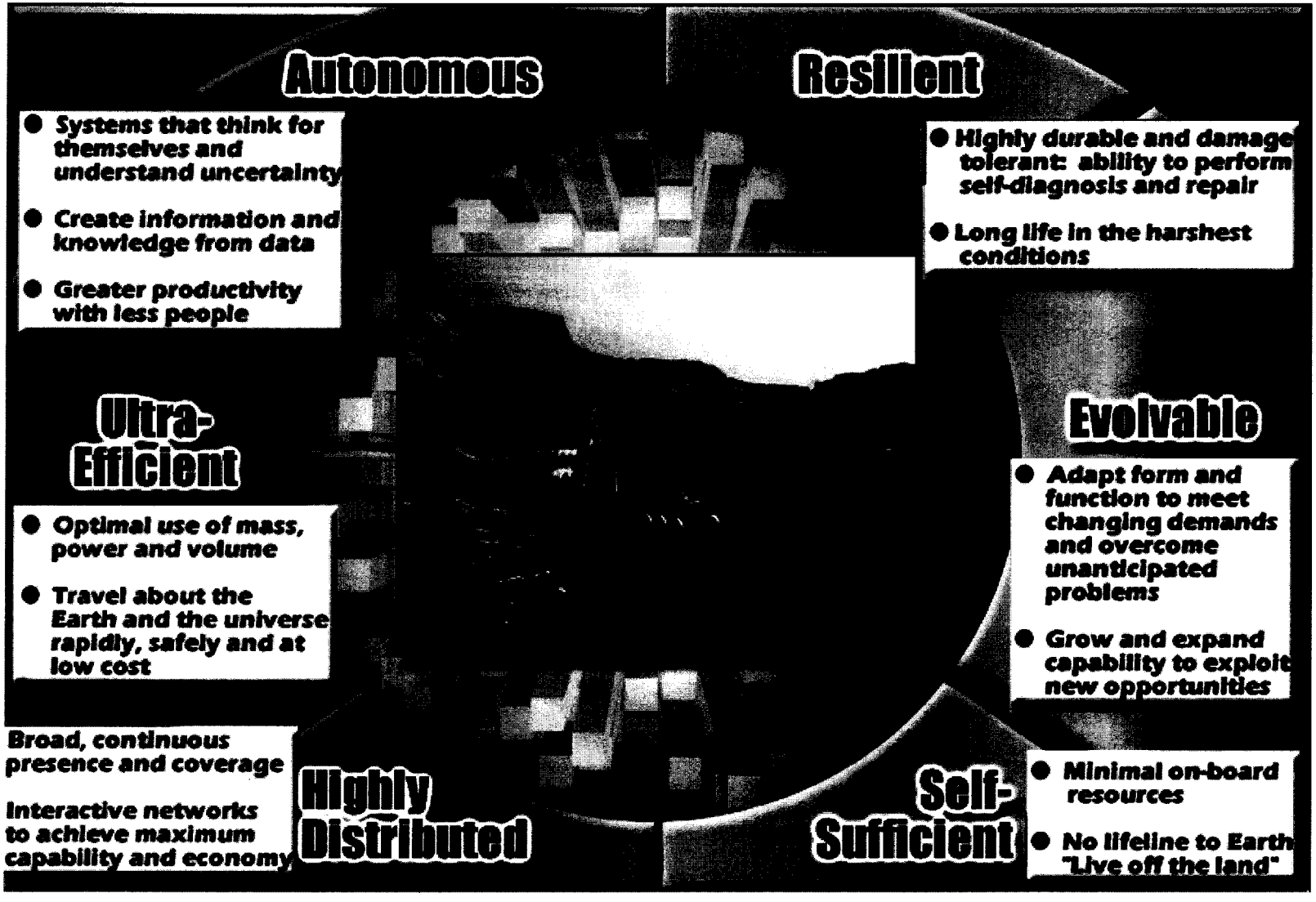
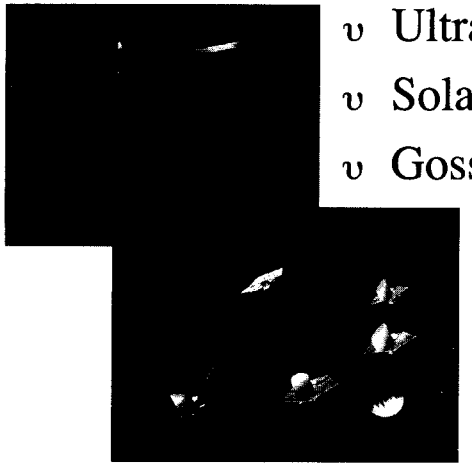
Goals for Future NASA Space Systems



