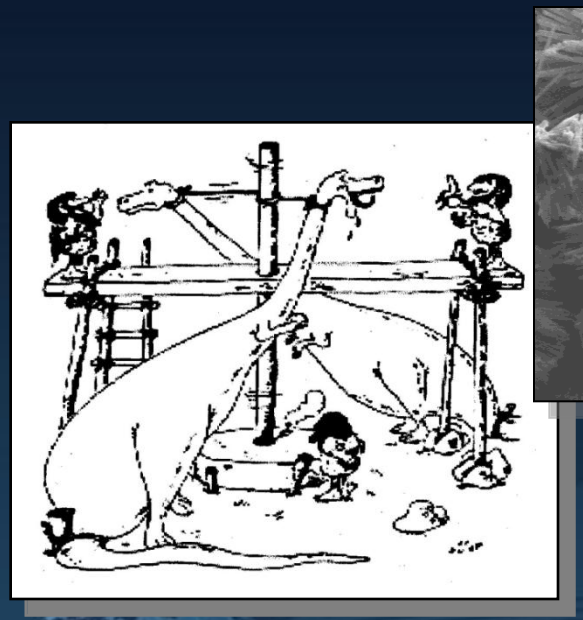
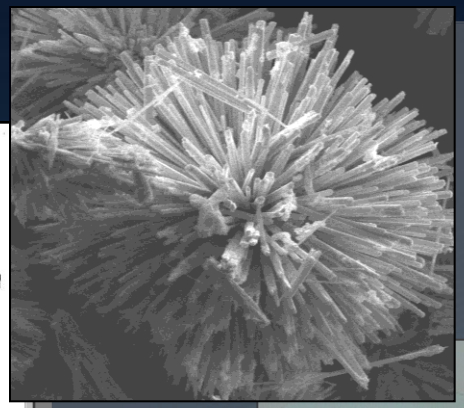
Design and Manufacture of Integrated Nanosystems

Nanomanufacturing Perspectives





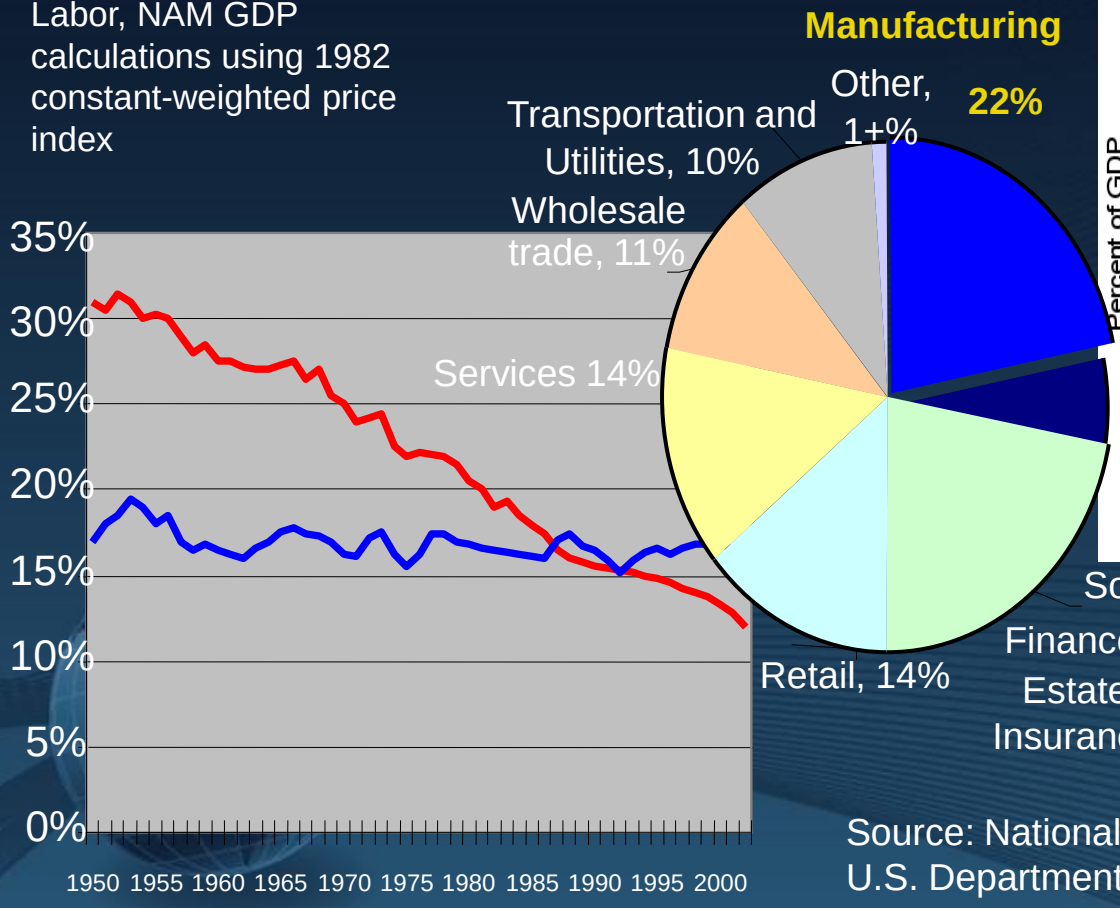
Dr. Haris Doumanidis, Marie Curie Professor & Director

