

Nano & Bio Technology For Aerospace



Turning Goals into Reality

May 2002



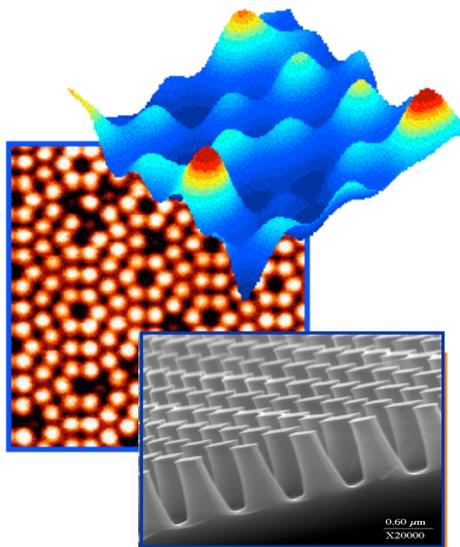
Dr. Barbara Wilson
Chief Technologist
Air Force Research Laboratory



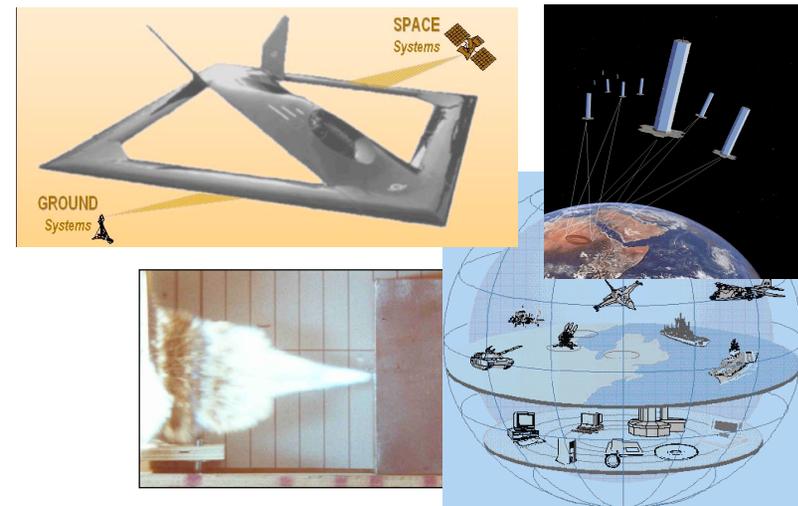
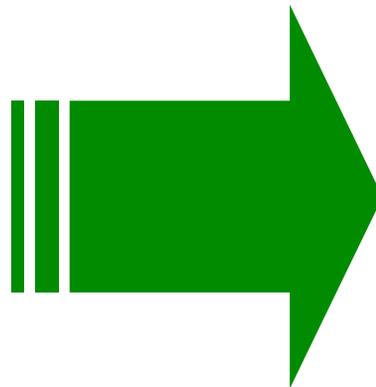
AFRL Nano Science & Technology



“Technology based on the ability to manipulate and control elements with dimensions < 100 nm”



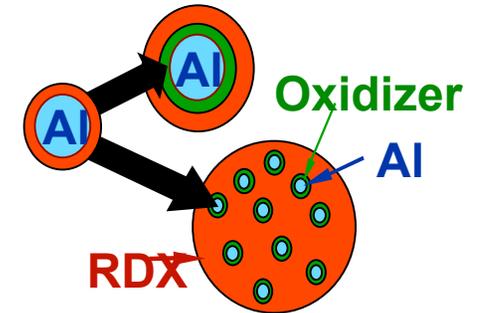
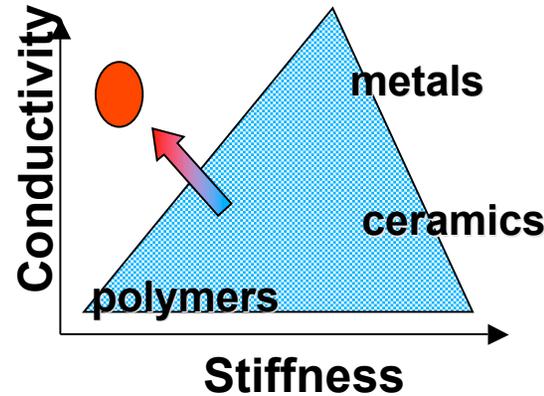
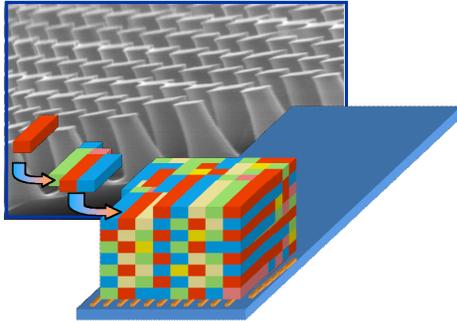
Focused R&D



