AFOSR: Basic Research-Game Changing Investments

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Air Force Research Laboratory
Contents

• AFOSR Overview

• Research Focus Areas; Transitions

• AFOSR International Program
AFOSR Mission

Discover, shape, and champion basic science that profoundly impacts the future Air Force

- ID Breakthrough Research Opportunities – Here & Abroad
- Foster Revolutionary Basic Research for Air Force Needs
- Transition Technologies to DoD and Industry

TODAY’S BREAKTHROUGH SCIENCE FOR TOMORROW’S AIR FORCE
AFOSR Roles
AF Basic Research Manager

• Identify Breakthrough Research Opportunities – Here & Abroad
  - Regular interactions with leading scientists and engineers
  - 64 workshops conducted; 195 conferences co-sponsored
  - Int’l liaison offices in Europe, Asia, Latin America
  - 227 short-term foreign visitors; 22 personnel exchanges

• Foster Revolutionary Basic Research for Air Force Needs
  - 1327 extramural research grants at 228 U.S. universities
  - 590 fellowships; 2224 grad students, 344 post-docs on grants
  - 268 intramural research projects at AFRL, USAFA, AFIT
  - 96 summer faculty; 50 postdocs/senior scientists at AFRL

• Transition Technologies to DOD and Industry
  - 153 STTR small business - university contracts
  - 700 funded transitions (follow-on-uses) from FY10 PI data call
AFOSR Supports University Individual Investigators

- **Goals**
  - Provide revolutionary scientific breakthroughs to maintain military air, space, and information superiority
  - Build collaborations between AFRL and universities

- **General Submission Process**
  - Researchers submit white papers to AFOSR program managers
  - Promising white papers lead to request for full proposals
  - Proposals merit reviewed for *excellence* and *relevance*
  - Individual grants awarded for up to 5-years in duration

- **Broad Agency Announcement (BAA) open at all times to innovative ideas** [http://www.afosr.af.mil](http://www.afosr.af.mil)
Multidisciplinary University Research Initiative (MURI)

- Achieve significant scientific advances
  - Capture attention of top researchers
  - Build on results of individual-researcher grants
  - Encourage multidisciplinary collaboration
- Up to $1.5M/yr for five years
- Typically 8-10 research topics per Service
  - Occasional joint topics
  - One or two awards per topic
- Currently there are 61 AFOSR MURI Projects (FY05-09)
  - 10 new projects in FY10
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AF/ST Technology Horizons

- Focus on 10-20-year time horizon
- Tech Horizons Grand Challenges:
  - Inherently Intrusion-Resistant Cyber Networks
  - Trusted Highly-Autonomous Decision-Making Systems
  - Fractionated, Composable, Survivable Remote-Piloted Systems
  - Hyper-Precision Air Delivery in Difficult Environments
- Not all the technologies require new basic science

Available at: http://www.af.mil/information/technologyhorizons.asp
Basic Research (Focus Areas)
(FY11PB - $351M)

Aerospace, Chemical & Material Sciences
• Aero-Structure Interactions & Control
• Energy, Power & Propulsion
• Complex Materials & Structures

Physics & Electronics
• Complex Electronics & Fundamental Quantum Processes
• Plasma Physics & High Energy Density
• Optics, EM, Comm, Signals Processing

Mathematics, Information & Life Sciences
• Info & Complex Networks
• Decision Making
• Dynamical Sys, Optimization & Control
• Natural Materials & Systems

University Research Initiatives
(FY11PB - $136M)
Aero-Structure Interactions and Control

• Objective: Characterization, modeling, and exploitation of interactions between unsteady aerodynamic flow fields and dynamic air vehicle structures.

• Critical Subjects Include:
  - Turbulence and laminar-turbulent transition
  - Flow control
  - Unsteady aerodynamics
  - Structural dynamics
  - Aero elasticity

30 kW Inductively Coupled Plasma Facility for High Temperature Material Testing
Energy, Power, and Propulsion

- **Objective**: Focus on the production, storage, and efficient utilization of energy.
- **Critical Subjects Include**:
  - Novel energetic materials
  - Combustion research
  - Thermal science
  - Novel propulsion methods
  - Catalysis chemistry
  - New ways in which energy can be produced/collected/stored/utilized

*Blue light (465 nm) is used to convert CO₂ to alcohols with a substituted pyradine catalyst and a p-GaP electrode.*
Objective: Future materials and structures that incorporate hierarchical design and functionality from the nanoscale through the mesoscale to effect functionality and/or performance characteristics to enhance the mission versatility of future air and space systems.