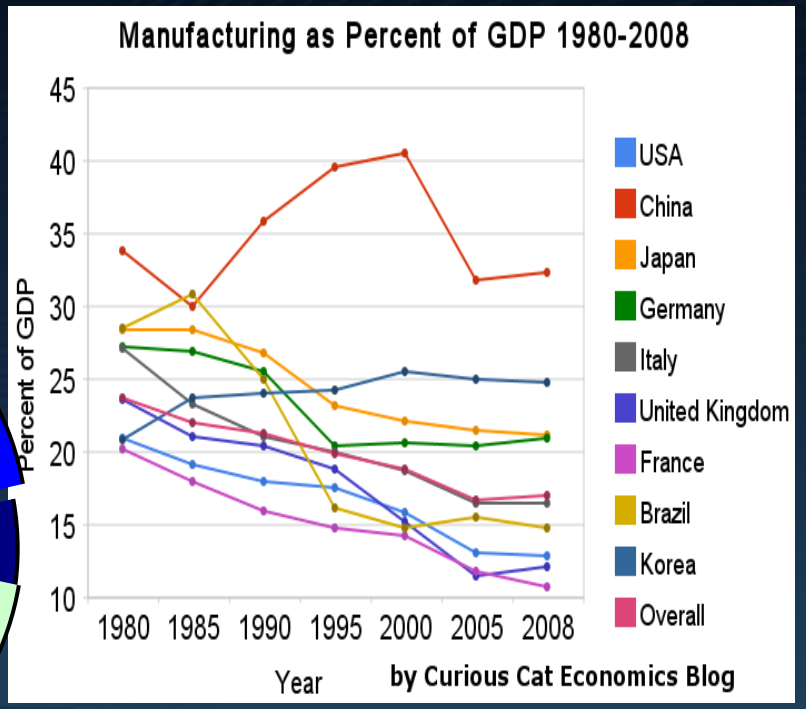
Nanomanufacturing Program – National Science Foundation

Tel: (703) 292-7557, Fax: (703) 292-9053, cdoumani@nsf.gov

Manufacturing Contribution to US GDP and Employment

Data Source: US Dept of Labor, NAM GDP calculations using 1982 constant-weighted price index

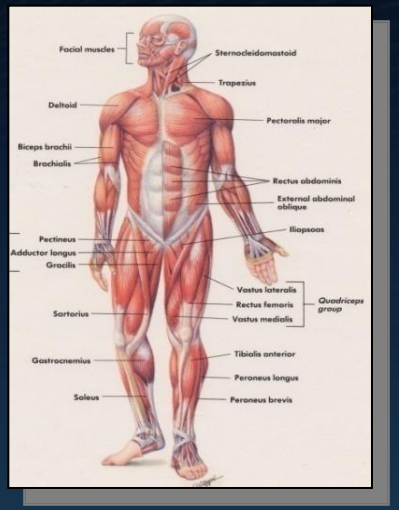


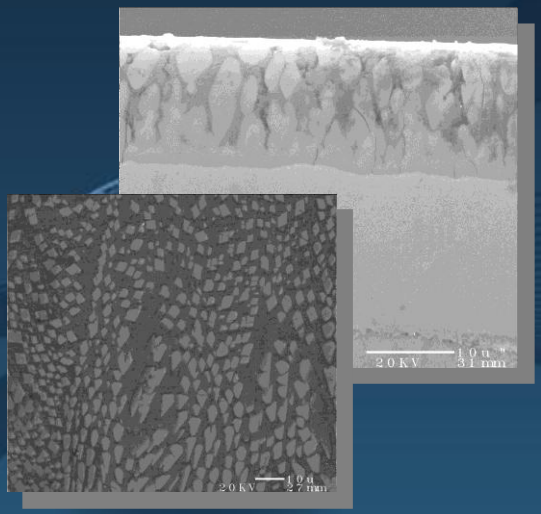


Source: National Association of Manufacturers, U.S. Department of Commerce

Nanomanufacturing Program
(www.nsf.gov/div/index.jsp?div=CMMI)

* Focus on manufacturing *scale-up* issues for high-rate industrial production: *producibility, predictability, productivity*
* Emphasis on systems *up-scaling* design and integration across dimensional/time scales: *nano-structures → functional devices → system architectures → products & services*

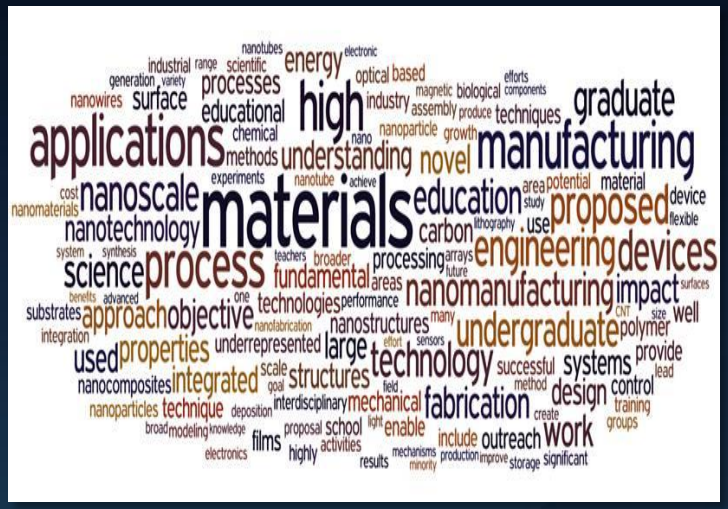




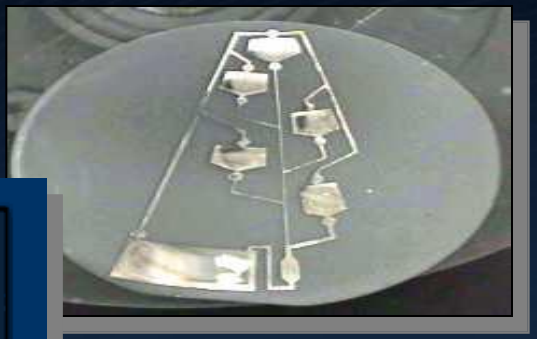
* Multi-functionality across energetic domains: *mechanical, electromagnetic, biological etc.*
* Intelligence/information value added at nanoscale: *materials, processes, equipment*
* Simulation, optimization, modeling and controls
* Physical and human infrastructure, impact to education, society, economy and environment

(e.g. Doumanidis C, The Nanomanufacturing Programme at NSF, *Nanotechnology* 13(3), 2002)

