Visions of the Future: Impacts of Nanotechnology on National Defense

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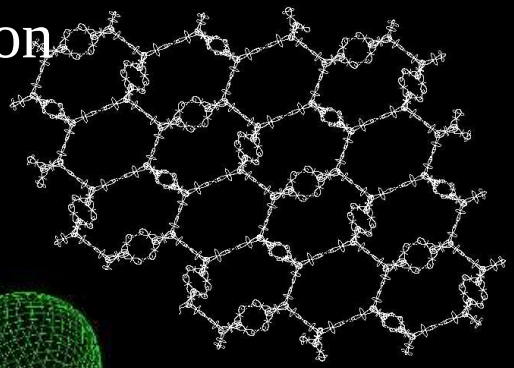
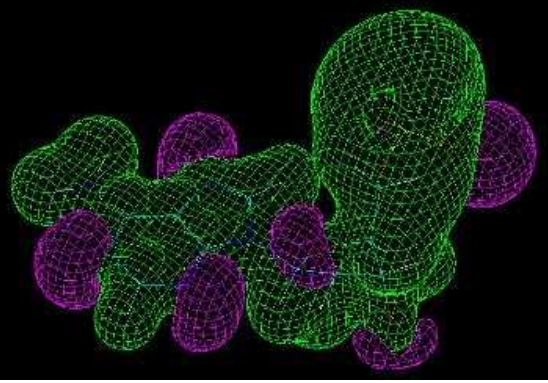
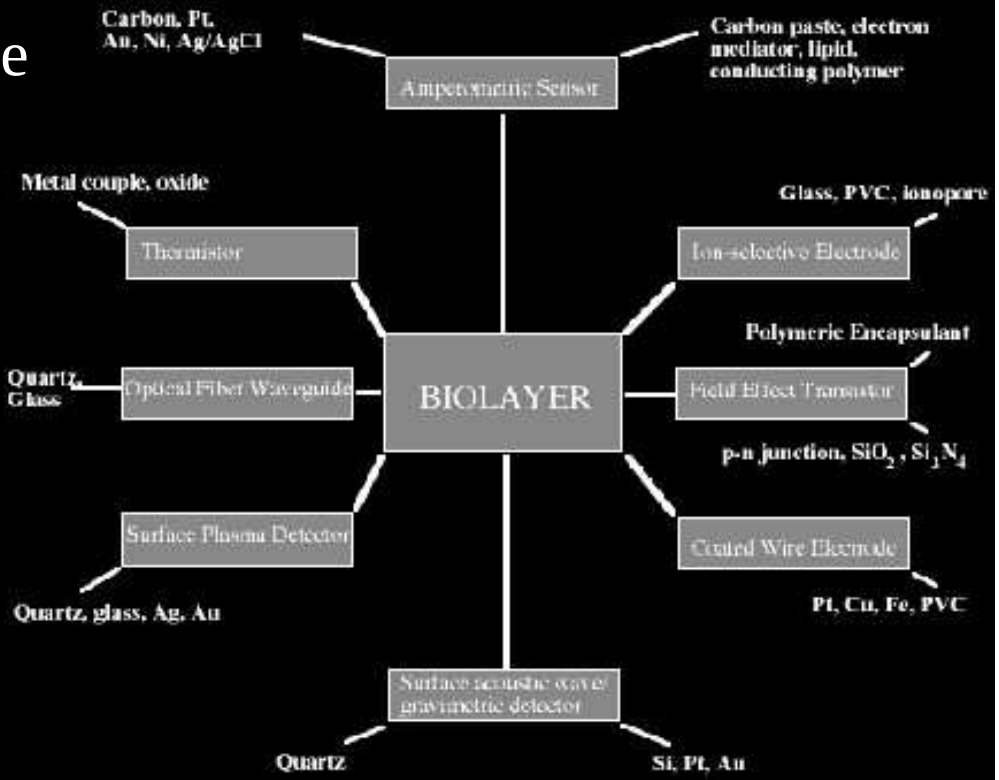
3/27/2010

Major Nanotechnology Enabled Defense Development Domains

- Nanostructured Materials – stealth, protection, intelligence, energy systems, hazardous environments, extreme endurance, self healing
- Telecomm / Computing / Embedded Intelligence
- Sensors / Detectors / Surveillance
- Integrated Devices / Robotics
- Transportation
- Aerospace







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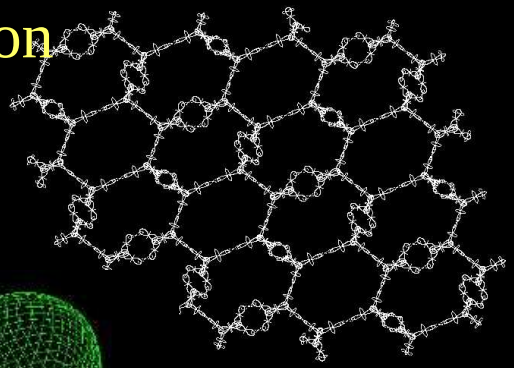
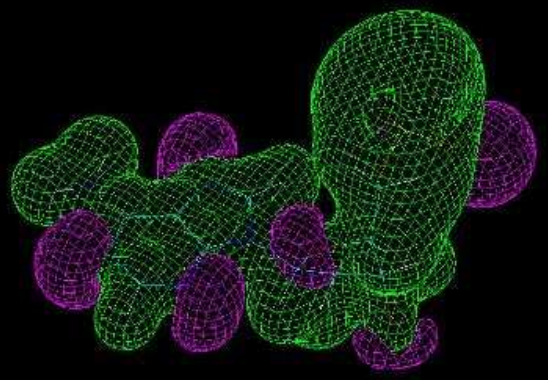
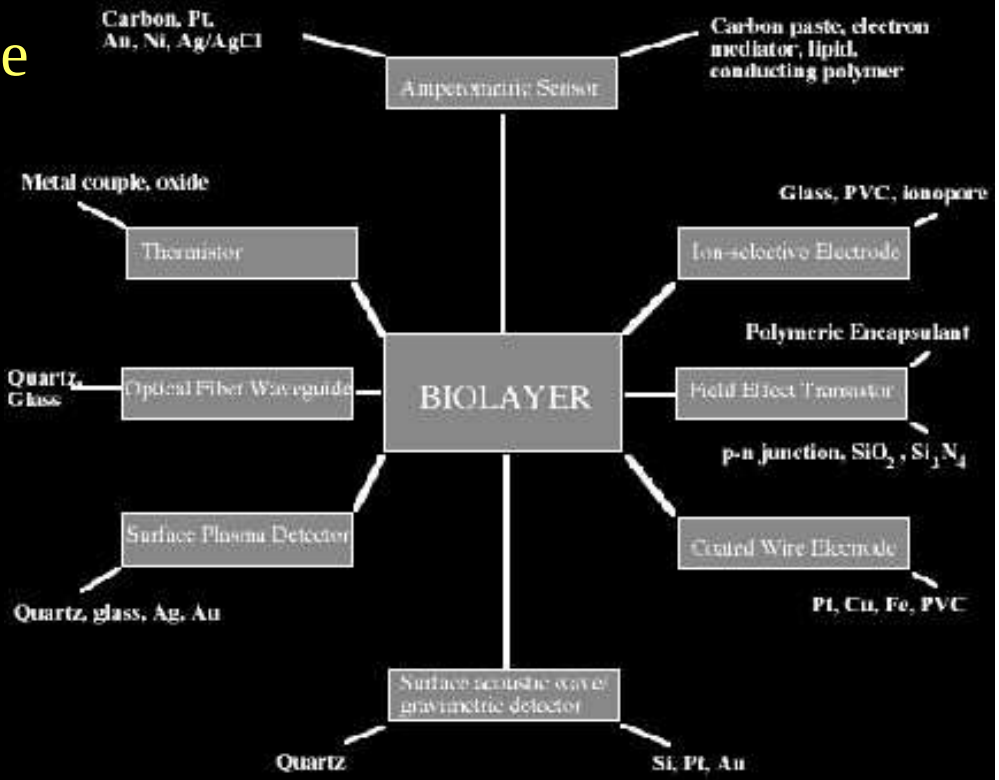
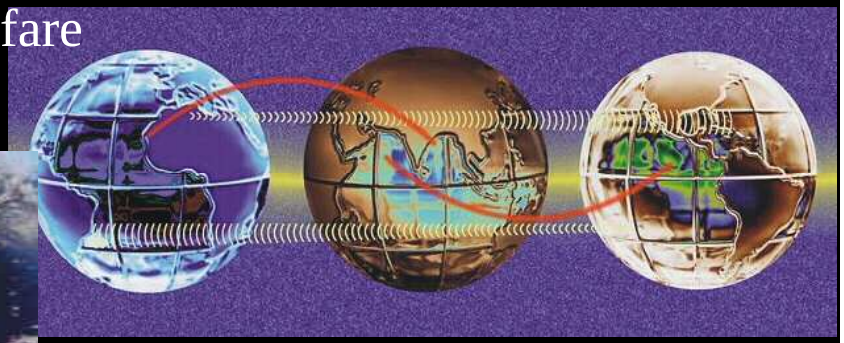


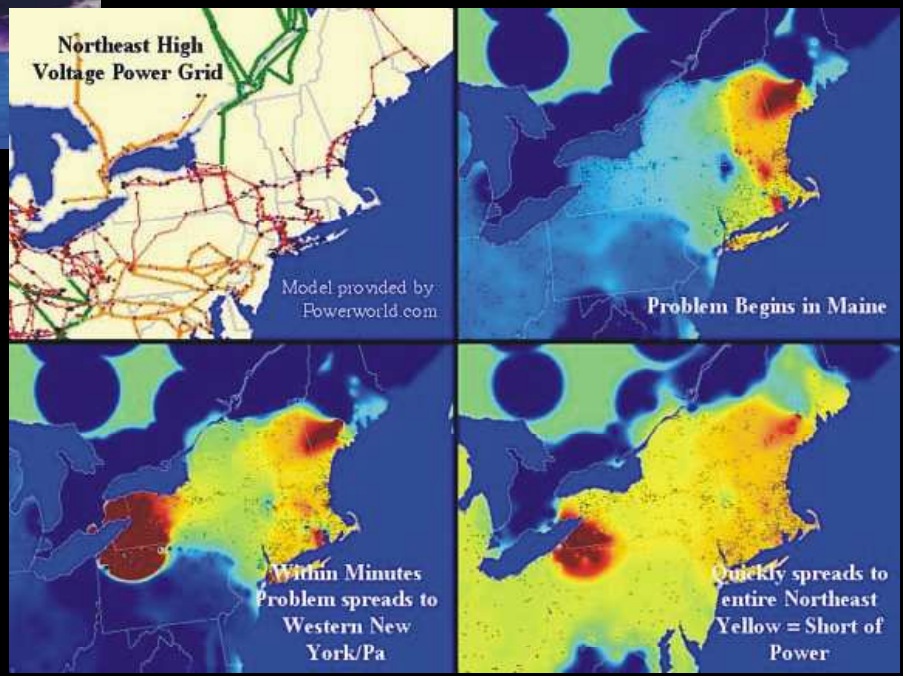




Define "Defense" - Nanotechnology as an Emergent Integrated Solution Platform for Strategic Intervention

- "Virtual" and "Hard" battlefields and threat domains
- Unconventional threats / "granular" urban warfare
- Autonomous realtime threat exposure
- Decentralized defense theaters

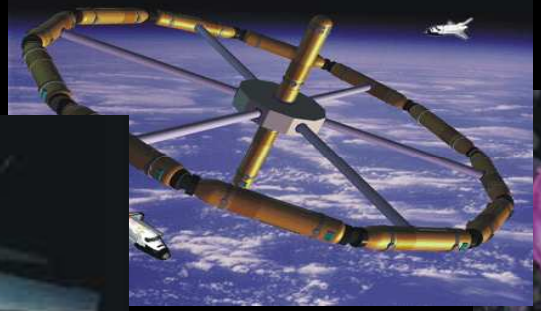


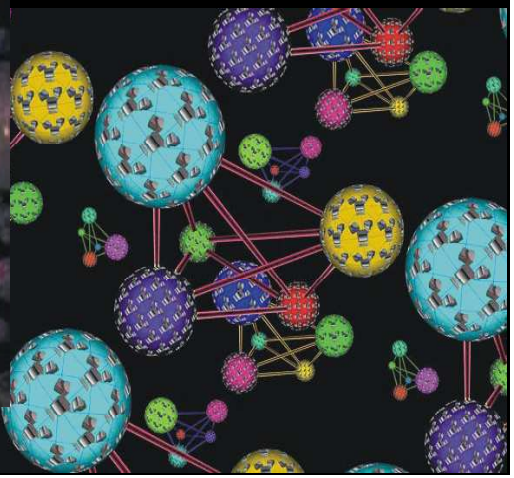


Nanotechnology in Defense

Future arenas of Advanced Materials, Integrated Systems, Adaptive Process Morphology

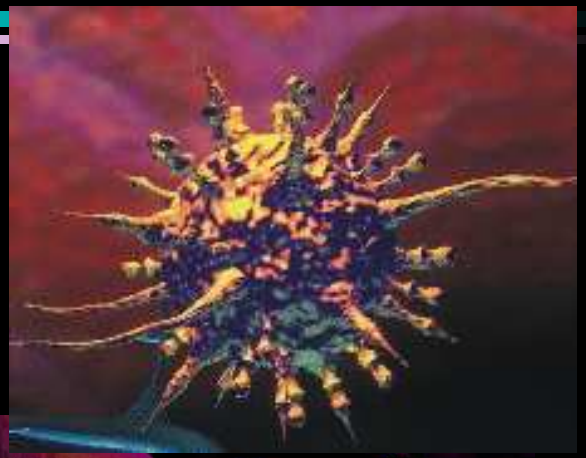
- Zero “time of flight” weaponry / laser, particle beam
- Alternative propulsion systems, microcavitation, gravity manipulation
- Micro-nano satellite “colonies”, autonomous vehicles, intelligent swarms
- “Smart” autonomous robots, distributed sensors, intelligences, artificial entities
- Integration of humans and autonomous intelligences
- Self healing / adaptive adaptive materials, systems, networks
- Anticipatory response to hyper-virulent, xenomorphic nano-organisms

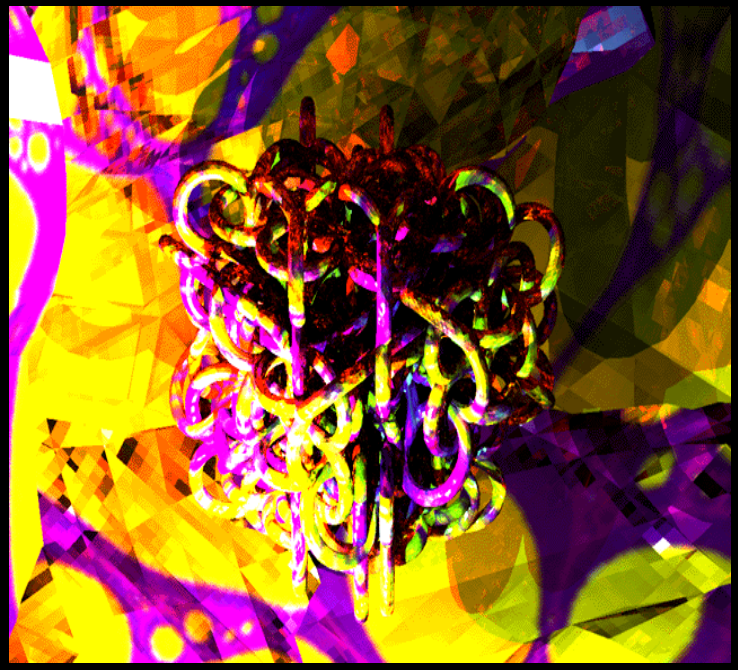


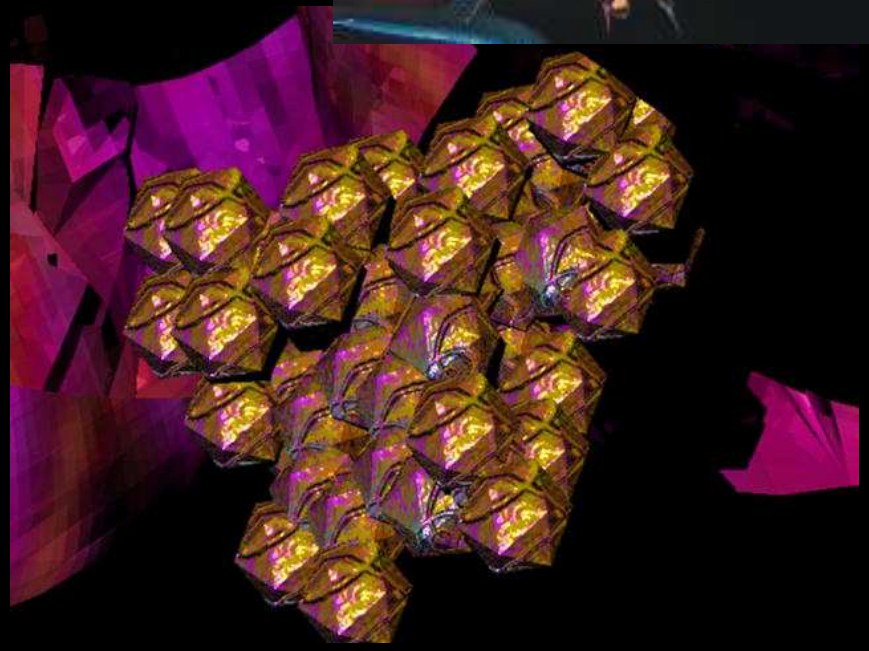


Hybrid Lifeforms / Synthetic Organisms
Integration of Living Systems

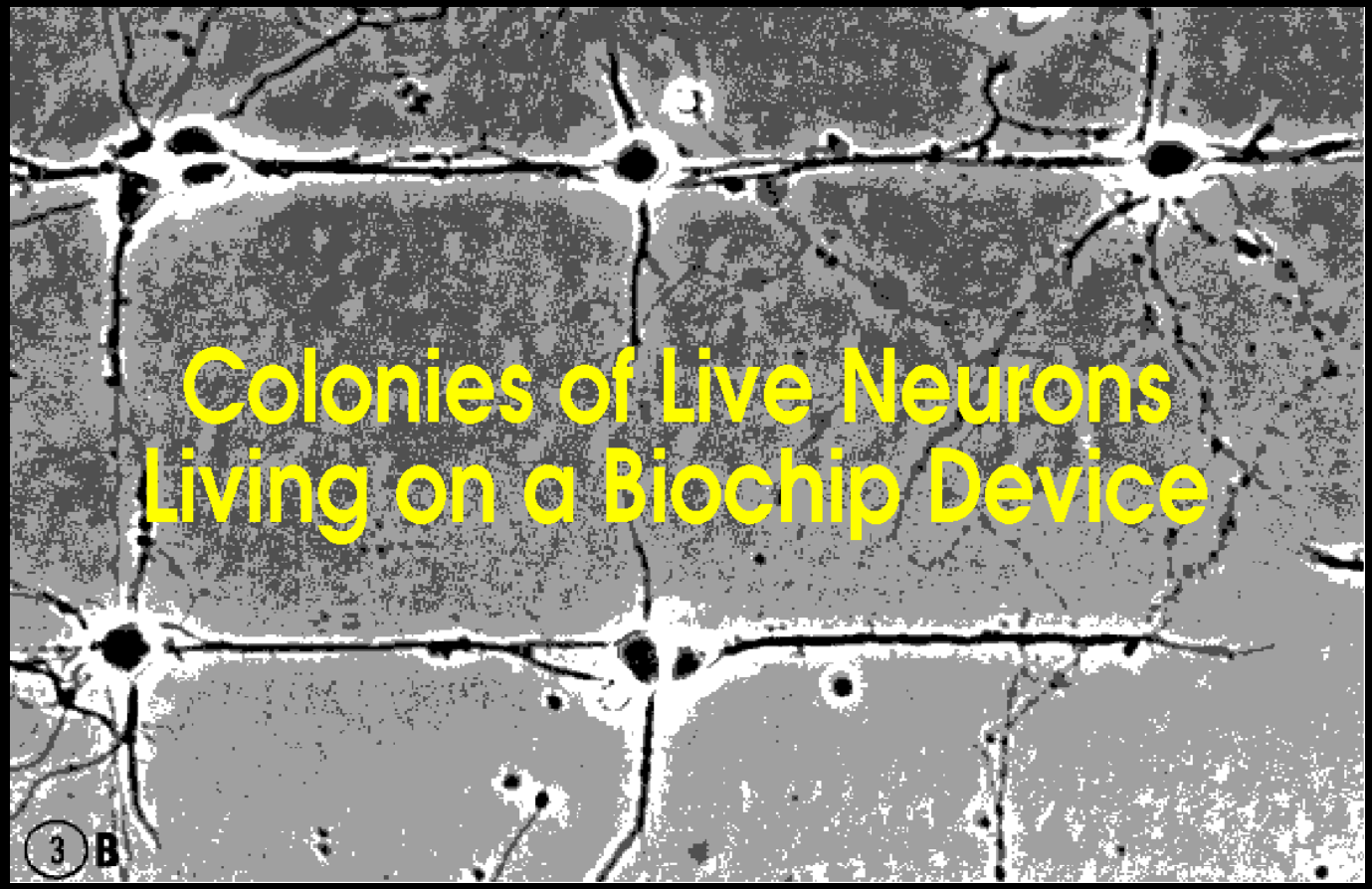
- Beta Cells
- Proteomic Targeting
- Quasi-viral components







Biopathogen Detection – Live Cells as Sensors



The Emergent Infotech / Biotech / Nanotech / Cognotech Operational Ecology

NBIC Conference

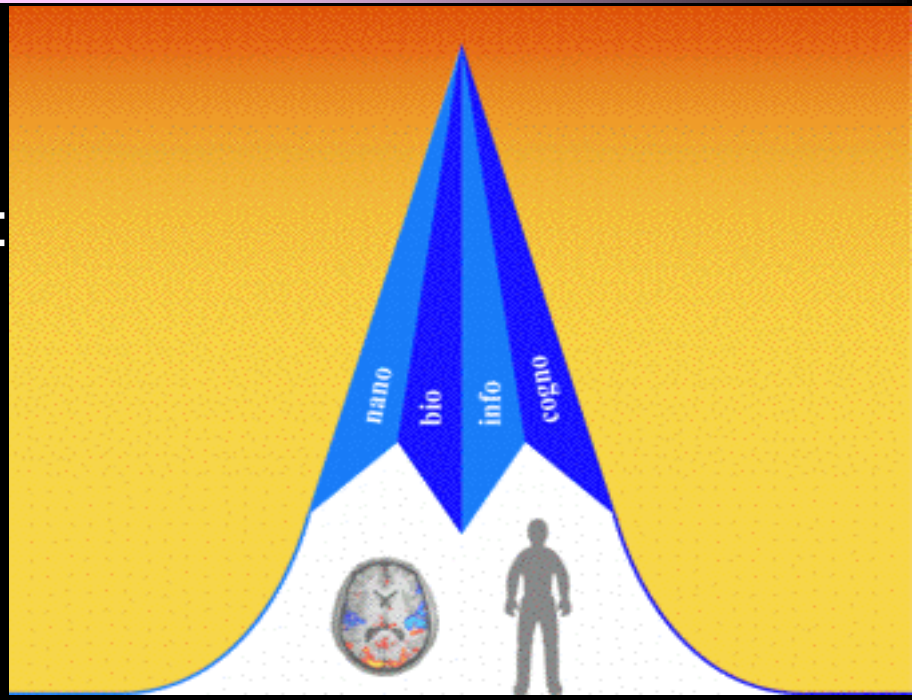
Converging Technologies

for Improving Human Performance:

Nanotechnology, Biotechnology, Information Technology and Cognitive Science

NSF/DOC-sponsored report

http://www.wtec.org/ConvergingTechnologies



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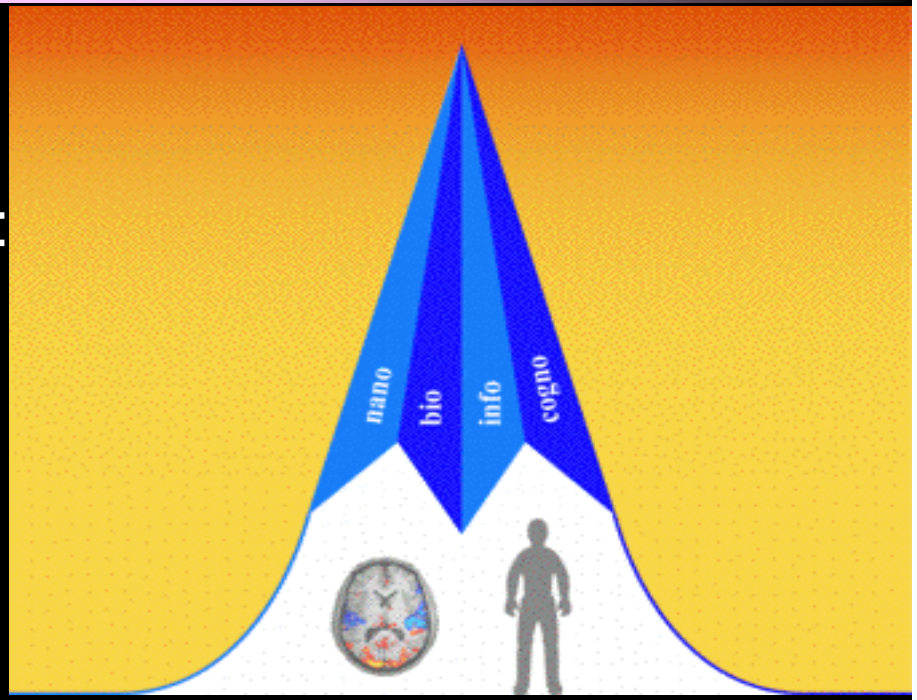


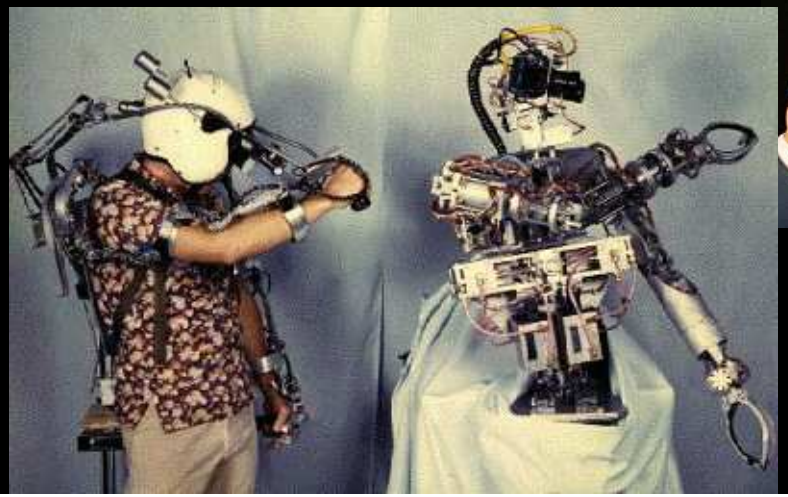
Most Important Key Features of Nanotechnology

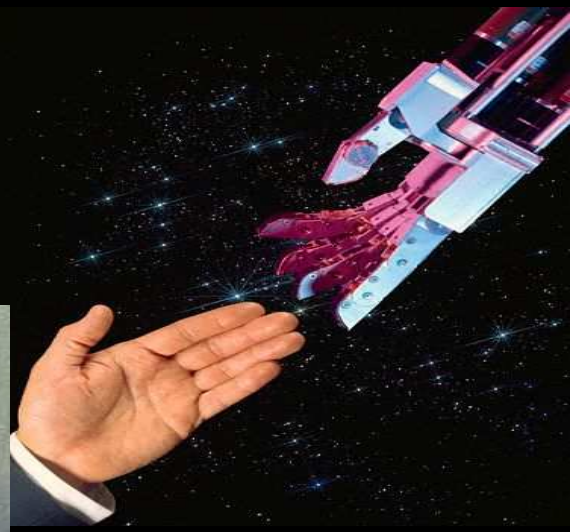
- It is not necessarily about nano-widgets or “tiny machines”
- It consists of an ever expanding collection of interrelated fabrication processes and systems that operate with the controlled manipulation of atoms and molecules.
- Nanotechnology is the gateway to system integration

Primary Objectives:

DARPA - Defense Advanced Research Projects Agency

- Keep human soldiers from harm
- Enhance human capacity, assisted enhancement
- Emphasis on “smart” technology instead of “replacement” technology

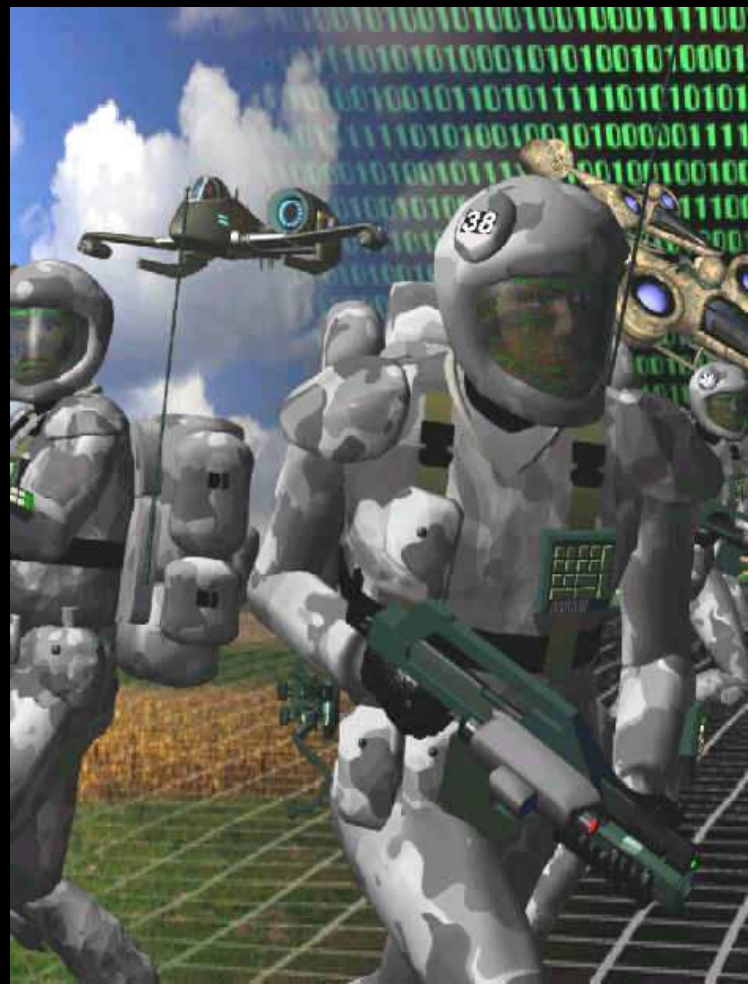




Soldier of the Future – Define “Soldier”

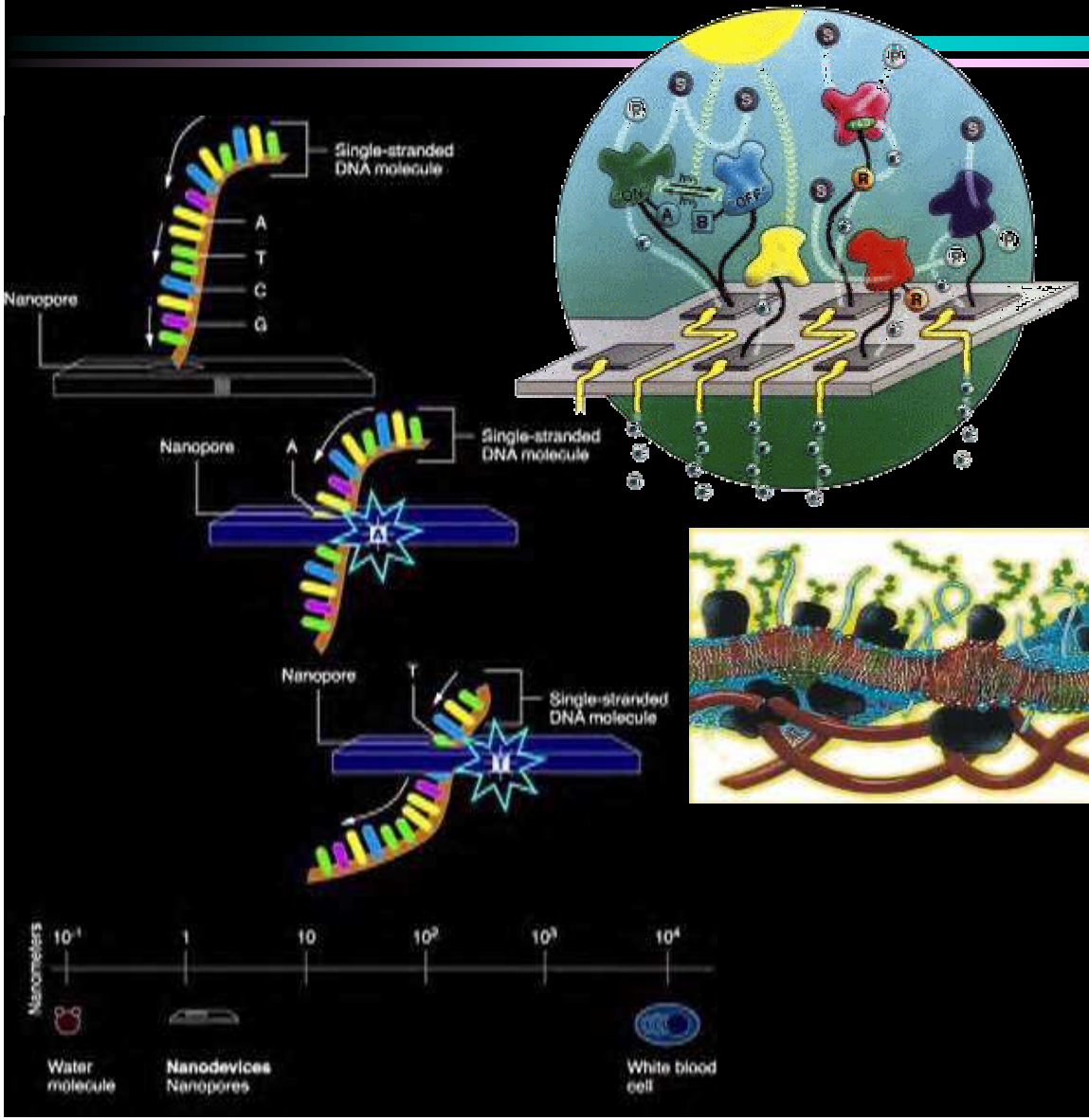
- ***Institute for Soldier Nanotechnologies***

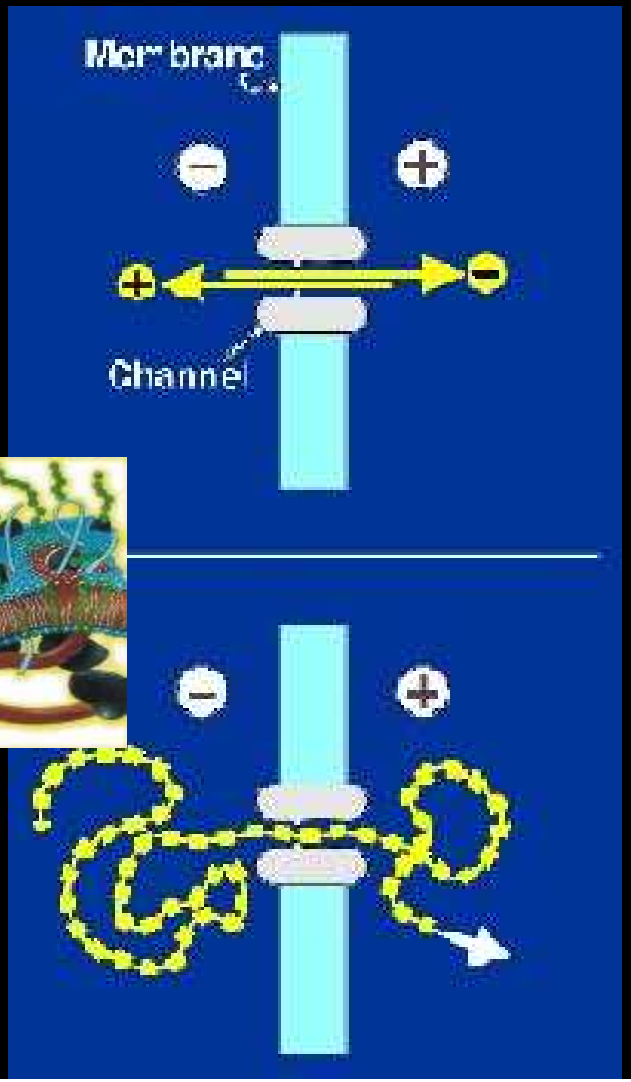
http://www.aro.army.mil/soldiernano/



Nanoporous Materials, Selective Membranes

“Smart” Skin / Integrated Molecular Sensors

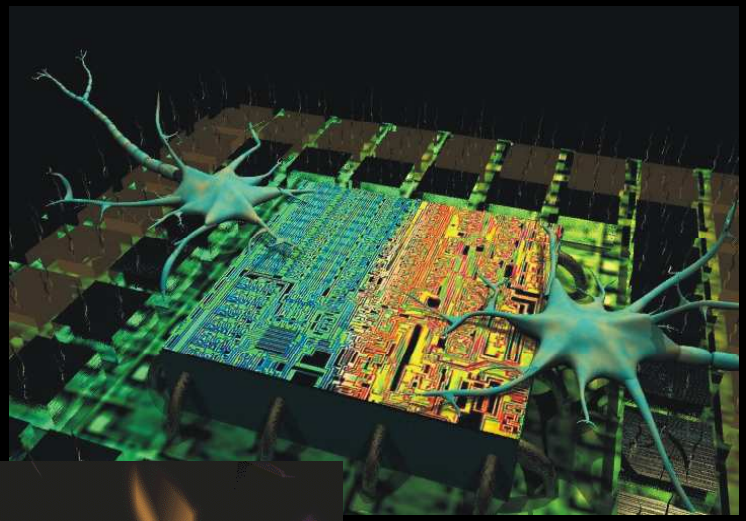


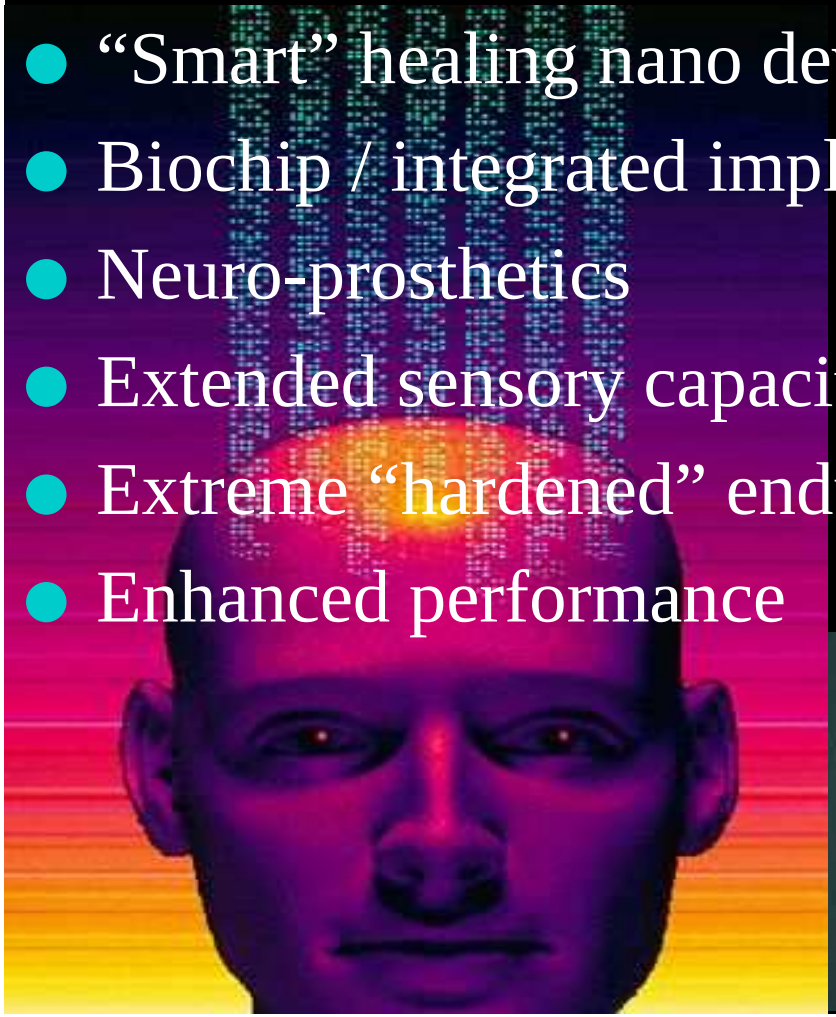


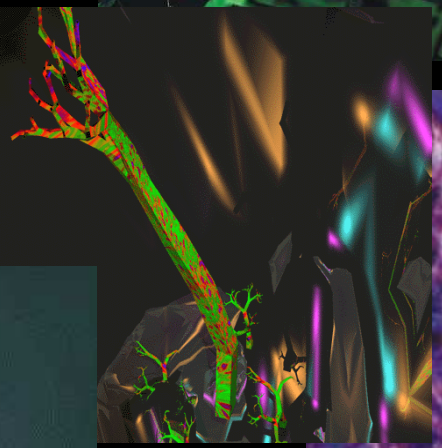
Nanotechnology Enabled

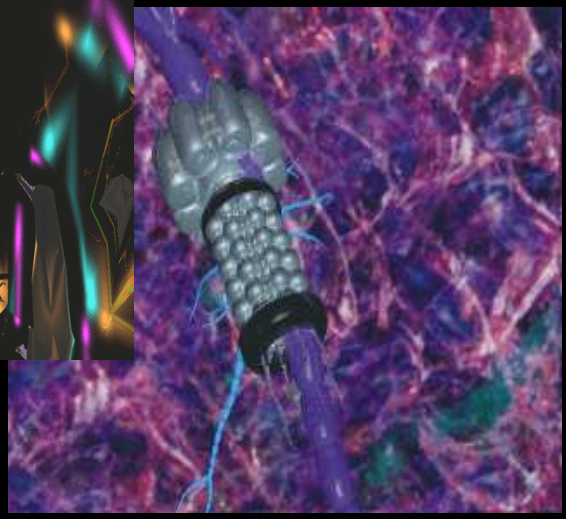
Human Enhancement, Human / Machine Interface

- Nano-enhanced tisuue
- “Smart” healing nano devices
- Biochip / integrated implants
- Neuro-prosthetics
- Extended sensory capacities
- Extreme “hardened” endurance
- Enhanced performance



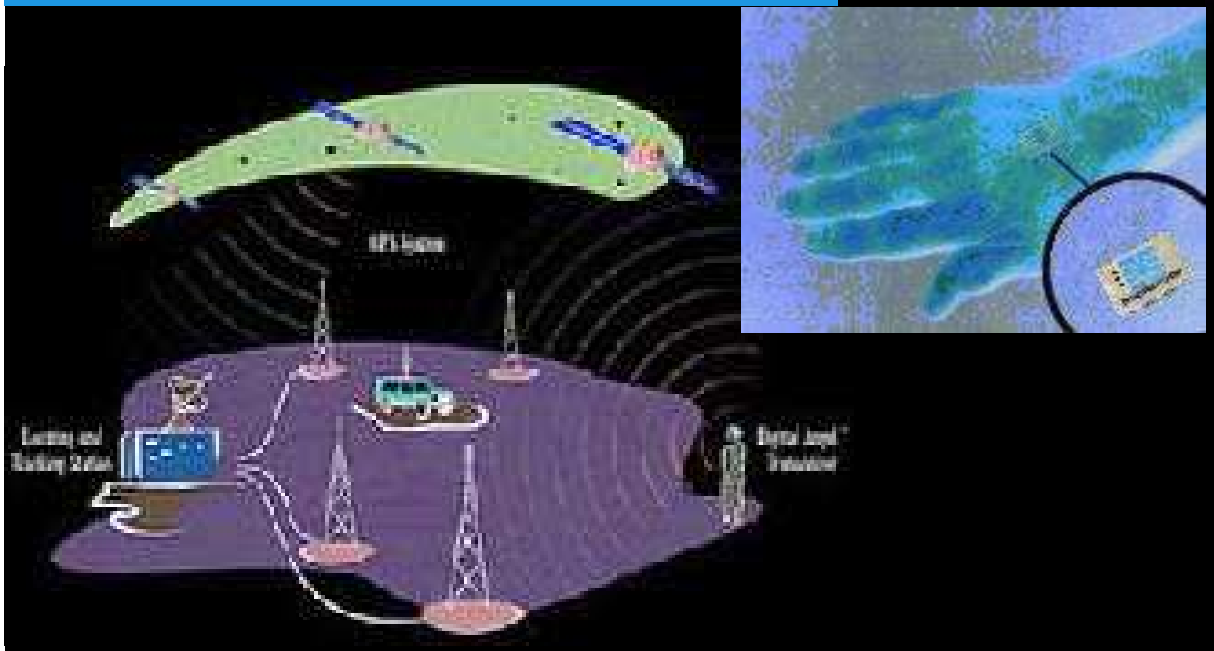


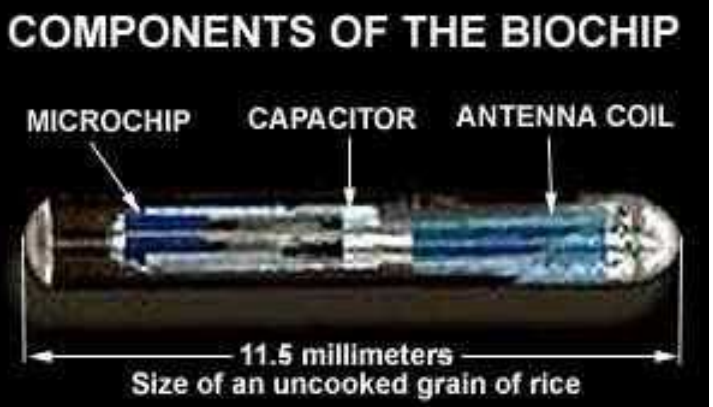




Integrated Human & “Virtual” Operational Ecologies - Future Biometric Immersion

Digital Angel™ CORPORATION

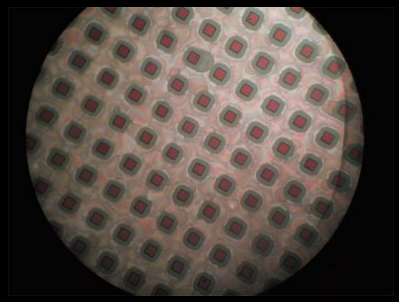


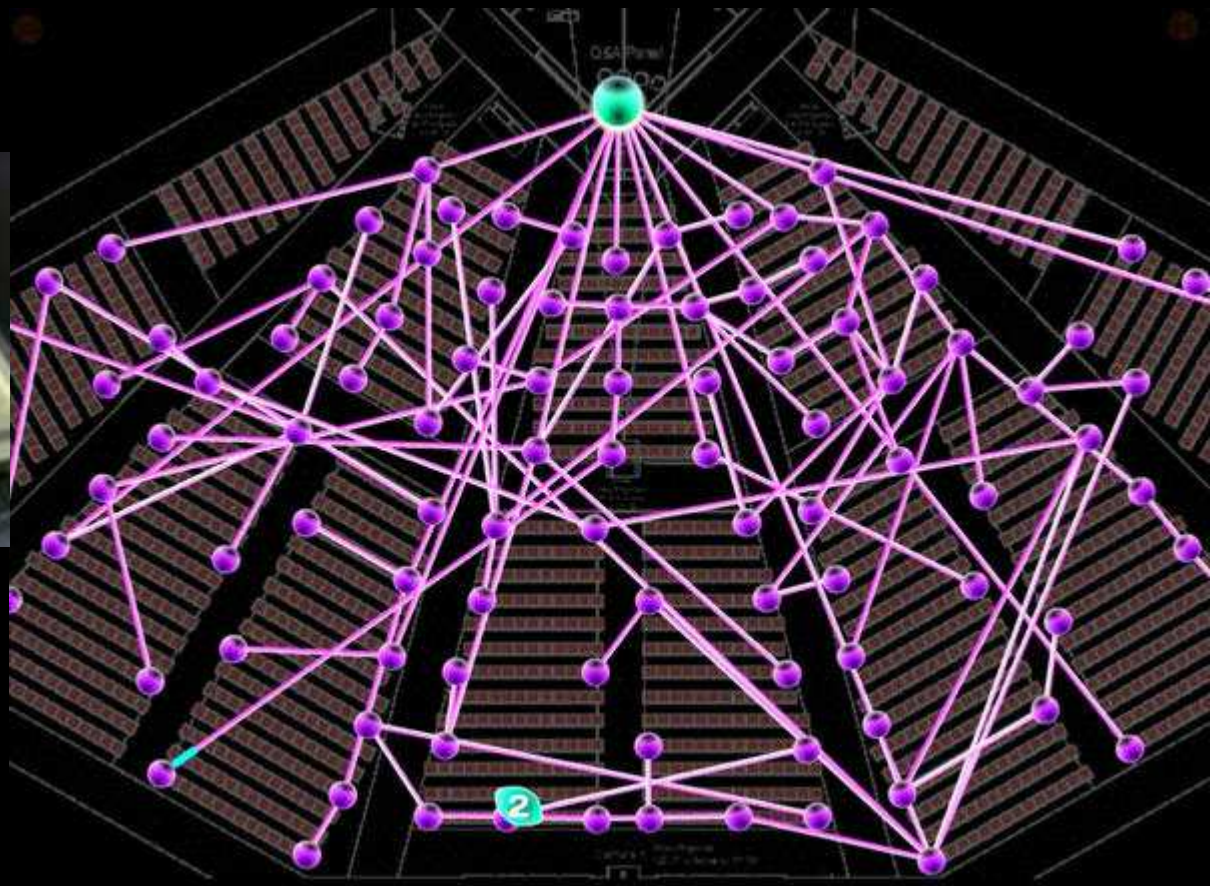


- Biochip Implants
- Distributed Sensors
- “Smart Dust”
- Molecular Sensors

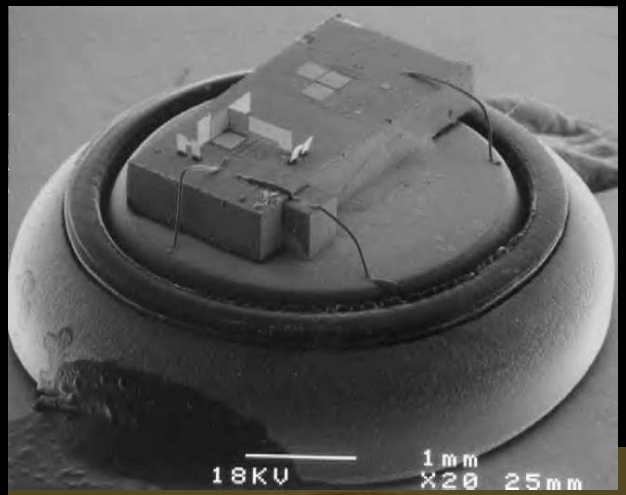
“Smart Dust”
Biometric Immersion

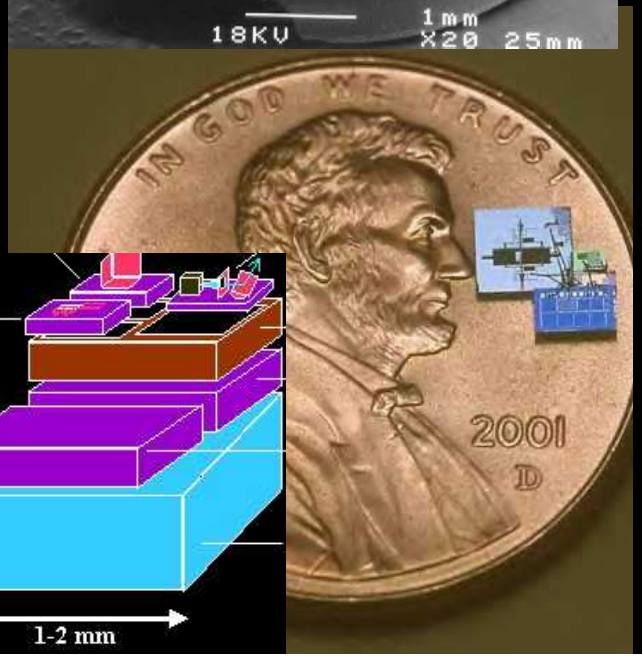
- Sensor “Swarms”



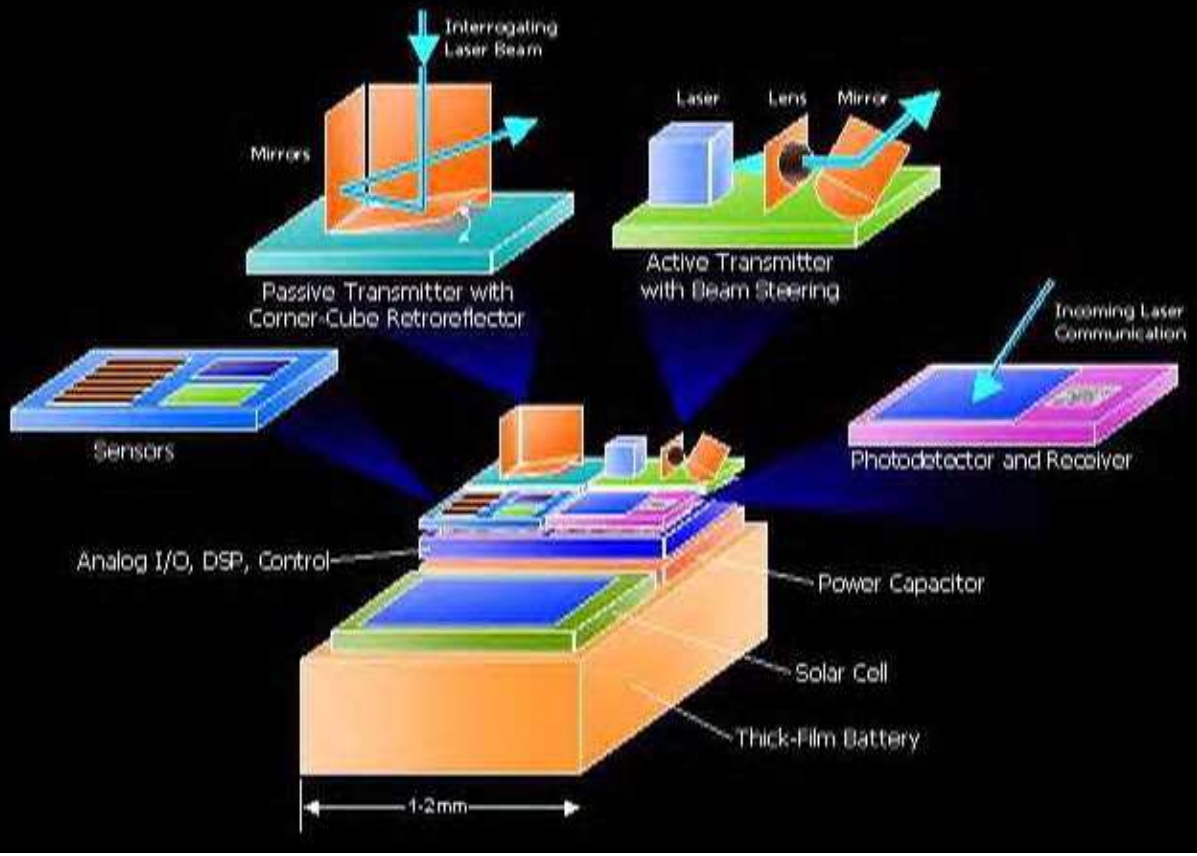


Future Biometric Immersion





- Autonomous Distributed Entities
- Ubiquitous Presence Monitoring



Biological Insight to Flight Control

University of California, Berkeley

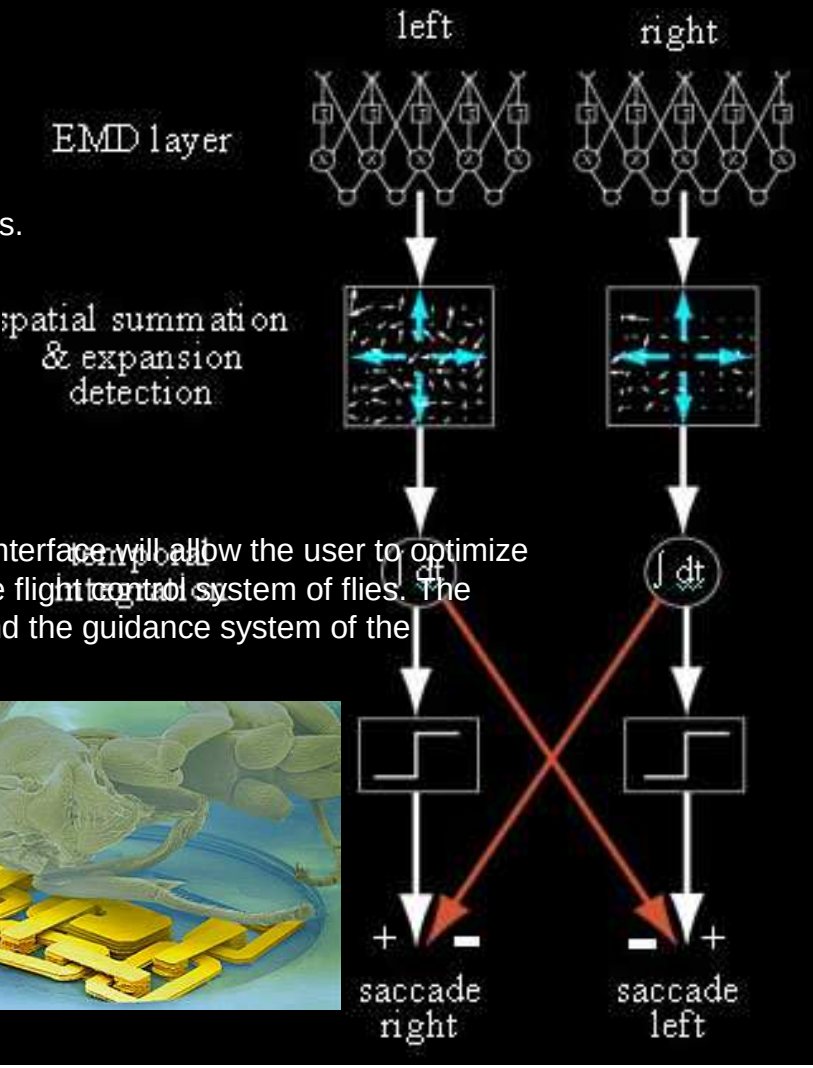
PROJECTED MILESTONES

•Complete measurement of free flight wing kinematics.

•Program tethered flight arena for mechanosensory closed-loop.