NASA Challenges

Many of NASA's challenges are not achievable by extensions of current technology

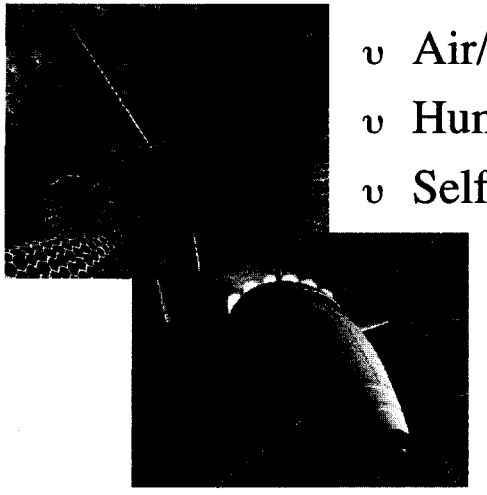
υ Size per Mass



- υ Ultra-large apertures
- υ Solar sails
- υ Gossamer spacecraft

Diameters > 25-50 m are not achievable by extension of current materials technologies

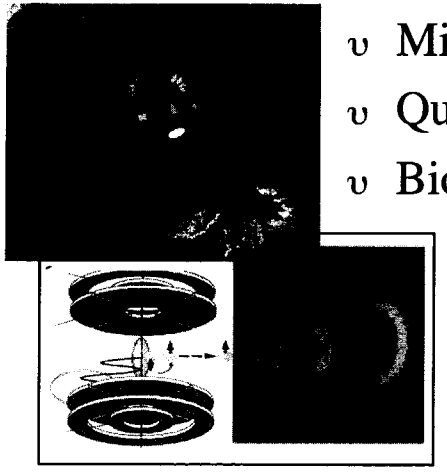
υ Strength per Mass



- υ Air/launch/space vehicles
- υ Human habitats in space
- υ Self-sensing systems

