Air Force Research Laboratory

AFOSR Overview

4 March 2013

Dr. Van Blackwood
Air Force Office of Scientific Research
Air Force Research Laboratory

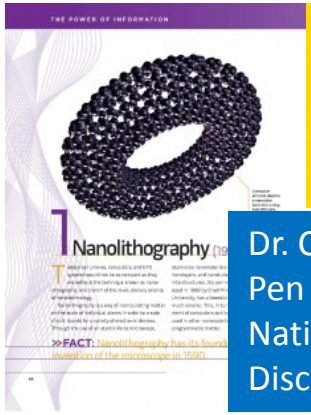
Integrity ★ Service ★ Excellence

AFRL

Why AF Invests in Basic Research

DSB Task Force Report on Basic Research

- **Probes today's technology limits and ultimately leads to future technologies**

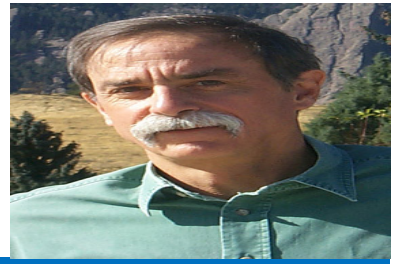


Dr. Chad Mirkin's research on Dip Pen Nanolithography was featured in National Geographic's '100 Scientific Discoveries That Changed the World'

- **Attracts the most creative minds to fields of critical DoD interest**

AFOSR Sponsored 71 Nobel Laureates

1997 Nobel Prize in Physics
Steven Chu Secretary of Energy



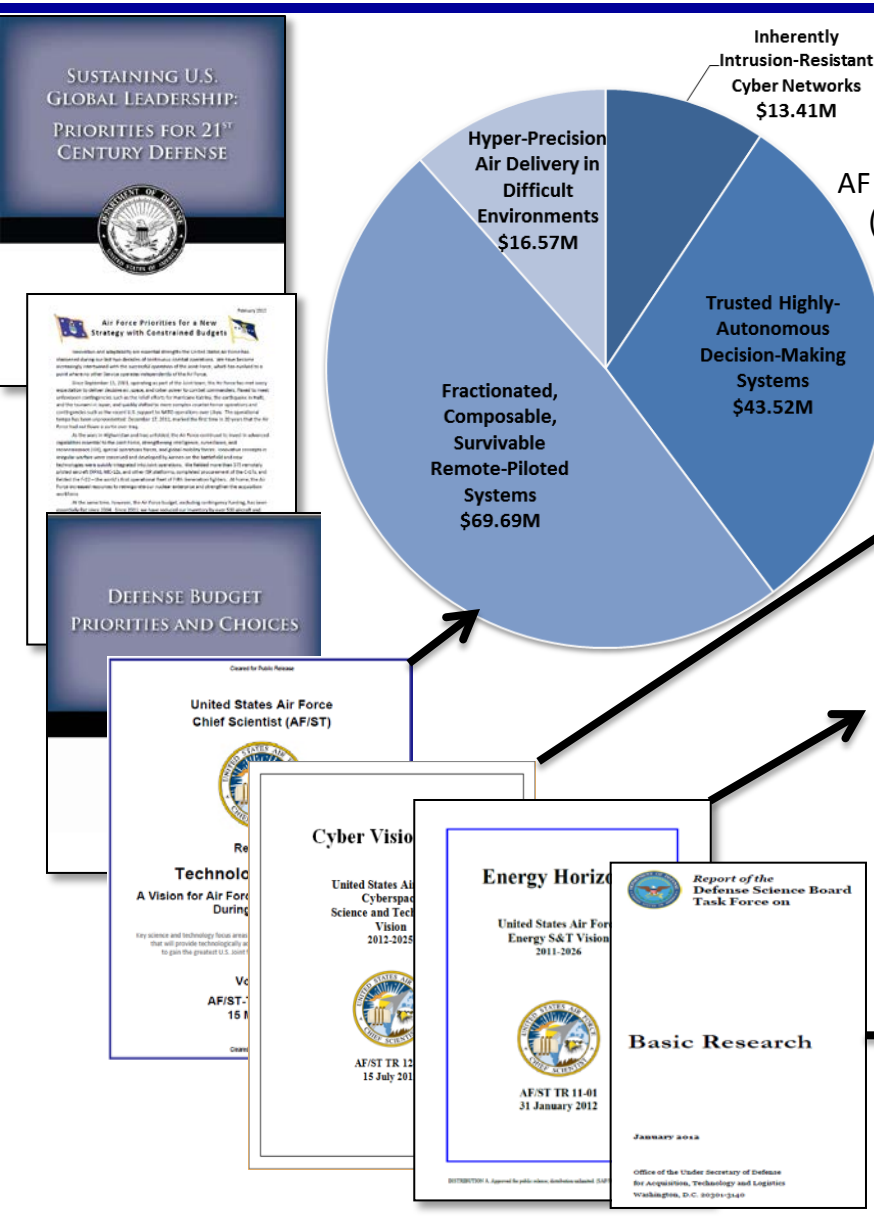
2012 Nobel Prize in Physics
Dr. David Wineland, Univ of Colorado/NIST

