray sources exhibiting high flux and narrow energy spread.
- Exploration of nonlinear QED physics with high intensity lasers (e.g. electron-positron pair production from vacuum).

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $2M/yr in the research supported by this initiative. It is highly encouraged that submitted proposals include strong experimental, theoretical and modeling components as well as international collaborations aimed at fostering joint research and the exchange of researchers. Proposals submitted under this initiative should support teams of typically 2-4 investigators with awards ranging from $500k-650k/yr for 3 years. Interested parties are encouraged to submit a White paper on their proposed effort no later than **April 12, 2013**. Full proposals are due by **May 31, 2013**.

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5. Lasers Physics for Scaling of Single Fibers to High Beam Quality and High-Power

Background: Fiber lasers today are regarded as the preeminent laser, having qualities which will enable scaling to high power levels with good beam quality. A recent proposal submitted to the EU science Department proposed replacing the CERN collider for elementary particle high energy research with a fiber laser system composed of the combination of several million individual fiber units that are brought to a focus. In addition, current thinking within the DoD and Europe is that the high brightness required for military applications will only come from advances in fiber lasers.

Radiation within a fiber is amplified and guided by the core of the fiber. Because of its long propagation length, high optical-to-optical conversion efficiencies are possible. Fundamental mode operation and therefore good beam quality is readily achievable in small core diameter fiber. In addition, due to a high surface to volume ratio, the heating effects typically found in solid state lasers are generally less severe.

Even with the progress that has been made in the development of high power continuous wave (CW) and pulsed fiber lasers, numerous challenges still exist. For both narrow and broad line-width optical fiber lasers, the onset of nonlinear and other effects tends to limit the achievable output power. Also, for pulsed lasers, material breakdown is an issue. For larger mode area fibers, beam quality can be an issue since such fibers are multi-mode. Considerable effort has been devoted to the development of specialty fibers to simultaneously enable high power with good beam quality, for example, large mode area photonic bandgap and large pitch photonic crystal fiber configurations. Another challenge is to expand the range of wavelengths where fiber lasers are currently available and to develop lasers that can be tuned over broad wavelength ranges. As an example, fiber lasers, other than hollow gas-filled lasers which lase on discrete wavelengths, are currently not available at wavelengths longer than 2.8 microns. Much work is needed to develop materials to enable lasing at new wavelengths. Once such materials exist, more work is necessary to develop the technology to fabricate optical fibers from such material.

In addition to the challenges listed above, there is an extensive field of application for compact devices containing fiber lasers operating from the visible to the far infrared due to easy doping of the fiber core with the active ions. Such fiber lasers have found applications in medicine for cutting and ablation; in the automotive industry for cutting and drilling applications; in bio-sciences; in laser gyroscopes for navigation; in sensors for national security; as well as the fields of communications, quantum information devices and plasmonic structures. For defense applications, the main direction of research has been toward the development of lasers for weapons applications, communications and encryption, as well as surveillance. Finally, if fiber lasers could be developed at new, interesting, wavelengths, even more applications will become possible.

Objective(s): This program would address the fundamental science behind the development and the scaling of individual CW and pulsed optical fibers operating between 1 and 8 microns to high power while maintaining fundamental mode operation and good beam quality. Such research would increase the fundamental knowledge of fiber lasers through the investigation of: 1. factors that are limiting or enhancing to power scaling; 2. novel fiber power scaling schemes; 3. novel optical fiber designs and their fabrication; 4. the development of optical materials that lase at new wavelengths and their fabrication into optical fibers; 5. new, untried, schemes to enable more efficient lasing or lasing at new wavelengths; as well as 6. new, untried, coherent combination schemes. The focus, which is two-fold, will be on new ideas and concepts that have the potential to be game changing when applied to current research problems or on new ideas and concepts, divergent from the current direction of research, having the potential to open up new areas to be explored.

Research Concentration Area(s): The proposed BRI seeks to address the following research challenges and goals for the third decade of high-power fiber laser science:

1. Development of new theories to explain the dynamics associated with scaling CW and pulsed optical fibers to high power. This may include the development of a fundamental understanding of the mechanisms behind the factors limiting or enabling the scaling of a fiber up in power. It also may include investigation of both the linear and nonlinear properties of new fiber materials which are critical for power scaling and transmission. Experimental validation of any new theories may also be included.
2. Development of new schemes for scaling of CW and pulsed fiber lasers to high power. Such schemes may involve novel: materials, pumping techniques, lasing mechanisms, pump wavelengths, fiber designs, temporal formats for pulsed lasers, mechanisms for waveguiding, etc. This may also include the investigation of architectures that further optimize thermal management such as large surface to volume ratio structures and structures having a non-concentrated gain region.
3. Development of new optical fiber designs and their fabrication. This may include the development of novel waveguiding schemes, the utilization of new materials (possibly Metamaterials), the usage of a mixture of laser gain and loss materials to maintain single fundamental mode operation and the development of novel fabrication methods. It may also include the usage of directly coupled waveguides for coherent propagation and the utilization of materials of uniform structure having minimal stresses at the interfaces (core/cladding). Along with this, technology needs to be developed to enable fabrication of these structures.
4. Development of new materials to enable lasing at new wavelengths and the improvement of existing materials as well as their fabrication into optical fibers. This may include the development of a full understanding of the level structure, oscillation wavelength, radiative decay times, atomic associations and clustering mechanisms, etc. for each type of active ion center. A full understanding of the various lasing mechanisms of the material should be obtained as well as the best way to prepare and optimize excitation of the material to enable efficient lasing. Also, materials having a high thermal conductivity to minimize thermal effects and materials having a high gain and/or small SBS/SRS gain coefficients to minimize nonlinear effects are of interest. In addition, this may include the development of the technology to enable fabrication of the material into an optical fiber which will guide light.
5. Development of new, untried schemes (other than new materials) to obtain lasing at hard to reach wavelengths. This may include novel Raman laser systems, novel pumping schemes, the use of nonlinear optics to obtain other wavelengths, etc.

6. Investigation of forward-leaning, untried novel coherent or spectral beam combining schemes to enable placement of near diffraction-limited power on a target down range. Such beam combining techniques may be hybrid, i.e., coherent/spectral and or passive/active. Development of techniques for combining the output of pulsed fiber lasers.
7. Investigation of additional ideas, not mentioned, that will advance the science of fiber lasers.

Many problems associated with the scaling of individual CW and pulsed fiber lasers up in power are unsolved. Also, fibers lasers at this point in time do not exist at many wavelengths which may have interesting applications. The goal of this BRI is to significantly advance the science associated with the current direction of fiber laser research as well as to open up new, exciting, promising, fiber laser research areas through new ideas and directions. The goal is to bring about a significant advancement in the state-of-the-art which may open up new applications for fiber lasers.

Resources: Approximately $1.8 M is available annually to support 3 year efforts awarded through this topic. Efforts from collaborative, multi-investigator teams are highly encouraged. It is highly encouraged that any submitted proposals include strong experimental, theoretical and modeling components as well as international collaborations aimed at fostering joint research and the exchange of researchers. Fiber lasers are a research area listed in the BAA of the EU Framework Process and are thus a major interest of the European Research Council (ERC). In addition, European countries are leaders in the world in high-power fiber lasers. Therefore, international components and collaborations are welcomed and encouraged.. Prior to submitting a basic research proposal, interested parties should contact the AFOSR Program Officers below to discuss the proposed research project. The awards are expected to have a start date of 1 August 2013 with the 1st period being 14 months and the next 2 periods running 12 months each. Formal proposals should be submitted by the spring of 2013.

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6. Metal Dielectric Interface: Charge Transfer in Heterogeneous Media under Extreme Environments

Background: High density capacitors and ferroelectric, oxide, and ceramic dielectric devices, both linear and non-linear, are a mainstay of electronic integrated circuits and energy storage devices for high technology products of the U.S. Air Force and DoD, where they perform essential functions such as storing electrical charge/energy, and blocking direct current while allowing alternating currents to propagate. Effective high dielectric permittivity is most effectively achieved by using metal-dielectric and semiconductor-dielectric capacitor structures. These interfaces are ubiquitous in electronics, particularly where triple points—metal plus two different dielectrics (generalized to include vacuum or air) with vastly different permittivity's are a source of failure under high external fields. This remains an important area where the fundamental description of the physics is an unsolved scientific challenge. The need to study fatigue and failure (dielectric breakdown at hetero-interface) stems from the high potential technological relevance of high energy density capacitors, and from the very controversial discussion of the underlying mechanisms during the last twenty years. The picture becomes more complicated when we include new time-scales to the variety of spatial scales already introduced by the hetero-structure. It is well known that as the power of the discharge increases, the achievable energy density exponentially decreases. The reason of this is also not definitively known, but clearly depends on the non-equilibrium transport of energy and charge through the structure and through these dielectric-metal interfaces.

Objective(s): This BRI aims to expand the scientific understanding of this problem through the incorporation of the new mathematical enterprises that are becoming a cornerstone of materials science and engineering. This allows the potential for capturing the dynamic relationship between structure and properties across the space and time scales that exist at the hetero-interface. The ultimate aim of this focused topic is to provide fully self-consistent and time-dependent solutions for the electron density functions (i.e., the coupled Schrödinger–Poisson equations) that can predict failure due to large dielectric-constant mismatches between heterogeneous structures, including predictive capability to understand the role of high-power operation. In particular, a unified approach is sought to understand the diverse phenomena observed at metal-dielectric and semiconductor-dielectric interfaces. The BRI requires incorporation of experimental characterization methods in creating efficient representations of hetero-interfaces, which can be used in conjunction with new overarching multiscale modeling framework for predictive material systems and development. Designing new materials with properties specifically tailored to withstand extreme environments (high power, repetitive operation, external temperatures, external electric fields, and internal strain fields of dissimilar materials and other combined loads) require fundamentally understanding thermomechanical extremes and their role on the electromagnetic performance of the material. Similar understanding of the fundamental transport of both charge and energy is required to provide a self-consistent understanding of these materials. Once these processes are understood, it will be possible to predict responses of capacitors and other dielectric devices under extreme environments using computational tools and couple this knowledge to experimental diagnostics that can rapidly confirm theoretical predictions. This will enable the high dielectric tunabilities that are most effectively achieved by using metal-dielectric and semiconductor-dielectric capacitor structures while providing the robust lifetime and resilience to extreme environments needed for DoD applications.

Research Concentration Area(s):

1. In the heterostructure between metal and dielectric interfaces, the lattice structure, stoichiometry, interface electronic structure (bonding, interface states, etc.), and symmetry all conspire to produce behavior different from the bulk constituents, including '*dead layer effect*' beneath the interface. It is not exactly clear whether the fatigue (the loss of switchable polarization) or catastrophic failure is related to the lower amount of electronic charge carriers, or actually the reduced number of vacancies. Similarly a lack of understanding clouds the role of charge and energy transport as the power level of the device is increased. As fatigue, to a fairly high degree, is a non-equilibrium process, the differentiation between the ranges of only charge state changes or increased number of ionic defects is not clear.

Many aspects of failure phenomenon at the hetero interfaces, both metal-dielectric and semiconductor-dielectric, have been only vaguely explicable by currently accepted mechanisms. (i) A scientific understanding that can produce quantitative descriptors is required to characterize the metal-dielectric and semiconductor-dielectric interfaces under extreme environment. Efforts will be supported in applied mathematics to model the link between microscopic (atomistic) and mesoscopic (microstructural) scales to elucidate energy storage and transfer mechanisms and enabling accurate prediction of the electro mechanical behavior. (ii) The research should explore mechanisms of constituent atom diffusion and metal ion drift in dielectrics to provide the conceptual framework of electrochemical physics through consideration of activity of the constituents under extreme environments of combined external fields (i.e., chemical and electrical). The definition of extreme environments should also encompass the non-linear dissipation of dielectric materials at low and high temperatures. (iii) Fundamental studies are required to develop the generalized knowledge for the strain-gradients that automatically arise in materials even in absence of external strain inducers, and the impact on the electronic states due to these factors.

2. Tools and diagnostic techniques from the hardware community for design and characterization of energy localization (ionic or electronic) and electronic excited states (non-equilibrium) will be supported. The BRI solicits projects that include the combined diagnostic techniques and experimental characterization methods in creating efficient representations of hetero-interfaces, which can be used in a new overarching multiscale modeling framework for predictive material systems and development. The vital relevance of assigning the most fatal fatigue mechanism to all its microscopic sources remains a frontier to be conquered and projects that can bridge theoretical and experimental efforts while comparing well to diagnostic results will be funded.

3. This BRI stresses a fundamental understanding of charge and energy through dielectric and metal interfaces at a variety of time scales and in a variety of conditions. It is not clear the complicated role between quantum mechanical effects and more traditional bulk transport concepts, especially when one considers the tunneling of charge through the potential barriers at hetero-interfaces. The rapidly emerging fields of quantum information and high-frequency solid-state communication technologies require a similar understanding of defects and traps in insulators and at the metal/insulator interface, and the impact of these features on charge and energy transport. Intriguingly, the further development of some quantum computing and quantum communication systems depends on reducing loss mechanisms to extremely low levels to prevent decoherence, which destroys quantum mechanical entanglement and causes loss of signal. Given the broad questions of understanding transport in complicated, real world microstructures, this effort also seeks to create insights with the design and diagnostics of the quantum states in solid-state materials with coherency, and control of the loss of energy, charge and information. This provides a potential link between the electrical engineering and material science of capacitors with the condensed matter physics of solid-state material transport in complex microstructures. This could provide next generation scientific tools to the material scientist working in the areas of quantum computing and quantum communication.

Resources: Interested parties are encouraged to submit a White paper on their proposed effort no later than April 12, 2013. Full proposals are due by May 31, 2013. White papers should briefly describe the proposed effort and describe how it will advance the current state-of-the-art; an approximate yearly cost for a three to five year effort should also be included. Researchers with White papers of significant interest will be invited to submit full proposals. Multidisciplinary team proposals also are preferred over single investigator efforts; however, smaller, single investigator proposals will be considered on a case by case basis. Subject to the availability of funds, AFOSR anticipates investing up to $2M per year in the research supported by this initiative.

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7. Nanoscale Building Blocks for Novel Materials

Background: For a century, the atom has been the building block of chemistry and the chemical bond between atoms remains the most fundamental and important concept in chemistry. It is now becoming possible that novel structures on the nanometer scale can be used as a new generation of building blocks to assemble materials with new sets of properties. Nanostructures such as nanocrystals, quantum dots, or other nanoscale cluster can act as “designer atoms” that can be bound together in arrays or networks by novel linkers that control the distance and interactions between the components. This program will seek to design and probe assemblies of these designer atoms and designer bonds to create materials with novel electronic, chemical and structural properties for U.S. Air Force applications.

There are four major elements of the proposed program: the building blocks, the linkers, methods of self-assembly, and resulting properties of the new materials. A wide range of nanostructures from metal nanocrystals to active semiconductor quantum dots can have a wide range of functions that could produce new properties for energy flow and charge transport when coupled in a network. Varying the size and strength of the coupling interaction between components and the composition of the linkers adds additional important dimensions to the types of materials that could be developed. For example, linkers ranging from chalcogenides to strands of DNA and proteins have recently been used as novel linkers between nanostructures that can be easily tailored. Novel methods of self-assembly will be explored to produce 2-D and 3-D networks of materials and extend some chemical concepts from the nanoscale to the mesoscale. The ability to tailor the size, structure, and morphology of building blocks and the strength of the coupling between these components provides a rich palette from which many intriguing new materials can be designed. Using these new building blocks to create mimics of other elements could prove to be an important way to eliminate the use of expensive elements in catalysts and other structures and devices, as well as producing replacements for critical materials used in electronic, energy, magnetic, and optical applications whose supplies might be vulnerable. Novel ways to control energy transport and charge flow in materials will also be explored.

Objective(s): In this initiative, we seek to develop a new paradigm for materials and molecular science in which new nanoscale building blocks and tailored bonds or linkers are utilized to create new materials. This program will explore new ground in a diverse class of new materials and new concepts of bonding that will enable mesoscale self-assembled synthesis of chemical systems rather than just chemical compounds. Novel electronic properties may emerge as coherent and correlated processes are established in this connected network of particles. Unique properties may emerge with applications in energy and charge transport, catalysis, functional materials, and electronic materials. The ability to mimic the properties of certain elements with assemblies or structures of other atoms will also be targeted in this program, as well as novel 3-D nanostructured materials.

Research Concentration Area(s): Research on creating new materials from nanoscale building blocks impacts several concentration areas: nanoscale synthesis; spectroscopic probing of new mesoscale structures and binding forces; and theory of how these structures interact and how new properties emerge. These components are tightly intertwined, as theory might predict new ways that nanostructures can be coupled that will have to be realized by synthesis and probed by spectroscopy. Advances are needed in ways to control nanoparticle assembly, binding, and linking with unique strategies that can vary degrees of electronic coupling and correlation between particles. Spectroscopic methods that probe properties and structures of nanoparticle networks will need to be demonstrated and utilized. Finally, theory will be utilized to understand the types of forces that are controlling the assembly and interactions between particles, and how resulting emergent properties are developing. As new properties are discovered, new concentrations will surely present themselves as additional application of this new paradigm emerge.

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $1M per year in the research supported by this initiative. Proposals submitted under this initiative should support small teams of typically 2-4 investigators with awards of about $500K per year for 3 years. Please note that this initiative emphasizes research that bridges the boundaries across multiple AFOSR portfolios. The submission of a White paper to one of the Program Officers for this initiative is strongly encouraged prior to the submission of a full proposal. Full proposals are encouraged by 30 June 2013.

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8. Perceptual and Social Cues in Human-like Robotic Interactions

Background: Future U.S. Air Force operations will heavily rely on autonomous systems. One important class of such systems includes those with physical effectors and mobility that in some ways emulate human abilities, i.e. robots. In order to optimize performance and minimize errors in the eventual use of robots in U.S. Air Force applications, research is needed to better understand the dynamics of human interaction with these devices. Yet, little is known about the how social design elements influence trust and performance within the overall human-machine system. These social design elements may be considered surface cues that users evaluate when making decisions to trust these technologies. Fundamental questions in this area remain unanswered, for instance: what impact does a humanoid design have on trust and human-machine performance?, what humanoid features (appearance, voice, personality) are the most influential to user trust of the system?, do non-physical social elements (i.e., voice, personality) have the same impact on user trust and system performance as physical appearance elements? This is a research area that is particularly ripe for international collaboration as the focus of the US robotics community has been on cognitive performance to emulate human characteristics while the foreign (particularly Asian) robotics community has concentrated on appearance and physical performance. An important goal of this work is to attempt to find the ideal blend of artificial intelligence (as perceived by the human) and mechatronics to achieve the most effective human-robotic partnerships.

Objective(s): This BRI is intended to initiate a basic research program that analyzes and develops the perceptual and social cues that drive trust perceptions and performance within human-robot interactions.

Research Concentration Area(s): Suggested research areas include the following: (1) Empirical (laboratory and field) studies to examine impact of socially-designed cues such as humanoid appearance, voice, personality, and other social elements on human trust and overall system performance, (2) comparative studies that compare the impact of physical "embodiment" features versus non-physical features to empirically determine which features have the most influence on human trust and overall system performance, (3) research on how to characterize application domains in terms of the importance of human characteristics in achieving success in those domains, (4) research on dynamic modeling of the human-robotic partnership to allow continuous improvement of joint performance in real-world applications.

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $2M per year in the research supported by this initiative. Proposals submitted under this initiative should support projects ranging from 300-500K per year for 3 years. The submission of a White paper to one of the Program Officers for this initiative is strongly encouraged prior to the submission of a full proposal. Full proposals are encouraged by 30 June 2012. Interdisciplinary and international collaborations are particularly welcome for this topic.

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9. Plasma – Surface Interactions in Reactive Environments

Background: Plasmas can create unique reactive environments that are of particular interest to the U.S. Air Force. The reactive behavior can depend on the composition of the plasma, electron energies, and surfaces with which the plasma interacts. Plasma-surface interactions are becoming increasingly important in applications such as understanding electrode erosion, hybrid plasma-catalyst systems, and the emerging area of micro plasmas, in which there is a higher percentage of surface area relative to the plasma volume than in more conventional plasmas. This effort seeks to develop the fundamental understanding of plasma-surface interactions that would enhance our ability to model these plasma systems, to control the reaction chemistry, and to guide the development of new materials and systems. This approach should focus and optimize performance of systems from low-power, low-temperature plasma discharges, while providing scientific insights on surface/plasma interaction that also pertain to high energy density situations such as high-power microwave devices and plasma-based thruster technology, such as Hall thrusters.
Plasma-surface interactions can affect reactivity in numerous ways including transient surface process (hot electron chemistry) or adsorbate reactions (electron and ion surface reactions). Surfaces may serve to sculpt non-Maxwellian, long tail electron energy distributions or promote the formation of radicals or negative ions, with dramatic effects on gas phase electron, ion or radical- molecule chemistry for another avenue of control. Plasmas can also be used to control how dynamical processes depend on length and time scales such that the interplay between transport and chemistry can be coordinated to increase the activity of a catalytic process, direct reactions toward a desired product, or enhance the durability of an active catalyst susceptible to poisoning by reacting away deposited products. The addition of electrons from plasmas (or other means) into catalysts can affect the physical and electronic structure of the catalyst, thereby affecting its activity and selectivity. Furthermore, control of input gas as well as operating power allows plasmas to achieve various regimes of ion density or frequency to promote either adsorption or desorption. Indeed, the new field of microplasmas specifically introduces the science of coupling the degrees of freedom associated with the surface physics to the thermodynamics of the plasma. Overall, there is the rich opportunity to overcome the limitations and constraints inherent in plasma processing and surface chemistry by combining them to achieve a new degree of flexibility and control of chemical reactions by systematically characterizing, understanding, and controlling their interactions.

Objective(s): This goal of the program is to explore and optimize fundamental processes pertinent to plasma-surface interactions for improved flexibility and control of electron energy, transient species, and transport (diffusion, deposition, etc.) properties. These advances will enable unique reaction conditions that permit novel and energy-efficient means of protecting or creating materials or utilizing energy for U.S. Air Force needs.

Research Concentration Area(s): This effort will be focused on enhancing our understanding of the coupling of surface chemistry with the energy and material transport physics of plasmas. Means to control catalytic chemistry using plasmas to affect surface reactions, chemical intermediates, electron energies, electronic excitation, and transport properties will be explored. New theoretical methods to model electron excitation of molecules and the effect of electron energy on reactivity will also be studied. Synergies between plasma and catalytic systems will be investigated, with the goal of producing the fundamental science to enable flexible systems that enhance a wide variety of DoD mission, including electrode erosion and surface modification, micro plasmas for counter-directed energy applications, novel fuel development, fuel reforming, enhancing combustion, remediation of hazardous materials, and nano-manufacturing.

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $1.6M/yr in the research supported by this initiative. It is highly encouraged that submitted proposals include strong experimental, theoretical and/or modeling components. International collaborations aimed at fostering joint research and the exchange of researchers may also be included. Successful proposals will demonstrate fundamental capability for innovative research combining both plasma and surface chemistry phenomena. Proposals submitted under this initiative could support teams of typically 2-4 investigators with awards ranging from $400k-600k/yr for 3 years, as well as efforts from individual investigators for smaller grants. Interested parties are encouraged to submit a White paper on their proposed effort no later than **April 12, 2013**. Full proposals are due by **May 31, 2013**.

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10. Socio-Digital Influence

Background: Contemporary (and future) conflicts will be characterized by the battle of information and attitudes, in conjunction with the traditional (kinetic) combat, where the key drivers of operational success may, in fact, rest in willingness of non-combatants to cooperate and support U.S. interests in the region. This reality suggests that the DoD place greater emphasis on the "influence levers" that exist within the cultural and digital domains. Events such as the Arab Spring demonstrated the impact that ubiquitous digital media can have on social movements. Yet, it should be noted, that the digital media did not cause the attitudes that served as catalysts for these events, but rather they served as a means to organize, shape, and monitor the psychological battle space. Technology offers a range of advantages when used for persuasive tactics, and these factors are likely variable when considering different cultural groups. Prior research suggests that rich sociological/psychological data collections are often needed to understand the gamut of factors that shape behavior among different cultural groups. By understanding both the role of cultural beliefs, behavior, and rituals and the role of technology such as social media, the DoD will become closer to understanding the levers of influence that exist throughout the globe.

Objective(s): This BRI is intended to initiate a basic research program that adds to the growing foundational understanding of the factors that influence the behavior of individuals and groups within the cultural and digital domains. It is hoped that this research will result in novel theories of influence within the socio-digital landscape and in empirical studies that identify mechanisms for influence within different groups.

Research Concentration Area(s): Suggested research areas include the following: (1) Empirical (laboratory and field) studies to examine the relevance of social influence tactics in different cultural groups; (2) Empirical studies to identify the antecedents of trust in different cultural groups; (3) Empirical studies to reveal the sources of influence that drive behavior in different cultural groups and in social media; and (4) Empirical and theoretical studies to discover new theories of influence (or test to evaluate whether new theories are needed) to explain influence within a global, digital domain.

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $2M/yr in the research supported by this initiative. Proposals submitted under this initiative should support projects ranging from $300-500K/yr for 3 years. The submission of a White paper to one of the Program Officers for this initiative is strongly encouraged prior to the submission of a full proposal. Full proposals are encouraged by 30 June 2012. Interdisciplinary and international collaborations are particularly welcome for this topic.

Research Topic Chiefs:

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11. Theory-based Engineering of Biomolecular Circuits in Living Cells

Background: The advances of the past three decades in recombinant DNA technology and measurement techniques have paved the way to the rising field of synthetic biology. Simple circuits composed of few genes in living cells, such as oscillators, toggles, and inverters, to control cell behavior have been built. Engineering biomolecular circuits in living cells has two main objectives. One is testing innovative mathematical principles underlying biological processes in a controlled fashion by constructing synthetic versions of the processes of interest. The other is engineering nano-scale self-reproducing living machines to perform a variety of tasks from bio-sensing, to turning waste into energy, to classifying environmental molecules. To reach these objectives, synthetic biology will have to design and implement robust circuits that are far larger and substantially more complex than those currently built. This ability, unfortunately, is still missing. There are two main types of obstacles: (1) system-level obstacles, which prevent an assembled circuit to behave as predicted and (2) fabrication/implementation obstacles. System-level obstacles are due to the fact that the discipline is currently not theory-based. These include impedance-like problems; competition for shared resources such as ATP, RNAP, ribosomes; impedance matching issues; poor robustness to variability in plasmid copy number, temperature, cell metabolic state; cell loading. Fabrication/implementation obstacles include interference with the proper functioning of the cell chassis, e.g., toxicity; plasmid instability; the availability of only a dozen of orthogonal promoters and transcription factors. Overcoming these obstacles requires the synergistic interplay of systems and signals, control theory, circuit theory, and dynamical systems disciplines with molecular biology, protein engineering, and microbiology disciplines. This topic provides the unique opportunity to implement this synergy toward the development of a fundamentally new theory-based framework to engineer robust biomolecular circuits.

Objective(s): The overall objective is to make synthetic biology a rational engineering discipline by creating a math and theory-based framework for modular design and fabrication.

Research Concentration Area(s): include, but are not limited to, (1) development of new mathematical tools, models, and computational techniques for the analysis and design of biomolecular circuits; (2) establishing a circuit theory for the modular design of biomolecular systems; (3) establishing general principles along with their biomolecular implementations for robustness to all sources of uncertainty cited above; (4) modular design of robust arrays of sensors that classify environmental molecules in a given set.

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $1.5m/yr in the research supported by this initiative. Proposals submitted under this initiative should support teams of typically 3-4 investigators with awards ranging from $500k-750k/yr for 3-5 years. Please note that this initiative emphasizes research that bridges the boundaries across multiple AFOSR portfolios. The submission of a White paper to one of the Program Officers for this initiative is strongly encouraged prior to the submission of a full proposal.

Research Topic Chiefs:

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12. Understanding the Interaction of Coronal Mass Ejections with the Solar-Terrestrial Environment

Background: Interplanetary Coronal Mass Ejections (ICME) are massive regions of energetic plasma that are ejected explosively from the sun into interplanetary space. ICMEs contain imbedded magnetic fields that define how the energy carried in the ICME couples into geospace. If an ICME encounters the magnetic cavity surrounding the Earth, the dayside magnetosphere is compressed and the nightside is expanded, and the resulting disturbance energizes geospace. Effects range from increased particle energies in the radiation belts to increased energy and heating of the thermosphere. Impacts on the U.S. Air Force mission include damage to satellites, communication disruptions, uncertainties in satellite trajectories due to changes in atmospheric density, and disruption of power grids.
Substantial progress in recent years has provided several key pieces that have been, or could be, integrated into a practical forecast of ICME impacts:

- Photosphere/corona/heliosphere observations and modeling to forecast the background solar wind through which an ICME propagates

- Coupling solar wind drivers, including ICMEs, to geospace models using satellite measurements at L1

- Coronal and interplanetary observations CME/ICME "launch" and transport

- ICME propagation modeling using observed "launch" parameters and background solar wind specification and/or heliospheric imager observations.

Despite advances in the key areas above, our ability to specify the *interior* magnetic topology of an ICME - in particular its out-of-ecliptic component (Bz) - and hence its geoeffectiveness, is minimal (except for the external sheath fields). The overarching goal of this BRI is to develop the needed understanding and methods to fill this gap.

Objective(s): The objective of this BRI is to perform basic research in key areas that determine ICME geoeffectiveness with a focus on the internal magnetic topology of ICMEs. The underlying motivation of this research is to enable development of a practical forecast of ICME geoeffectiveness with a lead-time on the order of 1-2 days before its arrival at Earth.

Research Concentration Area(s): This BRI seeks innovative approaches that may include, but are not limited to: observable identification, measurement techniques, modeling, and improving physical understanding. While the immediate objective is basic research, it is expected that successful proposals will provide a clear vision of how the research, if successful, will substantially contribute to the ultimate goal of a geoeffectiveness forecast capability.

Areas of investigation may include:

1. Improvements in forecasting and/or modeling the magnetic field structure within ICMEs (especially Bz) based on observables at the sun and/or modeling of the sun.

2. Techniques for observing or inferring the magnetic field structure within an ICME as it propagates through the heliosphere and interacts with the solar wind.

3. Quantifying the stability and/or evolution of the internal magnetic topology of an ICME as it propagates through the heliosphere under different conditions.

4. Methods for coupling and/or assimilating internal ICME magnetic structure with heliospheric propagation models to provide a satisfactory specification of the magnetic time profile at Earth as the ICME passes.

Resources: Subject to the availability of funds, AFOSR anticipates investing up to \$1.5M/yr in the research supported by this initiative. Proposals submitted under this initiative should support small teams of typically 2-4 investigators with awards ranging from \$300k-500k/yr for 3-5 years. Please note that this initiative emphasizes research that bridges the boundaries across multiple

AFOSR portfolios. The submission of a White paper to one of the Program Officers for this initiative is strongly encouraged prior to the submission of a full proposal. Full proposals are encouraged by 30 June 2012.

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13. Understanding the Psychological/Behavioral Effects of Advanced Weaponry

Background: The U.S. Air Force is on the leading edge of technology as evidenced by sophisticated Uninhabited Aerial Systems (UAS) capable of strike and Intelligence, Surveillance and Reconnaissance (ISR) operations, 5th generation fighter platforms armed with smart munitions aimed at precision effects, and cutting-edge Directed Energy (DE) weapons such as the Active Denial System, which incorporate non-lethal capabilities into the DoD toolkit. Yet, despite these technological advances, little is known about the effects of these technologies beyond their known bio-physical effects, suggesting that basic research is needed to examine their psychological and behavioral implications. Research is needed to better understand public reactions to such weapons. For example, how will individuals react to UAS being flown over their city or village? Are attacks from UAS perceived differently than attacks from manned platforms? How will the public react to novel non-lethal technologies such as counter-personnel directed energy weapons? Will this vary based on cultural beliefs? What are the societal barriers to introducing new weapon technologies in the battlefield?

Objective(s): The objectives of the current BRI research are to generate basic research in understanding the psychological/behavioral effects of current and future weaponry, and to foster a strong collaboration between academia and AFRL researchers to enable a nexus of research capabilities and findings related to understanding the effects of novel weapons.

Research Concentration Area(s): Suggested research areas include the following: (1) Empirical (laboratory and field) studies to describe and understand public perceptions of novel lethal and non-lethal weapons (with a specific emphasis on robotic platforms – Uninhabited Aerial Systems, and/or directed energy technology), 2) cross-cultural studies to investigate potential differences among different cultural groups in their perceptions of novel weapon technologies such as Directed Energy Weapons and UAS systems, 3) Modeling and simulation approaches which demonstrate the behavioral and psychological effects of lethal and or non-lethal weapons, and 4) basic research to better understand human sensemaking processes when interfacing with non-lethal weapons, for example how can military non-lethal technologies (or combination of technologies) be used to communicate basic instructions to naïve individuals (e.g., stop, turn around, warning).

Resources: Subject to the availability of funds, AFOSR anticipates investing up to $2M/yr in the research supported by this initiative. Proposals submitted under this initiative should support projects in the magnitude of $1M/yr for 3 years. It is anticipated that 2 awards will be made at this level. The submission of a White paper to one of the Program Officers for this initiative is required prior to the submission of a full proposal. Full proposals are encouraged by 30 May 2012. Interdisciplinary collaborations are particularly welcome for this topic.

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g. Other Innovative Research Concepts:

(Disclaimer: For reference only; Proposals **NOT** submitted under this BAA)

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.

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.

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

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

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Deputy for Technology Transition (AFOSR/CL)
Air Force Office of Scientific Research
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Arlington, VA 22203-1768

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h. Education and Outreach Programs

(Disclaimer: For reference only; Proposals **NOT** submitted under this BAA)

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

1) Air Force Visiting Scientist Program
2) Awards to Stimulate and Support Undergraduate Research Experiences (ASSURE)
3) Engineer and Scientist Exchange Program (ESEP)
4) National Defense Science and Engineering Graduate (NDSEG) Fellowship Program
5) United States Air Force/National Research Council Resident Research Associateship (NRC/RRA) Program
6) United States Air Force-Summer Faculty Fellowship Program (SFFP)
7) Window on Science (WOS) Program
8) Windows on the World (WOW) Program

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

1. Air Force Visiting Scientist Program

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

Point of Contact (POC):
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2. The Awards to Stimulate and Support Undergraduate Research Experiences (ASSURE)

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

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

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

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

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

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

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3. Engineer and Scientist Exchange Program (ESEP)

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

Basic Research Objectives: The primary goals of ESEP are to:

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

U.S. Air Force personnel are selected in a competitive process and are assigned for a 2-year tour. This may be preceded by 6 months of language training. Ad hoc placements (non-competitive) can be initiated by research sites; however, these are funded solely by their originators. Foreign S&E are usually assigned to US DoD organizations for 12 month periods; although assignments can be for shorter or longer duration. Each country bears the cost of supporting its participants in the program. AFOSR/IO is responsible for managing placement of all ESEP exchanges within the U.S. Air Force, and is the "one face to the customer" for all U.S. Air Force ESEP actions. SAF/IAPQ (Armaments Cooperation Division, Deputy Under Secretary of the Air Force, International Affairs), the executive agent, provides policy guidance. The Asian, European and Southern Offices of Aerospace Research and Development (AOARD/EOARD/SOARD) are AFOSR field offices located in Tokyo, London and Santiago. These offices act as overseas program liaison offices for US ESEP personnel working in Asia, Europe and South America.

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

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4. National Defense Science and Engineering Graduate (NDSEG) Fellowship Program

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

An awardee must be enrolled in a graduate program by Fall 2013; the graduate program must lead toward a Ph.D. Preference will be given to applicants in one, or closely related to one, of the following specialties: Aeronautical and Astronautical Engineering; Biosciences; Chemical Engineering; Chemistry; Civil Engineering; Cognitive, Neural and Behavioral Sciences; Computer and Computational Sciences; Electrical Engineering; Geosciences; Materials Science and Engineering; Mathematics; Mechanical Engineering; Naval Architecture and Ocean Engineering; Oceanography; and Physics.

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

The duration of an NDSEG Fellowship is thirty-six months cumulative starting in the fall of 2013. NDSEG Fellows may choose as their fellowship institution any accredited U.S. institution of higher education offering doctoral degrees in science or engineering. The availability of funds for the second and third years of each three-year award is contingent upon satisfactory academic progress.

In FY2013 NDSEG fellowships will provide stipends of $30,500, $31,000 and $31,500 in the first, second, and third years, respectively. Additionally, the NDSEG fellowship will pay the fellow's full tuition, required fees (not to include room and board) and minimum health insurance coverage offered through the institution, up to a total value of $1,000. Any excess insurance costs will be the responsibility of the fellow and can be paid using the stipend. The stipends will be prorated monthly based on a twelve-month academic year. If the fellow is not enrolled in an institutionally approved academic study and/or research during the summer months, financial support will not be provided. There are no dependency allowances. Persons with disabilities will be considered for additional allowances to offset special educational expenses.

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

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

NDSEG Fellowship Program c/o American Society for Engineering Education: 1818 N Street, N. W. Suite 600 Washington, D. C., 20036, (202) 331-3516; Fax: (202) 265-8504
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5. United States Air Force National Research Council Resident Research Associateship (NRC/RRA) Program

Program Description: The NRC/RRA Program offers postdoctoral and senior scientists and engineers opportunities to perform research at sponsoring U.S. Air Force laboratory sites.

Basic Research Objectives: The objectives of this program are: (1) to provide researchers of unusual promise and ability opportunities to solve problems, largely of their own choice, that are compatible with the interests of the hosting laboratories; and (2) to contribute to the overall efforts of the U.S. Air Force laboratories.

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

Senior Research Associateships are awarded to individuals who have held doctorates for more than five years, have significant research experience, and are recognized internationally as experts in their specialized fields, as evidenced by numerous refereed journal publications, invited presentations, authorship of books or book chapters, and professional society awards of international stature. Although awards to senior associates are usually for one year, awards for periods of three months or longer may be considered. Renewals for a second and third year are possible. U.S. citizenship is not a requirement. Senior associates must be eligible for access to unclassified government information systems; eligibility is also subject to a successful

background review and visit authorization that includes approved access to the U.S. Air Force base and its laboratory facilities.
Associates are considered independent contractors, and receive a stipend from the NRC while carrying out their proposed research. Annual stipends increase with additional years past the Ph.D. An appropriately higher stipend is offered to senior associates. Awardees also receive a relocation reimbursement and may be supported with limited funds for professional travel.

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

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

Point of Contact (POC):
Mr. Neville Thompson, AFOSR/CL, (703) 588-1779
DSN 425-1779, FAX: (703) 696-7364
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6. United States Air Force-Summer Faculty Fellowship Program (SFFP)

Program Description: The SFFP offers fellowships to university faculty to conduct research at one of the U.S. Air Force research facilities in the summer.

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

SFFP fellows conduct research in collaboration with U.S. Air Force researchers for a continuous summer period of eight to twelve weeks at the Technical Departments of the U.S. Air Force Research Laboratory, the US Air Force Academy, or the U.S. Air Force Institute of Technology. A final report is required at the completion of the summer appointment. Applicants must be U.S. citizens or permanent residents and have an earned Ph.D. in science or engineering. Fellows must be eligible for access to unclassified government information systems; the fellowship award is subject to a successful background review and visit authorization that includes approved access to an U.S. Air Force installation and its laboratory facilities.

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

Starting in Fiscal Year 2010, selected fellows may bring a graduate student with them to assist in research on their assignment.

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

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

Point of Contact (POC):
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7. Window on Science (WOS) Program

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

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

8. Windows on the World (WOW) Program

Program Description: The Windows on the World program provides outstanding U.S. Air Force scientists and engineers the opportunity to conduct full-time research at a foreign (non-government) host laboratory, or to perform full-time science and technology assessment activities for a period up to 179 days on temporary duty (TDY) status. The TDY is fully funded by AFOSR. Upon completion of the assignment the researcher returns to his or her U.S. Air Force activity. The host laboratory provides facilities, resources, and a letter of invitation. Typically the researcher is an U.S. Air Force scientist or engineer, at least at the GM/GS-13/DR-II level or its military equivalent. The researcher must be currently active in his or her field of expertise, be widely recognized as an expert, and have a strong publication record. Some knowledge of the language used by the researcher's host institution is desirable. The applicant must write a research proposal, preferably not to exceed 10 pages, but of sufficient depth and scope, so that it can be evaluated by the scientists at the participating organizations. The proposal must be endorsed by the applicant's Air Force Research Laboratory Technical Department Chief Scientist. Non-laboratory applicants, such as researchers at the Air Force Academy and Air Force Institute of Technology, should pass their proposals through the Chief Scientist of an AFRL Technical Directorate. Proposals that focus tightly on specific research problems or specific science and technology assessment topics will merit greater consideration than those that are of a survey nature. The researcher is required to submit a written report detailing his or her research effort and findings at the completion of the TDY. In addition, the researcher may be required to give a seminar-style presentation at AFOSR and/or the Air Force Research Laboratory site and provide feedback for purposes of program assessment. Lead-time to set up a "Windows" visit is approximately four months. More detailed information is contained in the AFOSR Brochure, "Windows on the World".