Factors of 10 - 100 are not achievable by current materials options

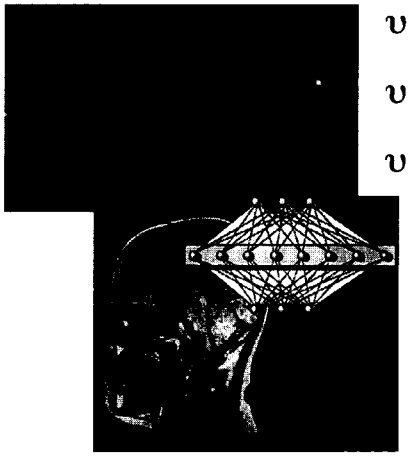
υ Capability per Mass & Power



- υ Microspacecraft
- υ Quantum-limited sensors
- υ Biochem lab-on-a-chip

Conventional device technologies cannot be pushed much farther

υ Intelligence per Mass & Power

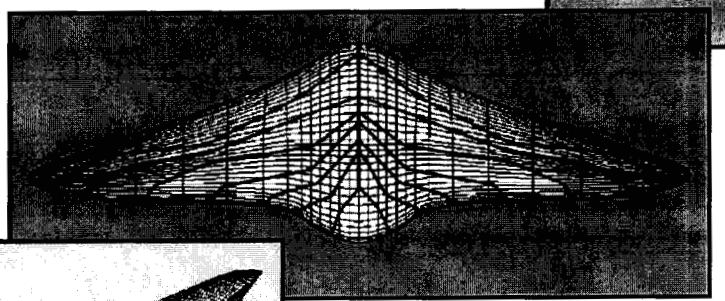


- υ Medical autonomy
- υ AI partners in space
- υ Evolvable space systems

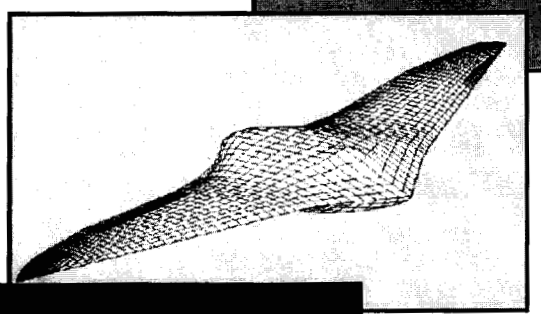
Current information processing technologies are approaching their limit, and cannot support truly autonomous space systems

Towards Advanced Aerospace Vehicles: "Nature's Way"

- Distributed self-assessment and repair
- Adaptive shape control
- Highly efficient propulsion
- Exploits Bio-Nano-Info technology revolution



Self-Healing Structure with "Central Nervous System"



Smart Structure with Active Flow Control

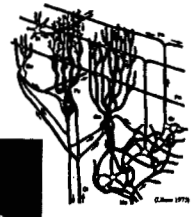
Modern Advanced Metal Aircraft

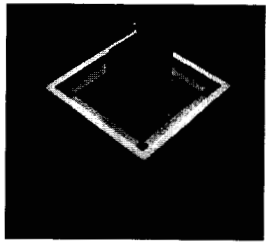
- Ultra Safe
- Whisper Quiet
- "Zero" Emissions
- Extreme Maneuverability
- High Survivability
- Ultra Low Fuel Burn

Advanced Technology Development

Time

Features of Biology



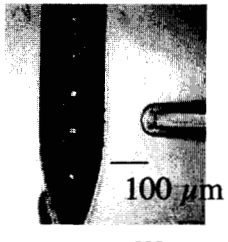


3-D neural net processor

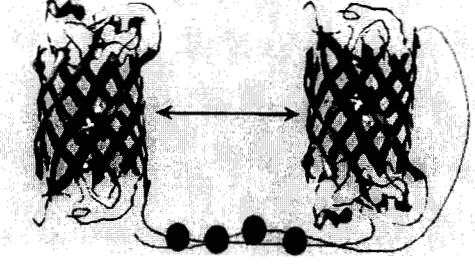
- Distributed and networked sensing and decision making
- Homeostasis via feedback (forward) control
- Information processing: Massively parallel, analogue and extremely low power consumption
- Capacity to adapt and evolve
- Fault tolerance through redundancy and architecture

Electronic Nose

Revolutionary & Evolvable computing



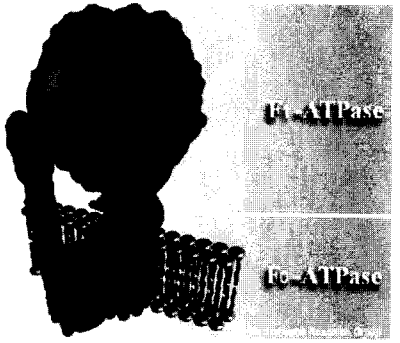
Neuron-silicon interfacing



Biomolecular sensors

NanoBioTechnology

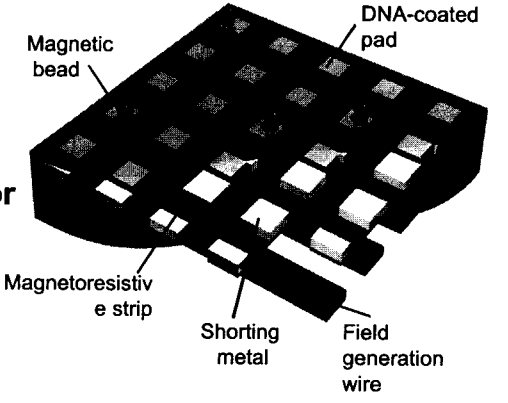
Chemistry/Physics of Biological Nanostructure