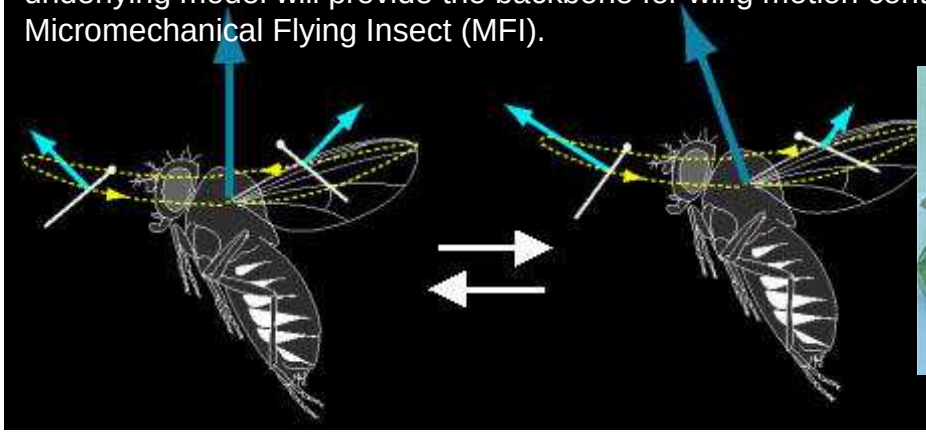
•Quantify influence of olfactory odors on visually-elicited flight maneuvers.

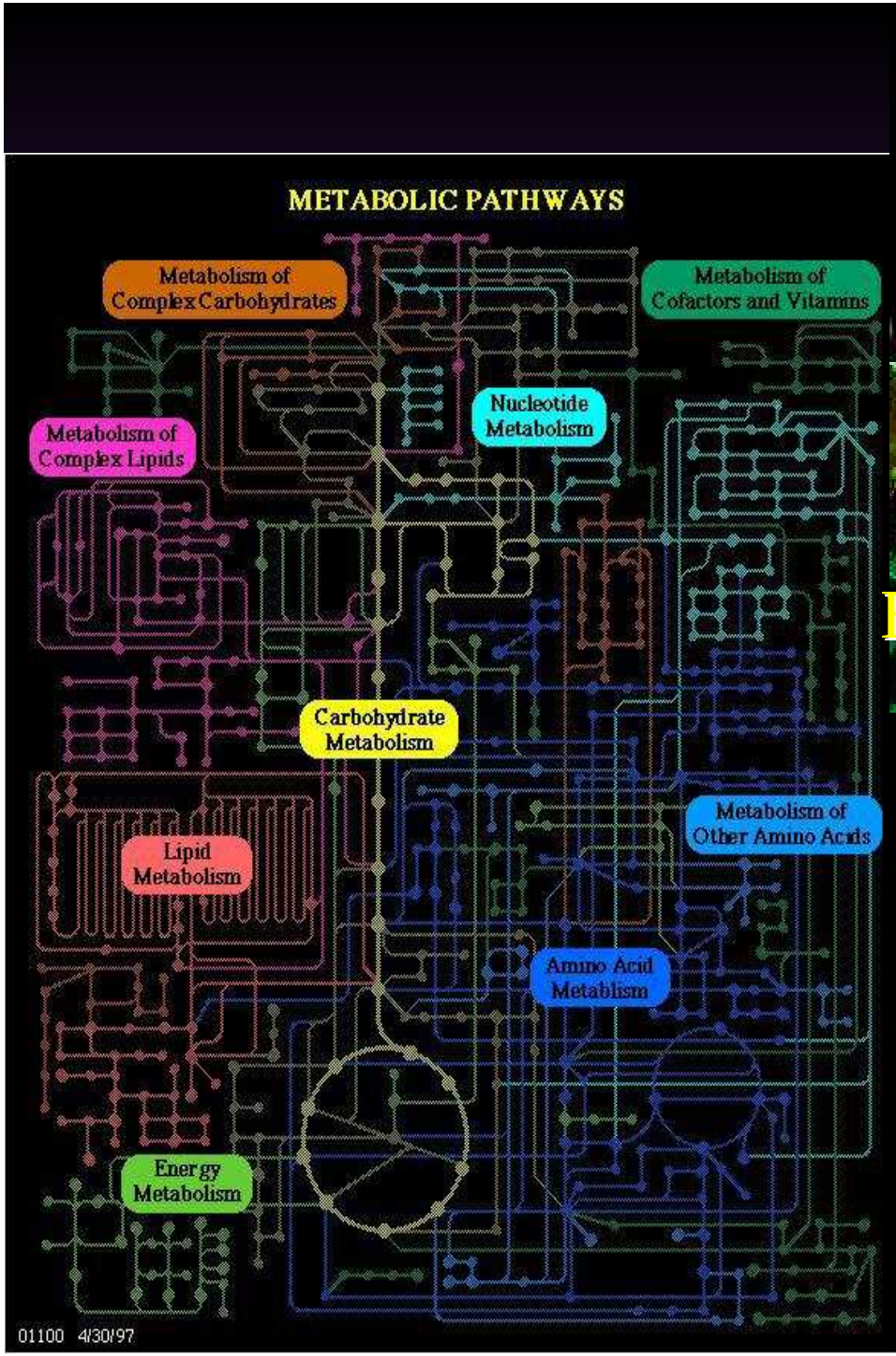
•Construct robotic gantry for testing flight control algorithms.



ENVISIONED DELIVERABLES

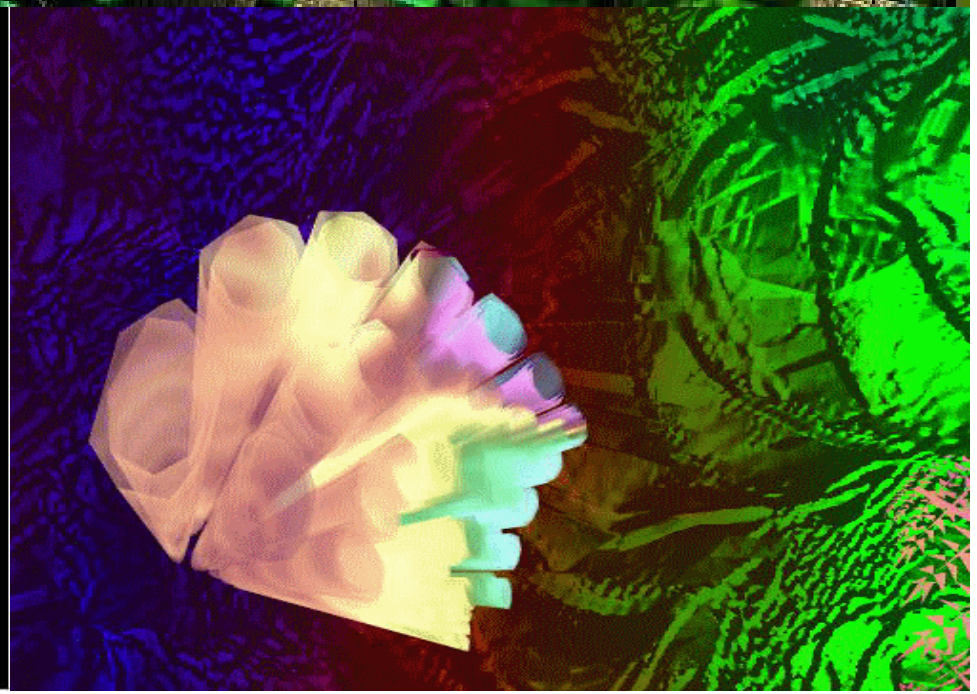
Design software for biomimetic flight control systems. A graphical user interface will allow the user to optimize features of a visual, inertial, and olfactory guidance system based on the flight control system of flies. The underlying model will provide the backbone for wing motion controller and the guidance system of the Micromechanical Flying Insect (MFI).





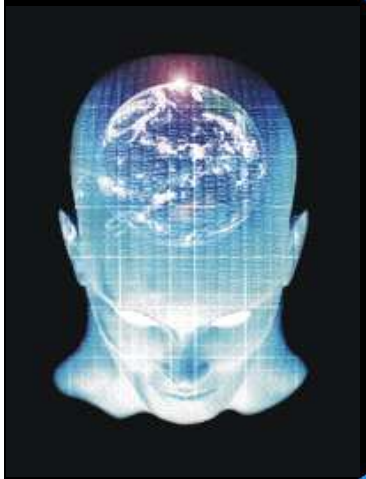
Process Convergence

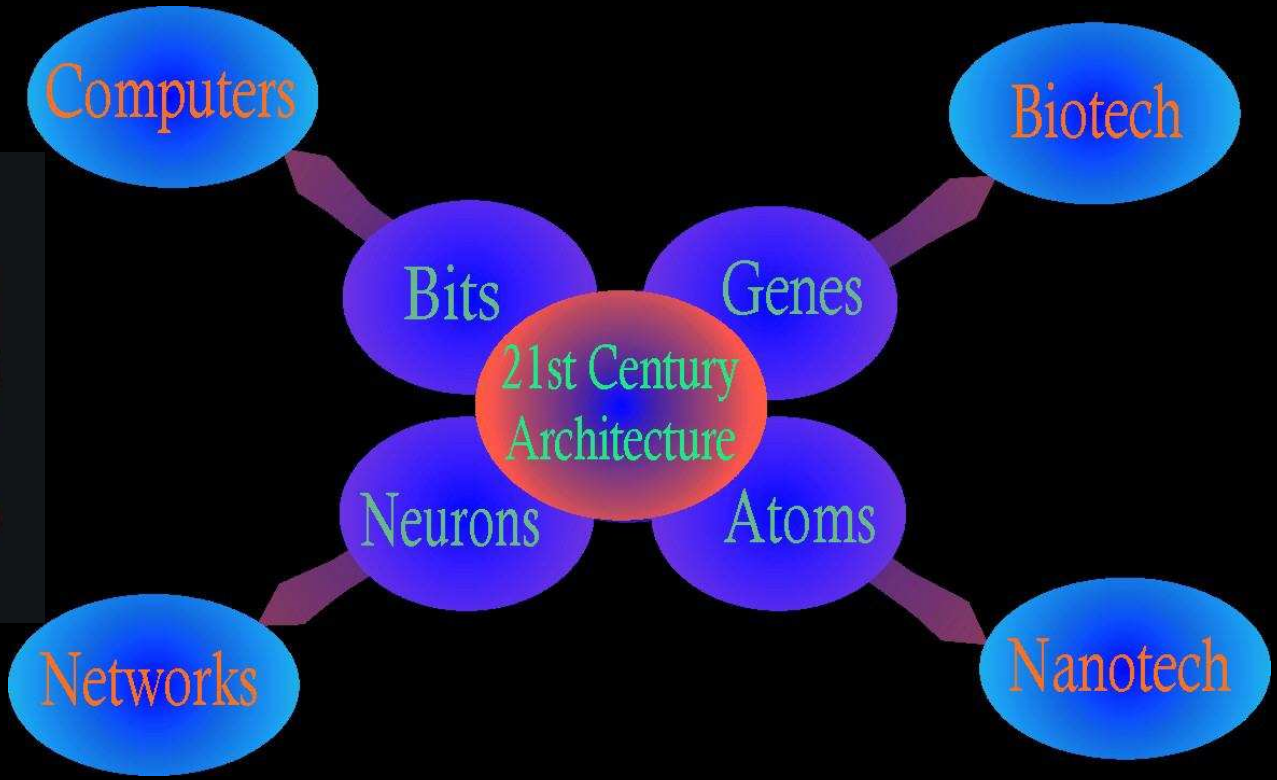
Bits, Atoms, Genes, Neurons



Think Different . . .
Think Holographic

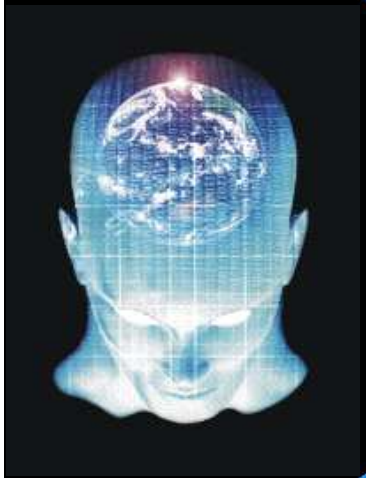
- Nano-industrial infrastructure is an evolving architecture of interrelated disciplines, technologies, organizational systems

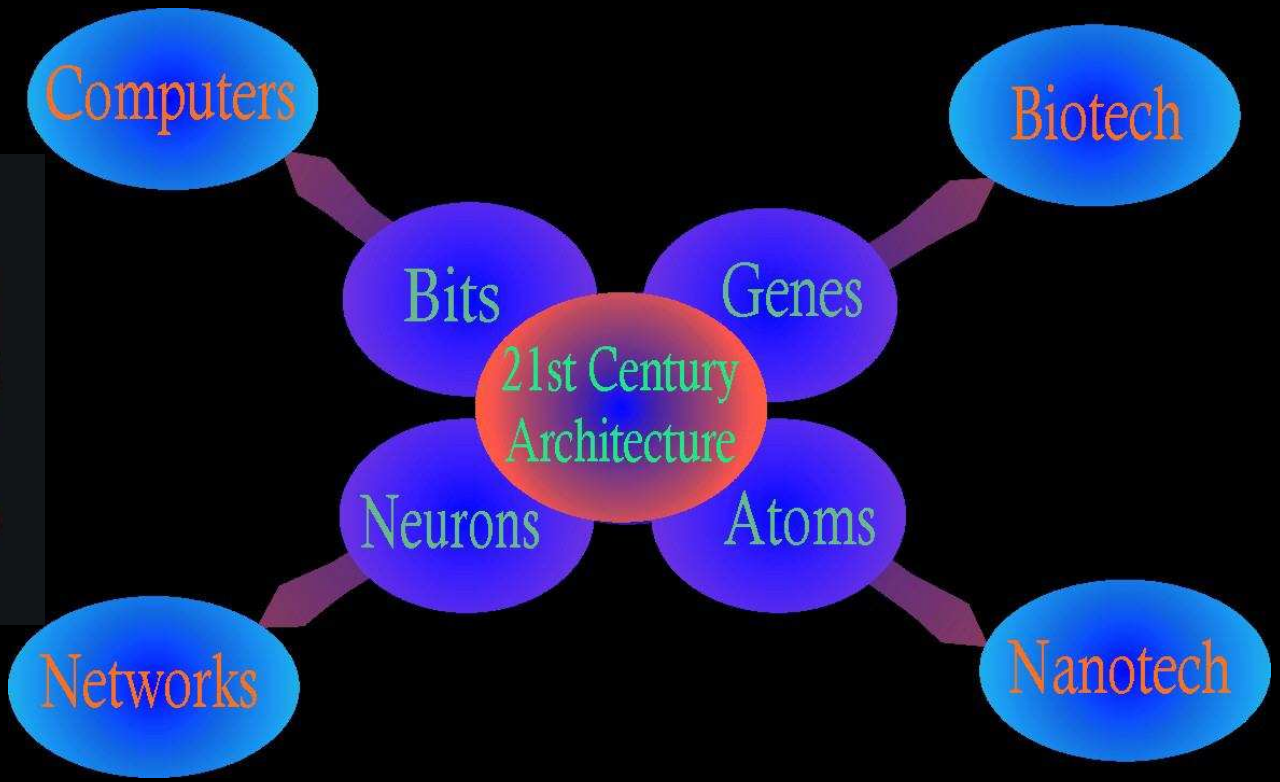




Think Different . . .
Think Holographic

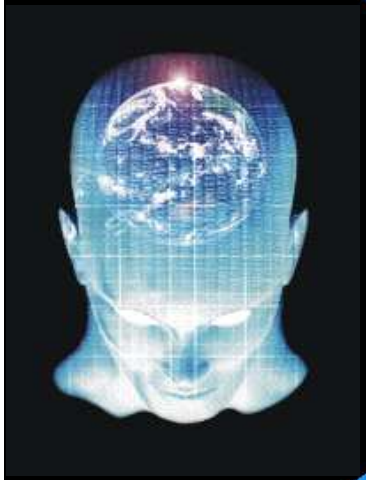
- Emergent threat domains are an evolving architecture of interrelated disciplines, technologies, organizational systems

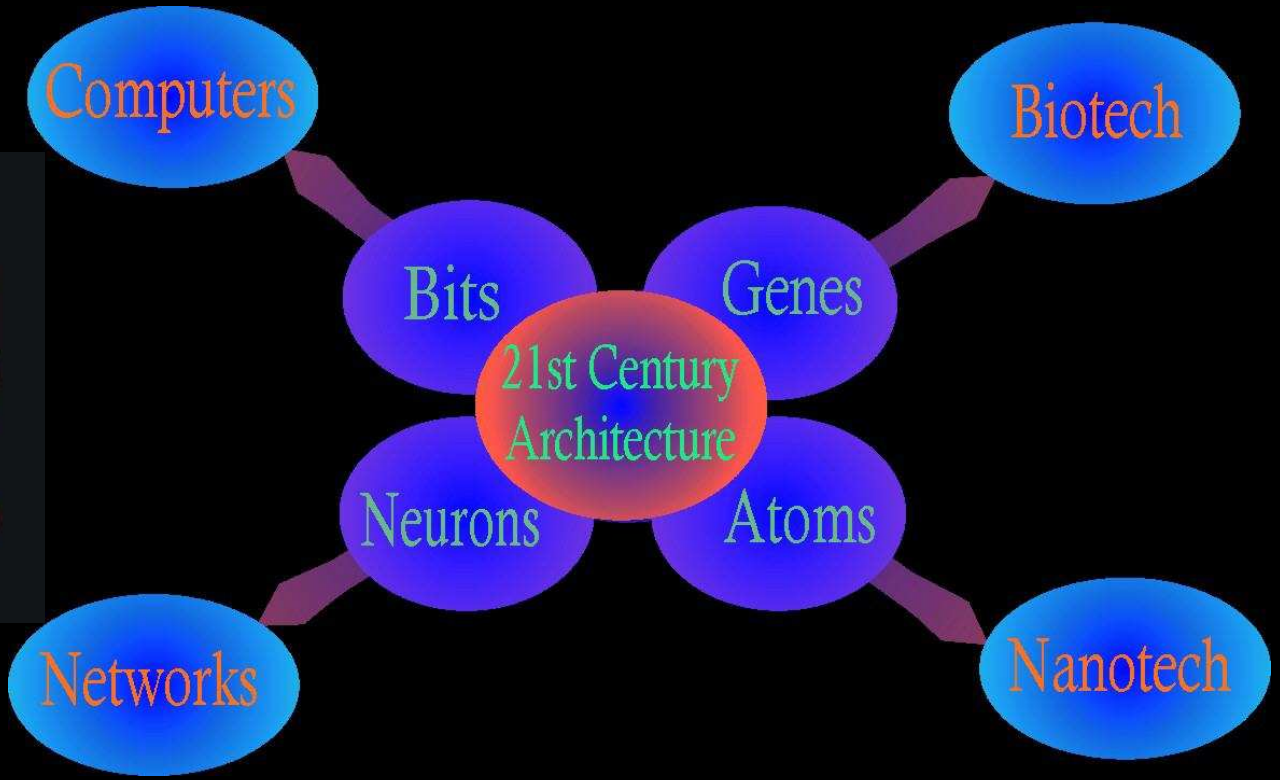


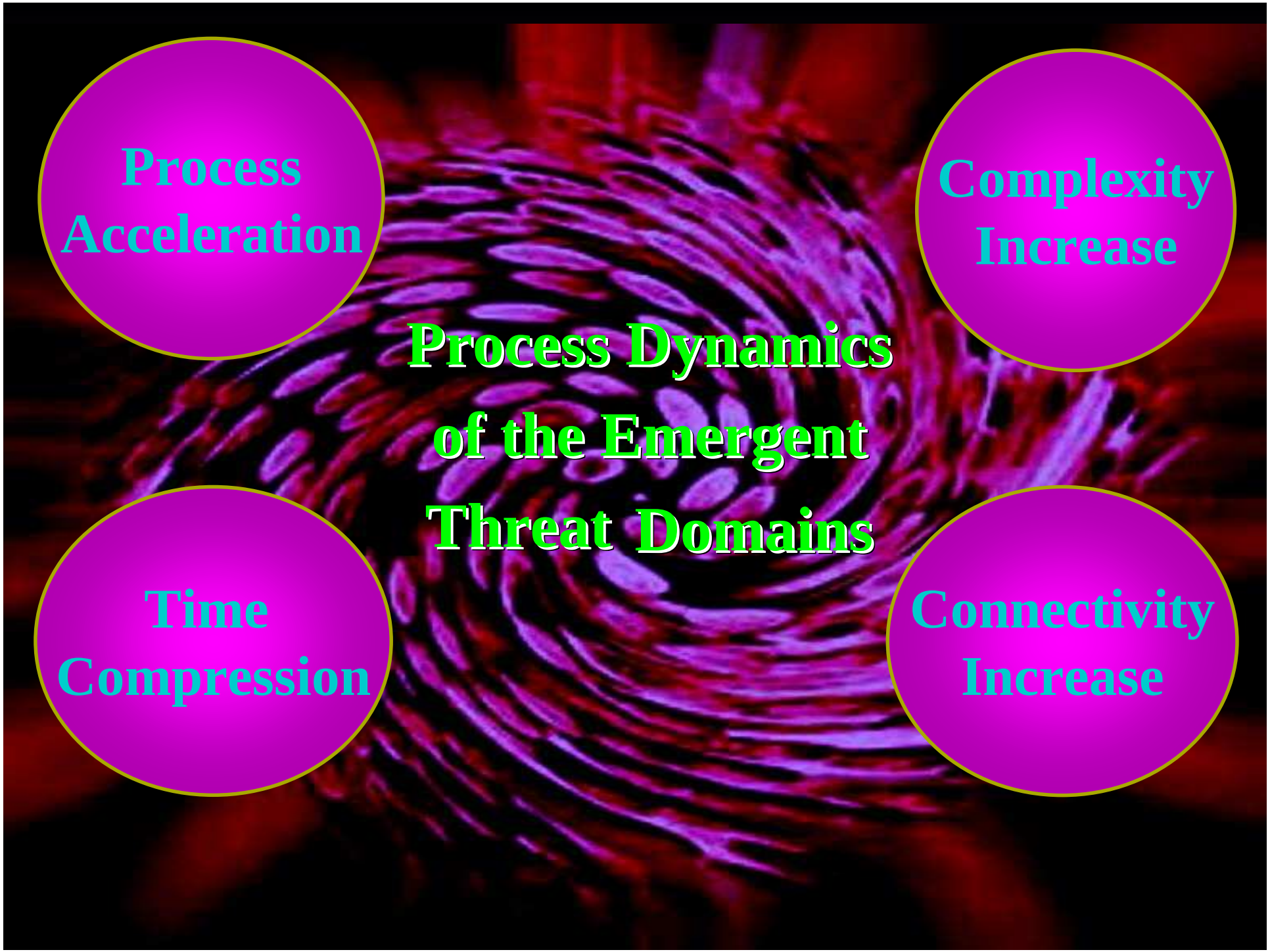


The enterprise of threat perception is entering a new era

- Emergent threat domains are an evolving architecture of interrelated disciplines, technologies, organizational systems



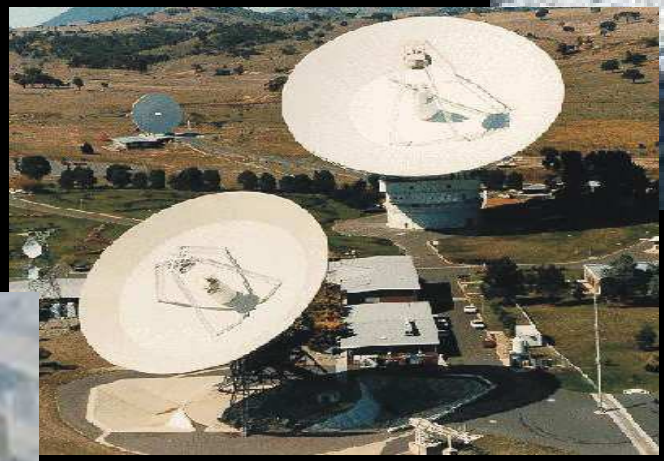



Process Acceleration
Complexity Increase
Process Dynamics of the Emergent Threat Domains
Time Compression
Connectivity Increase

DARPA - Nanotechnology Development

"Traditional" areas of deployment:

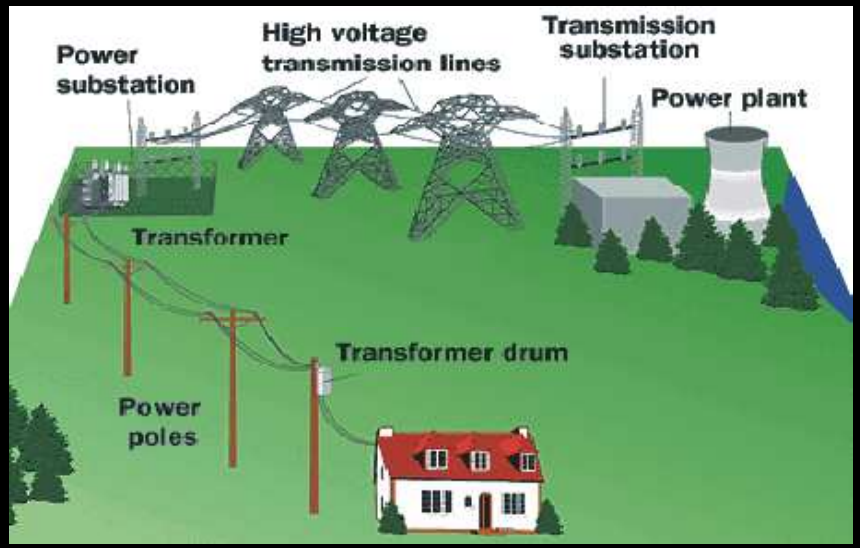
- Stealth
- Endurance
- Firepower
- Intelligence



DARPA - Nanotechnology Development

Emergent Domains of Deployment:

- Intelligent, autonomous process management
- Anticipatory, Adaptive, self healing
- System Sentience



DARPA - Primary Development Domains Enabled or Enhanced with applied Nanotechnology

NANOELECTRONICS/OPTOELECTRONICS/MAGNETICS

- Network Centric Warfare
- Information Warfare
- Uninhabited Combat Vehicles
- Automation/Robotics for Reduced Manning
- Effective training through virtual reality
- Digital signal processing and LPI

NANOMATERIALS "BY DESIGN"

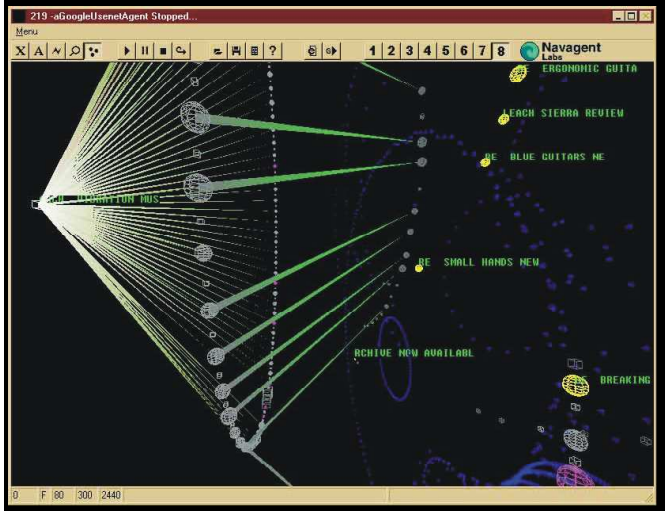
- High Performance, Affordable Materials
- Multifunction, Adaptive (Smart) Materials
- Reduced Maintenance - halt nanoscale failure initiation

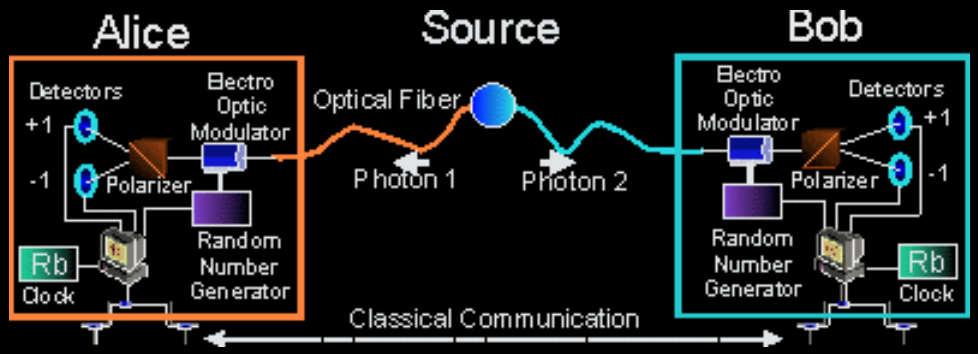
BIONANOTECHNOLOGY - WARFIGHTER PROTECTION

- Chemical/Biological Agent detection/destruction
- Human Performance/Health Monitor/Prophylaxis

Nanotechnology in Defense
Strategic Imperatives in the "Virtual" Battlefield

- Self healing network ecologies – Biological Metaphors in Computing
- Recon bots, defense bots, anticipatory autonomous "hunter/killer" bots
- Artificial life / immune systems / intelligences
- Next Generation Reconfigurable Computing Architectures
- Defensive Banking / Financial Transaction Systems, e-Currency
- Quantum encryption / quantum information networks

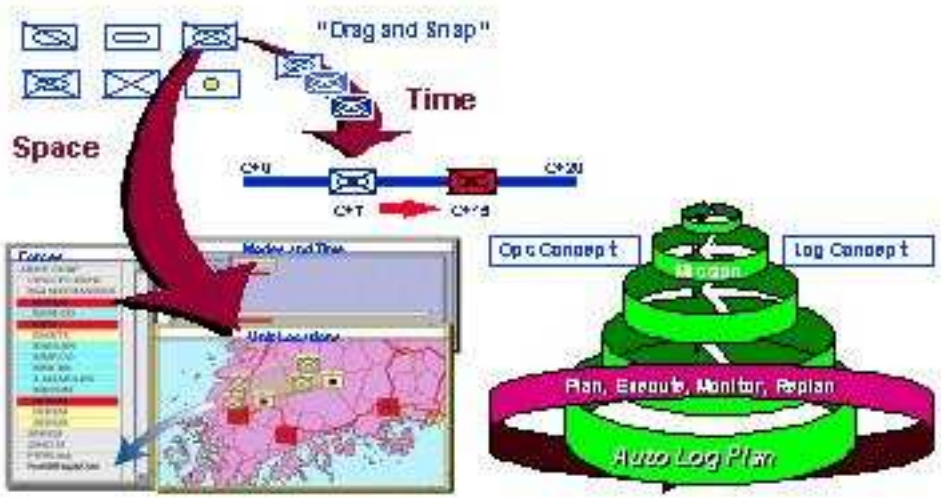




Grand Challenge

ISO

Automated Logistics Plan Creation

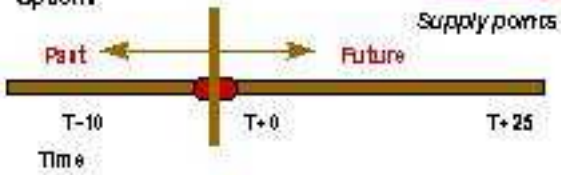


Real-time Logistics Situation Assessment

Advanced Situation Assessment

- Visualization and Data Manipulation Environments
- Automatic, Dynamic Graph Creation
- Automatic Explanations With Coordinated Text and Graphics
- Automatic Invocation of Models and Simulations
- Plan Sentinels and Automated Replan Options

Supply points (cylinders), units (bars), & warfocus



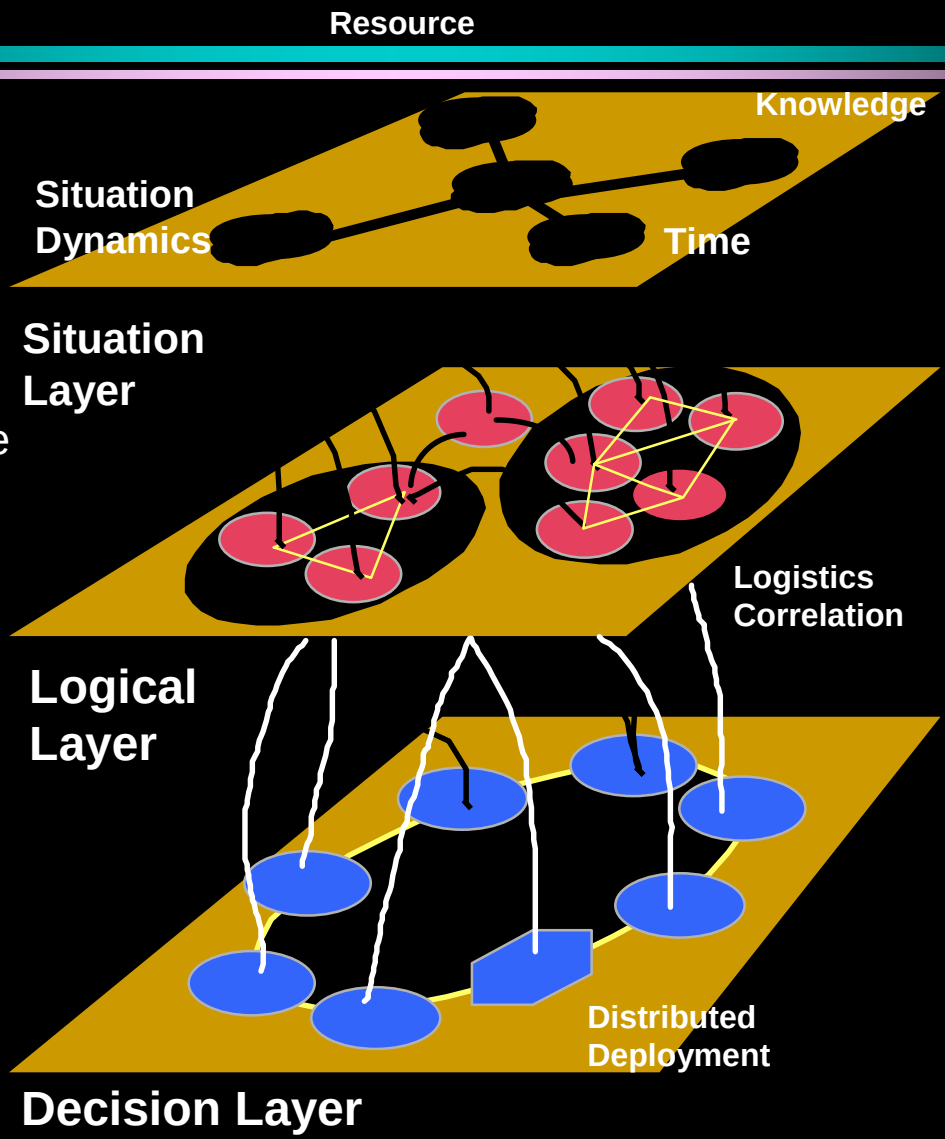
End-to-End Movement Control

- Continuous Monitoring & Sampling
- Automated Adjustments
- Replanning Triggered – Understanding Deviations – Weigh Alternative Solutions
- Recommend Adaptive Control Methods

End-to-End Rapid Supply

- Parts Rqd via Advanced Diagnostics
- Device provides Real-time Status of Local Parts Availability
- Real-time Request to DMAS and Immediate Audio Feedback
- Rapid Supply from Commercial Source to Front Line
- Prioritized and Optimized Shipment
- Order-ship-time in Hours, Not Days
- Interactive Voice Query

Autonomous Enhancement Enabled Decision Rendering Process Map



IT Resources & Infrastructure
- Data / Knowledge Services
- Process Integration
- Workflow Management

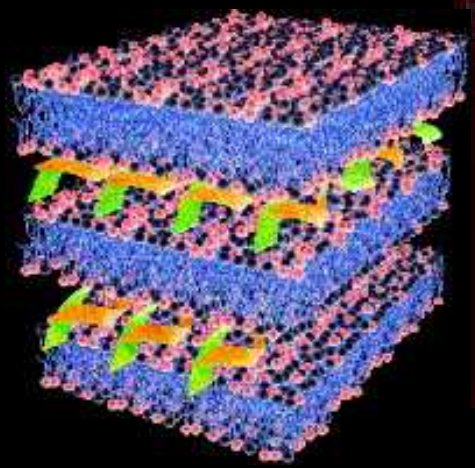
FUNCTIONAL MAP - Conceptual partitioning of functional domains

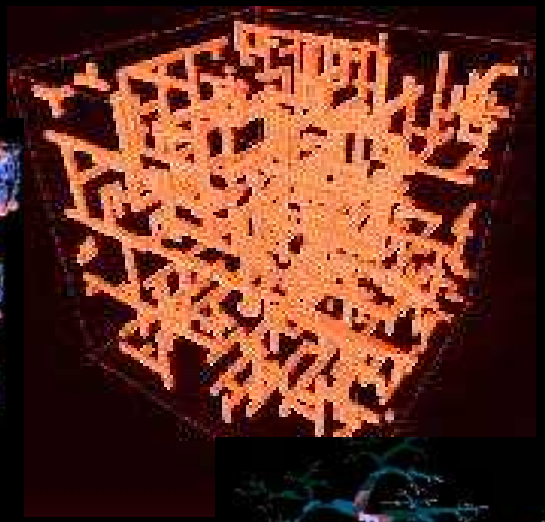
LOGICAL MAP - Functional partitions are separated into localized “process domains”

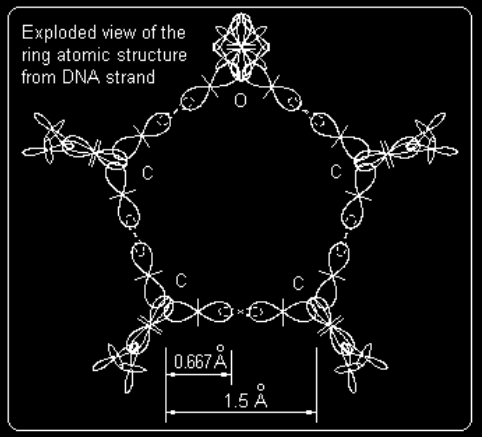
DEPLOYMENT MAP - Process domains are mapped onto distributed deployment sectors.

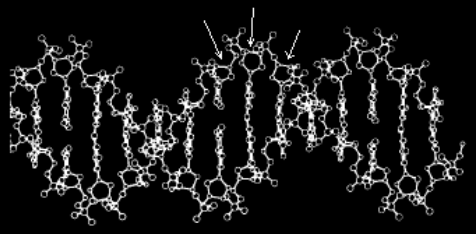
Biological Mimicry

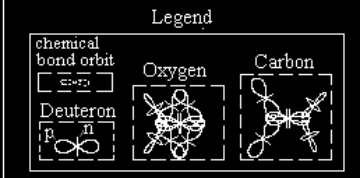
- Biological Metaphors in Computing
- Biologically Inspired Mechanical Systems
- Biologically Inspired Self Assembly / Self Organization
- Artificial Life Instigated forms of Intelligence, Autonomy









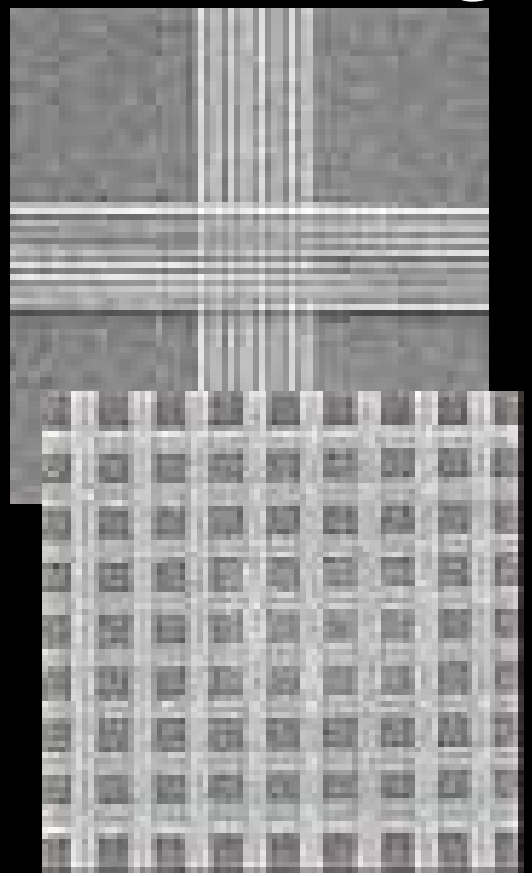


Nanoelectronics / Molectronics -

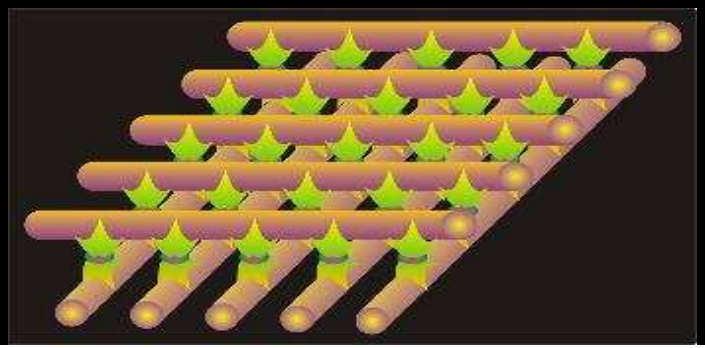
Reconfigurable logic arrays, memory fabrics

FPGA + Biological / Evolutionary Computation

= Self Healing Autonomous System Architecture



- FPGA Architecture is asyncrhonous (not confined by Finn's Law
- Extremely fault tolerant
- Functional identity is in the software, not the hardware
- Well suited for contiguous fabrication processes



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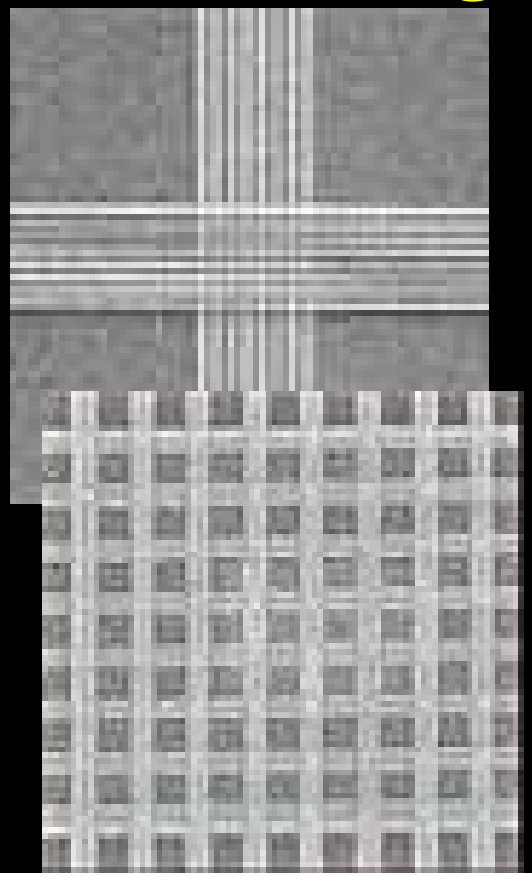

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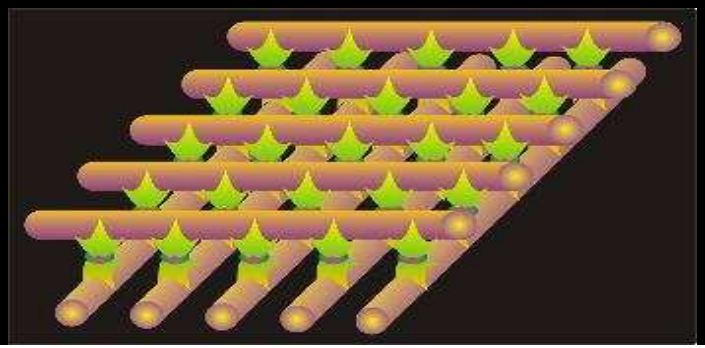
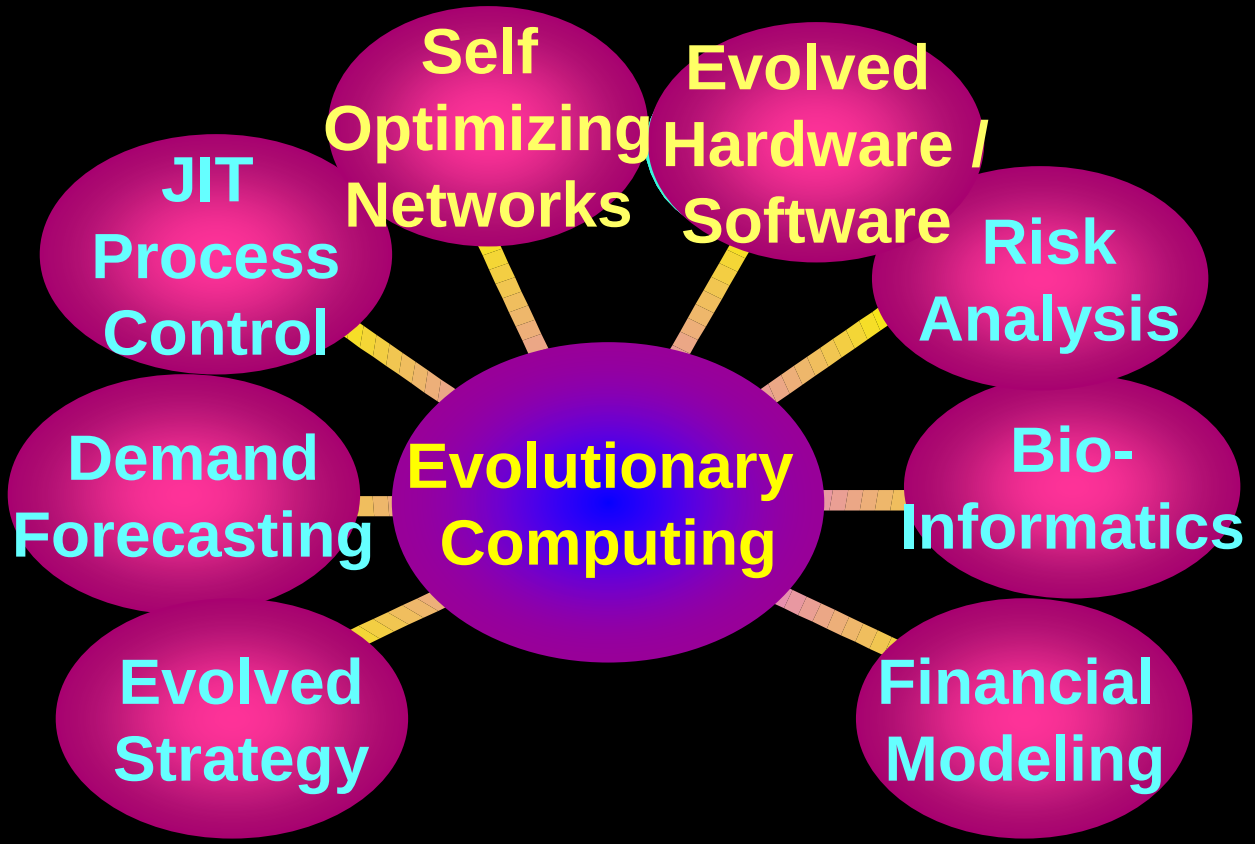


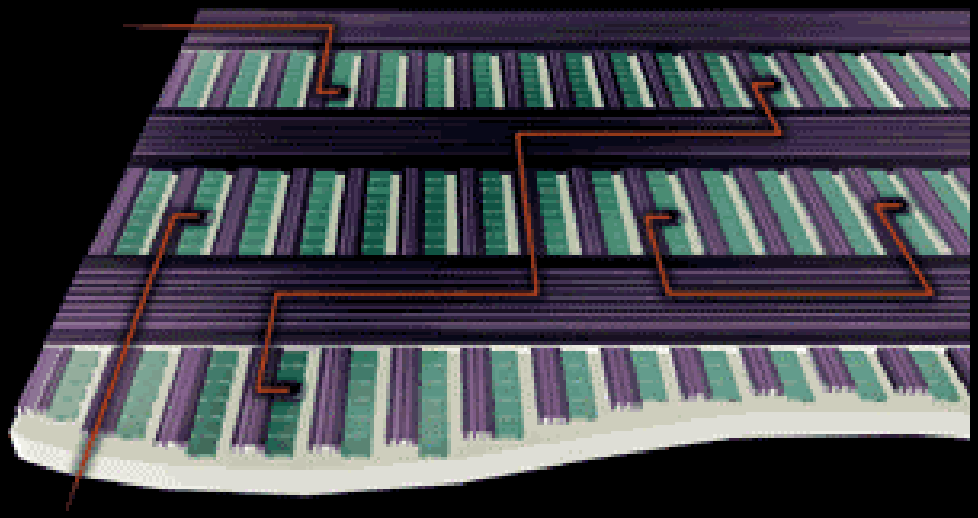
Convergence Node - Evolutionary Computing

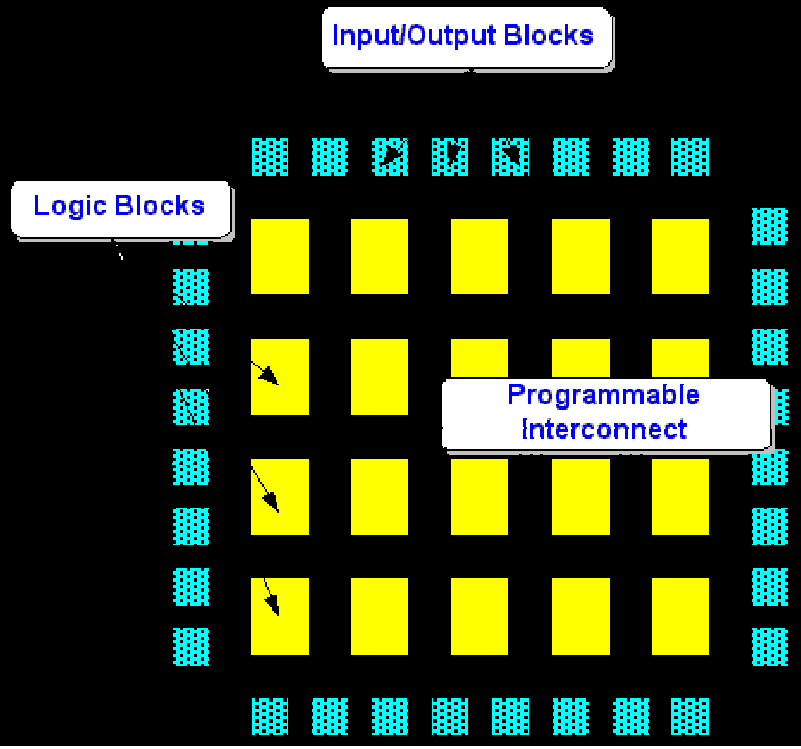
- Genetic Algorithms
- Self Evolving Systems
- Autonomous Functionalities



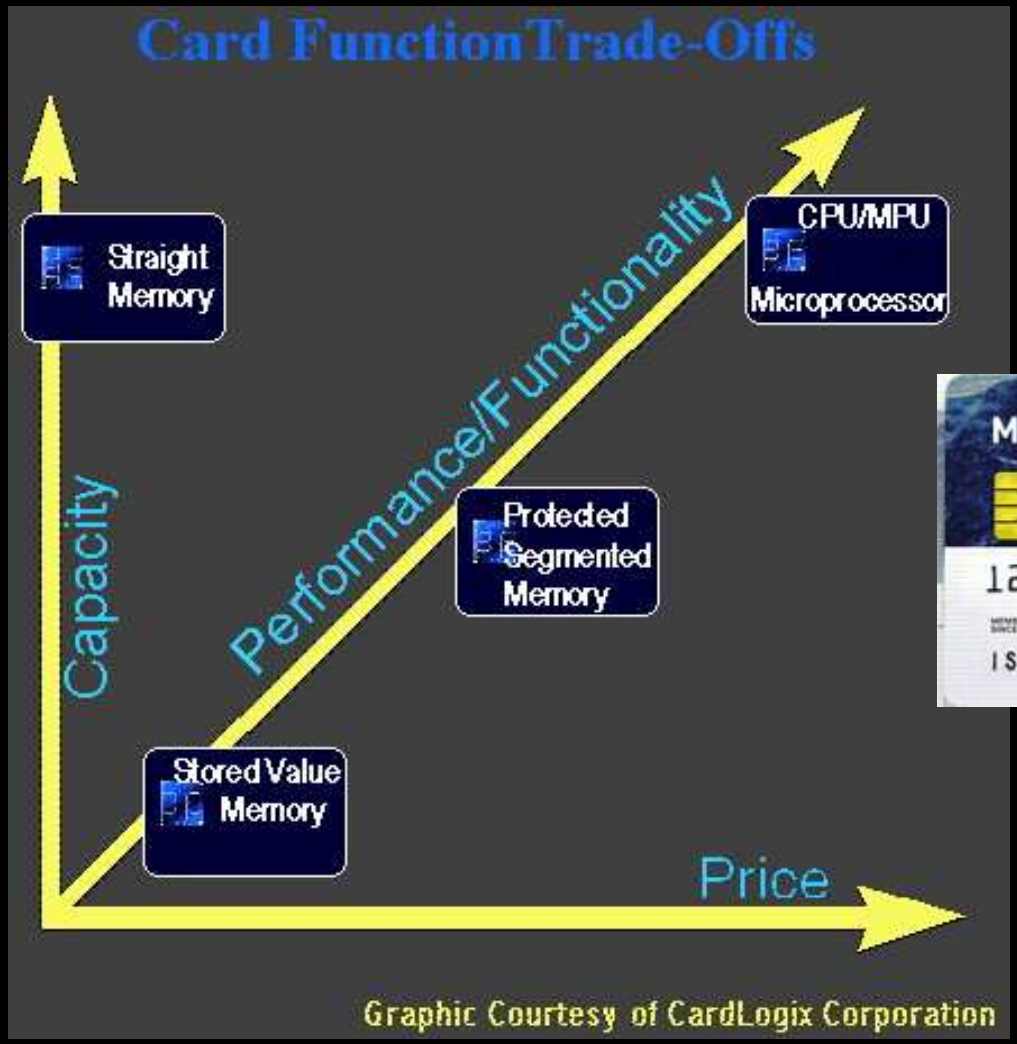
Reconfigurable Computing Architectures – Gateway to Unique Computational Resources

- Extreme Parallelism – speed not the real issue
- Enables evolutionary and biological metaphors in computing
- Extreme process morphology



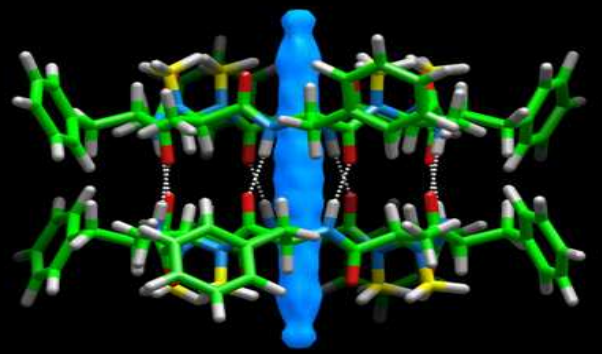


Embedded Intelligence – Protected Process Transaction Portals



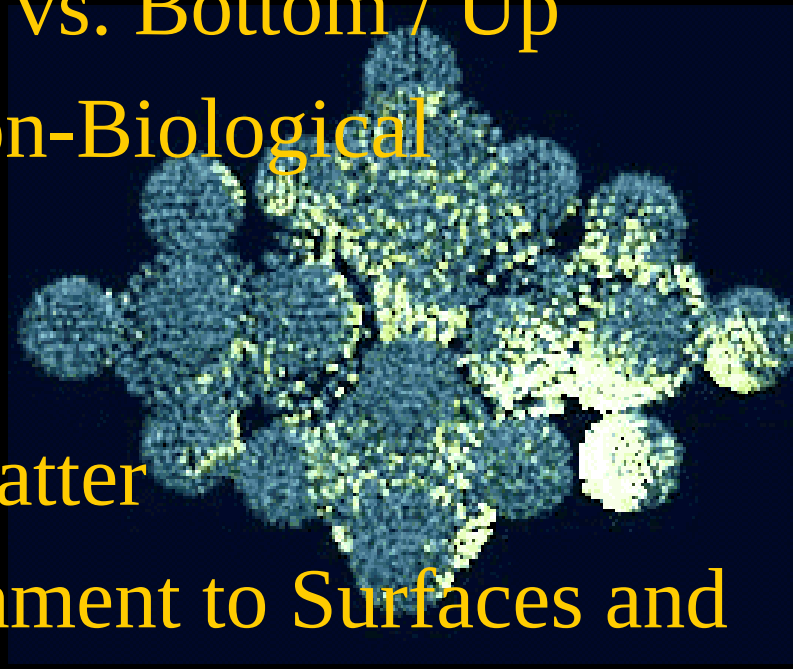
Example Nanofabrication Materials and Systems Enabled by Biological Materials and Processes

- "Printable" chemistries on diverse materials sensors, energy conversion, circuitry, displays
- SAM (Self Assembled Monolayers) reconfigurable logic arrays, memory fabrics
- Integrated 2D and 3D photonic and electronic structures
- Genetic "magnification" of biological materials with electronic and photonic properties
- Living organisms as biofoundries and nanomechanical systems

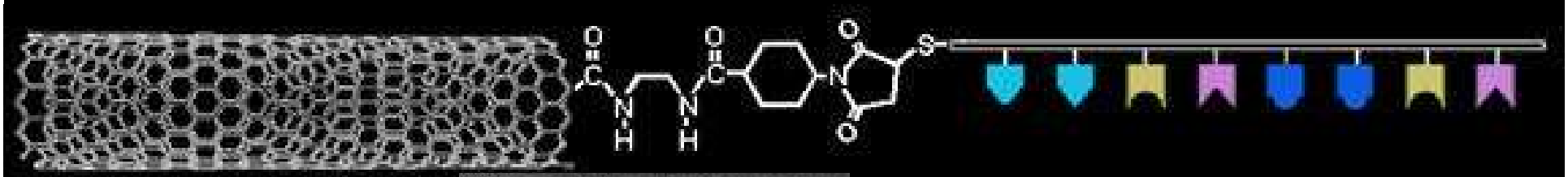


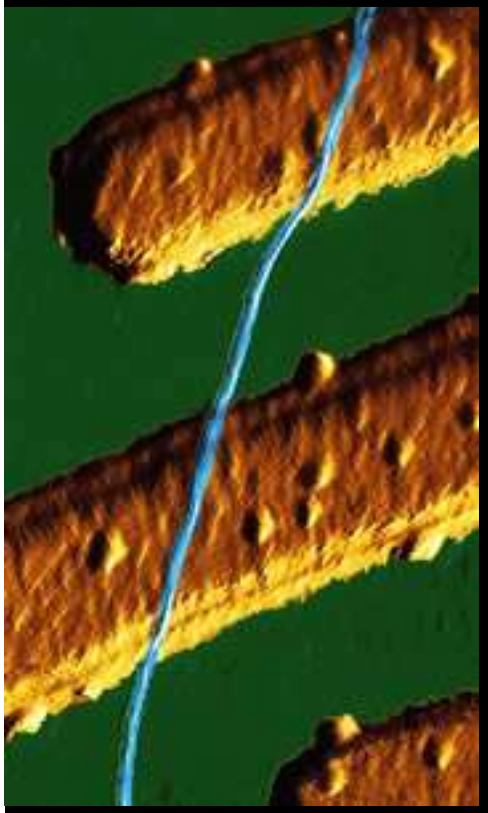
Example Enabling Development Paths

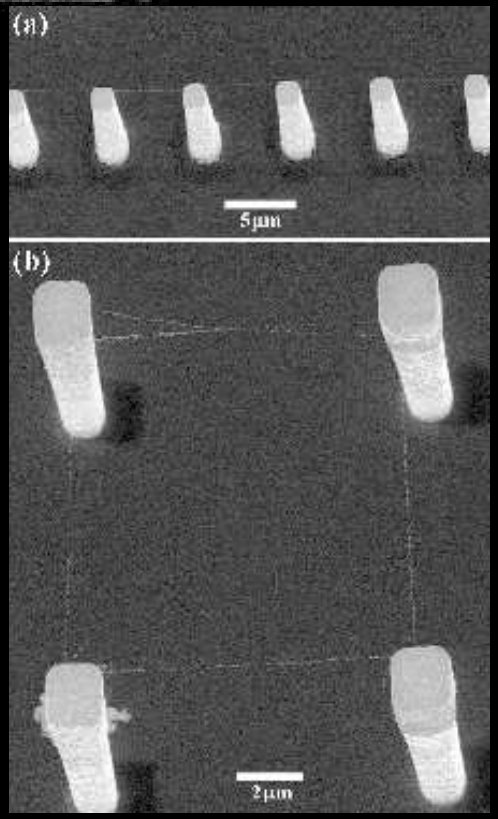
- Enhance “Friendliness” to Novel Materials in “Traditional” Micro-litho Fab Facilities
- Not Necessarily Top / Down vs. Bottom / Up
- Integrated Biological and Non-Biological NanoStructures
- Supra-molecular Synthesis
- Techniques for Patterning Matter
- Chemical Handles for Attachment to Surfaces and Scaffolds

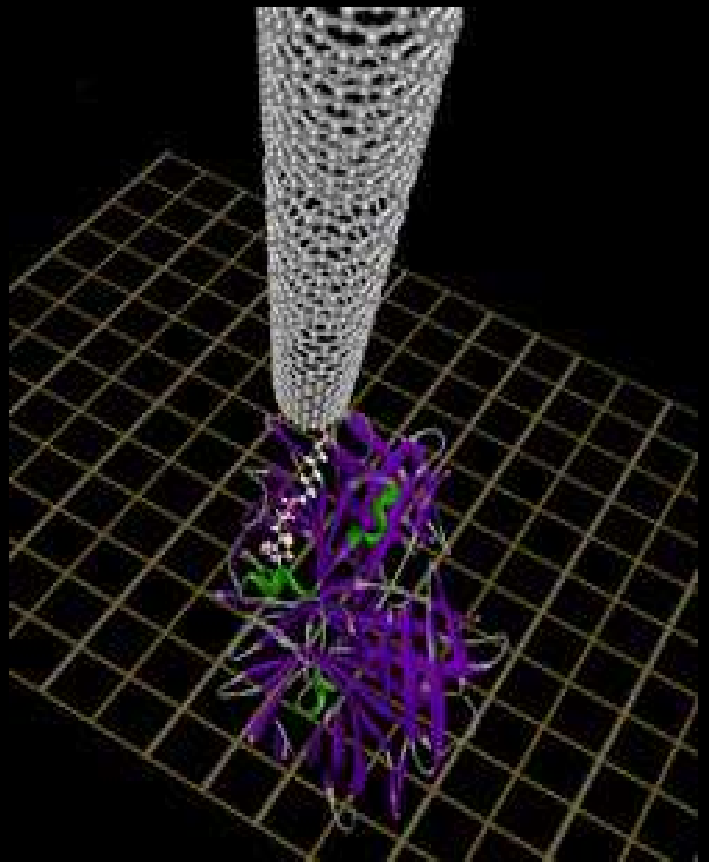


Example – Carbon Nanotubes Integrated with Organic Molecules / Biological Materials

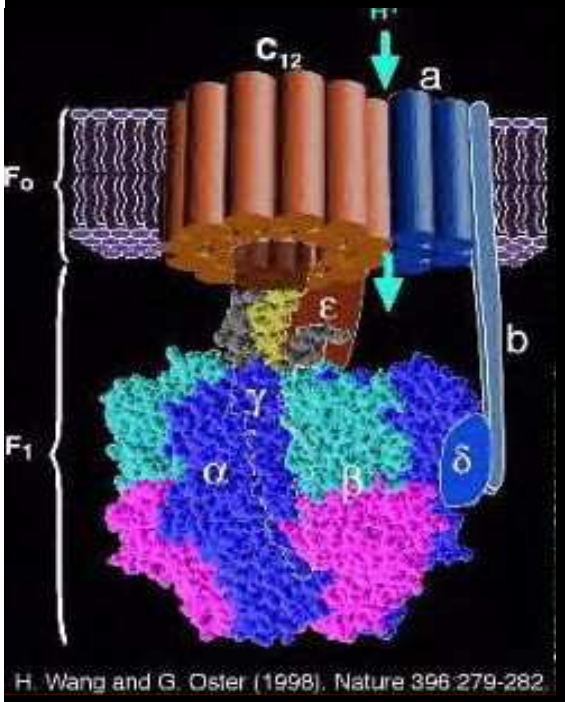




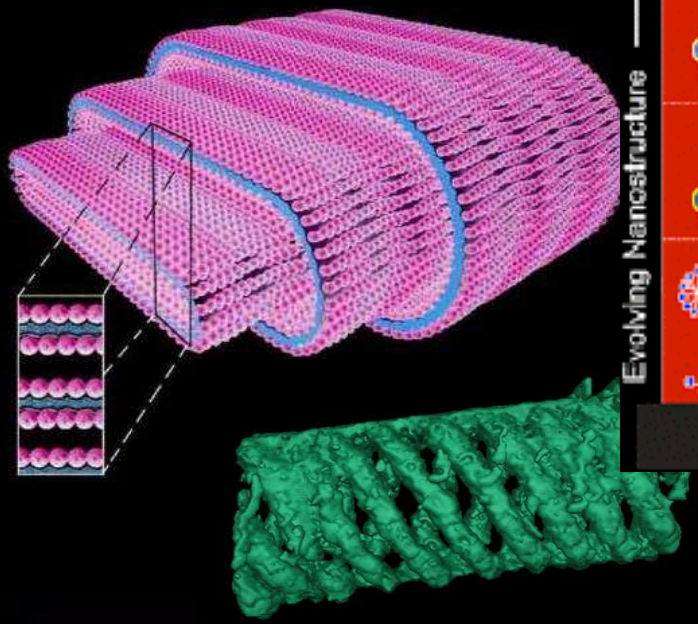


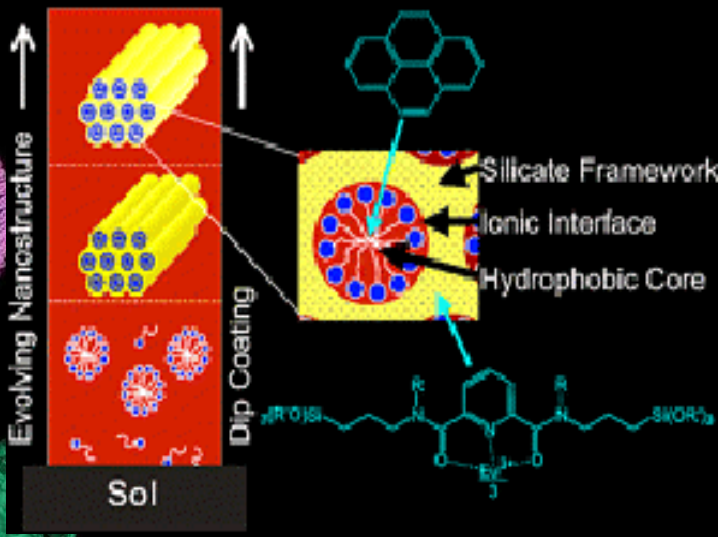


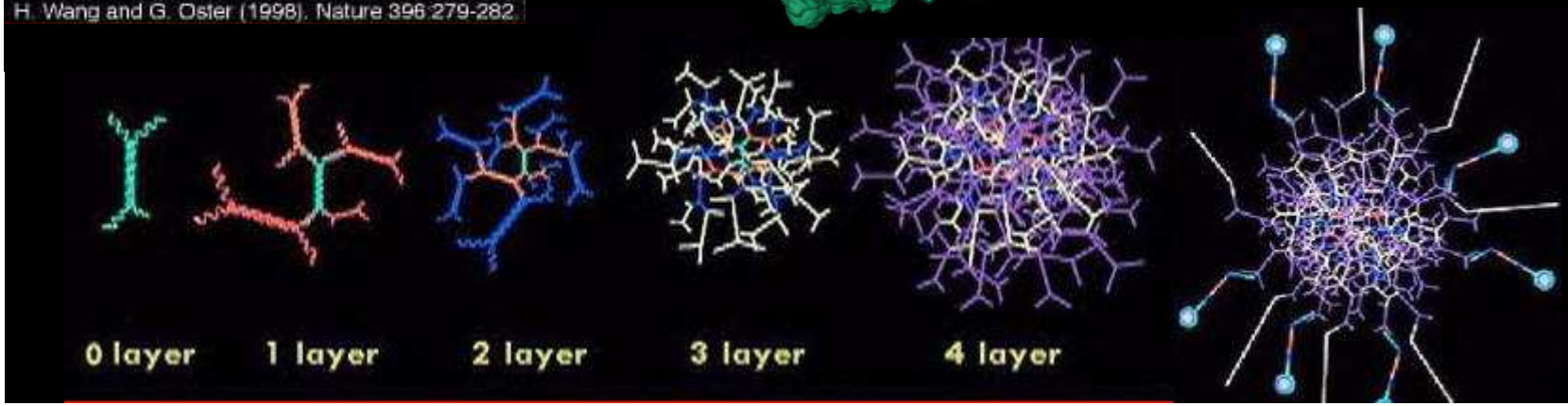
Molecules as Tools – Not Just Endproducts



H. Wang and G. Oster (1998). Nature 396 279-282

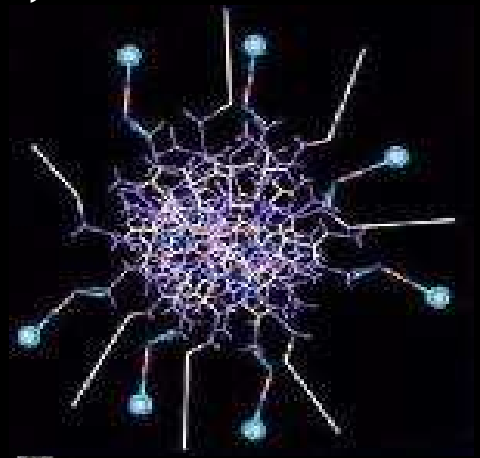


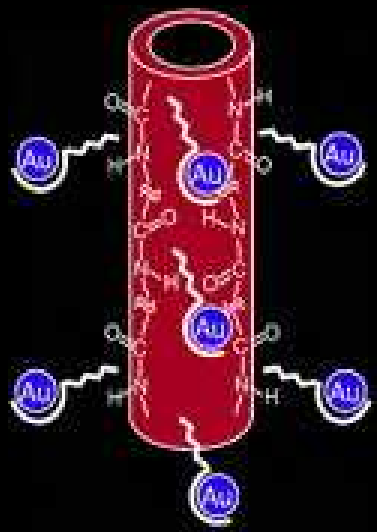


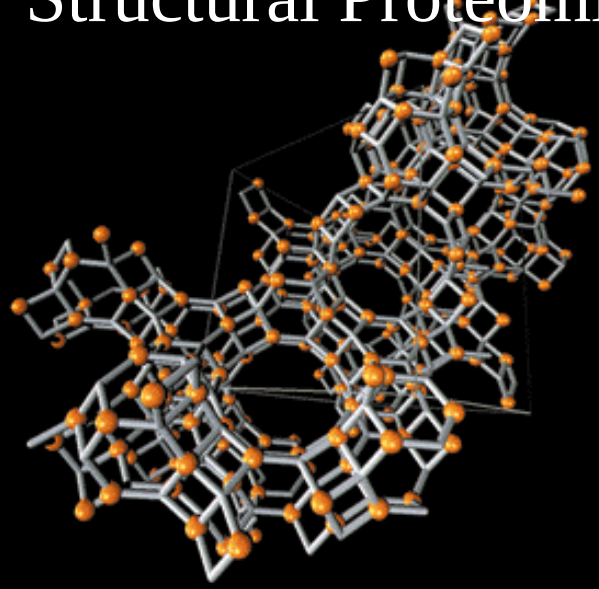


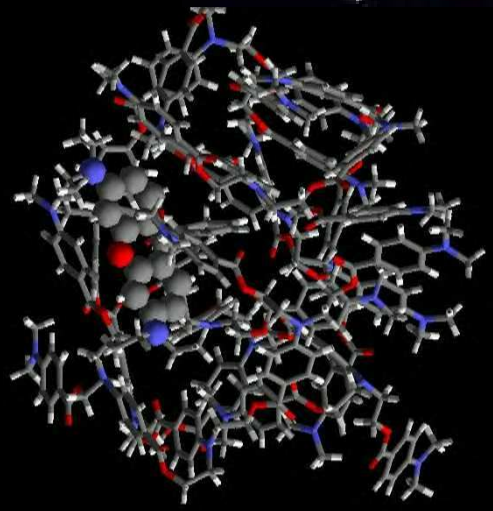
Molecular Components

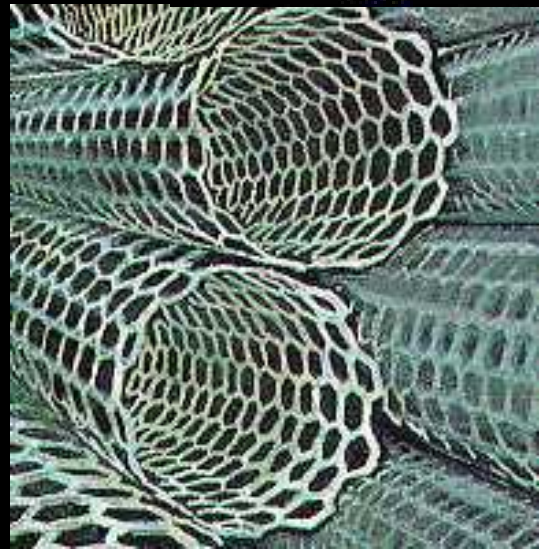
- Nanotubes – Carbon, Polymer, various materials
- Dendrimers
- Zeolites
- Organo-metallics
- Structural Proteomics





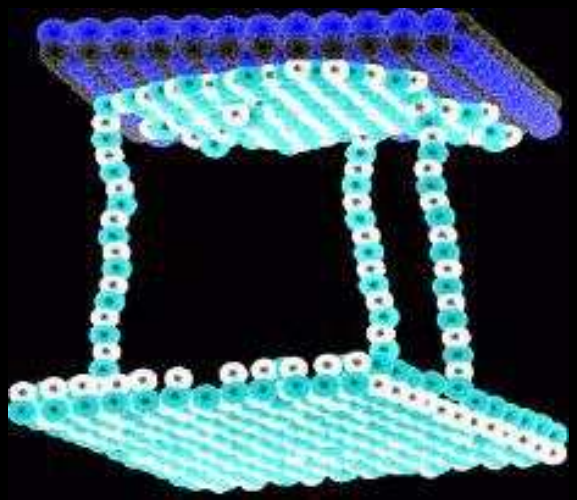


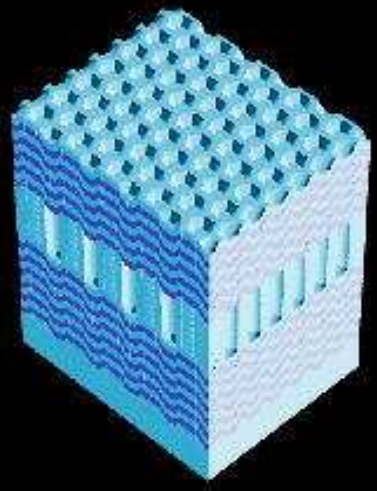


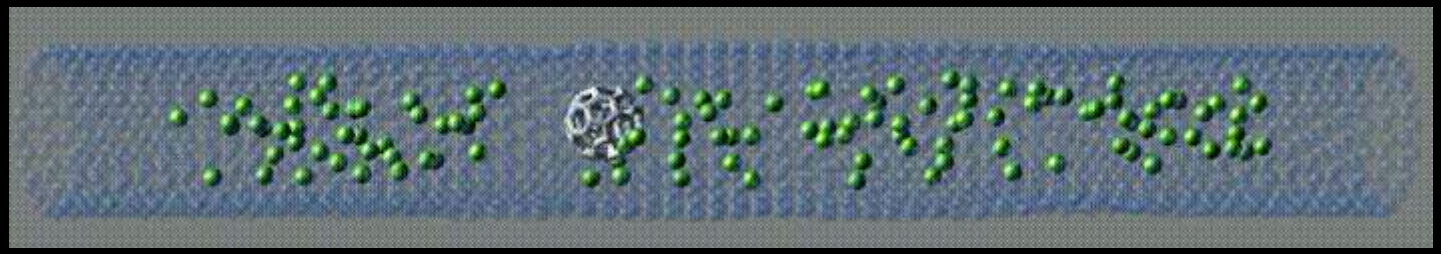


Complimentary Chemistries in Molecular Components

- Integration of organic and in-organic dopants with carbon nanotubes, dendrimers, various molecular structures

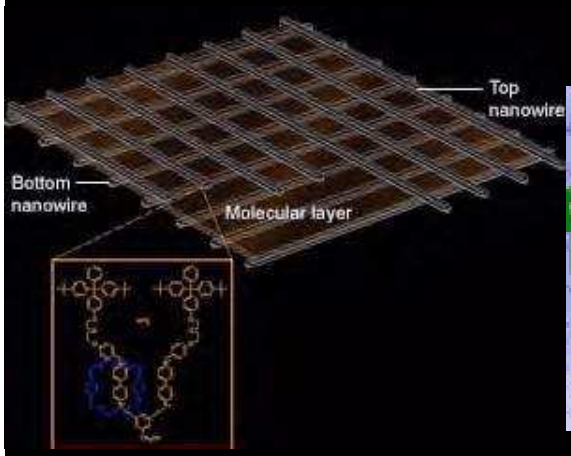


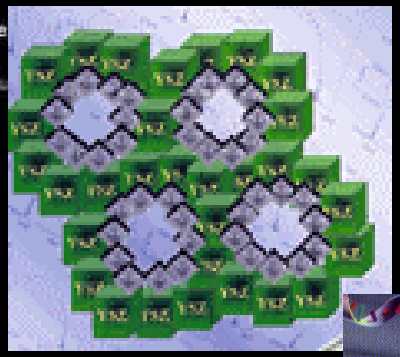


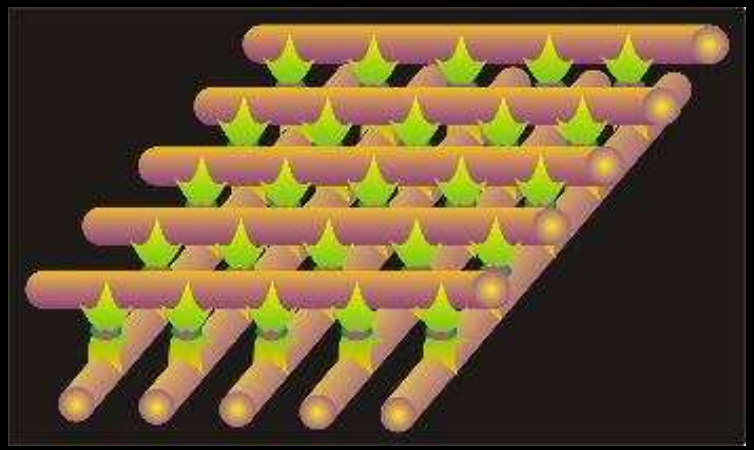


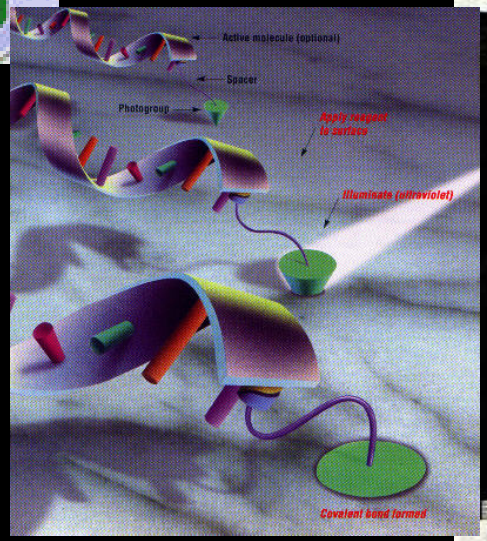
The goal is not just “little things”, but system integration