- **Creates a knowledgeable workforce in fields of critical DoD interest**

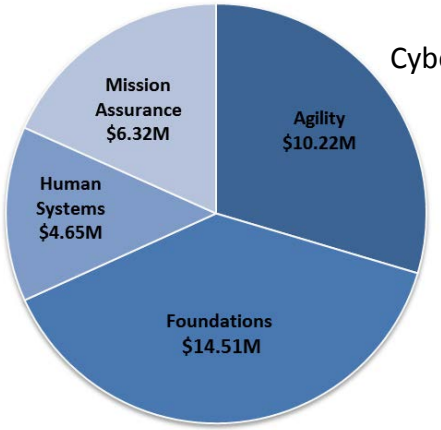
5 AFOSR PIs
Received PECASE Awards
in 2012

Dr. Matthew Squires, AFRL scientist, received an FY11 PECASE for his work in controlling laser cooled atoms

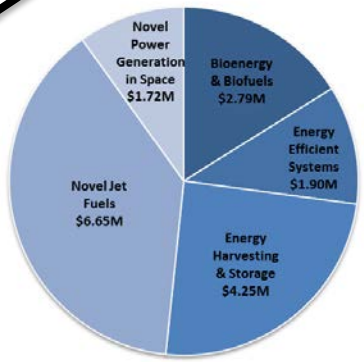
Air Force 6.1 ≠ NSF



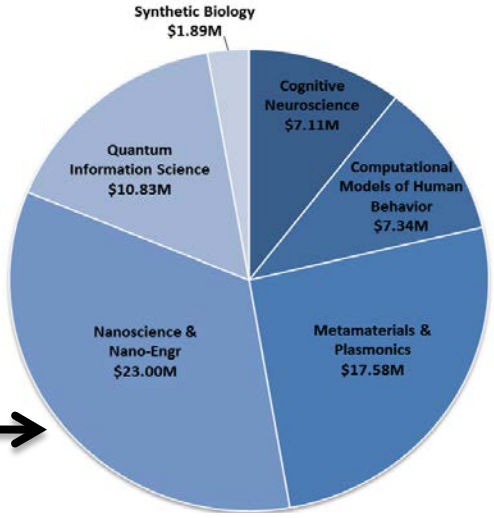
AF Technology Horizons (Grand Challenges)
$143.19M



Cyber Vision 2025
$35.75M



Energy Horizons
$17.30M



ASD (R&E) Six Disruptive Areas
$67.85M

Basic Research Strategy

Goals defined for Basic Research in AF S&T Strategic Plan :

- **Provide scientific leadership for the AF basic research enterprise**
- **Attract the Nation's/World's best S&Es to contribute to and lead AF/DoD research**
- **Ensure portfolio coherence and balance**
- **Foster connections between AF researchers and the National/International basic research community**
- **Maximize the discovery potential of the defense research business environment**

Focus on the Future AF with the ultimate goal to make Today's AF and Tomorrow's AF Obsolete!