Molecular Motor (Montemagno, Cornell)

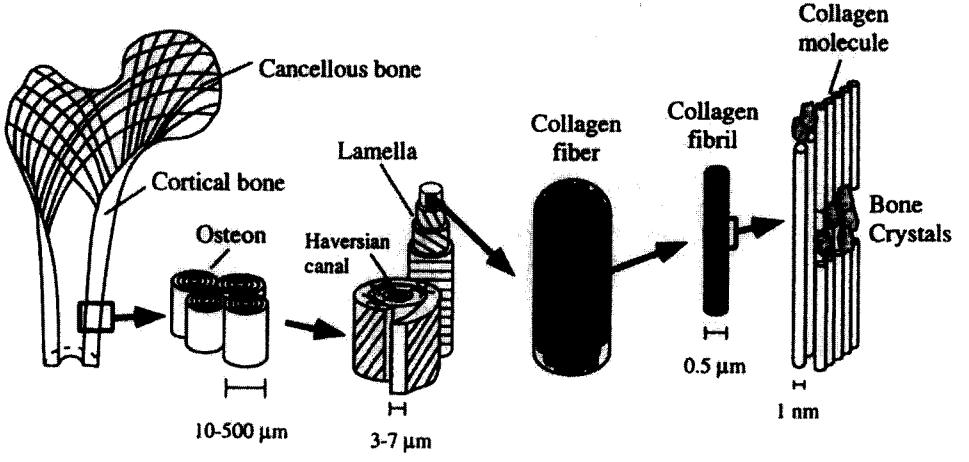
Earlier Detection and Treatment of Disease

Contrast Agents for Imaging
Sensors
Susceptibility Testing (DNA/RNA)



BARC Sensor
(Colton, NRL)

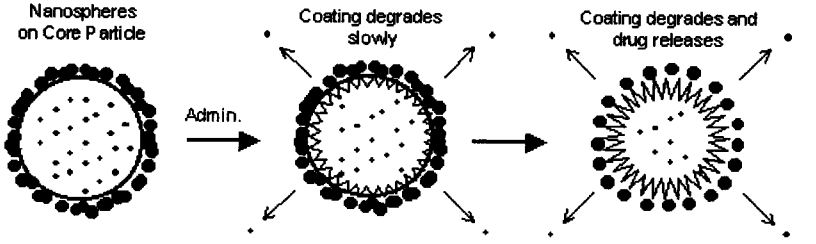
Improved Implants



Bone Structure (Siegel, RPI)