Point of Contact (POC):
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i. <u>Special Programs:</u>

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

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

Program Description: The DoD has been providing grants for research and educational equipment at HBCU/MI's.

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

AFOSR HBCU/MI program consists of two components:

AFOSR Core Research: Research and equipment proposals from HBCU/MI'S are reviewed by AFOSR Program Officers to create opportunities to broaden participation among diverse individuals, and institutions while reaching out to groups that have been underrepresented that are critical to the DoD/AFRL mission of leading edge discovery.

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

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2. Small Business Technology Transfer Program (STTR)

Program Description: The STTR Program is designed to provide an incentive for small companies, academic institutions, and non-profit research institutions, including federally-funded research and development centers (FFRDC), to work together to move emerging technical ideas from the laboratory to the marketplace.

Basic Research Objectives: The primary objective of the U.S. Air Force STTR program is to involve small businesses in Air Force-relevant defense research, and enable them to commercialize their innovative technologies for the advancement of U.S. economic competitiveness.

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

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3. Young Investigator Research Program (YIP)

Program Description: The U.S. Air Force YIP supports scientists and engineers who have received Ph.D. or equivalent degrees in the last five years and show exceptional ability and promise for conducting basic research.

Basic Research Objectives: The objective of this program is to foster creative basic research in science and engineering; enhance early career development of outstanding young investigators; and increase opportunities for the young investigator to recognize the U.S. Air Force mission and related challenges in science and engineering.

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

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j. University Research Initiative (URI) Programs:

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

1. Defense University Research Instrumentation Program (DURIP)

Program Description: This program is administered through the Air Force Office of Scientific Research, the Army Research Office, and the Office of Naval Research. The DURIP program is for the acquisition of major equipment by U.S institutions of higher education to augment current or develop new research capabilities to support research in technical areas of interest to the DoD.

Basic Research Objectives: DURIP is open only to U.S. institutions of higher education, with degree granting programs in science, math, and/or engineering. Proposing institutions should be seeking to purchase instrumentation in support of research areas of interest to the DoD, including areas of research supported by the administering agencies. Proposals to purchase instrumentation may request $50,000 to $1,500,000. Awards are typically one year in length. Details on the proposal submission process and further specifics on the DURIP can be found in the most recent DURIP announcement at **http://www.wpafb.af.mil/AFRL/afosr/**, under "Other Links"; "List of Broad Agency Announcements"; "Broad Agency Announcements – Current" or "Broad Agency Announcements – Archive" as applicable.

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Alternate POC:
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2. Presidential Early Career Award in Science and Engineering (PECASE)

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

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

To be eligible for the PECASE, an individual must be a U.S. citizen, national, or permanent resident with no more than five years from receipt of the doctorate degree. Each award will be $200K per year for five years. AFOSR awardees will be selected from among highly qualified institute of higher education principal investigators to AFOSR or former National Defense Science and Engineering Graduate (NDSEG) fellowship recipients. Candidates must hold tenure-track positions at U.S. universities. Individuals can not apply to the PECASE program but must be nominated by an AFOSR Program Officer and have a proposal that addresses U.S. Air Force research interests as described in the current AFOSR Broad Agency Announcement (BAA). Furthermore, the White House Office of Science and Technology Policy will make the final selection and announcement of the awardees.

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k. <u>Conferences and Workshops:</u>

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

<u>Technical Information:</u>

- Summary indicating the objective(s) of the conference/workshop
- Topic(s) to be covered and how they are relevant to AFOSR's mission of managing the U.S. Air Force basic research program
- Title, location, and date(s) of the conference/workshop
- Explanation of how the conference/workshop will relate to the research interests of AFOSR identified in Section III of the Broad Agency Announcement (BAA)
- Chairperson or principal investigator and his/her biographical information

- List of proposed participants and method (or copies) of announcement or invitation
- A note on whether foreign nationals will be present

Evaluation Criteria for Conference Support:

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

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

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

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

If you have questions concerning the scientific aspects of a potential proposal to AFOSR for conference or workshop support, please contact the Program 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 2012, AFOSR managed funding support for approximately 1960 grants, cooperative agreements, and contracts to about 400 academic institutions, non-profit organizations and industrial firms. This included grants, cooperative agreements and contracts to academic institutions, non-profit organizations and industry. About $350M 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. AFOSR particularly encourages proposals from small businesses; however, no portion of this BAA is set aside for a specific group. Proposals from Federal Agencies, including subcontracting/subrecipient efforts will not be evaluated under this BAA. Federal agencies should contact the primary POCs listed under each technical area to discuss funding through the internal Government procedures.

IV. Application and Submission Information

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

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

3. Content and Form of Application Submission –

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

If you prefer, or the Program Officer requests, you may submit a White paper, which should briefly describe the proposed research project's (1) objective, (2) general approach, and (3) impact on Department of Defense (DoD) and civilian technology. The White paper may also contain any unique capabilities or experience you may have (e.g., collaborative research activities involving U.S. Air Force, DoD, or other Federal laboratory.) The Program Officer may have additional guidelines regarding form, content and length of preliminary proposals so pay particular attention to the requirements included under each topic area.

For additional information regarding White papers, please see the AFRL BAA Guide for Industry at **http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=6790**

White paper Format

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

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

Full Proposal Format

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

http://www.grants.gov/assets/Organization_Steps_Complete_Registration.pdf to guide you through the process. To submit a proposal to through Grants.gov, applicants will need to download Adobe Reader. This small, free program will allow you to access, complete, and submit applications electronically and securely. To download a free version of the software, visit the following web site: **http://www.grants.gov/help/download_software.jsp**. Consult Grants.gov to ensure you have the required version of Adobe Reader installed. Should you have questions relating to the registration process, system requirements, how an application form works, the submittal process or Adobe Reader forms, call Grants.gov at 1-800-518-4726 or **support@grants.gov** for updated information.

(2) Submitting the Application

(a) For Electronic Submission – Application forms and instructions are available at Grants.gov. To access these materials, go to **http://www.grants.gov**, select "Apply for Grants", and then follow the instructions. In the Grants.gov search function, enter the funding opportunity number for this announcement (BAA-AFOSR-2013-0001). You can also search for the CFDA Number 12.800, Air Force Defense Research Sciences Program. On the Selected Grant Applications for Download page, click on 'download' under the heading 'Instructions and Applications' to download the application package.

The funding opportunity will be listed multiple times. The funding opportunity number is identical for each listing. Select the Competition ID and Competition Title for the 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. Waiting until the due date and time may result in applications being late. Common closing dates include the first, fifteenth and last day of any month. Potential applicants are reminded to plan accordingly. Also, please check Grants.gov prior to submission for any notices posted on Grants.gov offering alternate submission options as a result of system saturation. **Note: All attachments to all forms must be submitted in PDF format (Adobe Portable Document Format).**

Grants.gov provides links to PDF file converters at this site:
http://www.grants.gov/help/download_software.jsp.

(b) For Hard Copy Submission – For hard copy submission, the original proposal and copies must be delivered to the attention of the Program 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

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

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

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

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

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

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

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

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

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

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

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

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

Human Subject Use- Each proposal must address human subject involvement in the research by addressing Field 1 and 1a of the R&R Other Project Information Form. If Field 1 indicates "Yes", the U.S. Air Force must receive a completed OMB No. 0990-0263 form before a contract, grant, or cooperative agreement may be awarded to support research involving the use of human subjects. Attach the document to the R&R Other Project

Information Form. If using Grants.gov, a completed OMB No. 0990-0263 form shall be attached in field 12 of the R&R Other Project Information Form. Refer any questions regarding human subjects to Stephanie Bruce of the AFOSR Department of Mathematics, Information and Life Sciences at **stephanie.bruce@afosr.af.mil**

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

Environmental Compliance- Federal agencies making contract, grant, or cooperative agreement awards and recipients of such awards must comply with various environmental requirements. The National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. Sections 4321-4370 (a), requires that agencies consider the environmental impact of "major Federal actions" prior to any final agency decision. With respect to those awards which constitute "major Federal actions," as defined in 40 CFR 1508.18, federal agencies may be required to comply with NEPA and prepare an environmental impact statement (EIS) even if the agency does no more than provide grant funds to the recipient. Questions regarding NEPA compliance should be referred to the applicable AFOSR Program 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.

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

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

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

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

Project Narrative - Research Effort – Describe in detail the research to be performed. State the objectives and approach and their relationship and comparable objectives in progress elsewhere. Additionally, state knowledge in the field and include a bibliography and a list of literature citations. Discuss the nature of the expected results. The adequacy of this information will influence the overall evaluation. Proposals for renewal of existing support must include a description of progress if the proposed objectives are related.

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

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

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

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

Project Narrative – High Performance Computing Availability- Researchers that are supported under an AFOSR grant or contract and meet certain restrictions, are eligible to apply for special accounts and participation in a full-spectrum of activities within the DoD high performance computing modernization program. This program provides, at no cost to the user, access to a range of state-of-the-art high performance computing assets and training opportunities that will allow the user to fully exploit these assets. Details of the capabilities of the program can be found at the following Internet address: **http://www.hpcmo.hpc.mil**. Researchers needing high performance cycles should address the utilization of this program to meet their required needs. AFOSR Program Officers will facilitate the establishment of accounts awarded.

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

4. Other Submission Requirements

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

5. Application Receipt Notices.

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

b. For Hard Copy Submission – An applicant that submits a hard copy proposal to AFOSR will receive an email from the agency approximately ten days after the proposal due date to acknowledge receipt of the proposal and provide the agency's assigned tracking number. The email is sent to the authorized representative for the applicant institution.

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

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 selected for contract award, evaluation will be on a competitive basis according to Public Law 98-369, Competition in Contracting Act of 1984, 10 USC 2361, and 10 USC 2374. If selected for grant/assistance instrument award, evaluation will use merit-based competitive procedures according to DoDGARS citation of 32 C.F.R Sec 22.315. Proposals may be evaluated by Program 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. Non-Government evaluators are also required to sign nondisclosure agreements which prohibit them from disclosing proprietary information submitted by contractors. **However as previously stated in Section IV para 2, AFOSR is seeking White papers and proposals that do not contain proprietary information. If proprietary information is submitted it is the offerors responsibility to mark the relevant portions of their proposal as specified in Section IV para 2.**

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

Section I categories h & i provide information about AFOSR programs and awards that are not evaluated under this BAA. For information on submitting proposals for the Education and Outreach and Special Programs; see the hyperlinks in each section. Proposals submitted for Special Programs listed in Section I category k shall be evaluated under criteria as specified in their description. Proposals submitted for Conference

Support and Workshops listed in Section I shall be evaluated 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.

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

1. The likelihood of the proposed effort to develop new research capabilities and broaden the research base in support of U.S. national defense.
2. The proposer's capabilities integral to achieving 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.
3. Overall realism and reasonableness of proposed costs.

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

Proposals may be submitted for one or more topics or for a specific portion of one topic. A proposer may submit separate proposals on different topics or different proposals on the same topic. The U.S. Government does not guarantee an award in each topic area. Further, be advised that as funds are limited, otherwise meritorious proposals may not be funded. Therefore, it is important that proposals show strength in as many of the evaluation area as practicable for maximum competitiveness.

VI. Award Administration Information

1. Award Notices.

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

2. Reporting Requirements.

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

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

<u>3. Additional information for offerors seeking contract awards.</u>

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

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

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

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

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

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

(End of provision)

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

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

2. Contractors are required to provide 3 years of Total Case Incident Rate / Days Away, Restricted, or Transferred data rates with their proposal for Government evaluation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Date ________________________________

Printed Name and Title ________________________________

____

Signature ________________________________

(End of identification and assertion)

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

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

(End of provision)

VII. Agency Contacts

Should you have questions about a technical research area, contact the Program 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@afosr.af.mil**.

** Important Notice Regarding Questions of a Business Nature **
All questions shall be submitted in writing by electronic mail.
Questions presented by telephone call, fax message, or other means will not be responded to.

VIII. Additional Information

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

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

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

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

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

6. Responses should reference Broad Agency Announcement BAA-AFOSR-2013-0001.

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 oncampus 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** or **AskSAM@gsa.gov**

   Awardees must:

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

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

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

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

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

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

11. Grant Payment Process

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

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

Please note that each Grantee must be registered in 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 WAWF advising on the status of vouchers submitted for payment. The Grantee will also need to contact the WAWF Help Desk to register their CAGE code within the WAWF system. WAWF Help Desk information is available at the WAWF web site.

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

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

    Offerors should be aware that: OUSD (AT&L) DPAP Memo, Class Deviation, 22 Jan 13 http://www.acq.osd.mil/dpap/policy/policyvault/USA000323-13-DPAP.pdf precludes Contracting Officers from awarding FY12 funds to any corporation that has an unpaid delinquent tax liability or felony conviction under Federal law. This requirement, applicable to contracts and requiring a certificate from offerors, has not yet been implemented for grants. However, because Public law 112-74 does include grants, it is anticipated that OMB guidance for grant implementation will occur during the period this BAA is active.

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

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