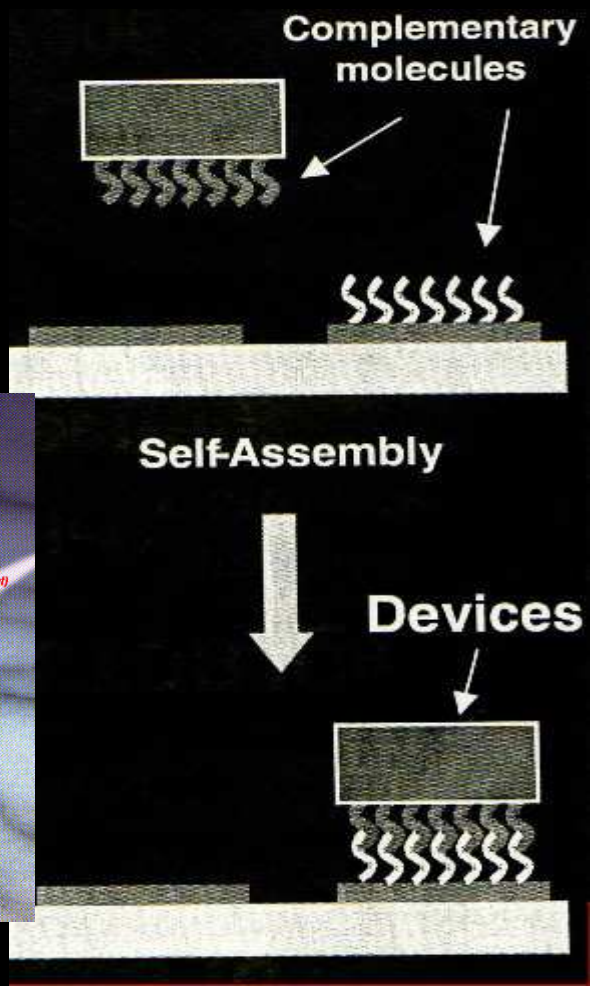
- Self Assembly > System Integration





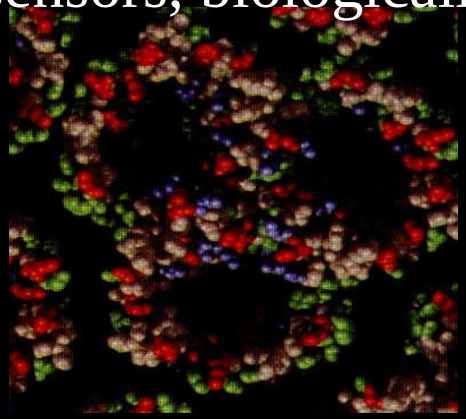




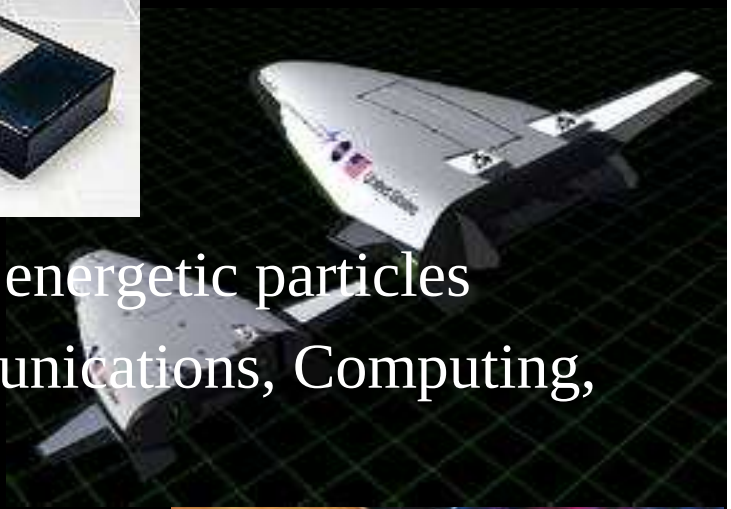


Army

- Interface/Surface Physics, Surface/Interface Chemistry
- Molecular Machines
- Quantum Information Physics
- Physical Behavior of Nanomaterials
- Polymer Nanostructures
- Integrated Systems Development
- Biopathogen sensors, biologically aware materials



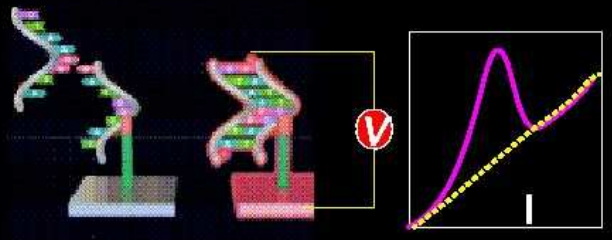
Air Force



- Micro / Nano Satellites
- Organic Nanostructures
- Aerospace Situational Awareness Sensors, energetic particles
- Nanoscale Integrated Electronics in Communications, Computing, Distributed NanoSensors
- NanoPhotonics, Quantum Computing
- Nanostructured Materials in Explosives, Propulsion Systems
- Zero time-of-flight Weaponry, Beam Propulsion Systems

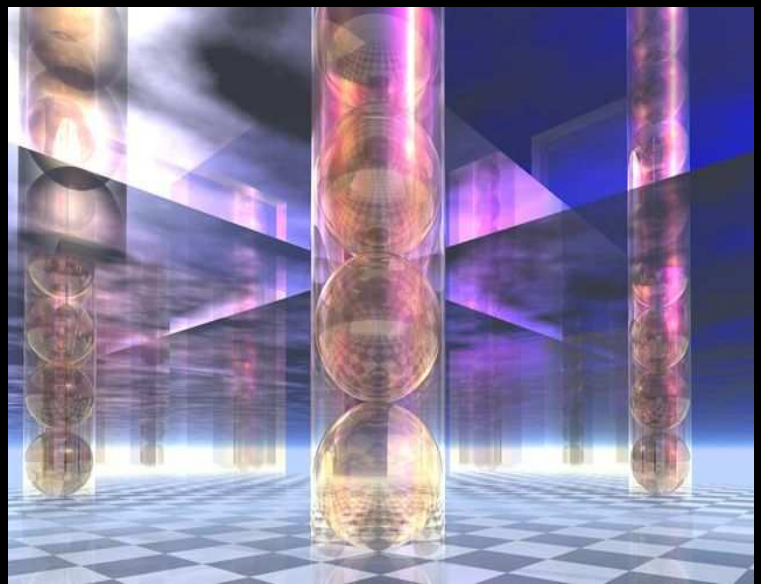
Navy

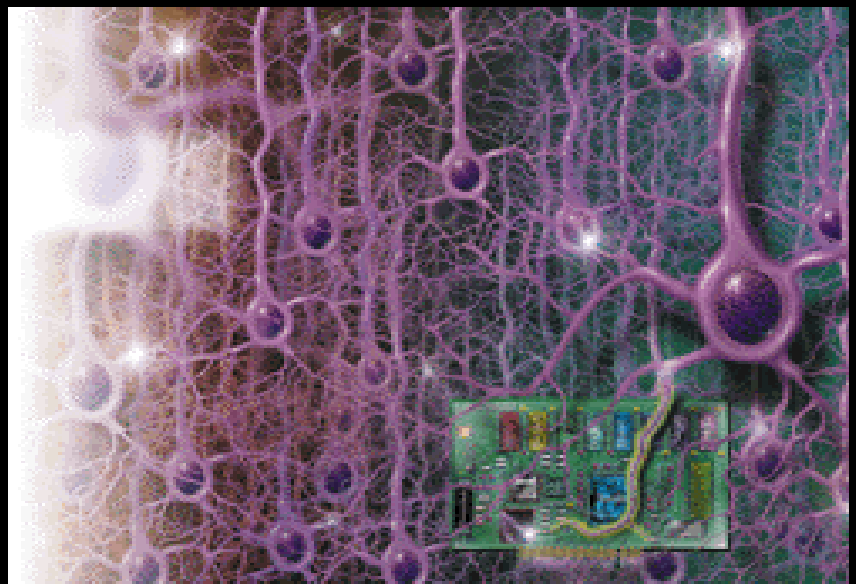
- Nanostructured materials in aerogels, batteries, fuel cells
- NanoOptical materials, photonics, organic LEDs
- Nanostructures in electrochemical systems
- Molecular electronics, nanotubules, NEMs, self assembly
- Enhanced Nanostructured Energetic Materials
- Zero time-of-flight Weaponry
- Spin electronics, quantum information processing



Emergent Strategic Defense Imperatives – Beyond just “Weapons & Soldiers”

- Knowledge complexity, scale, and velocity is exceeding human capacity for mission critical decision rendering compressed into ever shortening time scales.
- Development and deployment of complex metasystems of artificial autonomous entities, synthetic lifeforms, and emergent intelligences becomes the acceptable if not mission critical “culture norm” of the near future.
- Perceived boundaries of the “synthetic” and organic, the “virtual” and the real, are becoming enmeshed into an operational ecology continuum.





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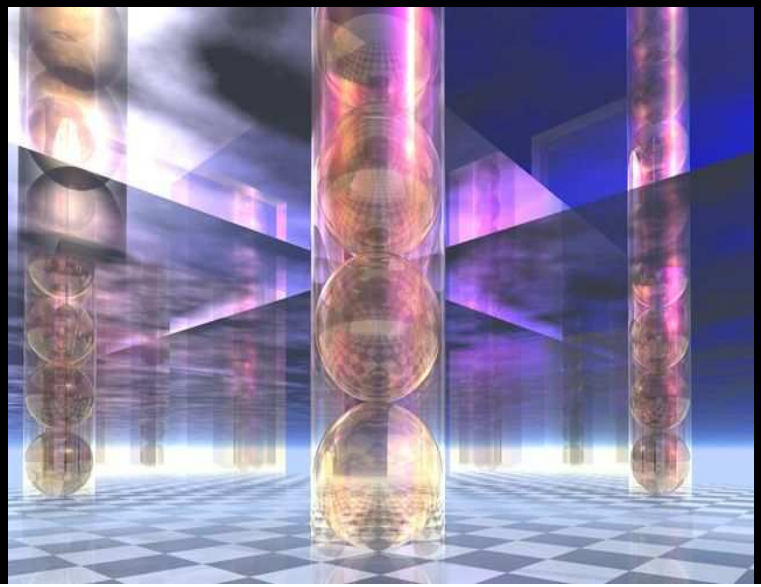

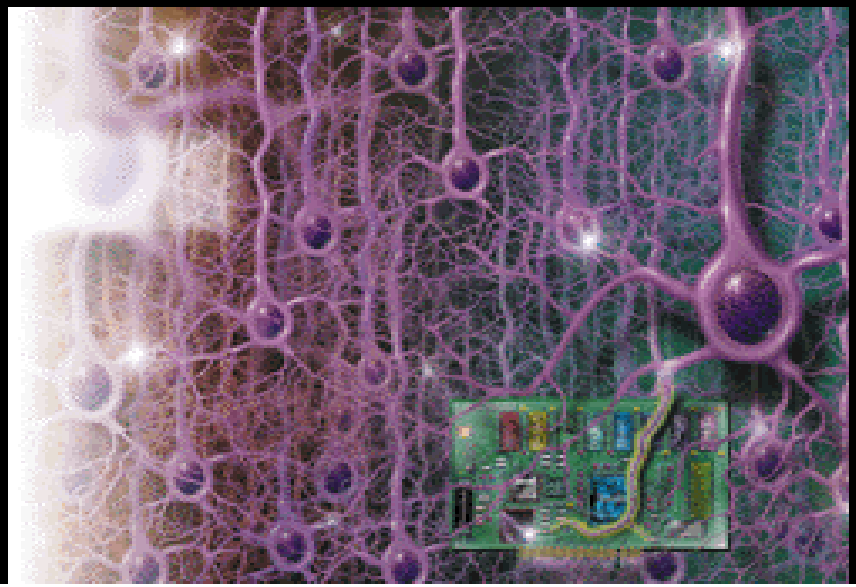

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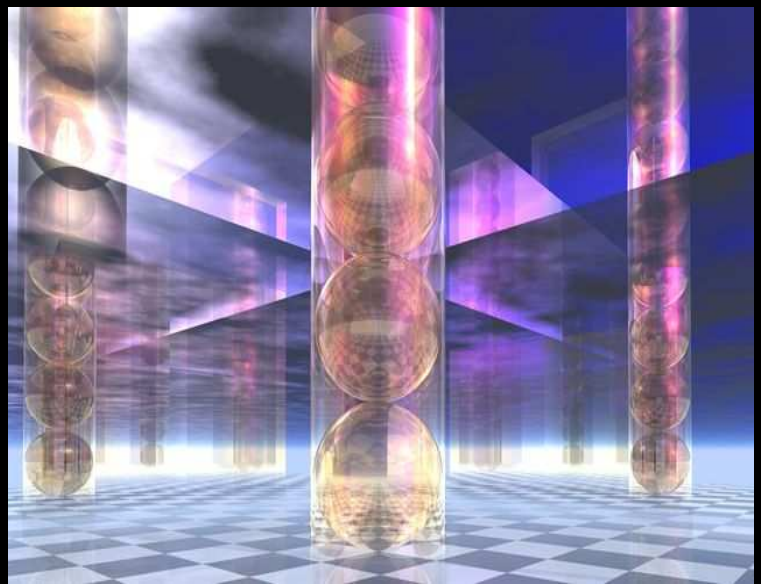

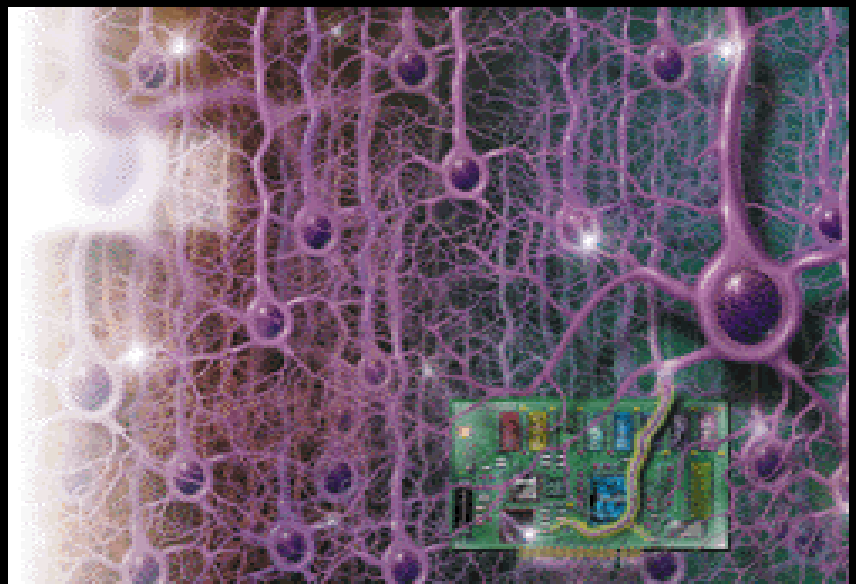

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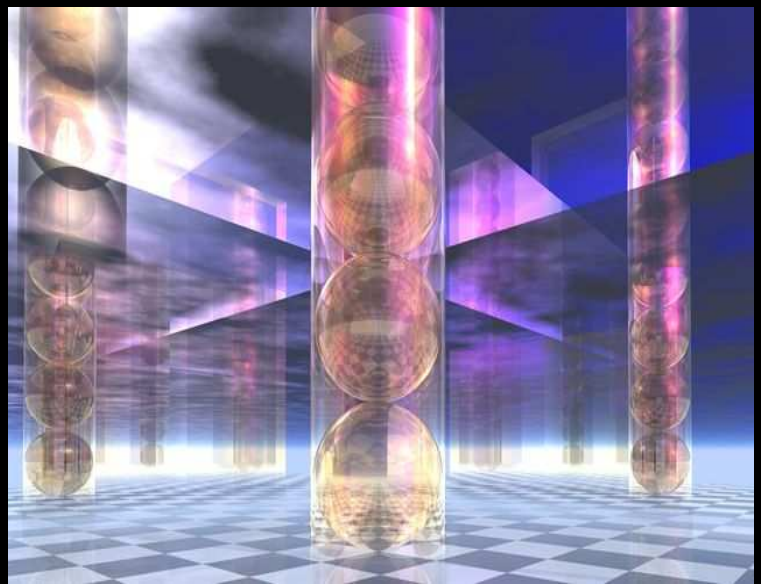

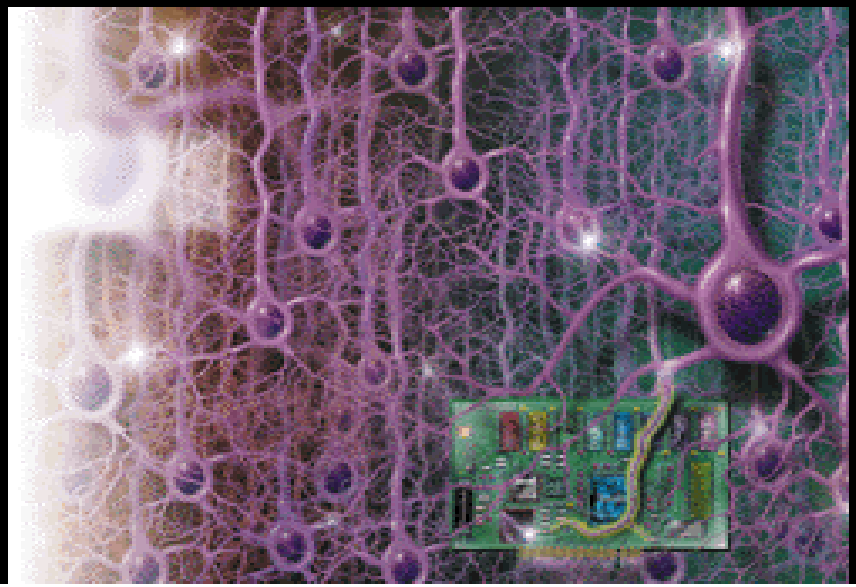

Nano Electronics & Photonics Forum

NanoElectronics & Photonics Forum Conference

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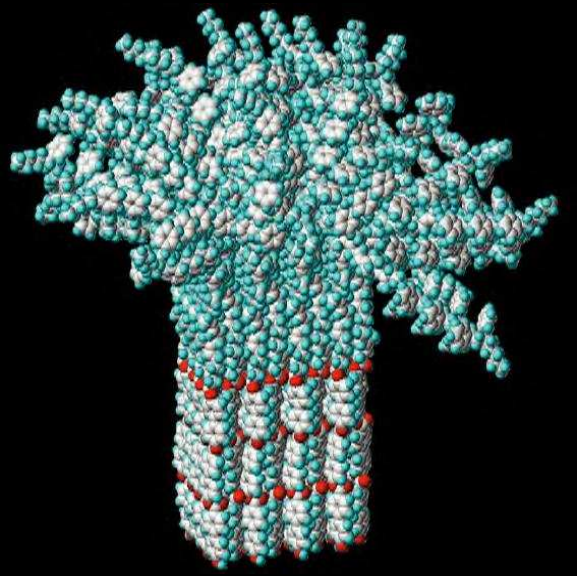

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a key competitive advantage in the next industria
revolution spawned by the convergence of interre
domains of applied nanotechnology in electronic
photonics.