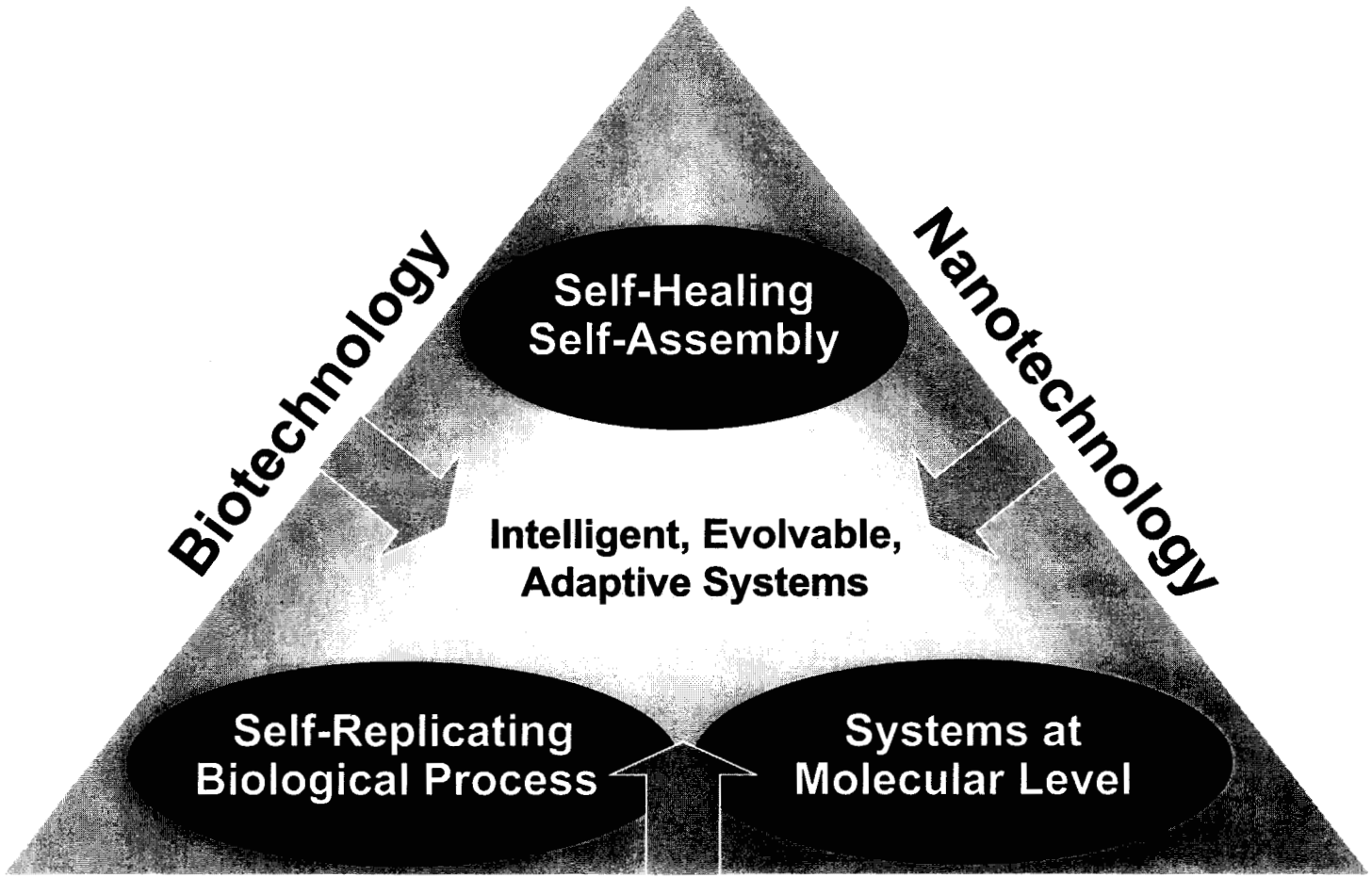
Therapeutic Delivery

Enhanced Solubility
Targeted, Local Delivery



Nanosphere enhanced drug solubility
(Nanosphere)

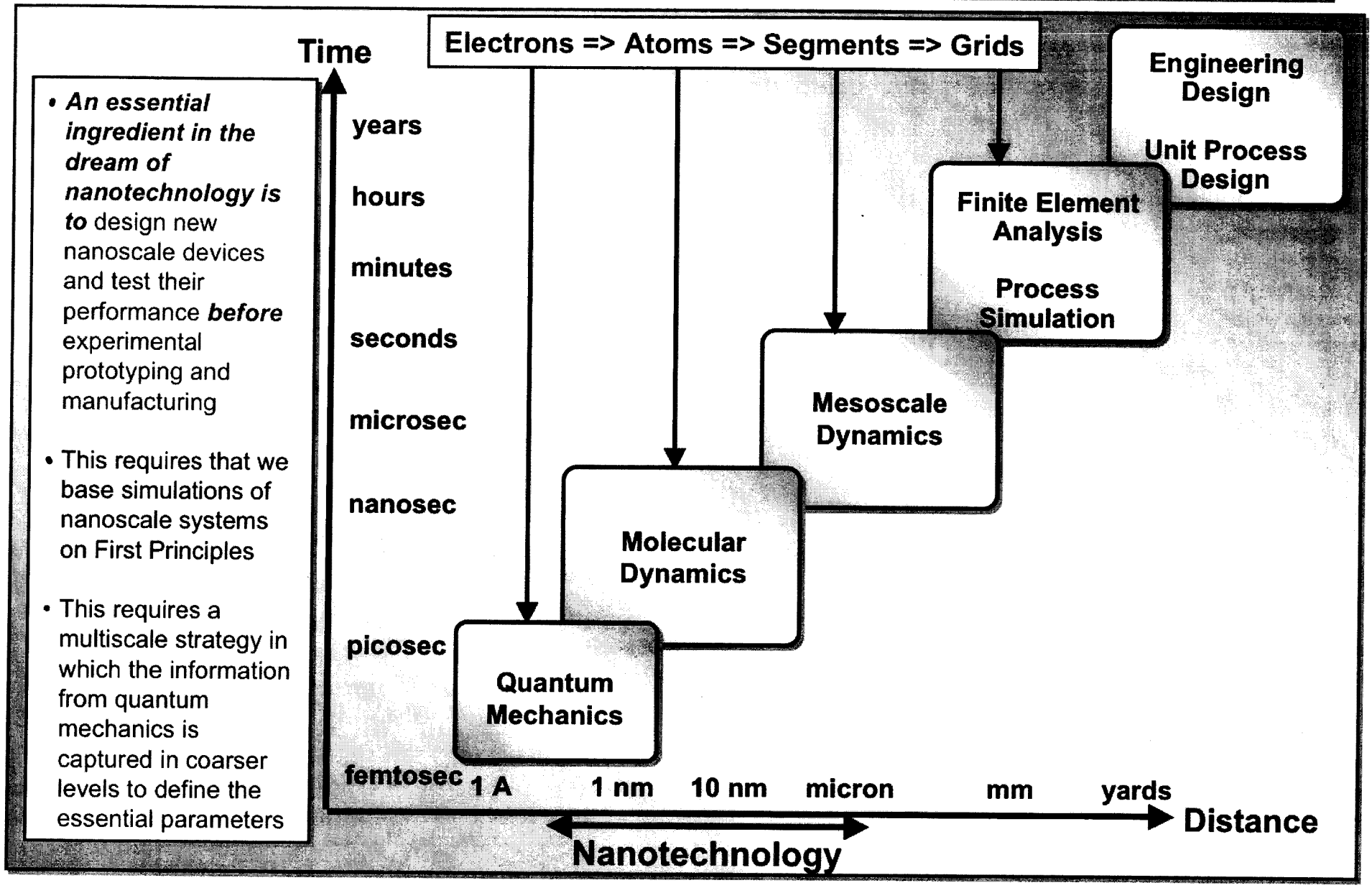
Revolutionary Technology Vision: The "Zone of Convergence"



Critical Nanotechnology Investment Areas

- **Nanostructured Materials**
  - High strength/mass, smart materials for aerospace vehicles and large space structures
  - Materials with programmable optical/thermal/mechanical/other properties
  - Materials for high-efficiency energy conversion and for low temperature coolers
  - Materials with embedded sensing/compensating systems for reliability and safety
- **Nano Electronics and Computing**
  - Devices for ultra high-capability, low-power computing & communication systems
  - Space qualified data storage
  - Novel IT architecture for fault and radiation tolerance
  - Bio-inspired adaptable, self-healing systems for extended missions
- **Sensors and Microspacecraft Components**
  - Low-power, integrable nano devices for miniature space systems
  - Quantum devices and systems for ultrasensitive detection, analysis and communication
  - NEMS flight system @ 1μW
  - Bio-geo-chem lab-on-a-chip for in situ science and life detection
- **University Research Engineering and Technology Institutes**
  - Bio-nano-information technology fusion (UCLA)
  - Bio-nanotechnology materials and structures (Princeton)
  - Bio-nanotechnology materials and structures (Texas A&M)
  - Nanoelectronics computing (Purdue)
- **Basic Nanoscience**
  - Biomolecular self-assembly and processing in space
  - Non-invasive diagnostic tools
  - Molecular signature for early detection
  - Tools for study of space-induced health effects

