Air Force Research Laboratory

Integrity ★ Service ★ Excellence

AFRL Overview

1 May 2015

Dr. Dan Miracle
Acting Chief Scientist
Materials & Manufacturing Directorate
Air Force Research Laboratory

SUMMARY

AFRL is a funding agency of world-leading aerospace R&D

AFRL is a world-class aerospace laboratory with opportunities to partner and collaborate

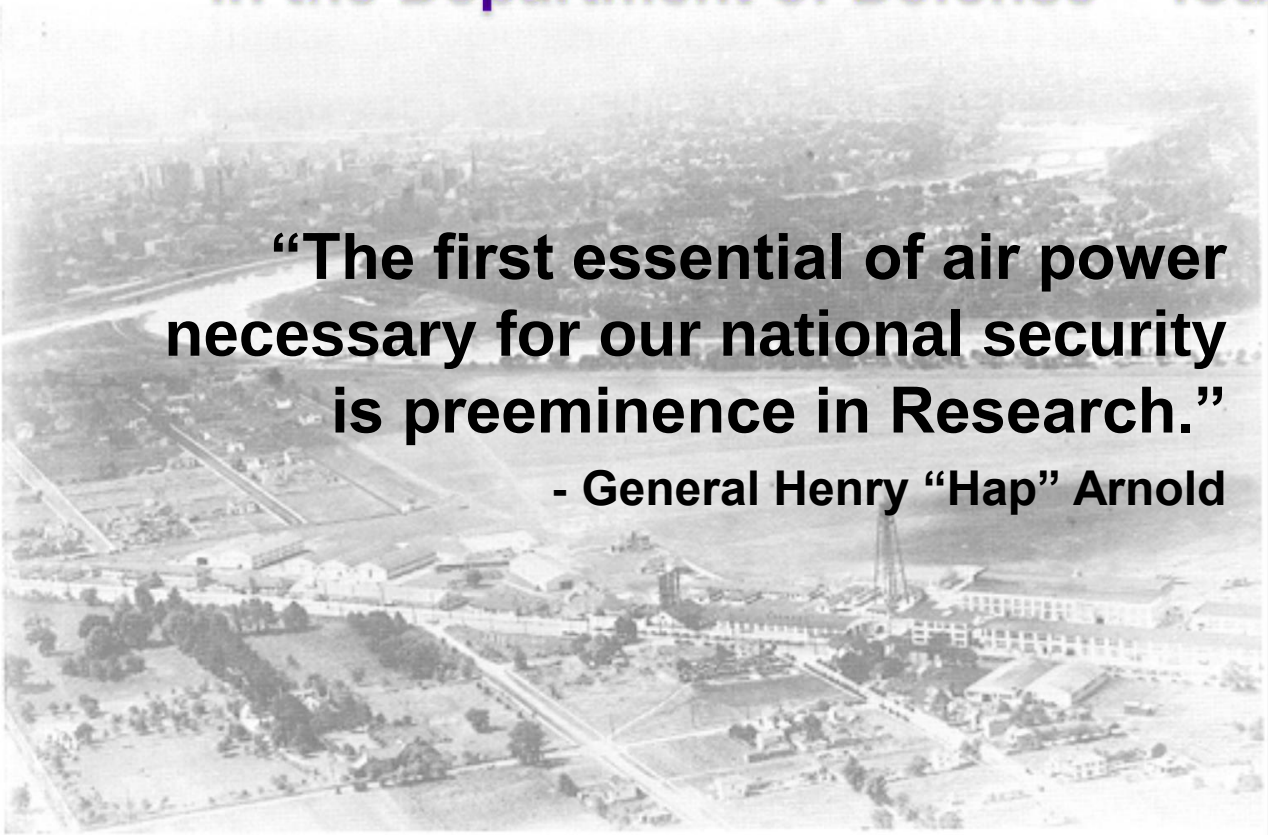
AFRL has a vision for future technologies to enable national defense & competitiveness

- **Additive manufacturing**
- **Integrated Computational Materials Science and Engineering (ICMSE)**
- **Hypersonic technologies**
- **Autonomy**
- **Directed energy**
- **Nano science and technology**

Air Force Research Laboratory

A Legacy of Research from the Wright Brothers

The Air Force Research Laboratory is the oldest laboratory in the Department of Defense – foun



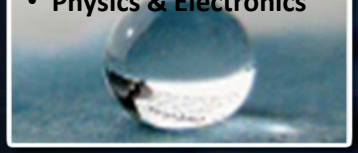
"The first essential of air power necessary for our national security is preeminence in Research."

- General Henry "Hap" Arnold

"…innovation – fueled by intelligent, creative Airmen – will remain a key part of who we are and what we value as a service." Gen Welsh, CSAF

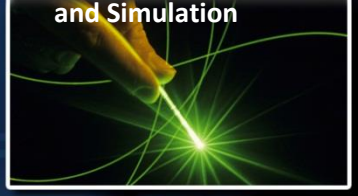
AFRL Technical Directorates

AF Office of Scientific Research
- Aerospace, Chemical & Material Sciences
- Education & Outreach
- Mathematics, Information, & life sciences
- Physics & Electronics



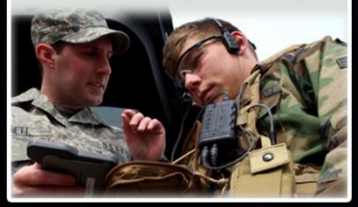
Aerospace Systems
- Air Vehicles
- Control, Power & Thermal Management
- High Speed Systems
- Space & Missile Propulsion
- Turbine Engines

Directed Energy
- Directed Energy & EO for Space Superiority
- High Power Electromagnetics
- Laser Systems
- Weapons Modeling and Simulation



Information
- Autonomy, C2, & Decision Support
- Connectivity & Dissemination
- Cyber Science & Technology
- Processing & Exploitation

Human Performance
- Bio-effects
- Decision Making
- Human Centered ISR
- Training



Munitions
- Fuze Technology
- Munitions AGN&C
- Munitions System Effects Science
- Ordinance Sciences
- Terminal Seeker Sciences

Sensors
- Advanced Devices & Components
- Layered Sensing Exploitation
- Multi-Int Sensing (RF/EO)
- Spectrum Warfare

Space Vehicles
- Space Electronics
- Space Environmental Impacts & Mitigation
- Space OE/IR
- Space Experiments
- Platforms & Operations Technologies

Materials and Manufacturing
- Functional Materials & Applications
- Manufacturing & Industrial Technology
- Structural Materials & Applications
- Support for Operations

AFRL Around the World

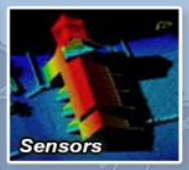
AFRL Headquarters

711th Human Performance Wing

Materials & Manufacturing

Aerospace Systems

Sensors



Information
Rome Research Site, NY

Rome Research Site, NY

Wright-Patterson AFB, OH

Edwards AFB, CA

Kirtland AFB, NM

Arlington, VA

AF Office of Scientific Research

Directed Energy

Space Vehicles

Ft. Sam Houston, TX

Eglin AFB, FL

Munitions
Eglin Air Force Base, FL

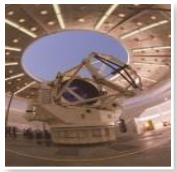
International Sites

London, UK

Tokyo, Japan

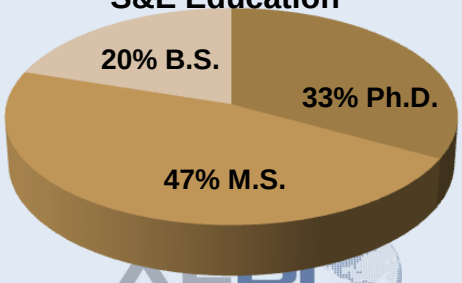
Santiago, Chile

Maui Research Site, HI



	Employees	Civilian	Military
Total	5,827	79%	21%
S&Es	3,455	80%	20%

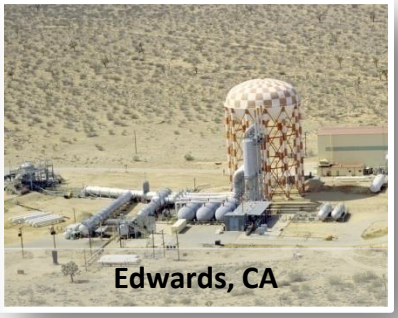
S&E Education



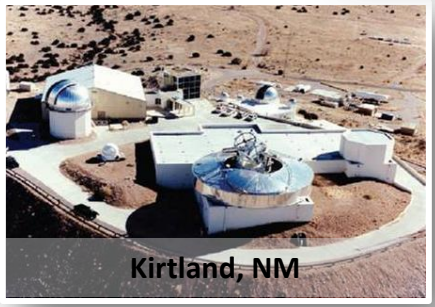
AFRL Major Research Facilities

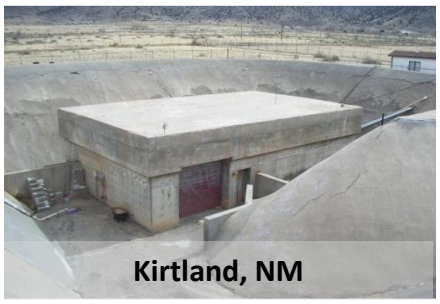

Rome, NY

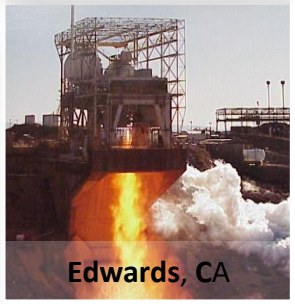

Eglin, FL


Edwards, CA


Maui


Kirtland, NM


Kirtland, NM


Edwards, CA


Wright-Patterson, OH


Wright-Patterson, OH


Wright-Patt, OH


Wright-Patterson, OH

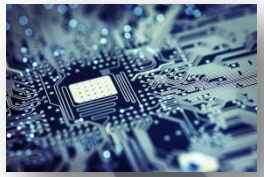

Wright-Patterson, OH

Turning Science Into Capability

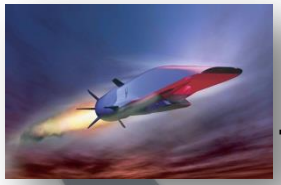
Driven by Service Core Functions

Vectored by Air Force Strategy + S&T Vision/Horizons + Product Center Needs + MAJCOM Needs

6.1 Basic Research



6.2 Applied Research



6.3 Advanced Tech Demo

~ $5B

Science Knowledge → Technologies → Capability Concepts → Warfighter

Outputs: ***New Technologies***

Outputs: ***Mature Technologies***

Outputs: ***Flagship Capability Concepts***

25 Years | *10 Years* | *5 Years* | *1 Year*

Initial Operating Capability Timeline

AFRL

Technology Focus Areas

$457M — Next Gen Aerospace Systems


Air Vehicles


Turbine Engines


Hypersonics


Autonomy

$354M — Weapons


DE Counter-Electronics


High Speed Strike


High Velocity Penetrating


Flexible Weapons

$327M — Space and Nuclear Deterrence


Space Access


Payloads


Space Platforms


Advanced Experiments

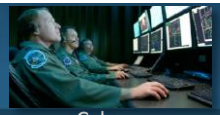
$263M — Intelligence, Surveillance, & Reconnaissance (ISR)


Human-Centered ISR


Synchronized Operations

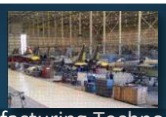
$225M — Command & Control, Cyber, Communications (C⁴)

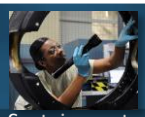

Processing, Exploitation, and Dissemination (PED)

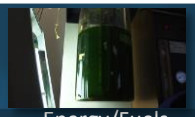

Cyber


Space Communications

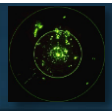
$153M — Affordability & Sustainment

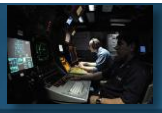

Manufacturing Technology

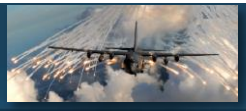

Sustainment


Energy/Fuels

$103M — Electronic Warfare / Electronic Protection (EW/EP)

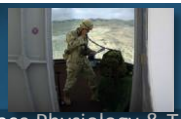

EW Plus

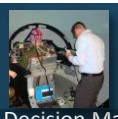

Distributed EW


Infrared countermeasures

$70M — Human Performance


Autonomy


Aerospace Physiology & Toxicology


Training & Decision Making Tech

Total: ~$1.95B, FY15 PB (No Devolved $)

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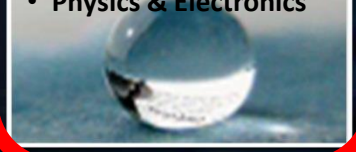

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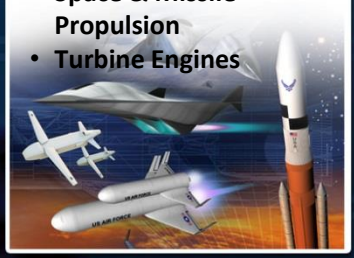

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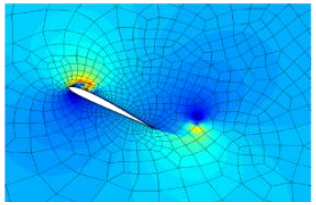
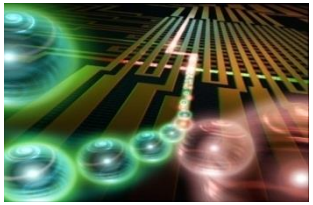
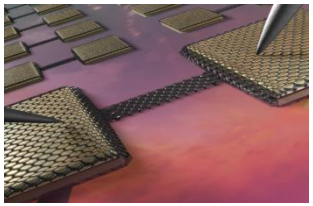
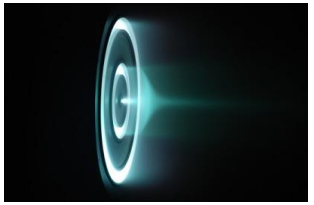
- Space Experiments
- Platforms & Operations Technologies

Materials and Manufacturing
- Functional Materials & Applications
- Manufacturing & Industrial Technology
- Structural Materials & Applications
- Support for Operations