AF Basic Research Manager

Mission: *We discover, shape, and champion basic science that profoundly impacts the future Air Force.*

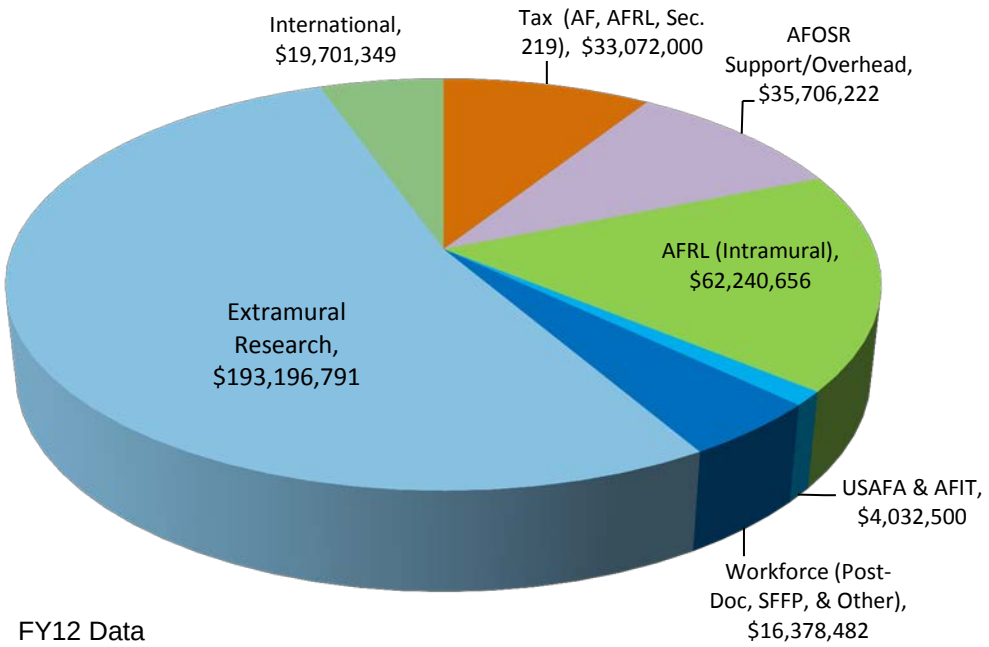
- **Identify Breakthrough Research Opportunities – Here & Abroad**
  - 60 Program Managers interacting with leading scientists and engineers across the globe
  - 3 International offices (London, Tokyo, Santiago)
  - Sponsored 165 scientific workshops and symposiums
- **Foster Revolutionary Basic Research for Air Force Needs**
  - 1291 extramural research grants at 201 U.S. universities
  - 313 intramural research projects at AFRL, USAFA, AFIT
  - 1900 PIs, 3500 grad students, 603 post-docs supported
- **Transition Technologies to DOD and Industry**
  - 907 funded transitions (follow-on-uses) from FY11 PI data call
  - AFRL is the principal transition path
  - 152 STTR small business - university contracts

AF Basic Research Budget

	FY 2011	FY 2012	FY 2013*
AF 6.1	350,978	364,328	361,787
OSD Devolved 6.1	135,601	140,273	141,153
Total $K	486,579	504,601	502,940

*FY13 PB

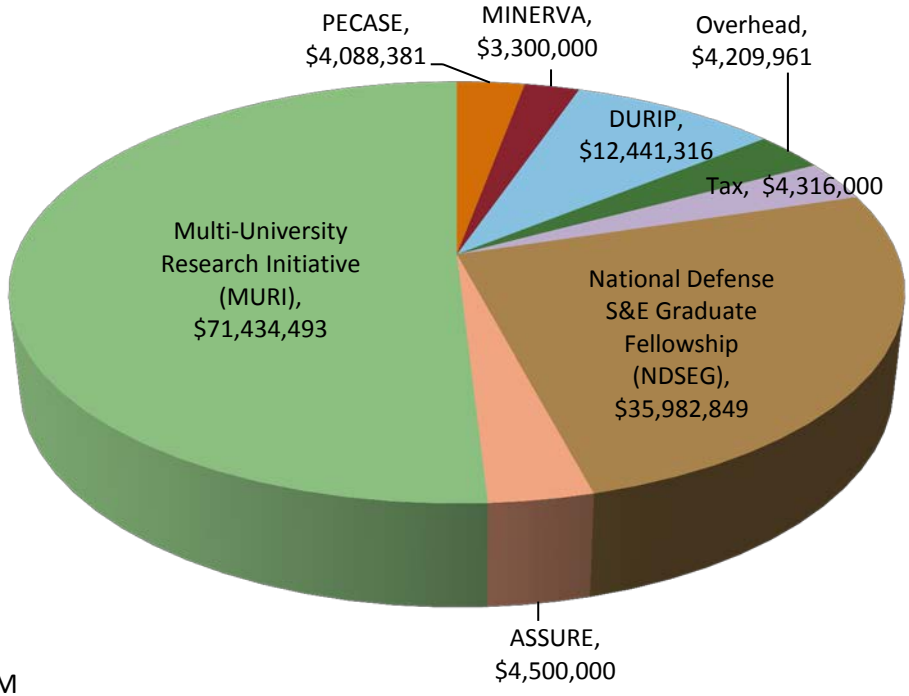
AF



FY12 Data

Total Intramural $82.6M (unburden)

OSD



Broad Academic Engagement Across the US

Top Funded Univ.

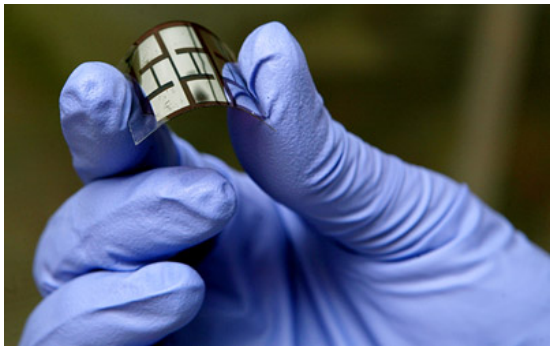
- Stanford
- Princeton
- Georgia Tech
- M.I.T.
- UC San Diego
- Univ of Michigan
- UC Berkeley
- Univ. of Maryland
- Univ. of Arizona
- Cal Tech

AFOSR Sponsored 71 Nobel Laureates

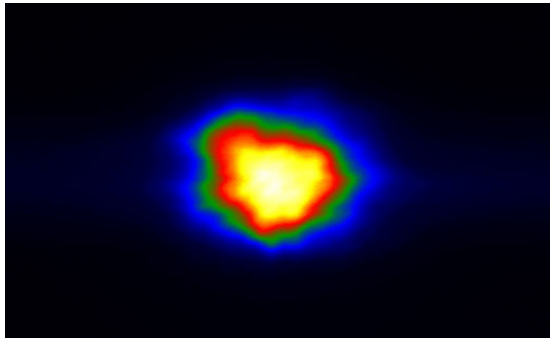
Current PI Awards & Recognitions:

- 4 - Nobel Prize winners
- 52 - National Academies members
- 2- President's Council (PCAST)
- 24 - Presidential Early Career Award
- 115 - Professional Society Fellows
- 131 - Young Investigator Program

Supporting the Scientific Foundations of Tech Focus Areas



Dr. Yueh-Lin Loo at Princeton University developed a new photovoltaic cell, which is more efficient and tougher than traditional cells and delivers 47% increase in electricity generation.



Dr. Alex Kuzmich at Georgia Tech researching entangled quantum memories for use in securing long distance transmission of secure information and quantum computing.

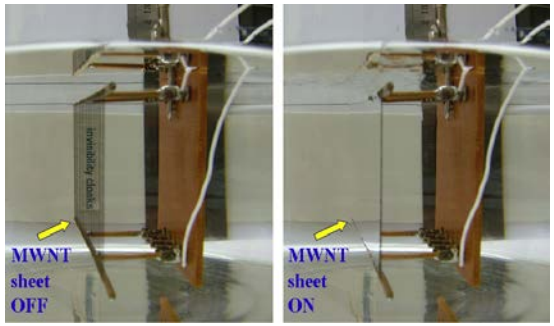
Weapons (Total $31.02M; In-House $11.58M):
- High power microwave devices
- Lasers and non-linear optics
- Energetic materials and combustion chemistry
- Thermal science

Human Performance (Total $17.57M; In-House $5.66M):
- Robust computational intelligence
- Mathematical basis for neurobiological processes
- Trust, autonomy, and the human-machine interface
- Effect of culture on influence
- Human Performance and Biosystems

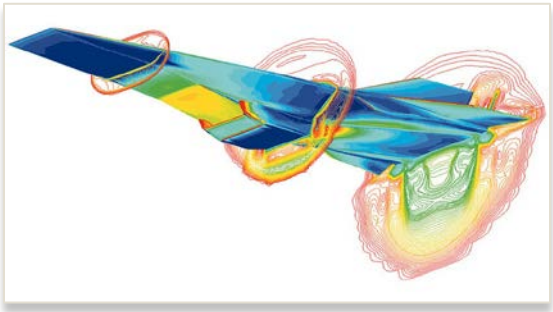
C2-ISR (Total $69.82M; In-House $10.26M):
- Novel Sensing Devices and Architectures
- Non-linear Optical Materials, Optoelectronics, and Nanophotonics
- EO signal processing and navigation
- Information fusion
- Novel RF devices and communication architectures

Cyber & Communications (Total $48.37M; In-House $4.26M):
- Science of cyber security
- Mathematics of complex networks
- Software/algorithms for advance computational architectures

Supporting the Scientific Foundations of Tech Focus Areas



Dr. Ray Baughman at University of Texas-Dallas used carbon nanotubes--which look like pieces of thread--and then heats them up rapidly until the objects beneath them effectively disappear.
Time Magazine List of Best Inventions for 2011



Model-free simulations of >Mach 3 shock turbulent boundary layer interactions. Dr. Graham Candler at Univ. of Minnesota and others uses computational fluid dynamics to study high-temperature reacting flows and hypersonic flows.

EP/EW (Total $9.57M; In-House $4.59M):
- RF propagation and RF-plasma interaction
- RF sensing surveillance, and signal processing

Affordability & Sustainment (Total $9.51M; In-House $2.57M):
- System-level analysis and modeling
- Aero-elasticity and structural dynamics
- Integrated Modeling

Next Gen Aerospace Systems (Total $151.80M; In-House $25.13M):
- Control in turbulent flow
- Multiagent, contested networked control
- Control of uncertain, information-rich, dynamic environments
- Unsteady aerodynamics and flow control
- Plasma discharges & non-equilibrium chemistry
- Energetic materials and combustion chemistry
- Thermal science and high temperature materials
- Novel or multifunctional materials

Space (Total $34.44M; In-House $13.20M):
- Space weather
- Multiagent, contested networked control
- Control of uncertain, information-rich, dynamic environments
- Thermal science

Diversity of Basic Research Activities

Nation is counting on us

Hypersonics Research

Identify, model and exploit critical physical phenomena in turbulent and high-speed flows.

Potential Impact

Enable efficient propulsion and structural systems for long range hypersonic strike in access denied environments.

Funding of world's only quiet hypersonic wind tunnel to examine aerodynamic characteristics of hypersonic vehicle.

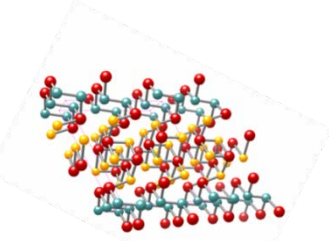
Rest of the world is out in front

Superconductivity

New superconductor with T_c = 23 K found! Explore layered metallic systems for optimal synergy between magnetic, structural & superconducting instabilities.

Potential Impact

Enables compact airborne power generation and gyrotron magnet for airborne high power microwaves.



Naturally occurring sulfur-bearing mineral Canfieldite ($Ag_8(Sn,Ge)S_6$ and related crystallographic structure.

Potential Game Changers

Bio-Sensing of Magnetic Fields

Discover the receptor mechanism(s) for biological magnetic sensitivity, especially at field strengths comparable to the geomagnetic background.

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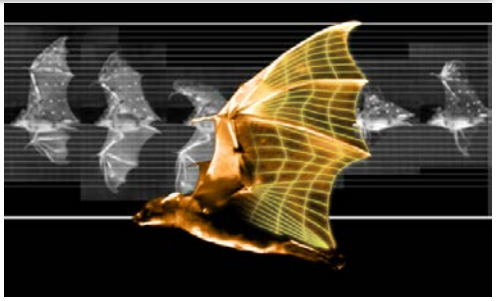
Potential Impact

Enable long-range navigation in a GPS denied environment by orientation to the geomagnetic field.



Bio-inspired research to develop multi-agent cooperative systems operating in dynamic, uncertain adversarial environments.

Shaping the Future

AF constantly reviews its portfolio to identify divestiture opportunities in order to fund new ideas

- Funded by levying a tax across prior year budgets of all research portfolios
- Program managers nominate research topics that are reviewed for scientific merit and alignment to the AF basic research strategies
- New research areas identified via a broad agency announcement

FY13 ($19M)

- Autonomic Material Systems
- Layered Structured 2D-Materials
- Pulse Laser Processing of Materials
- Sustainable Alloy Design - Rare Earth Metals
- Ultra-Scale and Fault-Resilient Algorithms
- Cyber Trust and Suspicion
- Catalytic Reactions in Endothermic Cooling Systems
- Energy Transfer in Multi-Physics Flow Phenomena
- Transformational Computing

FY14 ($20M)

- Bio-Sensing of Magnetic Fields
- Plasma – Surface Interactions in Reactive Environments
- 2D Materials and Devices Beyond Graphene
- Nanoscale Building Blocks for Novel Materials
- Theory-based engineering of biomolecular circuits
- Psychological/Behavioral Effects of Advanced Weaponry
- First Principles Modeling of Semiconductor Lasers
- Lasers physics for scaling of single fibers
- Laser-matter interactions in the relativistic optics regime
- Metal Dielectric Interface
- Perceptual & Social Cues in Human-like Robotic Interactions
- Socio-Digital Influence
- Interactions of CMEs w/ the Solar-Terrestrial Environment

Basic Research Initiatives
FY14

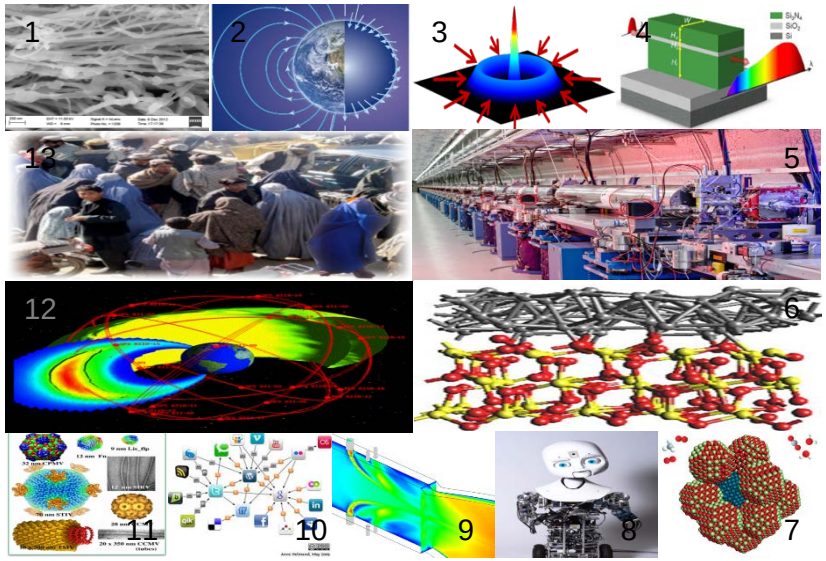
1. 2D Materials and Devices beyond Graphene: Grow, characterize and understand hetero-structures of different 2D materials with unique electronic, photonic, thermal and structural characteristics.

2. Bio-Sensing of Magnetic Fields: Initiates a basic research program to understand biological magnetic field sensation.

3. Development and Verification of Effective First Principles Modeling of Semiconductor Lasers under Non Equilibrium Operating Conditions: Support theory and measurements that are highly sensitive to detailed gain and index dynamics.

4. Laser-matter Interactions in the Relativistic Optics Regime: Explore and understand the rich variety of physical processes and potential new physics involved in the interactions of extreme light fields with matter.

13. Understanding the Psychological/Behavioral Effects of Advanced Weaponry: Understand the psychological/ behavioral effects of current and future weaponry



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

12. Understanding the Interaction of Coronal Mass Ejections with the Solar-Terrestrial Environment: Determine ICME geoeffectiveness with a focus on the internal magnetic topology of ICMEs.

6. Metal Dielectric Interface - Charge Transfer in Heterogeneous Media under Extreme Environments: Provide fully self-consistent and timedependent solutions for the electron density functions.

11. Theory-based Engineering of Biomolecular Circuits in Living Cells : Make synthetic biology a rational engineering discipline by creating a math and theory-based framework for modular design and fabrication.

10. Socio-Digital Influence: Result in novel theories of influence within the socio-digital landscape and in empirical studies that identify mechanisms for influence within different groups.

9. Plasma – Surface Interactions in Reactive Environments: 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.

8. Perceptual and Social Cues in Human-like Robotic Interactions: Analyzes and develops the perceptual and social cues that drive trust perceptions and performance within human-robot interactions.

7. Nanoscale Building Blocks for Novel Materials: 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.

Building International Relationship to Avoid Technology Surprise

- ***Building international goodwill***
- ***Strengthening partnerships***
- ***Avoiding technological surprise***
- ***Accelerating S&T achievements and transitions to the U.S.***

- Nanomaterials **(Taiwan, Korea)**
- Metamaterials **(Europe, Israel)**
- Fiber Lasers **(UK)**
- Hypersonics **(Australia, Brazil, Belgium)**
- Machine Cognition **(Japan, Australia)**
- Brain Science **(Korea)**
- Extremophiles **(Chile)**
- Plasma Science **(FSU)**
- SSA **(Chile)**
- Bio-Inspired Flight **(India, UK)**
- Quantum Info Sciences **(UK)**
- Ultra-Short Pulse Lasers **(Europe)**

Defense Science Board Report: **"It is important for DoD to be involved in the cutting edge of basic research on topics of specific interest to the Department- whether the cutting edge is in the U.S. or overseas."**
<u>Recommendation</u>: DoD increase the percentage of basic research funding that is invested internationally from 2.5% to 5%

Educating the Next Generation

- **National Defense Science and Engineering Graduate Fellowship (NDSEG - $36.0M)**
  - Full tuition assistance + $31K/per year stipend
  - Fellows do not incur any service obligation
  - Supports over 550 PhD-track graduate students
- **Awards to Stimulate and Support Undergraduate Research Experience (ASSURE - $4.5M)**
  - Provide undergraduates with research opportunities in S&E fields of DoD interest
  - Supports over 500 undergraduate students during summer months – managed by National Science Foundation
- **Junior Science and Humanities Symposia (JSHS - $.70M)**
  - Provide high school students to conduct an original research investigation in the STEM field.
- **Professional Society Meetings, Scientific Exchanges, and other Scholar Programs - $8.89M**
- **Historically Black Colleges & Universities and Minority Institutions (HBCU/MI)**

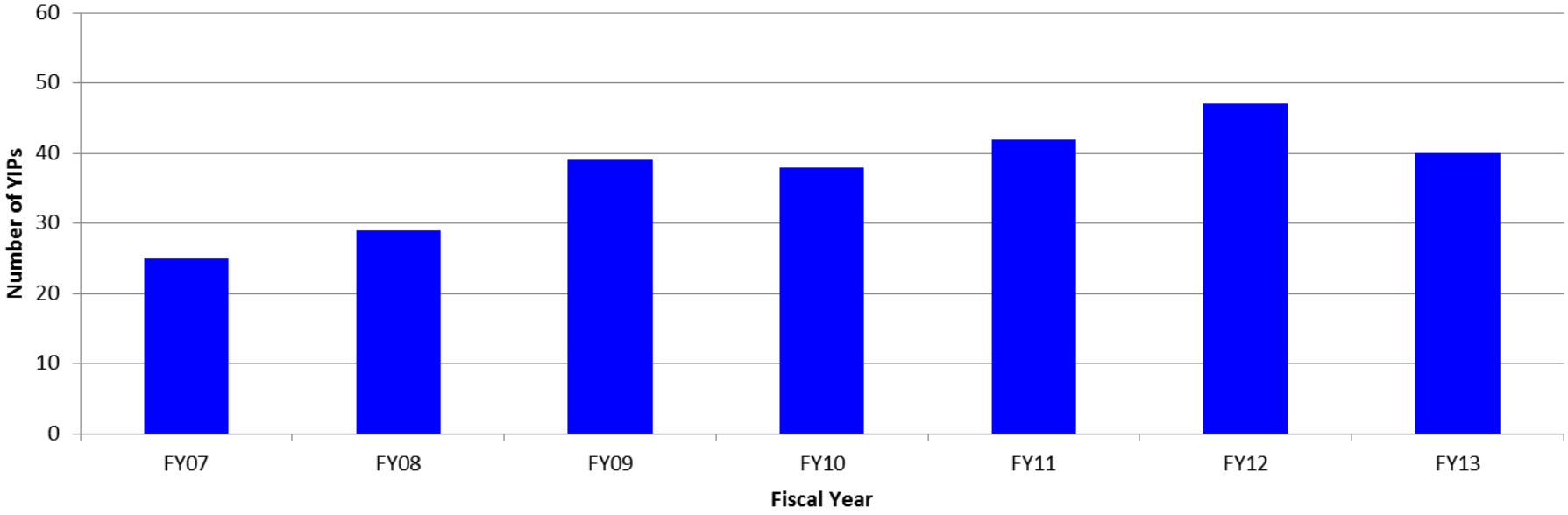
ASSURE site at Fort Johnson, NY

USA Science & Engineering Festival , DC

AFRL

Young Investigator Program (YIP)

- Develop long-term relationships with leading junior PIs
- 262 awards since FY07; 40 awarded in FY13
- Must have received PhD in the last five years
- Awards up to 5 years
- Goal: increase YIPs to >50/year



Summary

- **The White House and DoD strongly supports the basic research program**
- **AF basic research:**
  - **Probes today's technology limits and ultimately leads to future technologies**
  - **Creates knowledgeable workforce in fields of critical AF interest**
- **AF basic research investments are fully coordinated and leveraging opportunities are exploited for innovation**

"Innovation also demands basic research. Today, the discoveries taking place in our federally-financed labs and universities could lead to … New lightweight vests for cops and soldiers that can stop any bullet. Don't gut these investments in our budget. Support the same kind of research and innovation that led to the computer chip and the Internet."
- President Obama, State of Union Speech, 24 January 2012

Happy 60th Birthday

AFOSR

1951 - 2011

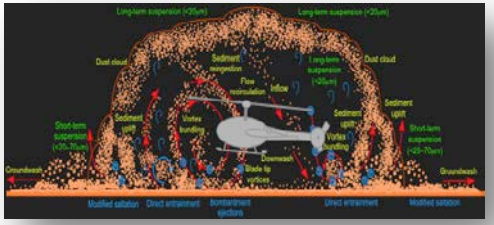
Basic Research Rapid Transitions

Rotorcraft Brownout

Real-time simulations with pilot inputs provide more realistic brownout predictions, an assessment of operational parameters on brownout severity, and permit the development of piloting strategies to mitigate brownout.

Enabling S&T

Simulations of 3-D, unsteady, vortically-dominated flows with sediment transport are very challenging. Simulations can be accelerated using advanced flow modeling, particle clustering techniques, and GPUs to enable real-time outputs.



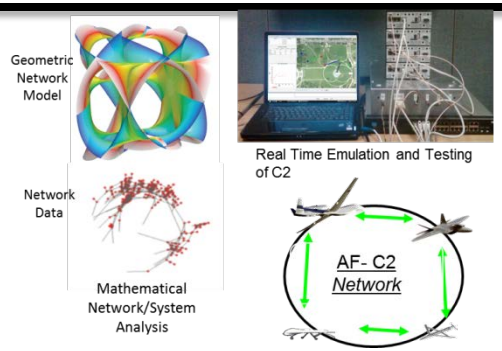
AFOSR - MURI → Univ of Maryland → Advanced Rotorcraft Technology (ART)

Command & Control Network Assurance

Dynamic assessment of resource failures and security threats can be tracked and managed in real time by measuring data transactions over hardware, software, or network.

Enabling S&T

Software on cloud networks is extremely dynamic and causes failures due to unpredictable resource usage. Information geometric models can be used to track these applications.



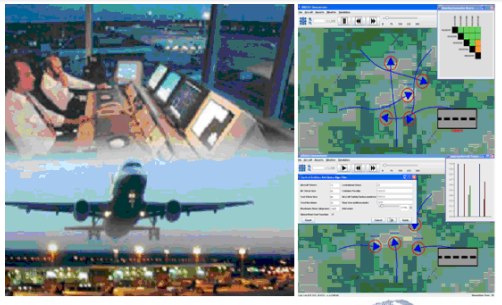
AFOSR → Princeton → STTR – Intelligent Automation, Inc → Electronic Systems Center

Autonomous Agents for Air Traffic Control

Developed a novel technique that can autonomously deconflict flight paths in congested air operations.

Enabling S&T

Modeling and simulation of large scale collective flight scenarios comprehensive empirical and analytic studies of system performance, scalability and solution convergence.



EOARD → Czech Technical University → FAA. MDA, Army, BAE

Improving the AF Organic Research Capability

- **Intramural Proposal Process**
  - Best new-start proposals endorsed by AFRL Directors
  - Proposals peer reviewed
  - 10% of recipients designated as “STAR” teams
- **Workforce Development**
  - Centers of Excellence (7 Active/3 Pending)
    - Tie selected universities to TDs
  - International personnel exchanges (30)
  - Postdocs (80) & summer faculty (99) & students (22) at AF research sites

Assures a healthy AF in-house basic research capability