Critical Subjects Include:
- Materials with tunable properties
- Adaptive morphing structures
- Active materials with on-demand shape and phase change
- Reconfigurable structures
Decision Making

- Objective: Discovery of mathematical laws, foundational scientific principles, and new, reliable and robust algorithms, which underlie intelligent, mixed human-machine decision making.

- Critical Subjects Include:
  - Robust human-machine decision making
  - Socio-cultural modeling
  - Mathematical analysis and models of individual human cognition and collective behavior

Combining sensor, intelligence, and database information resources to formulate hypotheses about adversaries’ intentions, information fusion.
Information and Complex Networks

- Objective: Reliable and secure exchange of information and predictable operation of networks and systems.

- Critical Subjects Include:
  - System and network performance prediction, design and analysis
  - Predict and manage network failure comprehensively
  - Information operations and security
  - Integration of models of computation and cognition for the specification and design of complex human-machine systems

Network Map
Dynamical Systems, Optimization, and Control

• To provide advances in in the science of autonomy including adaptive control for coordinating heterogeneous autonomous or semi-autonomous aerospace vehicles in uncertain, information rich, dynamically changing, adversarial, and networked environments.

• Critical Subjects Include:
  - Embedded optimization
  - Dynamical systems theory
  - Reliable scalable algorithms
  - Computational and discrete mathematics
  - Management of the effects of uncertainties
  - Robust adaptive control of complex systems

Simulation: 400 agents converge to equilibrium under the Adaptive NCE Control Law
Natural Materials and Systems

- Objective: Studying, using, mimicking, or altering the novel ways that natural systems build exquisite materials and sensors that often outperform manmade versions and perform under extreme conditions.

- Critical Subjects Include:
  - Biomimetics of materials and flight
  - Sensors
  - Interfaces
  - Extremophiles
  - Bioenergy

bfloGFP, a new family of fluorescent proteins from lancelet cephalochordate amphioxus
Complex Electronics and Fundamental Quantum Processes

- Objective: Pursue breakthroughs in information processing, secure communication, multi-modal sensing, computer memory, high speed communication and computing through exploration and understand of complex engineered materials and devices.

- Critical Subjects Include:
  - Non-linear Optical Materials
  - Optoelectronics and Nanophotonics
  - Ultracold Atoms & Molecules
  - Metamaterials & Graphene
  - Dielectric and Magnetic Materials
  - High Energy, Semiconductor and Ultrafast Lasers
  - High temperature Superconductors
  - Quantum Dots and Wells

Atomic-Layer Molecular Beam Epitaxy System
Plasmas and High Energy Density Nonequilibrium Processes

- Objective: Pursue understanding of fundamental plasma, non-linear electromagnetic phenomena, and the non-linear response of materials to high electric and magnetic fields.

- Critical Subjects Include:
  - Space weather
  - Plasma discharges & non-equilibrium chemistry/thermo
  - Plasma control of boundary layers in turbulent flow
  - RF propagation and RF-plasma interaction
  - High power beam-driven microwave devices

The simulated heliosphere during the Halloween storms.
Optics, Electromagnetics, Communication, & Signal Processing

• Objective: Pursue understanding of complex electromagnetic and electro-optical signals impacting space object imaging, secure reliable communication, on-demand sensing modalities, distributed multilayered sensing, automatic target recognition, and navigation.

• Critical Subjects Include:
  – Adaptive Optics and Optical Imaging
  – Laser Phenomenology
  – Precision Navigation and Timing
  – Sophisticated mathematics and algorithm development for extracting information from complex and/or sparse signals

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Hypersonic International Flight Research Experimentation (HIFiRE), is investigating the fundamental science of hypersonics technology and its potential for next generation aeronautical systems.
AFOSR International Enterprise

- Building international goodwill
- Strengthening partnerships
- Avoiding technological surprise

The Sun Never Sets on AFOSR
International Research Achievements

• Agent-Based Computing in Distributed Adversarial Planning: Michal Pechoucek, Czech Tech Univ (EOARD)
  A decision-making process through which an agent constructs a sequence of actions (possibly consisting of a single action only) leading to the desirable goal state of the world in an adversarial situation.

• Biomimetic Silicon Nanostructure: Li-Chyong Chen, National Taiwan University, (AOARD)
  Created nanostructure (nanotip) surfaces which mimic moth eye and surpass its function in anti-reflection in that they absorb almost all incident light.

• Laser-Induced Air Breakdown in Hypersonic Flow: Sao Jose dos Campos, Brazil (SOARD)
  Experimental study of hypersonic flow. Gearing up collaboration with Australian hypersonic project HIFIRE.
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AFOSR
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH