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Air Force Research Laboratory



100 YEARS OF U.S. AIR FORCE
SCIENCE & TECHNOLOGY

AFOSR Overview

13 MAR 2017

Dr. Frederica Darema, SES, IEEE Fellow
Director

Air Force Office of Scientific Research

Integrity ★ Service ★ Excellence



AFOSR Science and Technology Strategy

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

Identify breakthrough research opportunities here & abroad

- 26 Arlington-based Program Officers and 18 International Program Officers interacting with leading scientists and engineers across the globe
- 3 International offices (London, Tokyo, Santiago)

Find



Fund

Foster revolutionary basic research for Air Force needs

- 1166 research projects in FY16
 - 190 U.S. institutions
 - 46 States
- 293 intramural projects at AFRL, USAFA, and AFIT in FY16
- In FY16 384 international efforts in 43 countries in 5 continents

Forward

Transition technologies to DoD and industry

- AFRL is the principal technology transition path
- 38 SBIR/STTR contracts funded with FY16 funds
- Entrepreneurial impact - 74 spin-off companies

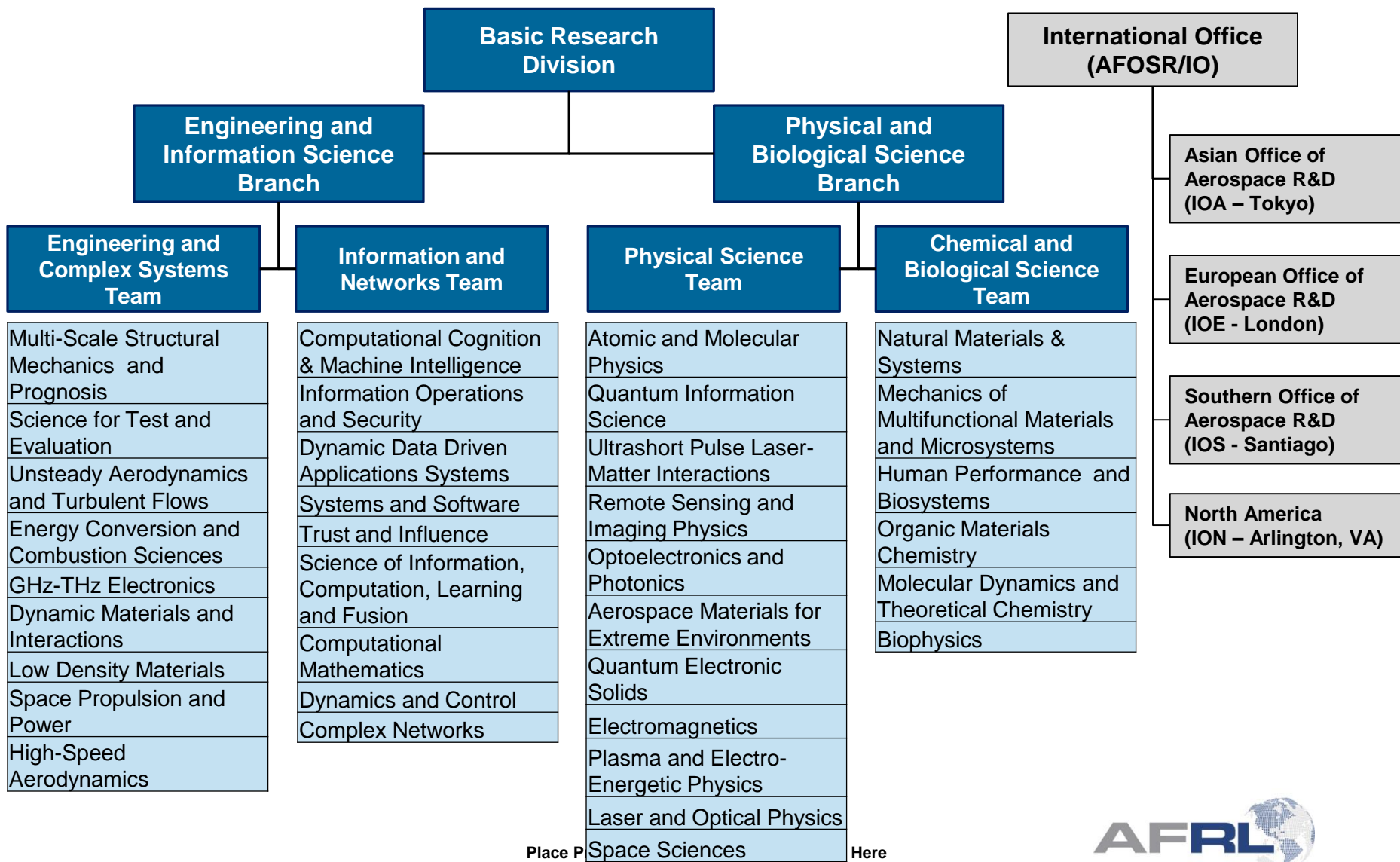


36 Programs in Basic Research Division and 20 Programs in International Office

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AFRL HERITAGE | 1917-2017
100 YEARS OF U.S. AIR FORCE
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Place P Here





Funding - Overall Investment Strategy



Investment Strategy Overall Approach & Impact

- Research scope that spans push (frontiers ideas) & pull (e.g. new capabilities for the AF)
- Partner with other Agencies, leverage ideas, research-communities, and their funding
 - In the US – Program Officers coordinate efforts with NSF, NASA, DARPA, ...
 - Internationally - Hypersonic Scramjet Testing (Australia), X-ray Free-Electron Lasers (UK)
- Overall Impact to AFMC & AFRL Technology Advances
 - Combinable Multi-kW Fiber Laser Amplifier research – AF/SAB challenge (2015)
- Publications
 - 7,693 publications from extramural efforts in 2013-2014 received citations from 47,765 papers published between 2013-2015
- Recognition
 - 78 AFOSR-supported Nobel Prize laureates
 - Program Officer, Dr. Gernot Pomrenke, led the NanoPhotonics \$200M DoD initiative, recognized by Vice President Joe Biden
- Patents & Companies
 - More than 1600 patents and 74 start-up companies

Research for New Air Force Capabilities

“excellence in science and transformative capabilities for the Air Force”

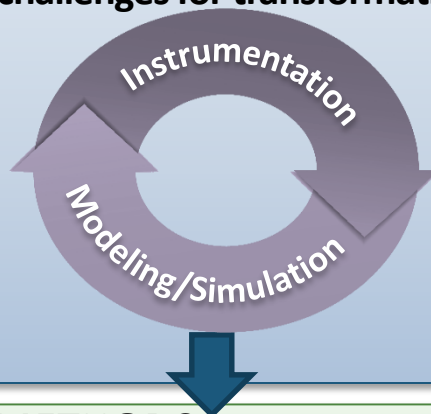
Force” OF U.S. AIR FORCE
SCIENCE & TECHNOLOGY

PROBLEM: Increasingly we deal with systems-of-systems and systems/environments that are
complex | heterogeneous | multimodal | multiscale | dynamic



AFOSR INVESTMENT STRATEGY

Pursue excellence in science through disciplinary and (increasingly) multidisciplinary research, to develop new methods for end-to-end systems capabilities, applied to key Air Force challenges for transformative impact to the Air Force



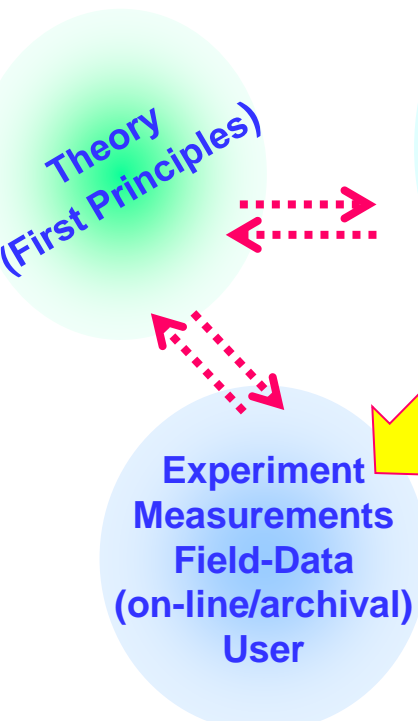
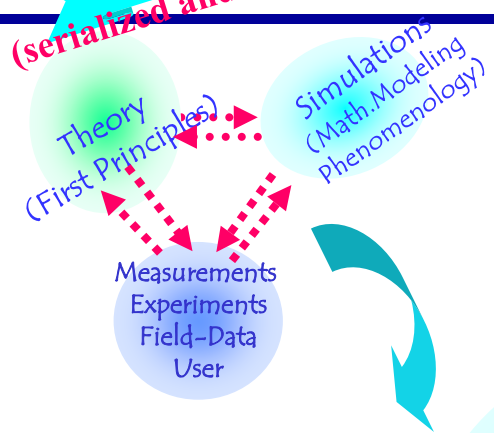
NEW METHODS - Paradigm Changing

- enable more accurate and faster modeling capabilities for analysis, prediction, & operational support
- enable decision support capabilities with the accuracy of full scale models
- support adaptive multimodal instrumentation and fault tolerance in instruments/sensors failures
- exploit ubiquitous embedded sensing & control for new test & valuation methods

AF CAPABILITY: understand, design, manage & optimize systems-of-systems across life-cycle



OLD
(serialized and static)



**Dynamic
Feedback & Control
Loop**

The DDDAS Paradigm (Dynamic Data Driven Applications Systems)

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InfoSymbiotic Systems

DDDAS: ability to dynamically incorporate additional data into an executing application, and in reverse, ability of an application to dynamically steer the measurement(instrumentation) processes

“revolutionary” concept enabling design, build, manage, understand complex systems

**Dynamic Integration of
Computation & Measurements/Data
Unification of
Computing Platforms & Sensors/Instruments
(from the High-End to the Real-Time, to the PDA)
DDDAS – architecting & adaptive mngmnt of sensor systems**

Challenges:
Application Simulations Methods
Algorithmic Stability
Measurement/Instrumentation Methods
Computing Systems Software Support

Synergistic, Multidisciplinary Research

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Enabling DDDAS Capabilities

Fundamental Challenges and Timeliness

- **Application modeling methods to support dynamic data inputs**
 - multi-modal, multi-scale, multi-fidelity models/simulations
 - dynamically invoke/select multiple scales/modalities/components
 - interfacing with measurement systems
- **Algorithms tolerant to perturbations from dynamic data inputs**
 - handling data uncertainties, uncertainty propagation, quantification
- **Measurements**
 - multiple modalities/fidelities, space/time distributed, data management
- **Systems Software methods supporting such dynamic environments**
 - dynamic/adaptive execution on heterogeneous/multi-hierarchical environments
{from the high-end/mid-range to real-time platforms-- beyond Clouds(Grids)
computation, communication, storage; programming models, run-time/OS, ...}

Timeliness -- Confluence across 4 emerging

DDDAS-Dynamic Data Driven Applications Systems

- **Unifying High-End with Real-Time/Data-Acquisition&Control**

Large-Scale-Big-Data (Large-Scale-Dynamic-Data)

- **“Big Data” + Ubiquitous Sensing&Control (2nd Wave of big-data)**

Large-Scale-Big-Computing

- **From the exa-scale to the sensor-scale/controller-scale**

Multi-core Technologies

- **Will be driven by sensor/controller and mobile devices**



DDDAS for new capabilities for Air Force Emerging Technological Horizons and Beyond



- Increasingly we deal with **systems-of-systems**, and **systems/environments that are complex, heterogeneous, multimodal, multiscale, dynamic**
- Need methods and capabilities
 - not only for **understanding**, and **(optimizing) design**...
- ... **but also manage/optimize systems' operational cycle, evolution, interoperability**
→ **DDDAS-based methods for across the life-cycle of systems**
- DDDAS – **beyond traditional modeling/simulation approaches and use**
 - **beyond the traditional instrumentation approaches and use**
- DDDAS enables:
 - **more accurate and faster modeling capabilities for analysis and prediction**
 - **decision support capabilities with the accuracy of full scale models**
 - **dynamic/adaptive and more efficient/effective management of heterogeneous resources; ability to compensate for faults**

DDDAS/InfoSymbiotics
is the **unifying** paradigm

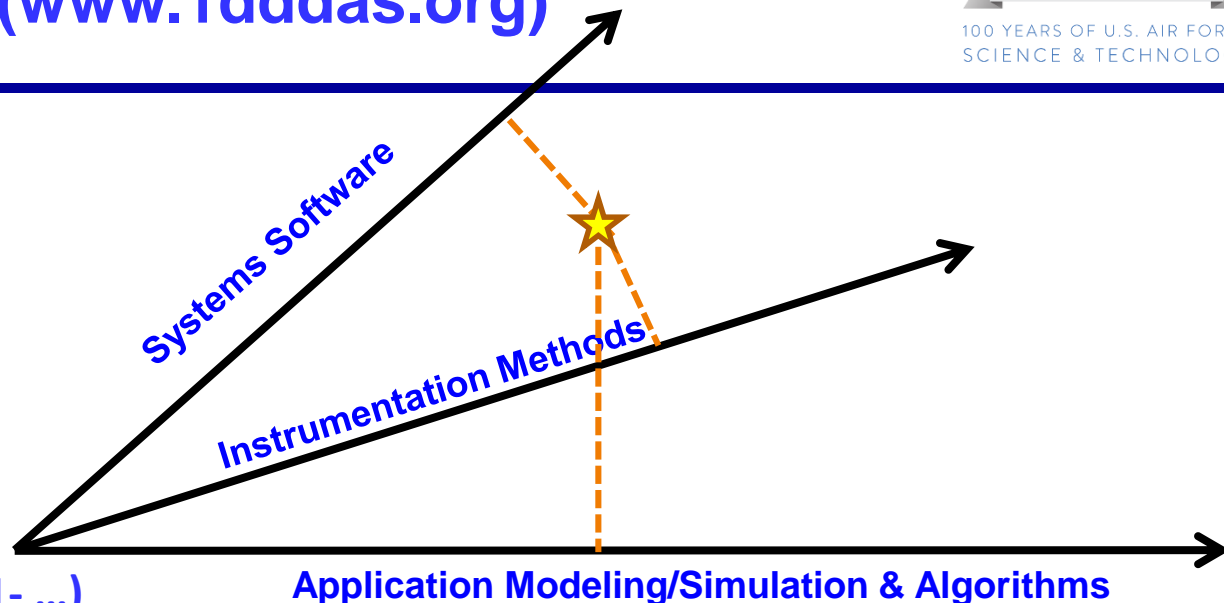


DDDAS Program Portfolio organization (www.1dddas.org)



Program Research Axes:

{Program Sub-Areas}



AFOSR DDDAS Program (2011- ...)

Thematic Areas:

*Materials modeling; Structural Health Monitoring for Decision Support;
Environment Cognizant Operation; Energy Efficiencies;
Autonomic Coordination of U(A/G)S Swarms;
Co-operative Sensing for Surveillance - Situational Awareness
Space Weather and Adverse Atmospheric Events;
CyberSecurity; Systems Software*

NSF-AFOSR DDS Initiative (2014) - Large-Scale-Big-Data & Large-Scale-Big-Computing
(Planned) Expanded Multi-Agency (2017) - InfoSymbioticSystems (DDDAS)
DDDAS collaboration with the TTCP Program (FY17)

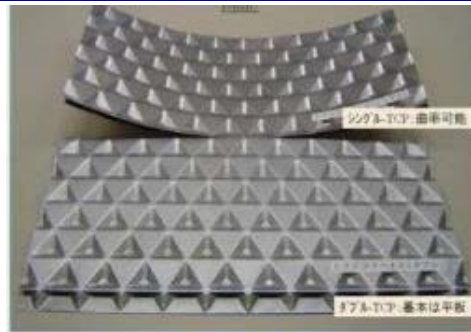


AFOSR Programs

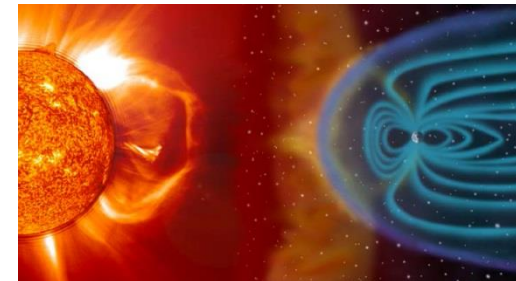
Supporting Basic Research in AFRL Technical Directorates



RI – Assured command & control



RX – Multifunctional materials



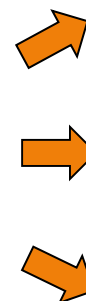
RV – Space science



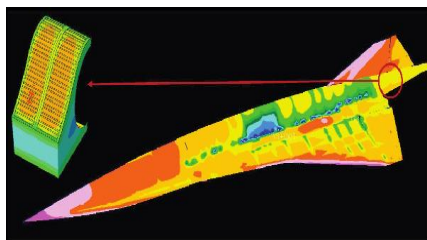
RH – Neural stimulation



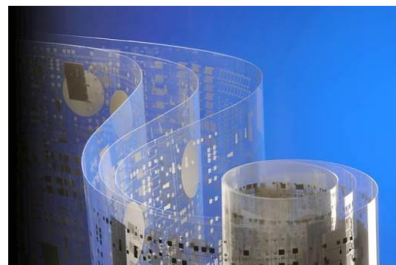
AFOSR



RD – Fiber lasers



RQ – Hypersonics



RY – Printed electronics



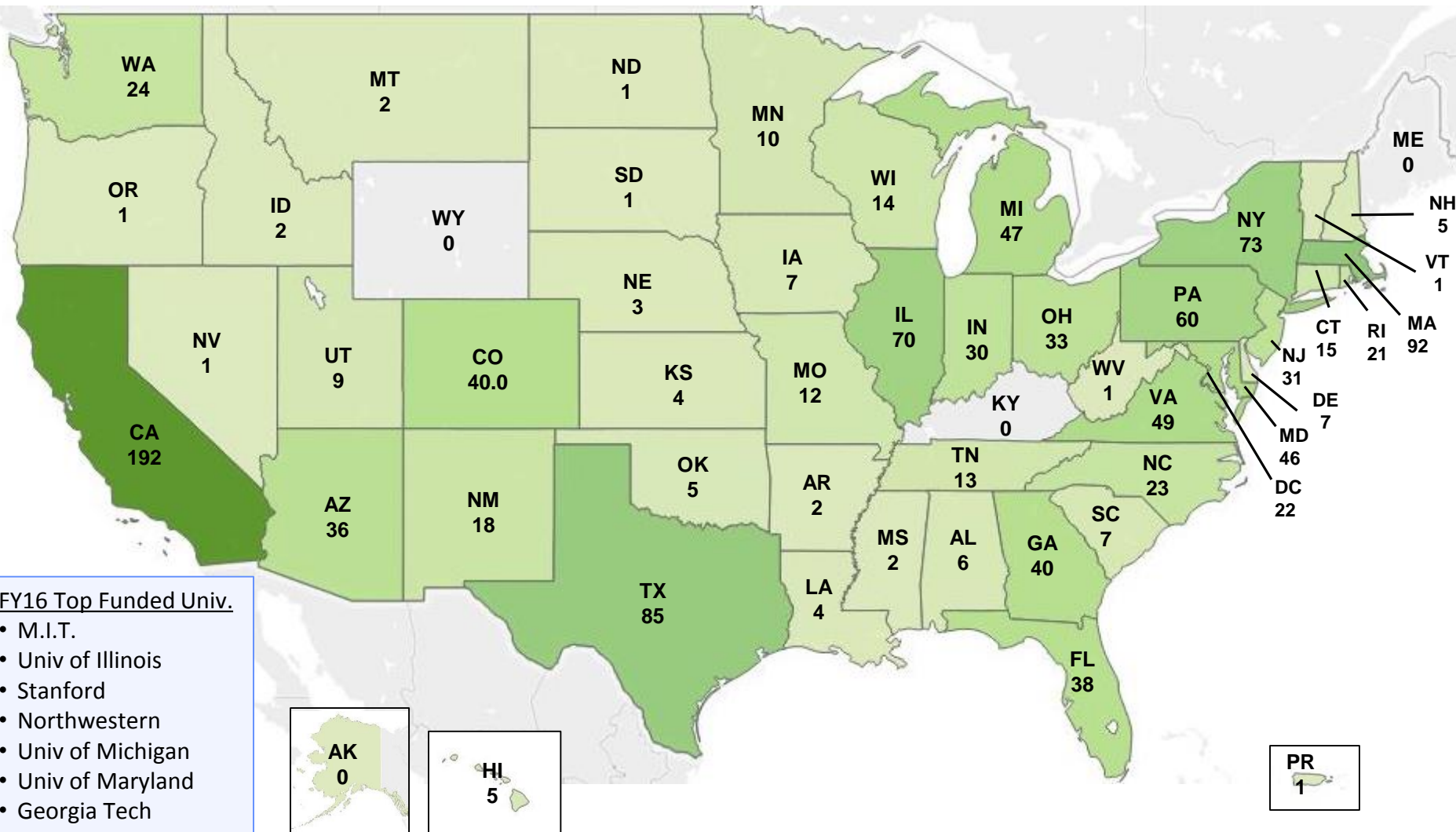
RW - Nature-inspired flight



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Broad Academic Engagement Across the U.S.

(3-Year Average Number of Grants by State)



FY16 Top Funded Univ.

- M.I.T.
- Univ of Illinois
- Stanford
- Northwestern
- Univ of Michigan
- Univ of Maryland
- Georgia Tech
- Univ of Colorado
- Carnegie Mellon
- UC San Diego

3 year average = 1214 grants/year

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Educating the Next Generation



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- **National Defense Science and Engineering Graduate Fellowship (NDGEG)**
 - Tuition, fees, insurance and stipend
 - Fellows do not incur any service obligation
 - Supported approx. 3,400 PhD-track graduate students since the program's inception
- **Awards to Stimulate and Support Undergraduate Research Experience (ASSURE)**
 - Provides undergraduates with research opportunities in S&E fields of DoD interest
 - Supports over 500 undergraduate students during summer months – managed by National Science Foundation
- **Historically Black Colleges and Universities/ Minority Institutions (HBCU/MI)**
 - Supports basic research and acquisition of equipment
- **Junior Science and Humanities Symposia (JSHS)**
 - Provides high school students an opportunity to conduct an original research investigation in a STEM field.



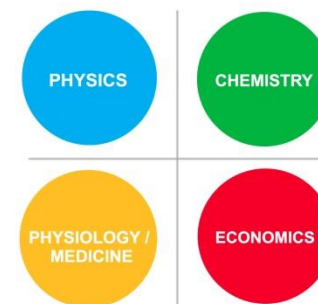
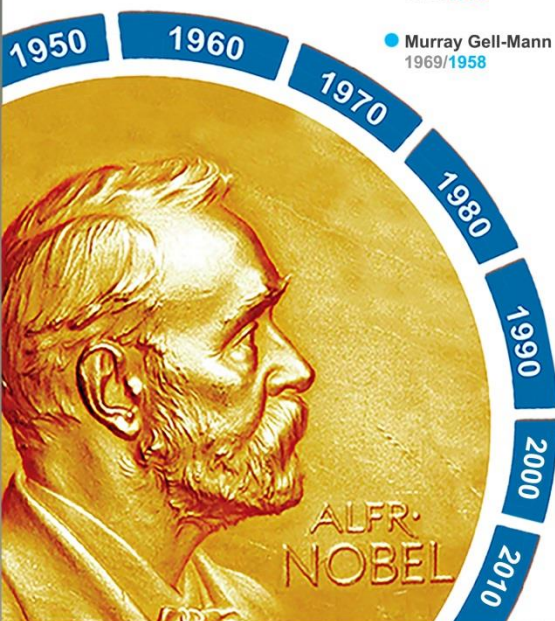
Junior Science and
Humanities Symposium



Dr. Abdalla Darwish and student at
Dillard University in Louisiana
(HBCU/MI Program)

78 AFOSR SUPPORTED NOBEL PRIZE LAUREATES

1950	1960	1970	1980	1990	2000	2010
<ul style="list-style-type: none"> ● Polykarp Kusch 1955/1954 ● Willis Lamb 1955/1954 ● John Bardeen 1956/1953 	<ul style="list-style-type: none"> ● Willard Libby 1960/1951 ● Robert Hofstadter 1961/1953 ● Eugene Wigner 1963/1958 ● Charles Townes 1964/1953 ● Robert Mulliken 1966/1952 ● Hans A. Bethe 1967/1953 ● Ragnar Granit 1967/1959 ● George Porter 1967/1962 ● Lars Onsager 1968/1966 ● Murray Gell-Mann 1969/1958 	<ul style="list-style-type: none"> ● Ulf Von Euler 1970/1959 ● John Bardeen 1972/1953 ● John R. Schrieffer 1972/1959 ● Nikolaas Tinbergen 1973/1961 ● Brian Josephson 1973/1968 ● Paul Flory 1974/1961 ● William Lipscomb 1976/1959 ● Phillip Anderson 1977/1968 ● John Van Vleck 1977/1964 ● Llya Prigogine 1977/1954 ● Herbert Simon 1978/1962 ● Sheldon Glashow 1979/1958 ● Abdus Salam 1979/1962 ● Steven Weinberg 1979/1958 	<ul style="list-style-type: none"> ● Walter Gilbert 1980/1959 ● Nicolaas Bloembergen 1981/1975 ● Kai Seigbahn 1981/1956 ● Arthur Schawlow 1981/1981 ● David Hubel 1981/1959 ● Thorsten Wiesel 1981/1959 ● Kenichi Fukui 1981/1962 ● Ronald Hoffman 1981/1980 ● S. Chandrasekhar 1983/1961 ● William Fowler 1983/1961 ● John Polanyi 1986/1981 ● Dudley Herschbach 1986/1979 ● Yuan Lee 1986/1971 ● Donald Cram 1987/1962 ● Melvin Schwartz 1988/1970 	<ul style="list-style-type: none"> ● Elias Corey 1990/1968 ● Jerome Friedman 1990/1961 ● Henry Kendall 1990/1961 ● Rudolph Marcus 1992/1962 ● Mario Molina 1995/1995 ● Richard Smalley 1996/1972 ● Steven Chu 1997/1988 ● Daniel Tsui 1998/1985 ● Ahmed Zewail 1999/1986 	<ul style="list-style-type: none"> ● Alan Heeger 2000/1988 ● Alan MacDiarmid 2000/1970 ● Jack Kilby 2000/1958 ● Herbert Kroemer 2000/1995 ● Paul Greengard 2000/1984 ● Eric Kandel 2000/1963 ● Wolfgang Ketterle 2001/1990 ● John Fenn 2002/1975 ● Daniel Kahneman 2002/1977 	<ul style="list-style-type: none"> ● Paul Lauterbur 2003/1956 ● Theodor Hansch 2005/1990 ● John Hall 2005/1991 ● Roy Glauber 2005/1962 ● Robert Grubbs 2005/1987 ● Thomas Schelling 2005/1960 ● George Smoot 2006/1985 ● Yoichiro Nambu 2008/1965 ● Andre Geim 2010/2008 ● Konstantin Novoselov 2010/2008 ● Daniel Shechtman 2011/1999 ● David Wineland 2012/1982 ● Francois Englert 2013/1963 ● Peter Higgs 2013/1964 ● Shuji Nakamura 2014/1991 ● Isamu Akasaki 2014/1991 ● Hiroshi Amano 2014/1991 ● William Moerner 2014/1995 ● J. Fraser Stoddart 2016/2008

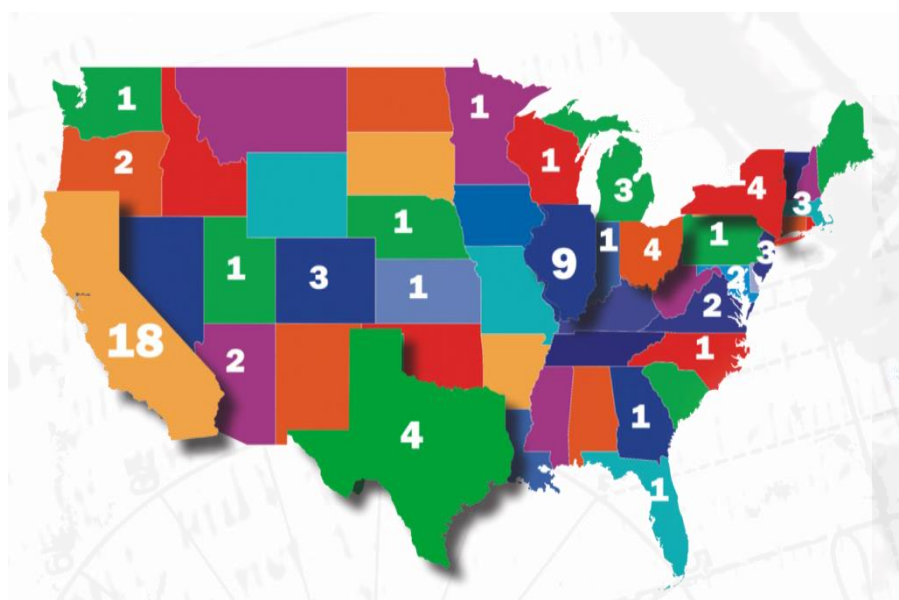


AWARD YR / SUPPORT BEGAN



Entrepreneurial Impact

- AFOSR has sponsored research resulting in more than 1600 patents
- Most citations for AFOSR funded patents come from industry
- AFOSR funding has resulted in or significantly contributed to the establishment of 74 cutting-edge startup companies



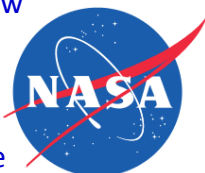
Europe

- Denmark
- Czech Republic



Scientific Partnerships

- Hypersonics Research
- Non-equilibrium flow
- Digital Twin
- Nanocomposites
- Living With a Star Steering Committee



NIST

- Nanophotonics



- Partnership for Research in Optical Technology
- Multi-agency Materials Genome Initiative

- Origami Structures, aero
- Solar and heliospheric physics
- Decision Making, Social and Behavioral Science, plasma chemistry, and others



Working with many industry and international teams on various research topics



- Ultracold atoms, Quantum sensor-magnetometry
- Microplasma for counter HPM
- Plasma-based logic circuits for rad-hard applications
- Photonics, High-power energy, Many more...



- Nanoenergetics: co-crystallization
- Combustion Chemistry



- Complex Networks OSTP/NITRD committee member



National Institutes of Health

- Cognition

- Combustion Working Group
- Multi-Agent Sys.



- Alternative energy Interagency
- Pulse Power Energy
- High temperature superconductors



- Many joint reviews
- Metamaterials research
- Laser propagation
- Graphene research
- Alt Navigation
- Other areas



Space Weather





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International Outreach



EOARD

EUROPEAN OFFICE OF AEROSPACE RESEARCH
AND DEVELOPMENT
London, United Kingdom

- *Identifying research of AF interest*
- *Engaging with collaborators*
- *Building relationships*

- *Leveraging foreign resources*
- *Transitioning S&T to the U.S.*



SOARD

SOUTHERN OFFICE OF AEROSPACE RESEARCH
AND DEVELOPMENT
Santiago, Chile

AOARD

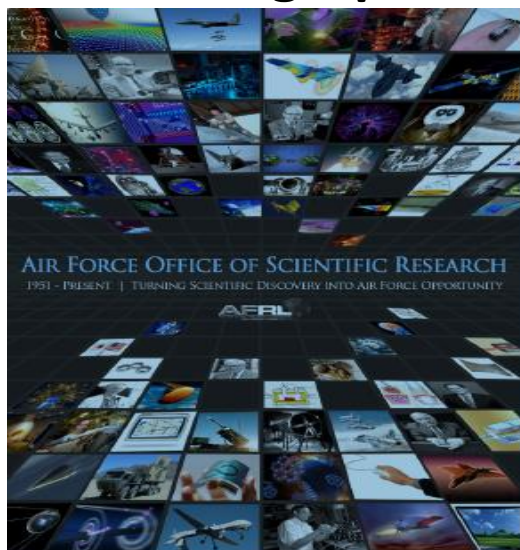
ASIAN OFFICE OF AEROSPACE RESEARCH AND
DEVELOPMENT
Tokyo, Japan

The Sun Never Sets on AFOSR



AFOSR Resources

60th Anniversary Monograph



Technical Strategic Plan



2016 Broad Agency Announcement (BAA)

BROAD AGENCY ANNOUNCEMENT (BAA)

1. Agency Name
Air Force Office of Scientific Research
Arlington, VA
 2. Funding Opportunity Title
Research Interests of the Air Force Office of Scientific Research
 3. Announcement Type
This is the initial announcement.
 4. Funding Opportunity Number
BAA-AFRL-AFOSR-2015-0001
 5. Catalog of Federal Domestic Assistance (CFDA) Number
12.800
 6. Due Date
This announcement remains open until superseded. Proposals are reviewed and evaluated as they are received. While proposals overall may be submitted at any time, specific topic instructions may recommend proposal submission by specific dates in accordance with (IAS) 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.

1

AF S&T Horizons – 10, 20, ... + beyond
Technology Horizons; Global Horizons; *Energy Horizons*; ... Autonomy Horizons



<https://community.apan.org/wg/afosr/>



AFOSR

Research Areas Events Secure Upload Public File Share More

<https://community.apan.org/wg/afosr/>

This group requires membership for participation - click to join



1917-2017

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Research Areas

Aerospace Materials for Extreme Environments
Atomic and Molecular Physics
Biophysics
Computational Cognition and Machine Intelligence
Computational Mathematics
Dynamic Data Driven

BASIC RESEARCH FUNDING OPPORTUNITIES

AFOSR invites proposals in broad research areas through the general BAA and other broad agency announcements. Proposals submitted under the BAAs are evaluated using a peer or scientific review process and selected for award on a competitive basis.

To apply for AFOSR funding opportunities listed in the BAA, visit www.grants.gov. All application forms and instructions are provided on the site. You can search grants.gov by CDFA numbers 12.800, 12.630 and 12.910. There you can also search for opportunities by all grant issuing agencies.

Quick Links:

[2015 AFOSR BAA](#)
[AFOSR Funding Opportunities](#)
[Search for other opportunities on Grants.gov](#)

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OPM RSS

Open with Option for
Unscheduled Leave or
Unscheduled Telework -
Operating Status of the
Washington, DC area Federal
Government

4 months ago



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Social Media



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www.facebook.com/afosr



www.twitter.com/afosr



www.youtube.com/TheAFOSR





Summary



- AFOSR executes the Air Force's basic research program, effectively and with notable accomplishments & outcomes
 - Broad scope of programs aimed to discover, shape, and champion the world's best science
 - Relevant to Air Force priorities and AFRL tech needs
 - Highly-qualified Program Officials
 - Healthy (but uncertain) budget
- Strong collaborations with other funding agencies (US&abroad)
- *Excellence in science* - accomplished through fostering in the U.S and abroad, *for transformative capabilities for AF & Nation*





Funding(\$M) - Overall Investment Strategy



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AF Basic Research Budget (\$M)

	FY11	FY12	FY13	FY14	FY15	FY16	FY17**
AF 6.1 Core	351	364	362	373	389*	375*	341
OSD Devolved 6.1	136	152*	141	138	147*	142	145
Total	487	516	503	511	536	517	486

* Includes Cong Add; ** FY17 PB

Investment Strategy Overall Approach & Impact

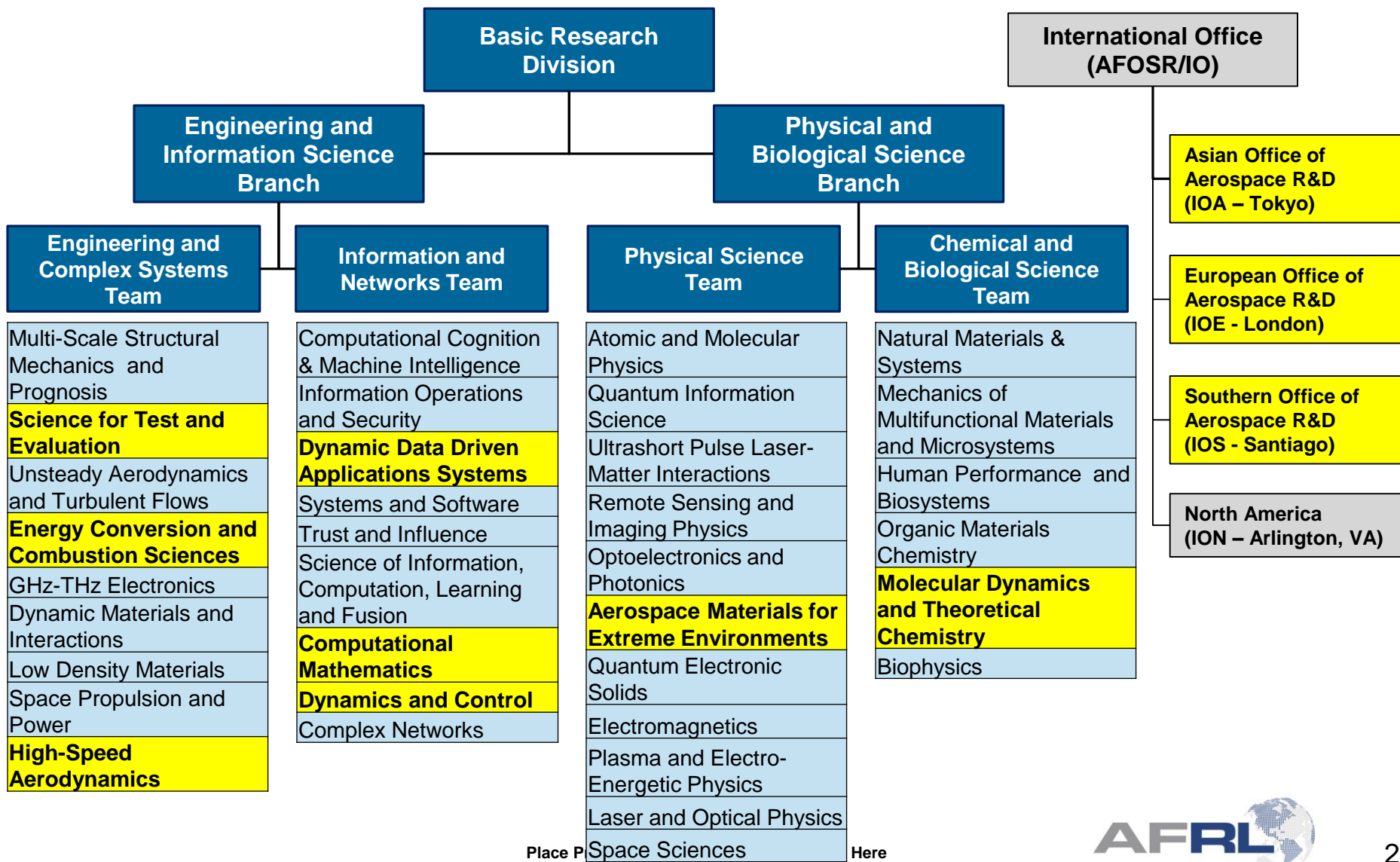
- Research scope that spans push (novel ideas) & pull (e.g. Game Changers)
- Partner with other Agencies, leverage ideas, research-communities, and their funding
 - In the US – Program officers coordinate efforts with NSF, NASA, DARPA, and many others
 - Internationally - Hypersonic Scramjet Testing (Australia), X-ray Free-Electron Lasers (UK)
- Overall Impact to AFMC & AFRL Technology Advances
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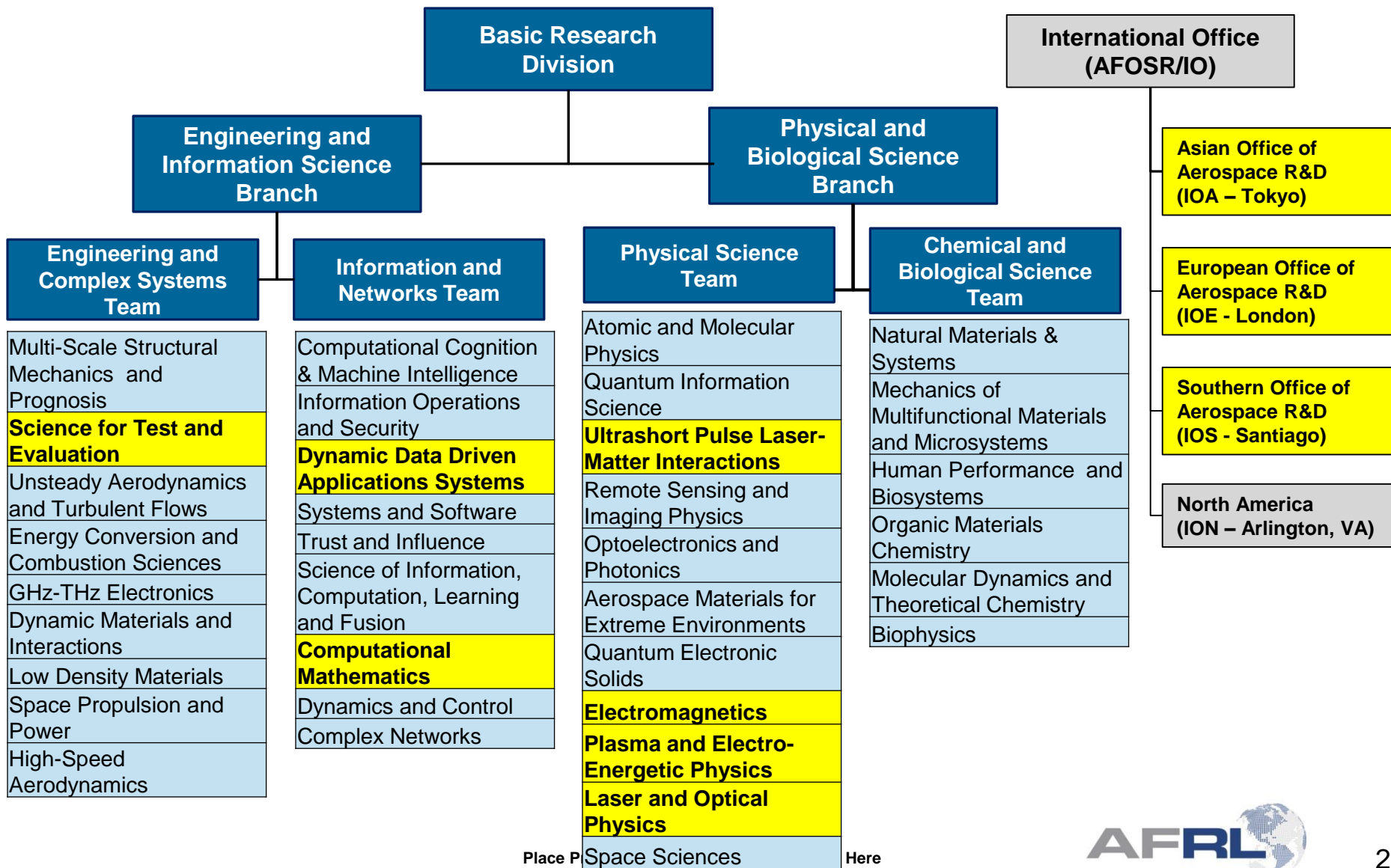


Support to Game Changers Hypersonics





Support to Game Changers Directed Energy

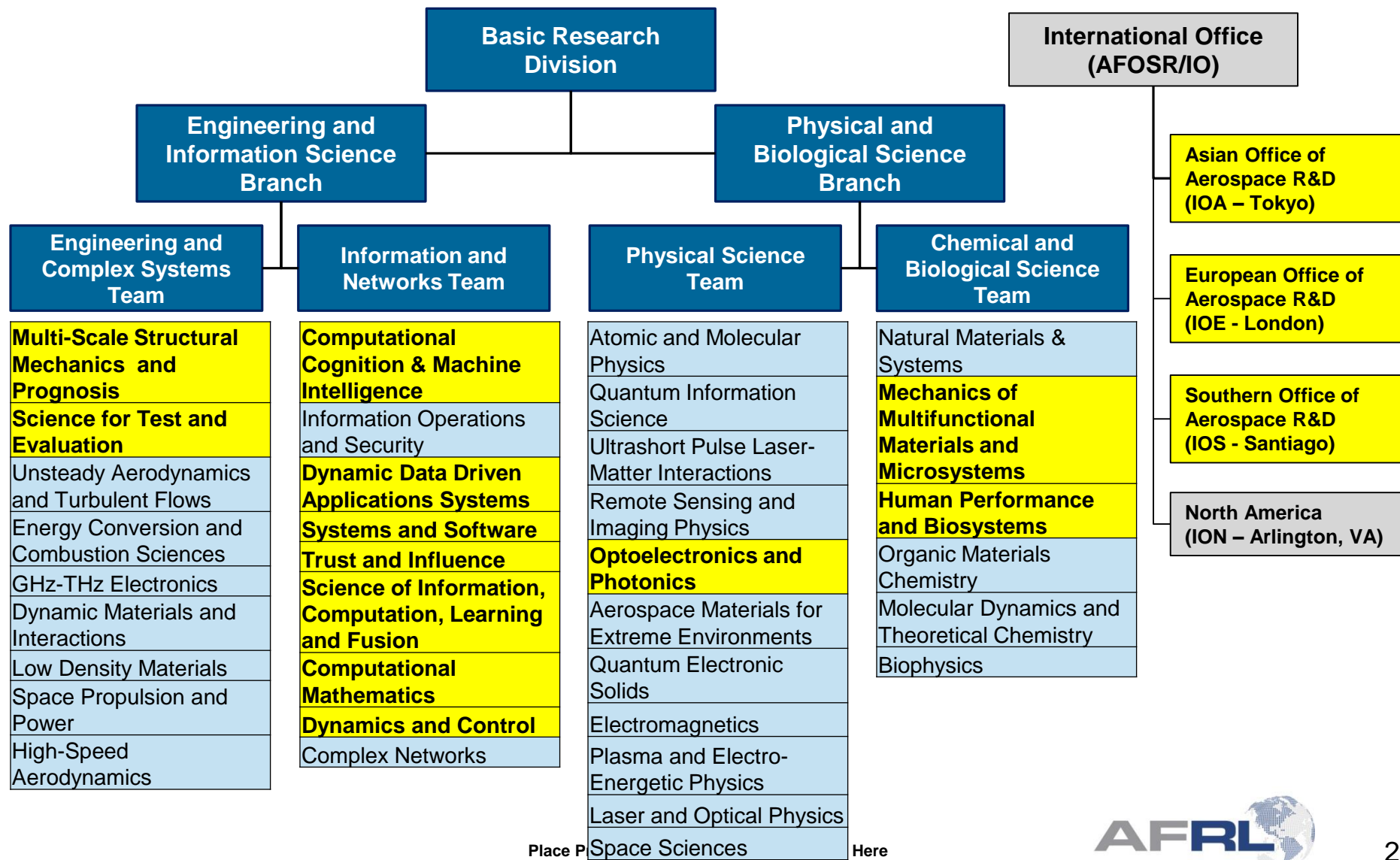




Support to Game Changers Autonomy

(in engineered systems and through human-machine synergism)

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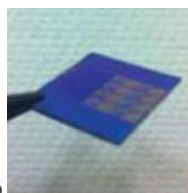
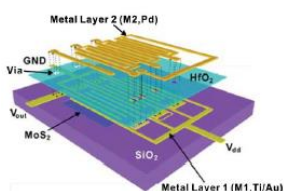


Pull and Push Emphasis Areas - Examples

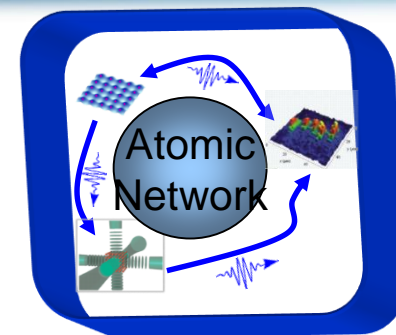
Hypersonics



Nanotechnology



Quantum Science & Engineering



Directed Energy



Unmanned Systems



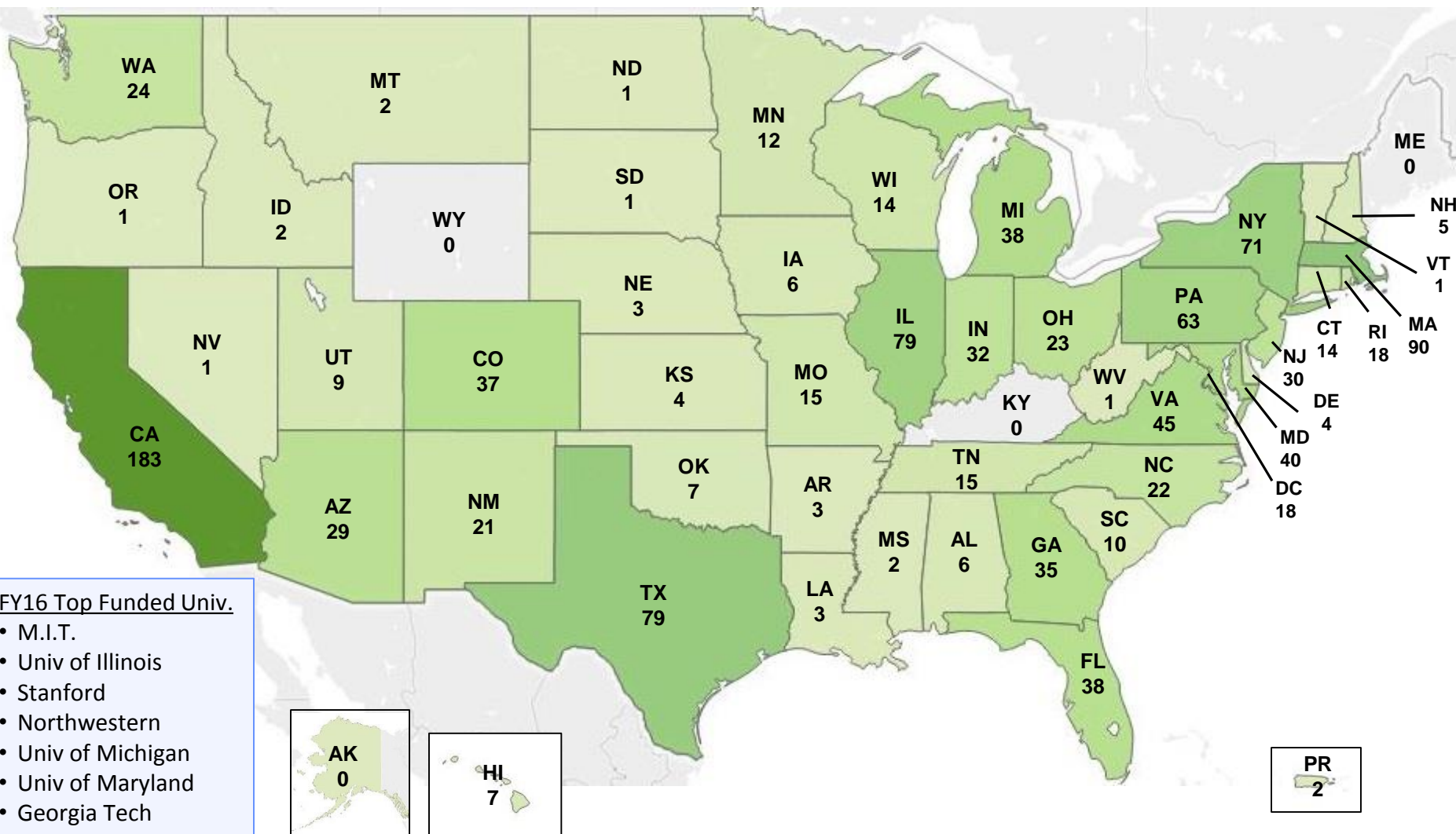
Human Machine Teaming





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FY16 Grants by State



FY16 Top Funded Univ.

- M.I.T.
- Univ of Illinois
- Stanford
- Northwestern
- Univ of Michigan
- Univ of Maryland
- Georgia Tech
- Univ of Colorado
- Carnegie Mellon
- UC San Diego

Total of 1166 grants in FY16

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Basic Research Innovation and Collaboration Center

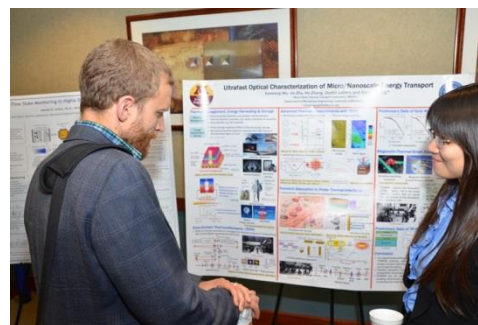
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- Established in Dec 2012 via a Partnership Intermediary Agreement with Virginia Tech Applied Research Corporation
- Objectives:
 - Enhance collaborations between academia, industry, government
 - Develop new tech transition and tech transfer partnerships
 - Explore new opportunities for developing the next generation of S&Es



Additive Manufacturing Challenge



Annual Young Investigator Program Meeting





Basic Research Innovation and Collaboration Center

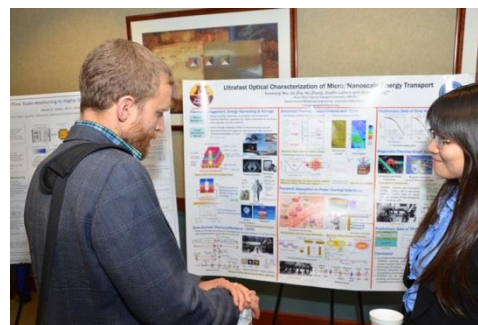
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Additive Manufacturing Challenge



Annual Young Investigator Program Meeting