Revolutionary System Capabilities



Nanotechnology Focus Areas



**Nano
Structured
Devices**

**Nano
Engineered
Materials**

**Nano
Energetics**

**Foundation & Tools:
Modeling - Nano Assembly & Fabrication - Characterization**



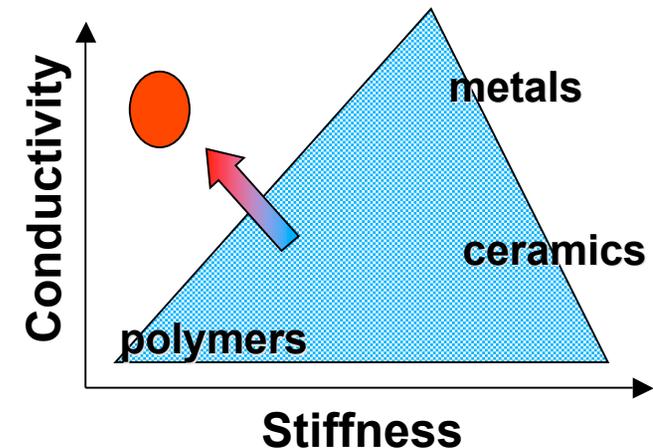
Nano Engineered Materials

Potential Return on Investment



Investments in

- Nanoengineered composites
- High-energy-density materials
- Adaptive & self-healing materials
- Nanostructured electronic/OE materials
- Quantum mechanical & molecular dynamics modeling



Offer Potential For

- 10-100x stronger materials - lightweight aerospace vehicles
- 2x increase in temperature, 100x lifetime materials for turbine engines
- Ability to simultaneously optimize multiple desired materials characteristics, e.g. electrical and structural characteristics
- Adaptive materials - dynamic stealth, improved survivability of aerospace assets



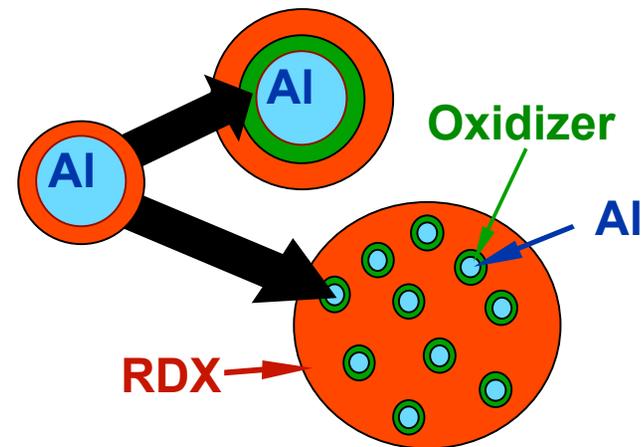
Nano Energetics

Potential Return on Investment



Investments in

- Nanostructured explosives and fuel additives
- Nano controlled catalytics
- Nano engineered photovoltaics



Offer Potential For

- 10-100x improved power density/energy release rate/ package volume and increased safety – miniature smart munitions
- Improved munitions blast control – better coupling of energy to target, lower collateral damage
- Stable, 5-10x more efficient propellants – safer, high-thrust-to-weight-ratio propulsion systems, increased weapon loadout, affordable access to space
- Improved power generation, conditioning & control for aerospace vehicles – enhanced global reach



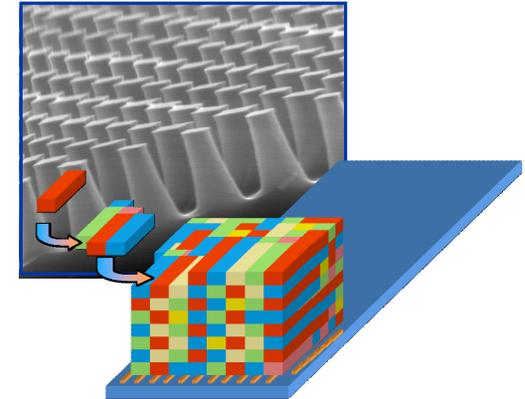
Nano Structured Devices

Potential Return on Investment



Investments in

- Nano processing/comm devices, circuits, ICs
- Nano actuators, controllers, sensors, photonics & integrated NEMS
- Revolutionary computing architectures – quantum, molecular, optical
- Quantum communications & cryptography



Offer Potential For

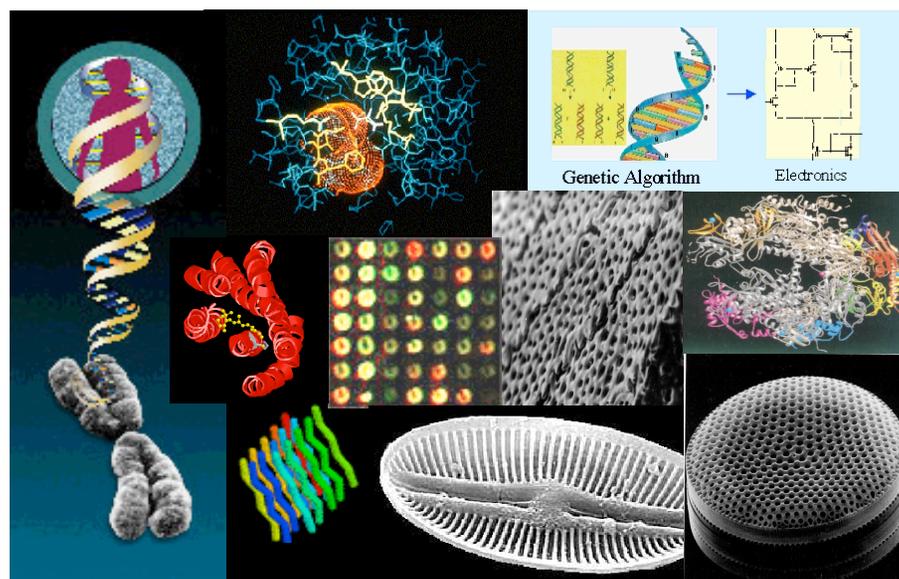
- 10-1000x higher speed, lower power higher density electronics – on-board processing for target tracking/ID and autonomy
- Exponential speed up for hard problem solution, e.g. scheduling, multi-asset control
- 10-1000x smaller sensors, actuators & NEMS – new surveillance capabilities, e.g. microsats constellations, UAVs, UCAVs and large, space-based membrane apertures
- High-bandwidth, secure communications - information dominance