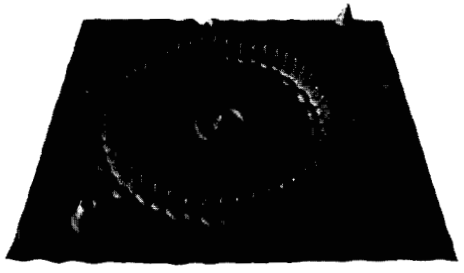
Multi-Scale Simulation Hierarchy



- ***An essential ingredient in the dream of nanotechnology is to*** design new nanoscale devices and test their performance ***before*** experimental prototyping and manufacturing
- This requires that we base simulations of nanoscale systems on First Principles
- This requires a multiscale strategy in which the information from quantum mechanics is captured in coarser levels to define the essential parameters

Assembly

ATOMIC/MOLECULAR MANIPULATION

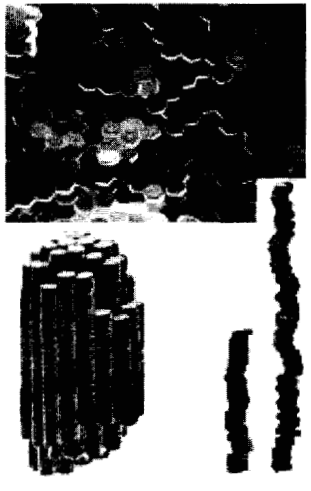


Quantum Corral
(D. Eigler, IBM)

SELF ASSEMBLY

DEFECT MINIMIZATION

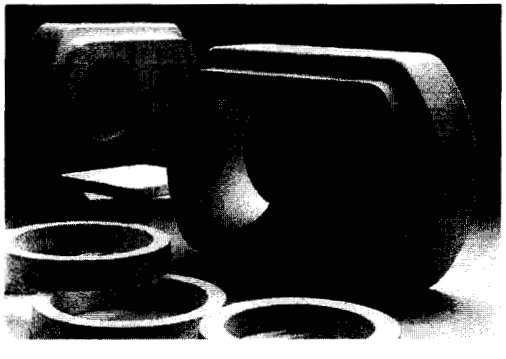
DIRECTED HEIRARCHICAL



Self Assembled A*u*
(Whitesides, Harvard)

MATRIX EMBEDDED (COMPOSITE)

COMPACTION



Net Shape Forming via Consolidated Titania and Alumina Nanoparticles

(R. Siegel and Nanophase Technology Corp.)

COATING

NASA Research in Nanotechnology

Aerospace Vehicle Materials and Structures

Program Elements

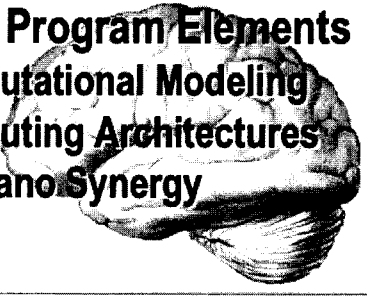
- Nanotube Fiber Development
- Composite Matrix Development
- Multifunctional Structures

11 Participating Universities

Nano-Electronics and Computing

Program Elements

- Computational Modeling
- Computing Architectures
- Bio-Nano Synergy



11 Participating Universities

High Temperature Materials

Program Elements

- CNT / Polymer & Ceramic Matrix Comp
- High Temperature Nanotubes (e.g. BN)
- Nanostructured Alloys & Coating

7 Participating Universities

Sensors and Components for Microspacecraft

Program Elements

- Nano S/C Components for Harsh Environments
- Nano Component Integration
- Quantum Dot Devices