AFOSR (Arlington) Technical Departments

Dynamical Systems & Control	Quantum & Non-equilibrium Processes	Information, Decision, & Complex Networks	Complex Materials and Devices	Energy, Power, and Propulsion
				

Research Areas				
Dynamics & Control	Atomic & Molecular Physics	Systems & Software	Natural Materials & Systems	Molecular Dynamics & Theoretical Chemistry
Computational Mathematics	Plasma & Electro-Energetic Physics	Complex Networks	Low Density Materials	Space Power & Propulsion
Optimization & Discrete Mathematics	Remote Sensing & Imaging Physics	Dynamic Data-Driven Application Systems	GHz-THz Electronics	Human Performance & Biosystems
Test & Evaluation	Space Sciences	Information Operations & Security	Mechanics of Multi-functional Materials & Microsystems	Energy Conversion & Combustion Sciences
Flow Interactions & Control	Electromagnetics	Trust & Influence	Organic Materials Chemistry	Aerothermodynamics & Turbulence
Multi-Scale Structural Mechanics & Prognosis	Ultrashort Pulse Laser-Matter Interactions	Robust Decision Making in Humans	Optoelectronics & Photonics	Dynamic Materials & Interactions
Turbulence & Transition	Biophysics	Science of Information, Computation & Fusion	Aerospace Materials for Extreme Environments	
	Laser & Optical Physics	Mathematical & Computational Cognition	Quantum Electronic Solids	
		Robust Computational Intelligence		

https://community.apan.org/afosr/default.aspx

Extramural Programs (OSD)

- **Multi-University Research Initiatives**
  - Multi-disciplinary in focus
  - Five years in duration, up to $1.5M/year
- **Defense University Research Instrumentation Program**
  - Used by universities to purchase major pieces of equipment to augment or develop research capabilities
  - Up to $1.5M per award, but often less
- **Centers of Excellence**
  - University-AFRL TD partnership to: (a) perform excellent research, (b) strengthen AFRL in-house capabilities, (3) educate students and provide opportunities for hiring the best of them
  - Typically $1M/year for five years, but can be less
- **Presidential Early Career Award in S&E**
  - Recipients must be within five years of their doctorate
  - $200K/year for five years

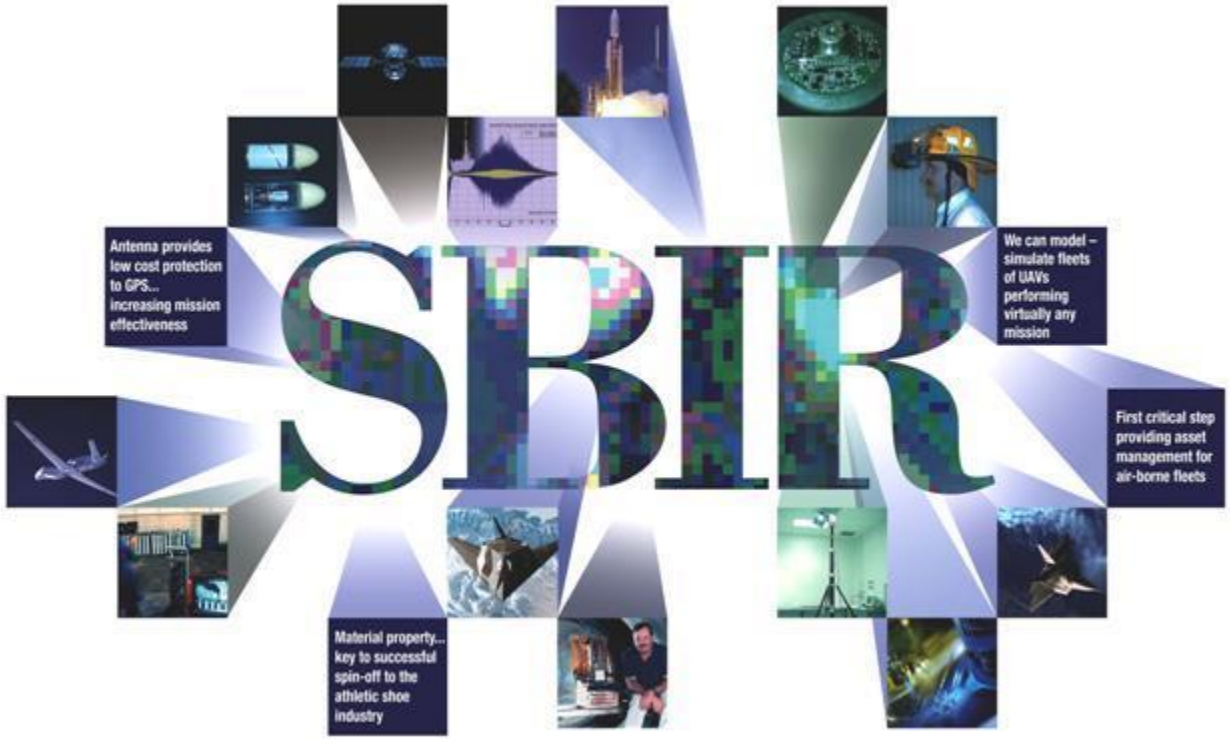
Extramural Programs

- **Grants**
  - Approximately 1300 research grants at more than 200 U.S. universities
  - Supporting over 1400 Principal Investigators, 3500 grad students, and 600 post-docs
- **Young Investigator Program**
  - Early career grants for exceptional candidates
  - On average, $120K/year for three years

Intramural Programs

- **National Research Council Programs**
  - Researchers work at AFRL laboratories
  - Within five years of doctorates, term is typically two years
  - Senior Researchers: international experts, term is typically one year
- **Summer Faculty Fellowship Program**
  - Faculty work 8-12 weeks at AFRL, AFIT, or USAFA
  - Graduate students may accompany faculty
- **Windows on the World**
  - Air Force S&E can visit a foreign (non-government) laboratory for up to 179 days to conduct research
- **Air Force Visiting Scientist Program**
  - An Air Force S&E can visit a U.S. university or industry lab for up to 179 days to conduct research
- **Engineer and Scientist Exchange Program**
  - AF S&Es can work up to two years at a foreign defense lab

Small Business Innovation Research/ Small Business Technology Transfer



Federally mandated programs requiring 2.6% (SBIR) and .35% (STTR) of Air Force extramural RDT&E budget

Congressional Goals & Purpose

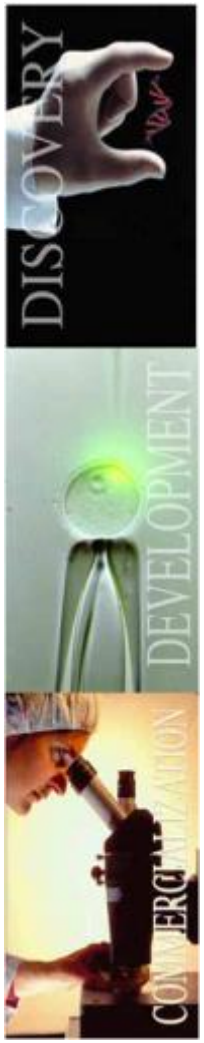
SBIR/STTR:

- Stimulate technological innovations
- Increase small business participation in federally funded R&D
- Foster and encourage participation by minority and disadvantaged firms in technological innovation
- Increase private sector commercialization of federally supported R&D

STTR Specific:

- Foster technology transfer between small business concerns and research institutions

AF SBIR/STTR Projects



- **PHASE I** – 372 awards FY11, ~340 awards FY12
  - **Feasibility Study**
  - **SBIR: Up to $150K, 12-month Award**
  - **STTR: Up to $150K, 6-month Award**
- **PHASE II** – 214 awards, ~170 awards FY12
  - **Full Research/R&D**
  - **SBIR/STTR: Up to $1M, 2-year Award**
- **PHASE III** – 45 awards = $260M FY10
  - **Non-SBIR/STTR Funds**

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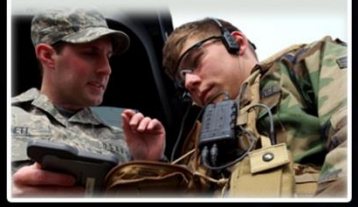

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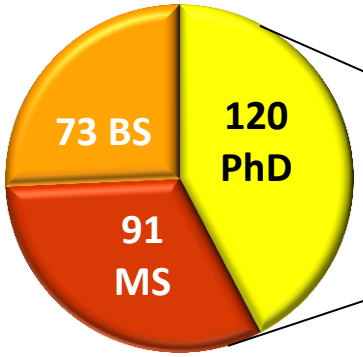
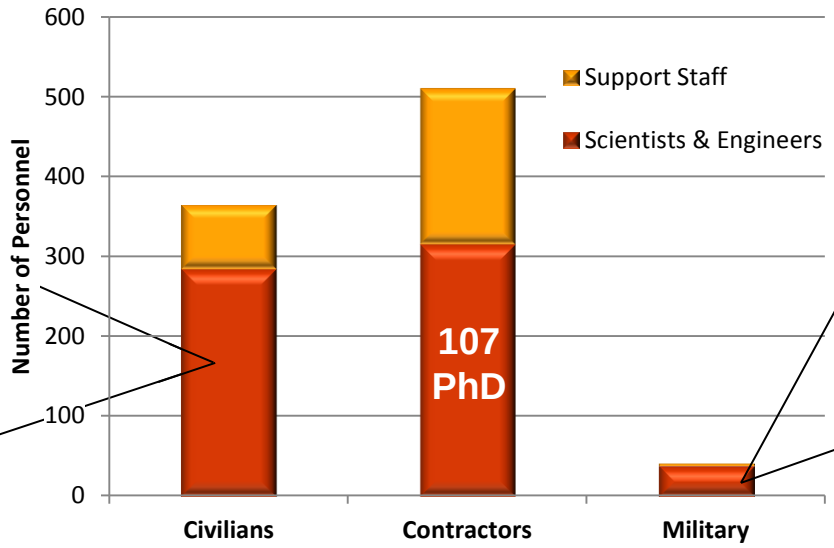
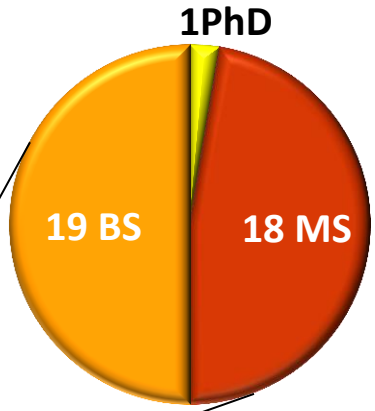
- Structural Materials & Applications
- Support for Operations

MATERIALS & MANUFACTURING DIRECTORATE Workforce

Total Workforce:
917 personnel







- Materials/Metallurgical Eng.
- Chemists/Chemical Engineers
- Research Physicists
- Mathematicians
- Human Factors Engineers
- Aero/Astro Engineers
- Civil/Industrial Engineers
- Biologists/Microbiologists
- Mechanical Engineers
- Computer Eng/Computer Sci
- Electrical Engineers
- Ops Research/Systems Eng

Core Technical Competencies & sub-CTCs

Structural Materials & Applications CTC

Materials State Assessment
Ceramic Matrix Composites
Organic Matrix Composites
Metals

Functional Materials & Applications CTC

Materials for Survivability & Protection
Human Performance Assessment
Materials for ISR

AFRL RX is the ONLY organization with the mission and capability to cover the entire life cycle of aerospace materials for the nation – from discovery through processing, development and manufacturing, to sustainment of fielded systems.

MATERIALS & MANUFACTURING DIRECTORATE

Manufacturing Technology CTC

Mfg of Electronics and Sensors
Mfg for Propulsion and Structures

Support for Operations CTC

Systems Support

Functional Materials & Applications (RXA)

Material Systems to Generate & Control Information and Energy

Photonic Materials

Electronic Materials

Soft Matter Materials

PRIMARY R&D FOCUS

PRIMARY APPLICATIONS

Survivability
ISR Platforms
Human Perform. Assess.
Integrated Power
Sustainment (Bio-corrosion)

CHALLENGES & OPPORTUNITIES

- Integrated Laser/HPM hardening material solutions to ensure access to denied environments
- SWIR/MWIR/VLWIR & tunable RF materials and sub-components for agile ISR (resolution, bandwidth, SWAP, reliability)
- Integrated flexible hybrid electronic constructs for human assessment, autonomy, ISR and multifunctional components
- Non-traditional mat'ls, processes and digital design (i.e., bio, nano, meta) to enable low cost, custom material solutions

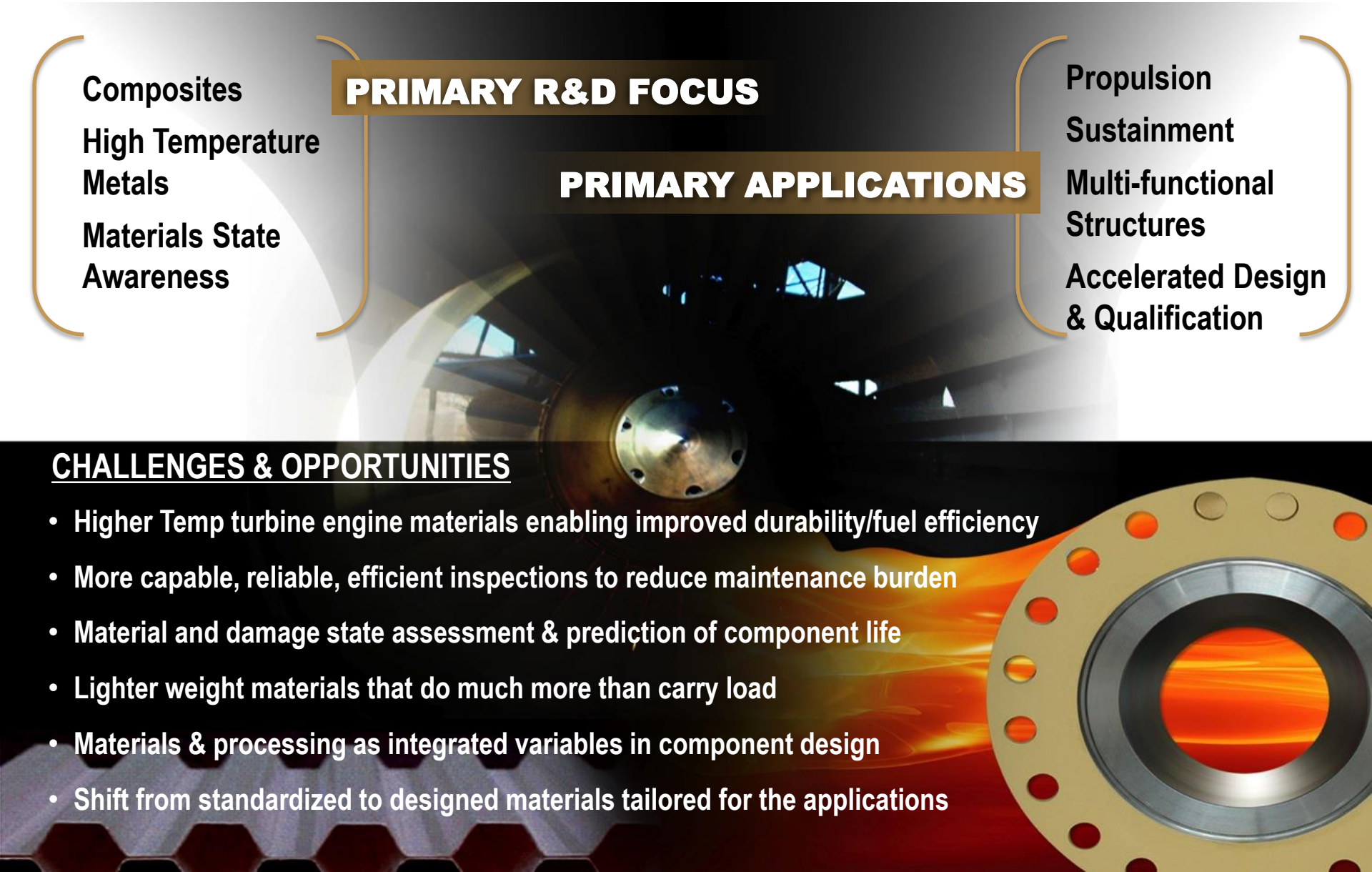
Structural Materials & Applications (RXC)

PRIMARY R&D FOCUS

- Composites
- High Temperature Metals
- Materials State Awareness

PRIMARY APPLICATIONS

- Propulsion
- Sustainment
- Multi-functional Structures
- Accelerated Design & Qualification



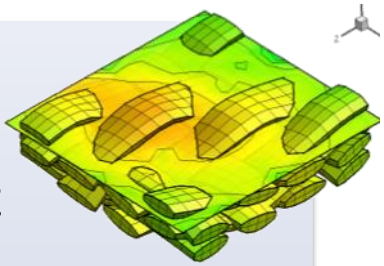
CHALLENGES & OPPORTUNITIES

- Higher Temp turbine engine materials enabling improved durability/fuel efficiency
- More capable, reliable, efficient inspections to reduce maintenance burden
- Material and damage state assessment & prediction of component life
- Lighter weight materials that do much more than carry load
- Materials & processing as integrated variables in component design
- Shift from standardized to designed materials tailored for the applications

Research Teams

Research Teams in Functional and Structural Materials:

- Provide critical mass (people, $) and agility for in-house research
- Focus on key competency areas — present & future
- Enhance interface between basic science & materials development
- Enhance cross-discipline collaborations



Functional Materials CTC

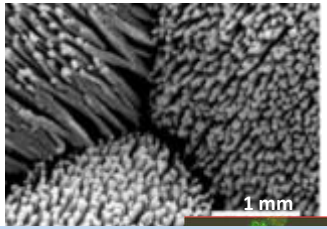
- **Biological Materials & Processing**
- **Flexible Materials & Devices**
- **Advanced Nanoscale Electronic M&P**
- **Quantum Semiconductor M&P**
- **Hardened Materials & Processing**
- **Optical Materials & Processing**

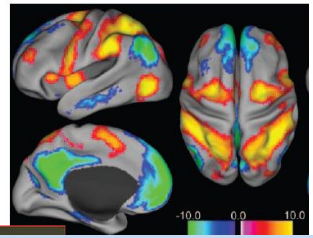
Structural Materials CTC

- **Ceramic Materials & Processes**
- **Organic Matrix Composite M&P**
- **Composites Performance**
- **Metallic Materials & Processes**
- **Metals Probabilistic Performance Prediction**
- **Characterization, Sensing, & Analytics**

CoE: Bio-nano-enabled Inorganic/Organic Nanostructures and Improved Cognition (BIONIC)

Nano





Cogno

Georgia Institute of Technology

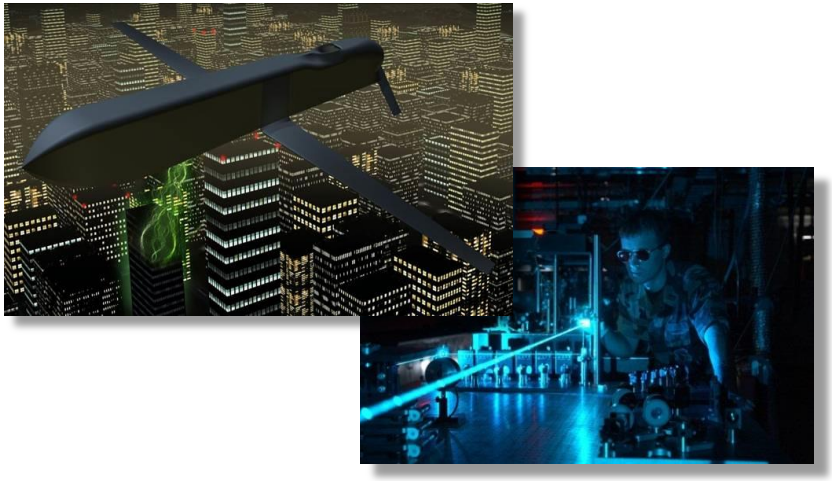
THE OHIO STATE UNIVERSITY

1) Supported BIONIC students: 49 graduate students, 2 undergraduates
   2 Post-docs
2) Co-authored BIONIC/AFRL papers: 29
3) Co-authored BIONIC/AFRL presentations: 53
4) Co-authored IP: at least 3 invention disclosures and 1 provisional patent application
5) Leveraged/Attracted resources: at least $5.9 million in support obtained from DoE, MURIs, SRC, and DURIP awards enabled by research conducted within BIONIC
6) Number of RXers involved: 9 Civilians + 11 O/S contractors
7) Number of GA Tech faculty : 10 active faculty members
8) Number now employed in RX: 3 Civilians, 2 On-Site Contractors

Game Changers

Hypersonics

- Survivable, fast-flying
- Defeat deep layered A2/AD strategies



Directed Energy

- High Power Microwave alternative to kinetic weapons
- Lasers with air & ground selectable effects & reduced collateral damage

Autonomy

- Facilitates decisions at speed of computing
- Self awareness & troubleshooting intelligence to aid mission performance

AFRL/RX Engagement & Investment in Additive Manufacturing

AFRL/RX AM Activities

- Major Historical Contributions (~$20M)
  - F-15 Pylon Rib Substitution
  - Qualification rules for implementation
  - AM Deposition Assessment
  - Ceramic AM for Casting Molds
  - Process Model Development
- Ongoing Major Activities (~$50M)
  - Metallic AM Inspection Benchmarking for AF
  - Manufacturing Variability Quantification for Aerospace
  - Flexible Electronics Consortium Leaders
  - Integrated Flexible Electronics & Packaging
  - DARPA Open Manufacturing
  - Metallic AM for Liquid Rocket Engines
  - AM of Ceramic Cores for Airfoils
  - Direct Part Mfg of HT Thermoplastic Composites
  - Sustainment Opportunity Assessment & Risk-based Decision Tree

America Makes

- *A Defense-wide Manufacturing S&T team-led, Multi-agency collaboration between industry, government and universities*
- *Public-private partnership (Gov't Investment $30M)*
- *AFRL introduced the idea, established the institute, manages the program, and maintains leadership role.*

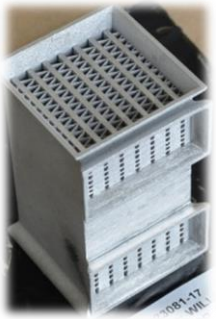
Major In-House Low-TRL Research

- Thermoset Composite Processing
- ICME Approach to Metallic AM
- Stretchable Electronic Materials
- Functional Ink Development
- ORNL/MDF Partnership

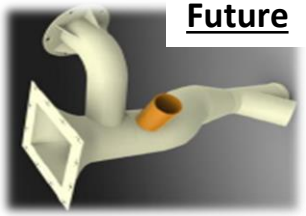
AM Potential to the AF: Structures

Expanded Component Geometries

Multiple component families geometries are constrained by conventional manufacturing capabilities, including ducting, fuel nozzles, heat exchangers and turbine airfoils



Today



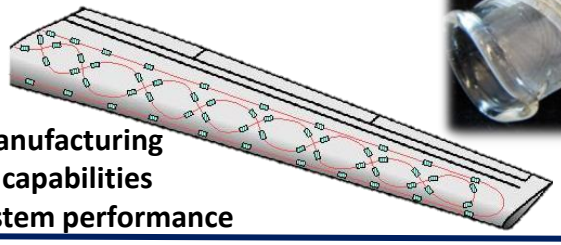
Future

Potential for
- **Part Consolidation**
- **Lead-Time Improvements**
- **Performance Benefits**

Functionally-Embedded Structures

Embedding devices within structure could enable improved communication, real-time structural health monitoring, …

- **Reliable, integrated electronics printed directly on structure**
- **Conformal antennas adapted into load-bearing structure**
- **Distributed electronics for flight-control feedback and structural health monitoring**



Potential for
- **Simplified manufacturing**
- **New sensing capabilities**
- **Improved system performance**

Unintended Spares and Obsolescence

Re-manufacture of components with obsolete manufacturing routes are expensive and have long lead times due to tooling requirements associated with conventional processing approaches

Current Issues:
- **Long Tooling Lead Times**
- **Low Production Volumes**
- **Material Substitution Re-certification**

Potential for
- **Improved Lead Times**
- **Reduced Cost (LRP)**

Component Repair

Repair rather than replacement of end-of-life components could drastically reduce the AF sustainment burden but viable repair technologies are difficult to tailor to aerospace requirements

Current Issues:
- **Current components NOT designed FOR repair**
- **Unvalidated repair processes and inspection requirements**

Potential for
- **Repair-able components**
- **Reduced Sustainment Burden**

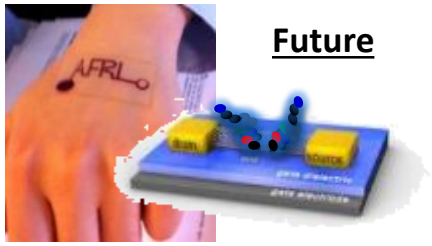
AM Potential to the AF: Electronics

Human System and Cognition

Human Performance limits capability in MANY Military Missions ….and New Technologies are Needed to Sense, Assess and Augment the “Man-in-the-Loop”

- Information Overload
- Missed Intelligence
- Threat/Danger Missed

Today



Future

Embedded Electronics for ISR and EW

Information and tracking in contested environments (A2/AD) is foundational to decision making and force projection

- **Communication (conformal apertures)**
- **Distributed electronics for feedback and structural health monitoring**

Direct RF-Optic

Integrated Power for Autonomous Ops

Energy limits operational capabilities and mission impact for large time and distances scenarios

Issues:

- **Cost & Weight**
- **Scale-up**
- **Durability**

Integrated Power harvesting, storage, and management

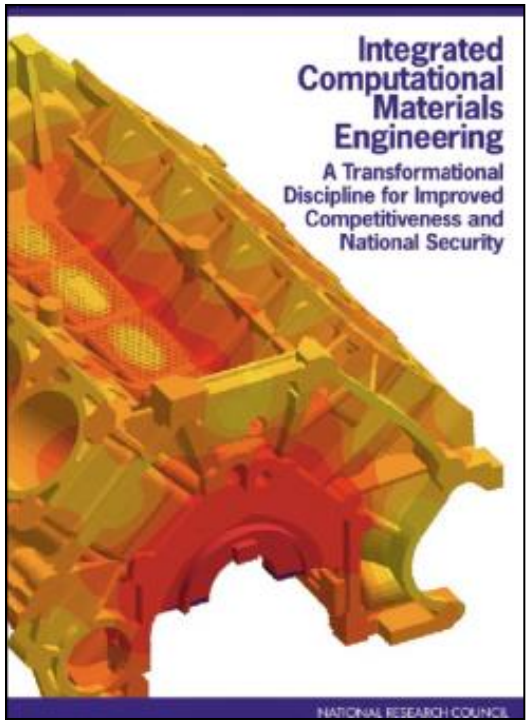
Expected 1.5X – 3X increase in flight endurance.

Survivable Electronics

Precision effects with smaller, low profile munitions pressing requirement for current and future platform effectiveness

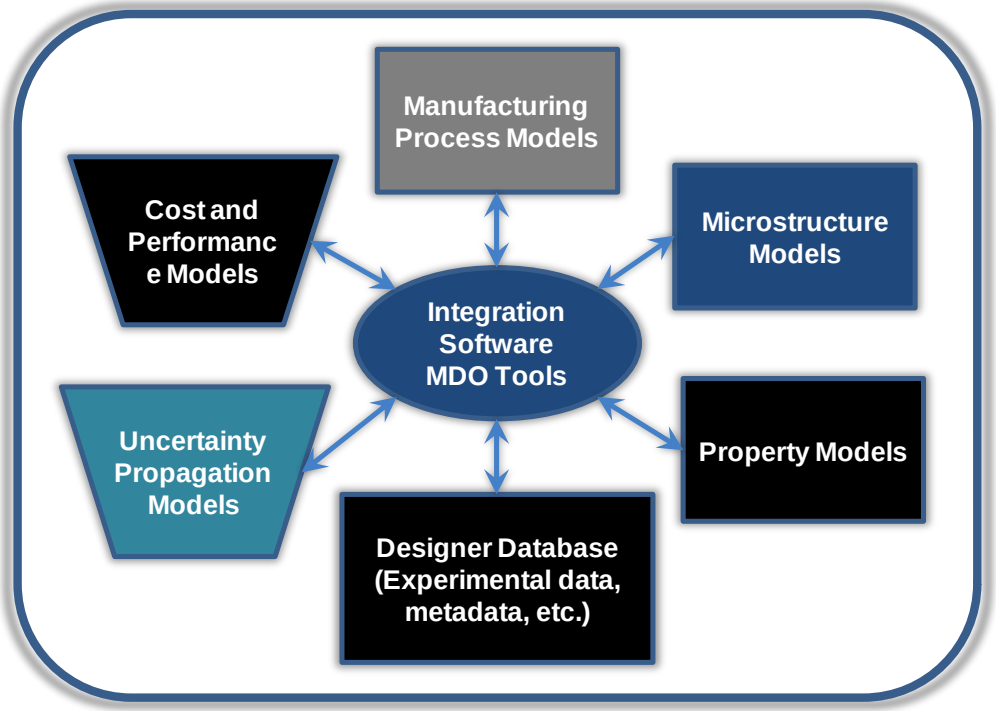
- **Robust electronics in extreme environments (shock, vibration, thermal)**

Integrated Computational Materials Engineering



Integrated Computational Materials Engineering (ICME) is the integration of materials information, captured in computational tools, with engineering product performance analysis and manufacturing-process simulation.

Emphasis on "I" and "E"



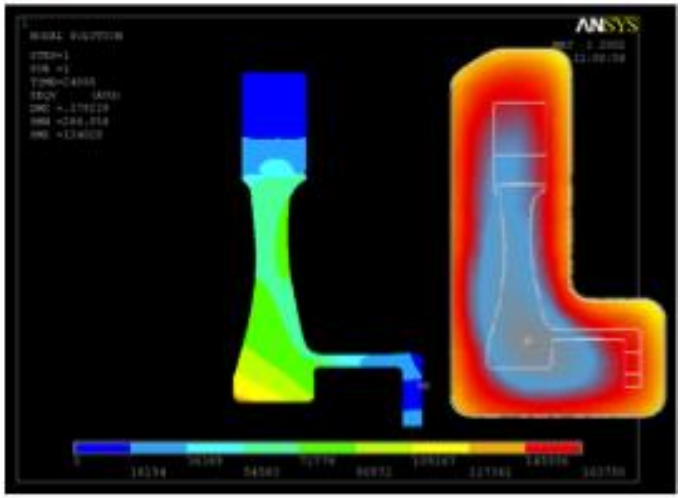
- ICME is an emerging discipline
- Experiments are key to ICME
- ICME requires a cultural shift

Development of ICME requires cross-functional teams focused on a common goal or "foundational engineering problems"

ICMSE FOUNDATIONAL ENGINEERING PROBLEM

DARPA

Rim initiated fracture



Bore initiated fracture

Allowing concurrent optimization of processing/microstructure and disk geometry enabled
~ 20% Part Weight Reduction &
~19% Burst Speed Increase.

Integrated tool & models reduced development and test cycle by greater than 50%

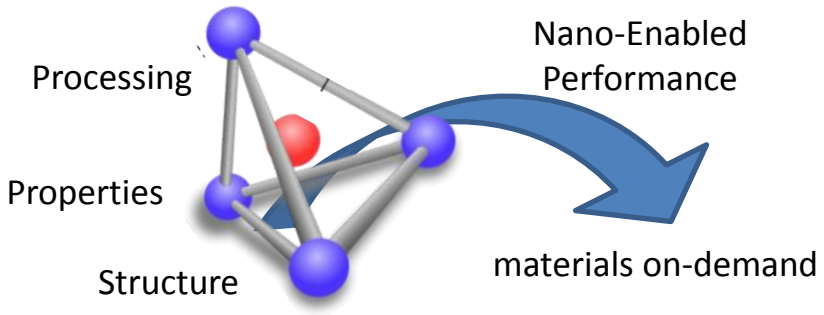
- demonstrated improved design capability (5% in speed)
- identified and tested process outside of experience base
- eliminated subscale experimentation
- mapped & integrated material property spatial variation into structural performance
- provided insight into material impact (failure location)
- readily integrated and responded to evolving model capability

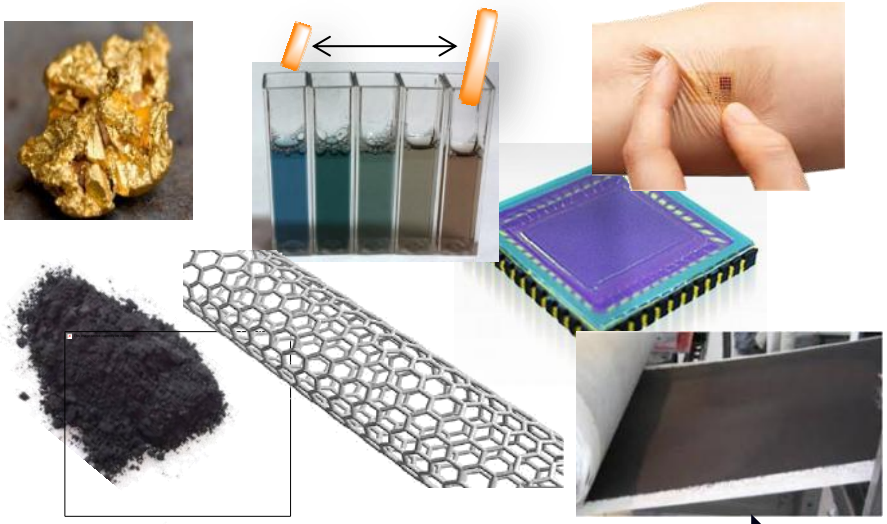
Game Changing NanoTechnologies

- Ordering-Up Performance for Aerospace Dominance -

Nanotechnology[1]

Controlling materials from 1-100 nm





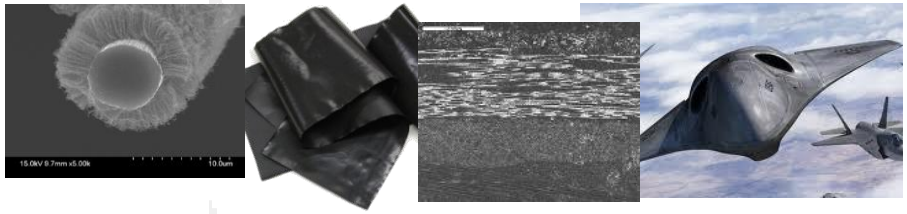
[1] US NNI, ANSI-NSP TAG, ISO/TC 229, IEC/TC 113, ASTM E56

Today's *Nano*-enabled Aerospace Products[2]

Infrared sensors with enhanced sensitivity and range

Optical filters to protect the pilot from lasers

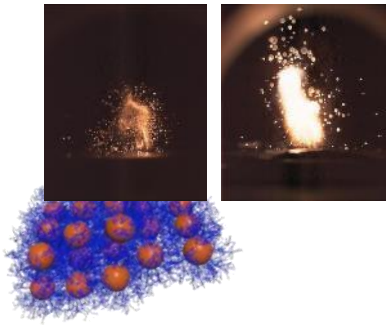
ESD & EMI protection for electronics and signature



$XXXB Aerospace Impact 20xx

[2] AFRL Nanoscience Technologies, 2010, http://www.nano.gov/node/132

Air Force Research Laboratory
Nano Development



AFRL "Nano" Program[1]

$500K $4M $30M

1995 2000 2010

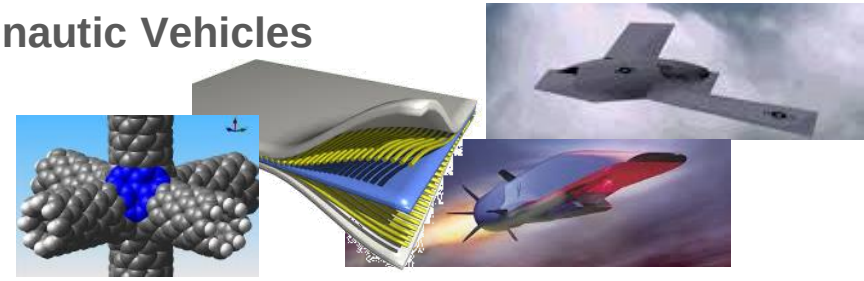
US NNI[2] $270M $1.5B

Global[2] $825M $7.8B

Commercial[3]

$731B revenue[3]

Aeronautic Vehicles



Integrated ISR

2015 2030

Directed Energy

Human Performance

From NanoTechnology to Technologies Exploiting Nano

SUMMARY

AFRL is a funding agency of world-class aerospace R&D

AFRL is a world-class aerospace laboratory with opportunities to partner and collaborate

AFRL has a vision for future technologies to enable national defense & competitiveness

- **Additive manufacturing**
- **Integrated Computational Materials Science and Engineering (ICMSE)**
- **Hypersonic technologies**
- **Autonomy**
- **Directed energy**
- **Nano science and technology**

Questions?

Legacy of World-Leading Aerospace Technology Development

Early Flight | Space Age | Modern Flight | Cyber Domain | Future

MATERIALS & MANUFACTURING DIRECTORATE

AIR FORCE RESEARCH LABORATORY

Mission

LEADING the discovery, development, and integration of affordable warfighting technologies for our air, space, and cyberspace force.

Strong Cadre of Scientists & Engineers

- *24 RXers have been recognized as 45 Technical Society Fellows*

- *17 RXers have 23 Technical Society National Leadership Positions*

EXECUTIVE PRESIDENT, SAMPE
VICE PRESIDENT, AMERICAN SOCIETY FOR COMPOSITES
DIRECTOR, TMS BOARD OF DIRECTORS/CHAIR, STRUCTURAL MATERIALS DIVISION

DIRECTOR, SPIE BOARD OF DIRECTORS
2 DIRECTORS, MRS BOARD OF DIRECTORS
2 COUNCILORS, AMERICAN CHEMICAL SOCIETY DIVISIONS

- *RX has 30 of 161 AFRL Fellows*
- *RX has 4 of 26 Senior Scientists (STs)*

- ***RX collaborates with:***

Nobel Laureates ***NAE Members*** ***NAS Member*** ***IOM Member***

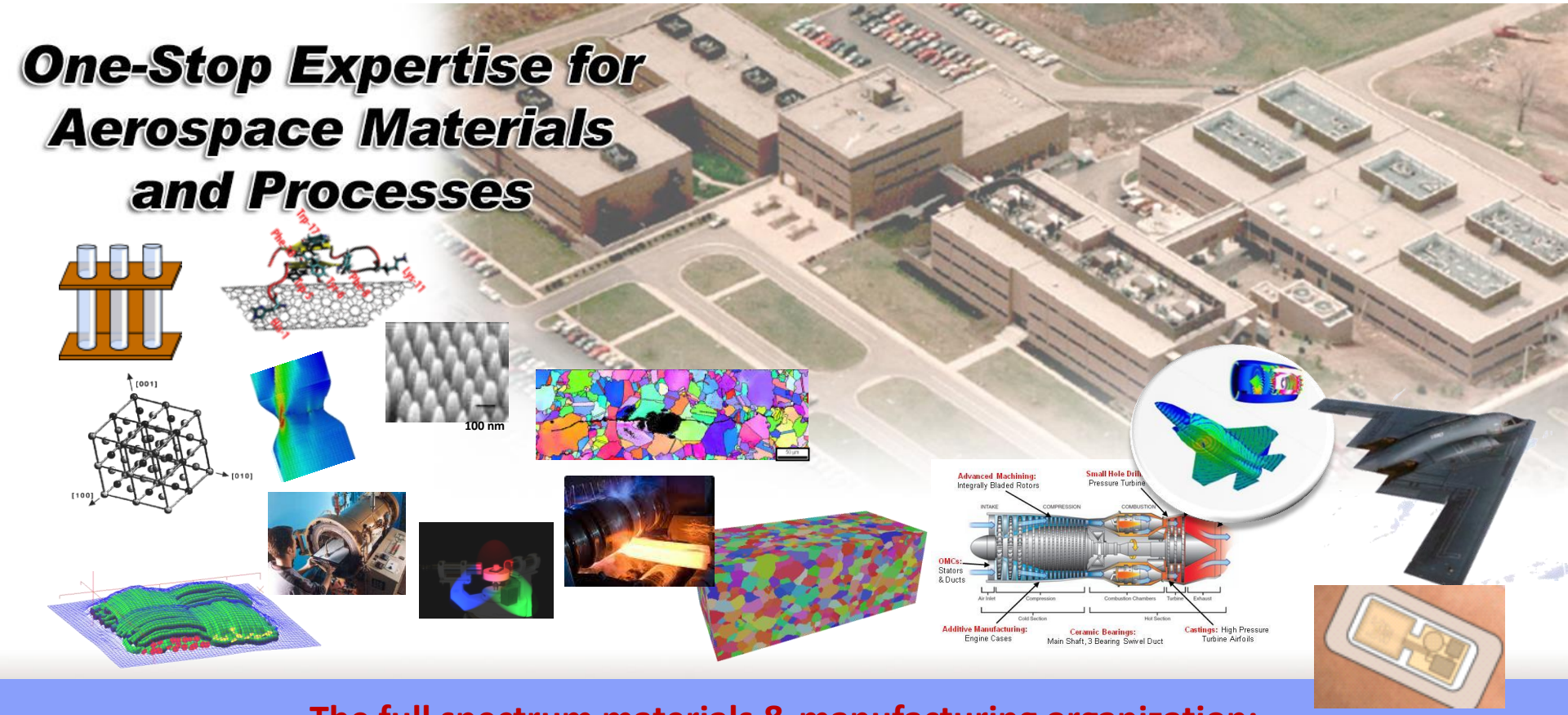
NATIONAL ACADEMY OF ENGINEERING

NATIONAL ACADEMY OF SCIENCES 1863–2013 Celebrating 150 Years of Service to the Nation

INSTITUTE OF MEDICINE OF THE NATIONAL ACADEMIES

AFRL

Materials and Manufacturing Directorate… A National Asset



The full spectrum materials & manufacturing organization:

Metals / Ceramics / Composites / NDE / Semiconductors / Polymers / Photonic Materials / Biomaterials
Structural / Propulsion / Weapons / Sensor / Survivability Applications
Discover... Design... Manufacture... Transition... Support