AFRL Biotechnology



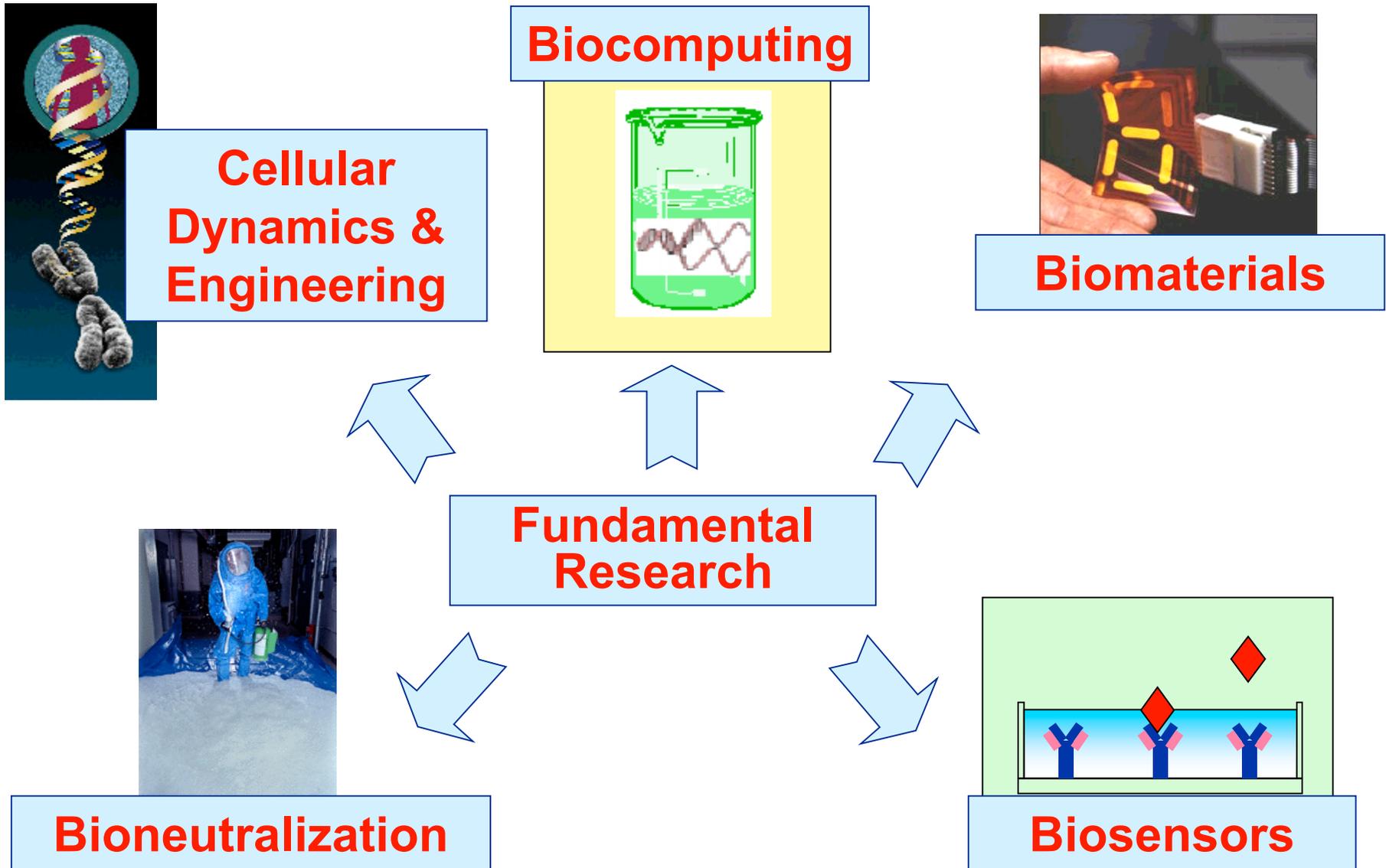
“The ways and means of exploiting biological systems at the molecular level, to provide new products and capabilities.”



Biological solutions for bio and non bio AF challenges



Biotechnology Focus Areas





Aerospace Biotechnology

Proposed Investment Areas



Biomaterials

- **Bottoms-up fabrication: Biocatalysis and synthesis by microorganisms**
- **Smart skins: Dynamic, biomimetic, environmentally-adaptable coatings**
- **Bio-inspired materials: Self-powering, self-assembling materials & structures**
- **Bio-energetics: Charge separation, charge pumping, and energy transduction**

Fundamental Research

- **Toxigenomics**

Biocomputing

- **Biologically based concepts for data storage and processing**

Bionutralization

- **Decontamination strategies for chemical and biological agents**
- **Methodologies to validate bionutralization**

Biosensors

- **Non-cryo IR sensors incorporating biomolecular recognition and biomimetic strategies**
- **Simultaneous, rapid multiple bio-threat point detectors**