12 Participating Universities

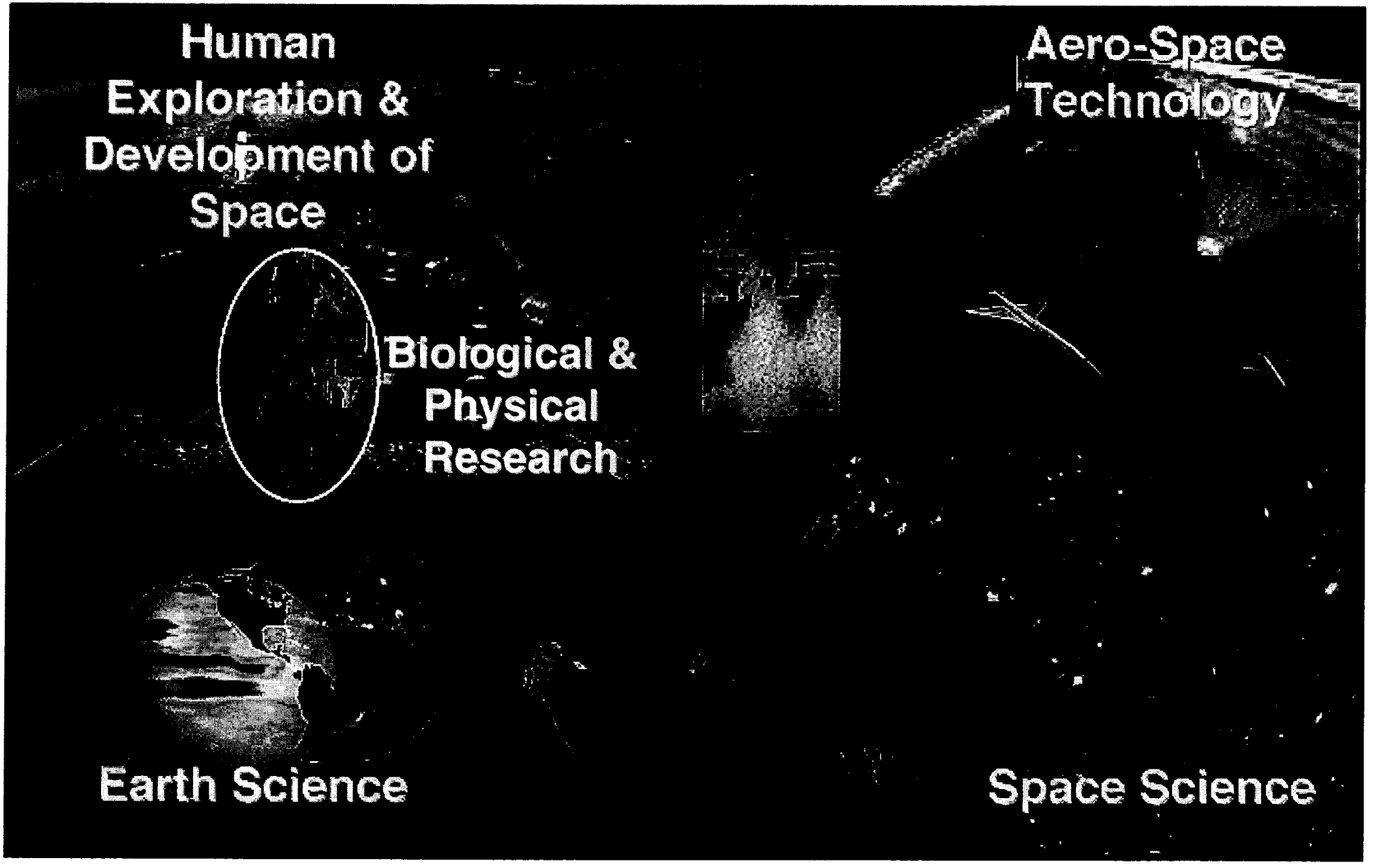
Barriers and Challenges for Nanotechnology

- **Production of nanomaterials**
  - Quantity, quality, control of properties & production in specified forms
- **Characterization at both atomic and bulk scale**
  - Fundamental mechanical, electrical and optical properties
- **Modeling & Simulation**
  - Prediction of physical/chemical properties and behavior from nanoscale to macroscale as well as models for material production
- **Applications Development**
  - Tools and techniques for applications of nanotechnology
  - Verification of predicted behavior/performance in actual environments
  - Systems Analysis to guide technology development

Convergence of Nano-, Bio-, & Info- Technologies: A NASA Perspective

4th Roundtable on Micro/Nanotechnologies for Space

Noordwijk, The Netherlands
20-22 May 2003

Minoo N. Dastoor
Office of Aerospace Technology
NASA

NASA's Strategic Enterprises