Cellular Dynamics & Engineering

- **Control systems for intelligent affordable, robust autonomous systems**



Aerospace Biotechnology

Potential Investment Payoff

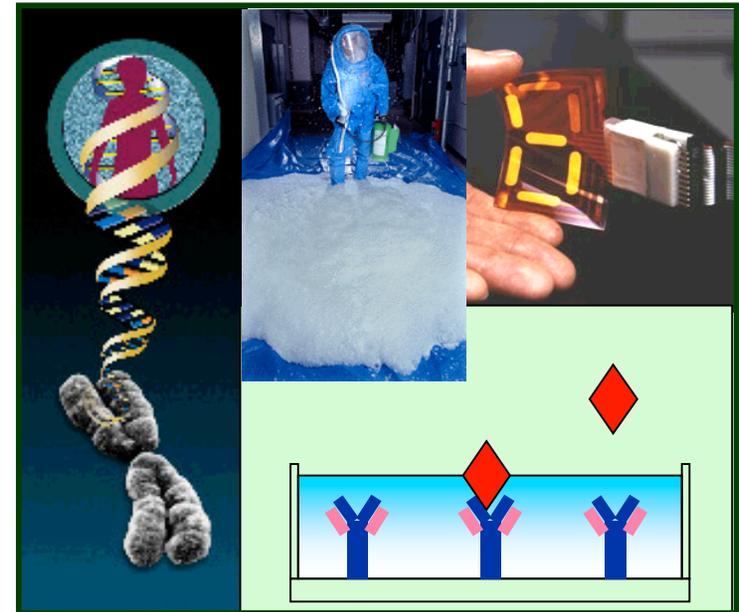


Investments in

- Understanding biological sensing mechanisms
- Distributed sensing and actuation systems
- Neural network architectures
- DNA information storage and processing
- Biomimetic control architectures
- Self-healing and adaptation mechanisms

Offer Potential For

- 10-1000x more sensitive detection and signal extraction
- 1000x higher information storage density
- 1000x lower power and higher speed computational systems
- Radically improved decision making
- Greatly simplified control architectures for complex and distributed systems
- Adaptable, self protecting, self diagnosing and self-healing space systems
- Self-assembled complex systems



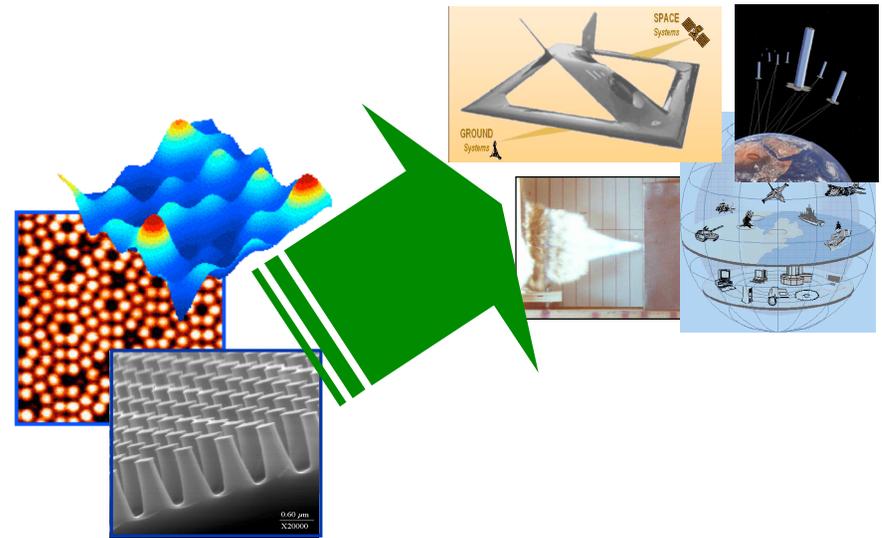


AFRL Nano and Bio Technology



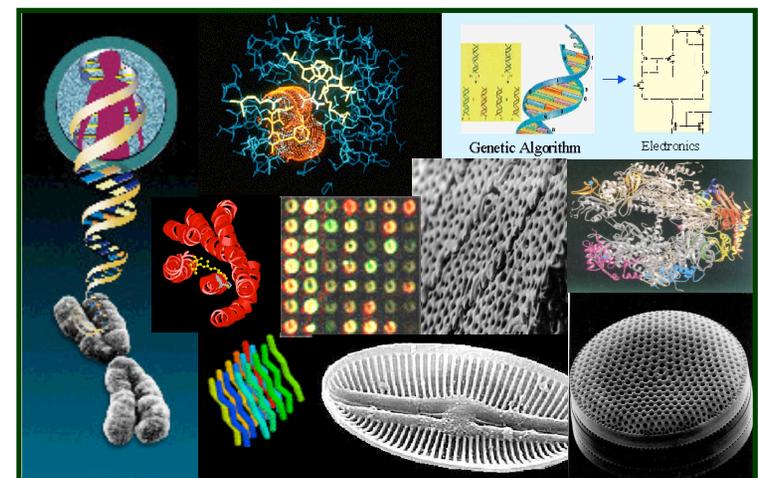
Nano Science & Technology

- Nano engineered materials
 - Nano energetics
 - Nano structured devices



Aerospace Biotechnology

- Cellular dynamics & engineering
 - Bio materials
 - Bio sensors
 - Bio neutralization
 - Bio computing





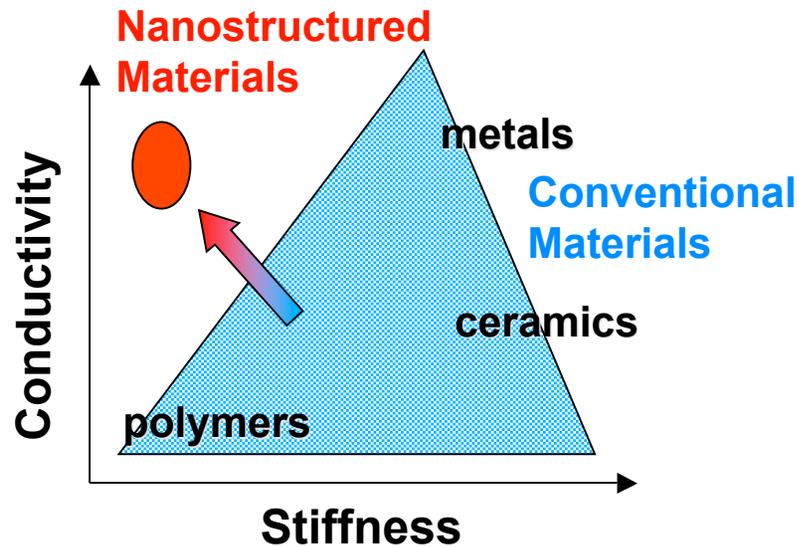
Back Ups





Nano Engineered Materials

Example: Conductive Elastomers



Materials by Design

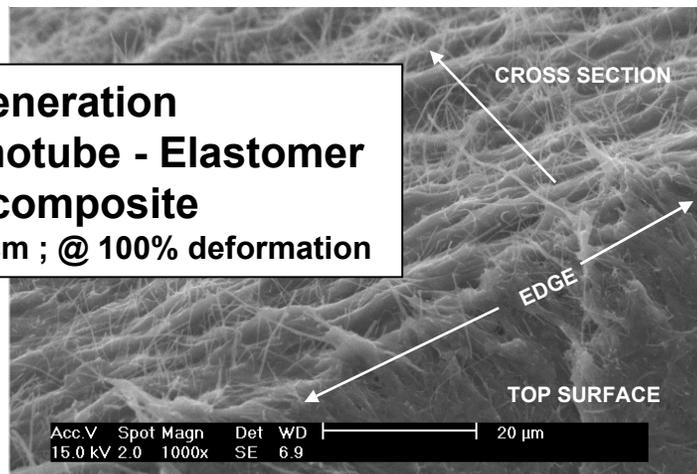
Control of material structure at the nanoscale avoids classic performance-processing trade-offs, enabling the design and manufacture of revolutionary new materials with unique *combinations of properties*

- Independently tailorable structural, thermal, electrical, optical and/or magnetic properties
- Dynamic properties, e.g. self-diagnosing & self-healing materials

Payoff to the Warfighter

- Improved LO maintainability & dynamic stealth
- Broadband, lightweight EM shielding
- Lower weight, higher temperature engine materials for greater thrust and longer range

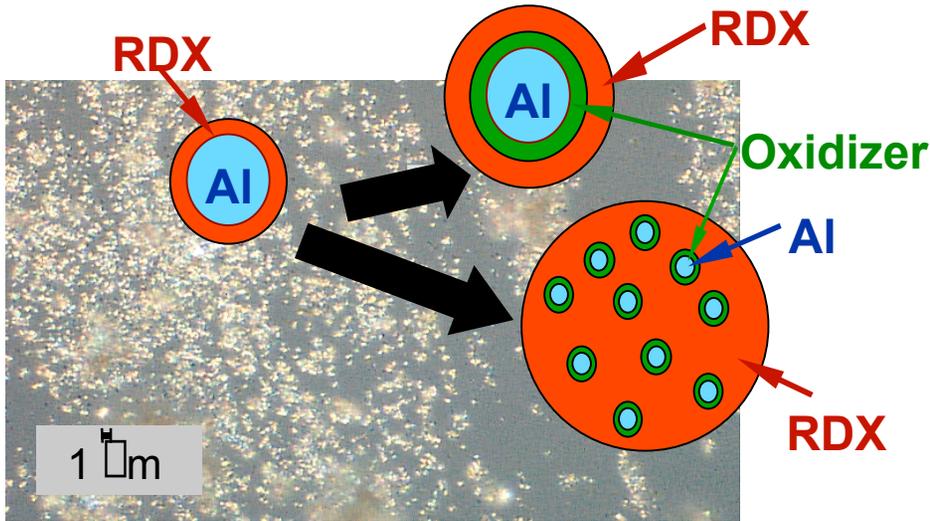
**1st Generation
C-Nanotube - Elastomer
Nanocomposite**
1-10 S/cm ; @ 100% deformation





Nano Energetics

Example : Nano Structured Explosives

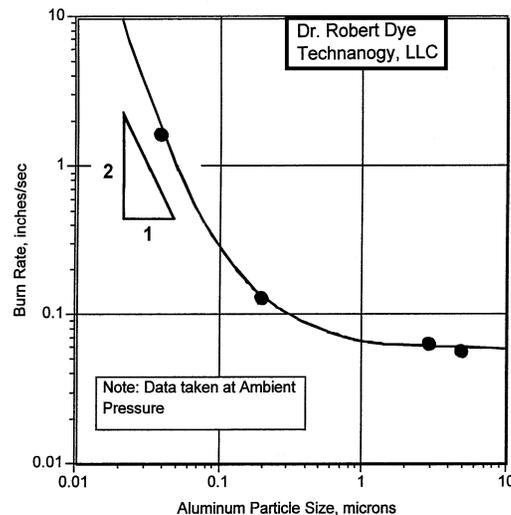


Nanoscale Aluminum, Coated by RDX

Nano fuel particles coated by oxidizer

- 100x power – increase in energy release rate
- 2x total energy – greater surface and internal volume free energy available
- 10x efficiency – near 100% complete reactions
- 10x safer – lower sensitivity to mechanical initiation
- More compact - no binder

Burn Rate vs. Particle Size



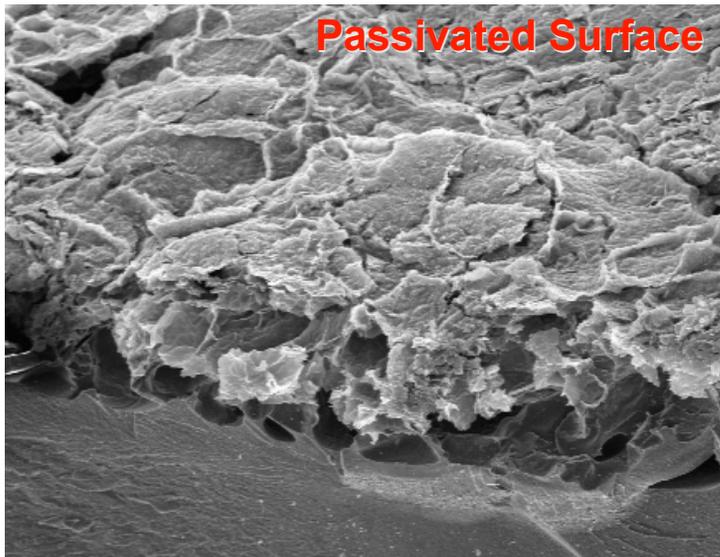
Payoff to the Warfighter

- Smaller, safer munitions
- More kills per sortie
- Decreased logistics tail
- Enables small, weaponized UAVs

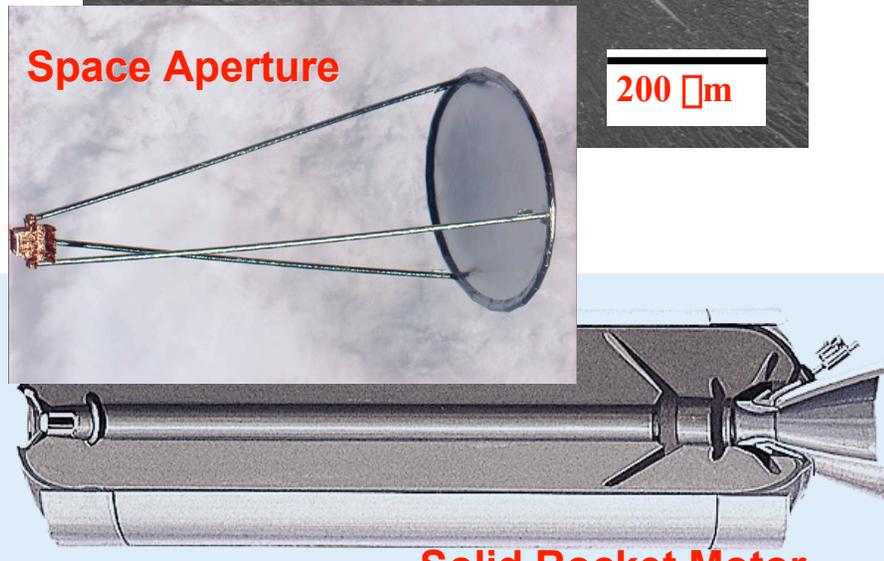


Nano Engineered Materials Example

Pay off in Aerospace Structures



Passivated Surface



Space Aperture

200 μ m

Solid Rocket Motor

Technology Description

- Control distribution and arrangement of nanoparticles in polymers
- Generate desirable new properties while maintaining processibility & low cost
 - 2x higher temperature operation
 - 100x lifetime - self-passivating surfaces
 - Insensitivity to space environment

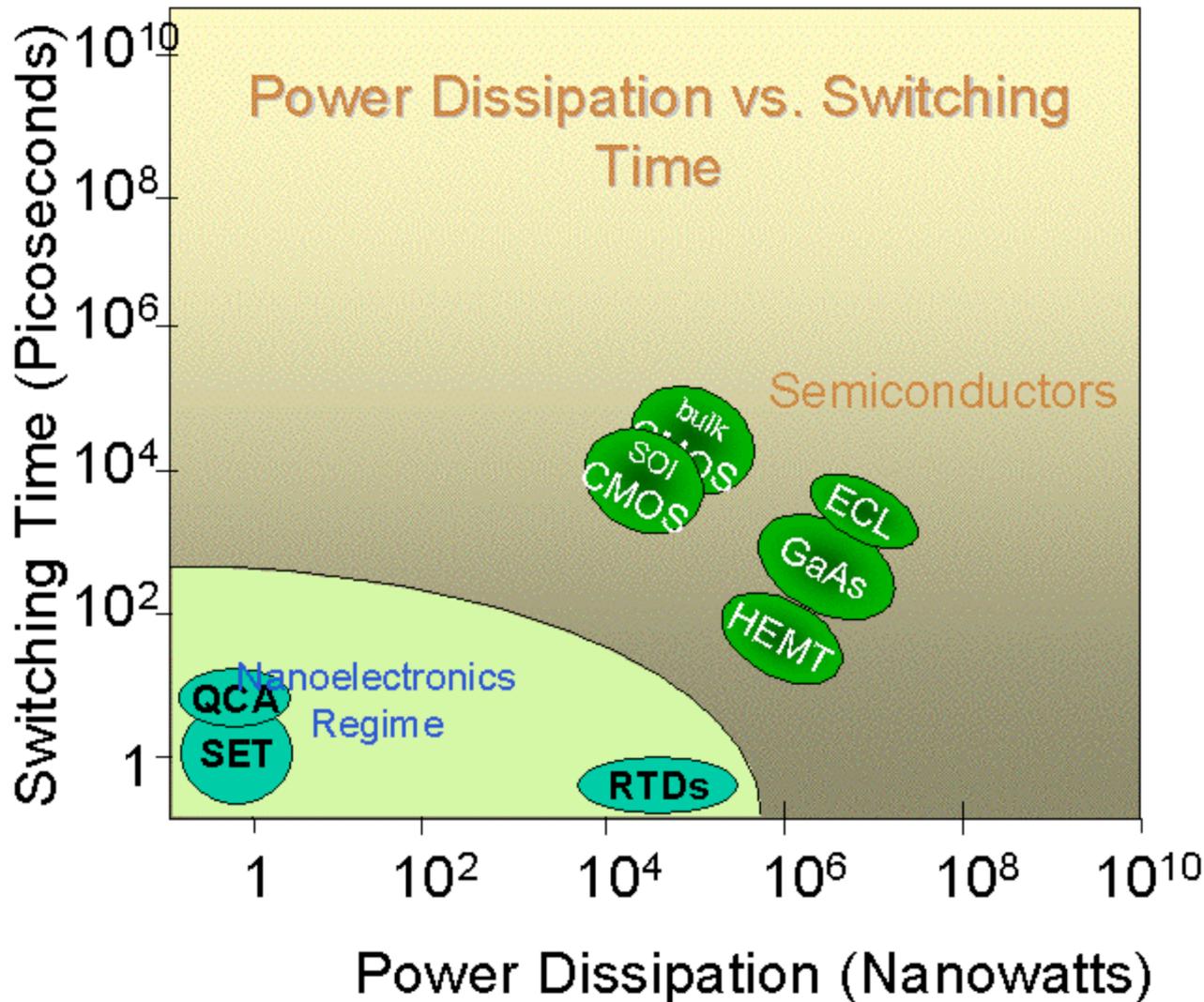
Benefits to the Warfighter

- Provides 10-100x greater service life for rocket and space environments
- Superior insulation material for solid rocket & high-temperature turbines
- Low-mass, low-cost structural material for large space apertures



Nano Structured Devices

Example : High-Speed Devices



Processing Power

Nano devices offer the potential for orders of magnitude increase in speed and simultaneous reduction in power

Payoff to the Warfighter

- Orders of magnitude increase in on-board processing capability
- Real time information extraction from complex sensor systems to aid decision makers

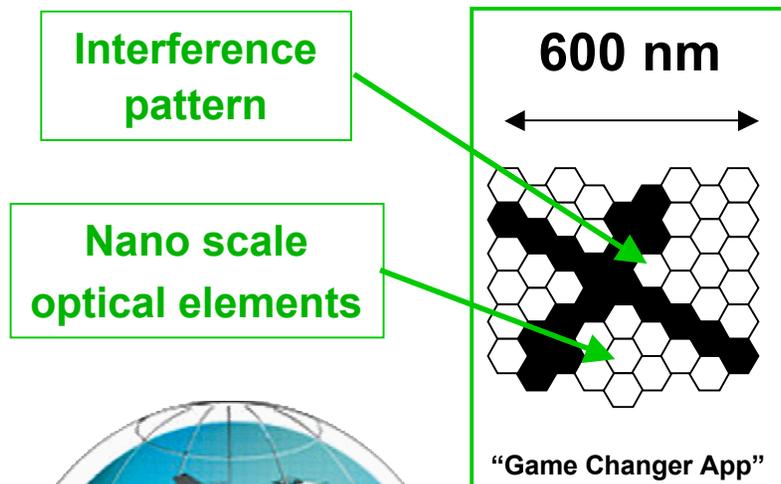


Nano Structured Devices Example

Payoff in New Display Capability



Nano Scale Holographic Grating



Digitizing Holographic Gratings

- Exploit coherent electromagnetic scattering from nano structures to generate an immersive, 3D holographic display

Benefits to the Warfighter

- True 3D representation of the battlespace for enhanced tactical and strategic battlespace awareness
- More realistic heads-up displays for pilot situational awareness
- Superior combat training simulations



System Example: Generation after Next Surveillance Satellite

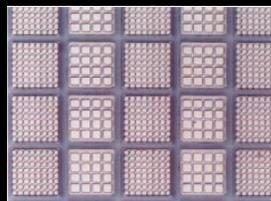


Nano-engineered electronic materials

(self protecting)

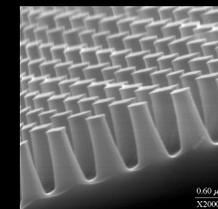


Broadband, reconfigurable sensors
(rapid, unambiguous target ID)

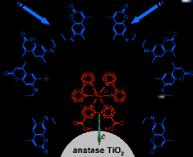


Large membrane, nano-controlled apertures
(10x lighter)

Reconfigurable EO properties
(dynamic stealth)

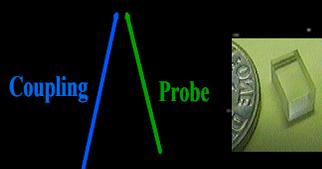


Molecular photovoltaics
(2x SOA efficiency)

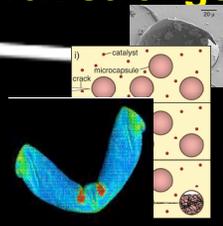


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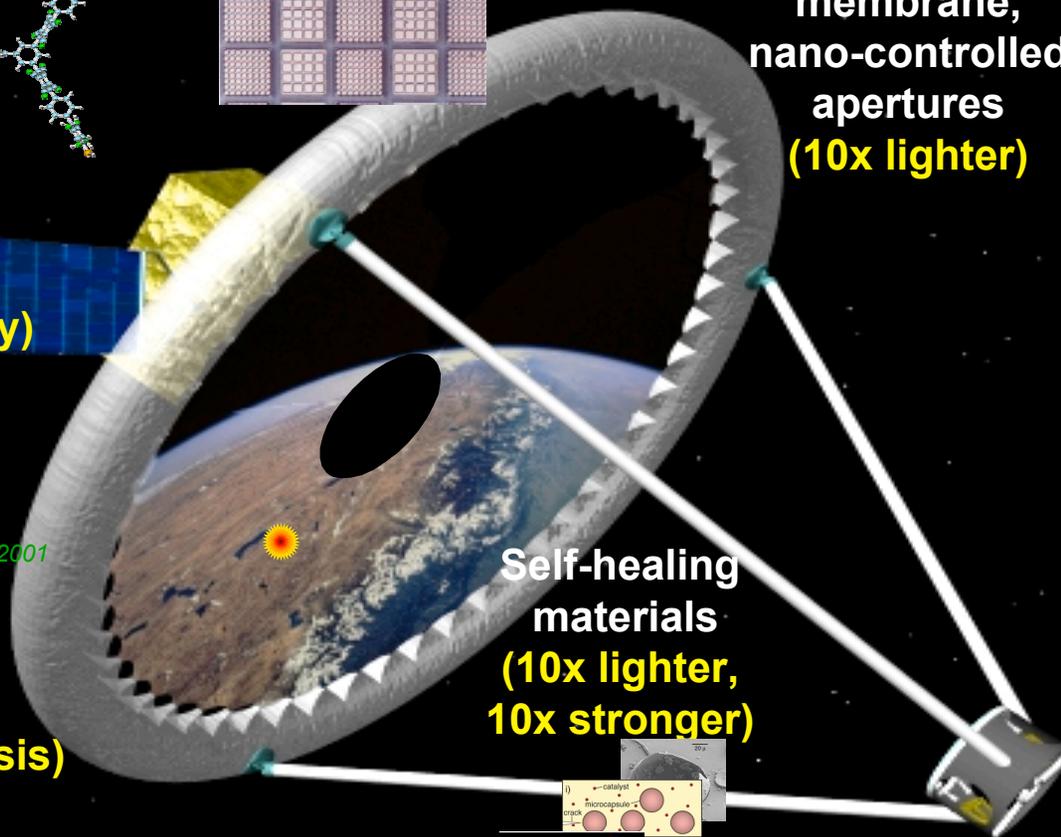
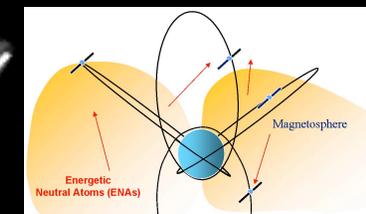
Quantum-computing
(on platform analysis)



Self-healing materials
(10x lighter, 10x stronger)



Nano sensors
(ubiquitous hazard alert)

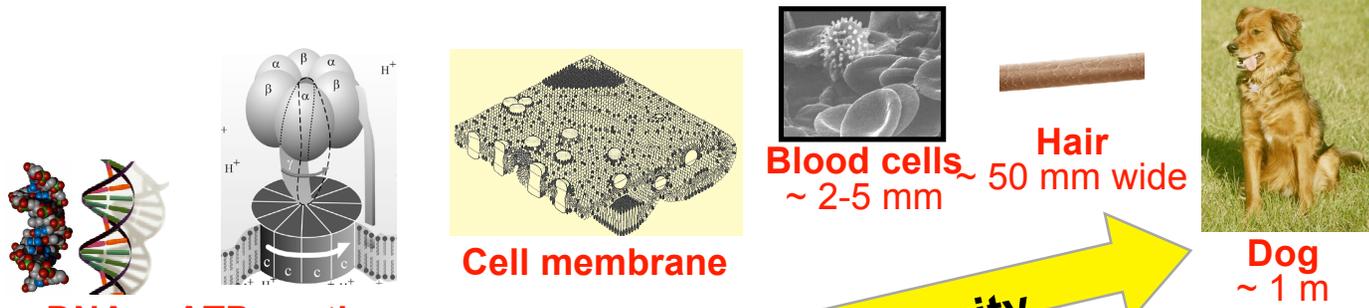




Nano/Bio/Info Convergence: The 21st Century Revolution



**Natural
Organisms**



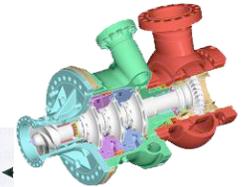
Biological Systems Scale & Complexity

1 nm 1 μm 1 mm 1 m

Systems

**Building
Blocks**

Artificial Systems Scale & Complexity



**Artificial
Systems**