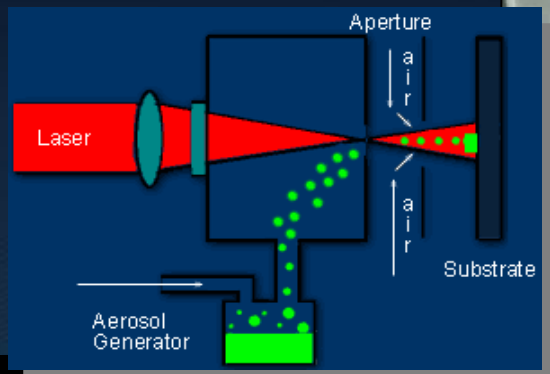
Diversity of Activities and Communities

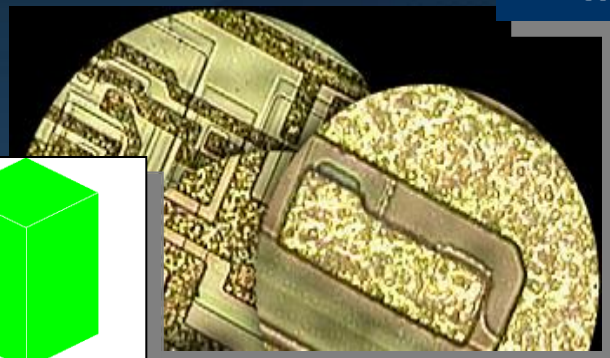


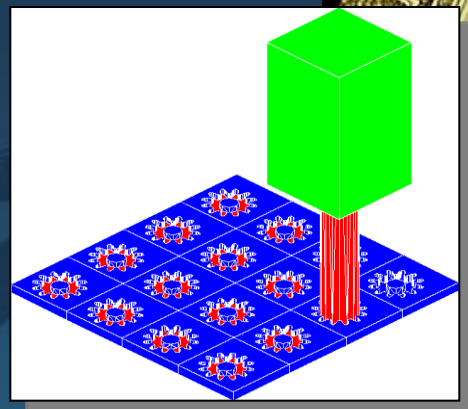
NNI-NSE
Manufacturing Processes



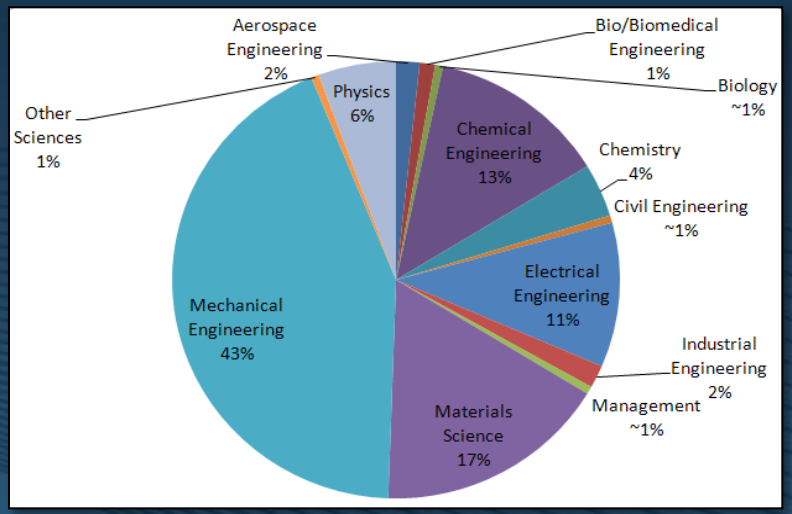
(J. Lee, Ohio State U)





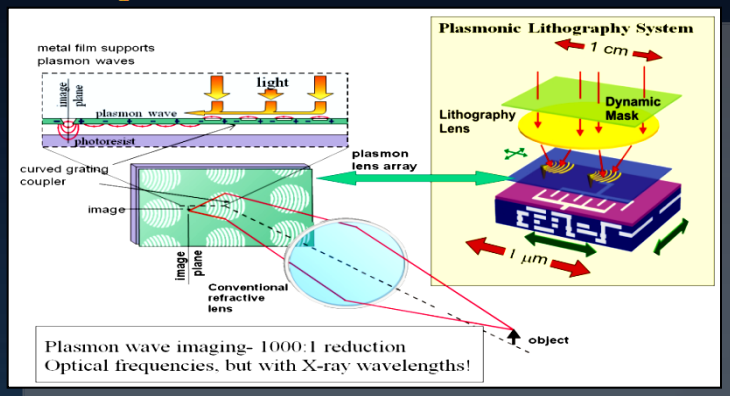


(S. Girshick, U. Minnesota)

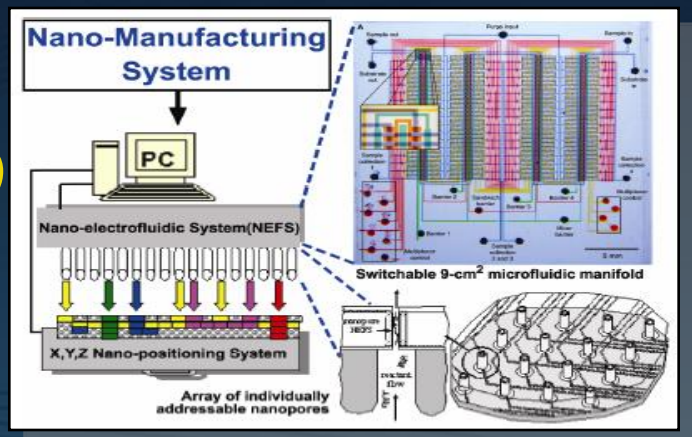


(e.g. Doumanidis C, Durham D, Editorial Micro/Nano-Technology, *J Comp Aid Design* 1268, 2007)

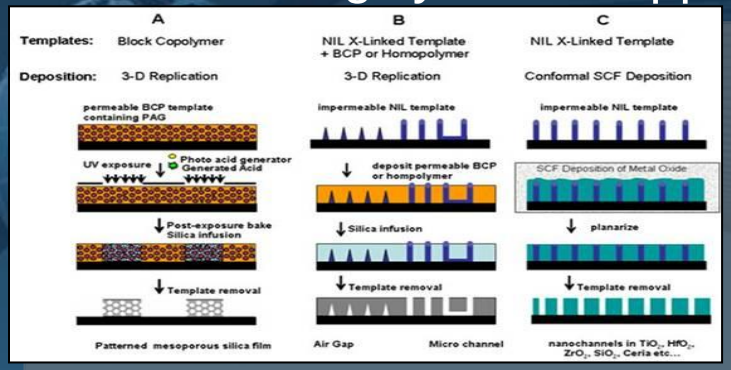
Nanoscale Science and Engineering Centers (NSEC) in Manufacturing



* Scalable and Integrated Nano Manufacturing *(SINAM- X. Zhang, UCLA/UC Berkeley)*
  - -plasmonic imaging lithography
  - -ultra molding & imprint lithography
  - -field assisted parallel nanoassembly



* Center for Nano Chemical-Electrical-Mechanical Manufacturing *(NanoCEMMS, P. Ferreira, UIUC)*
  - -nanoscale molecular gate arrays
  - -nano-photodetector array sensing
  - -manufacturing system & applications

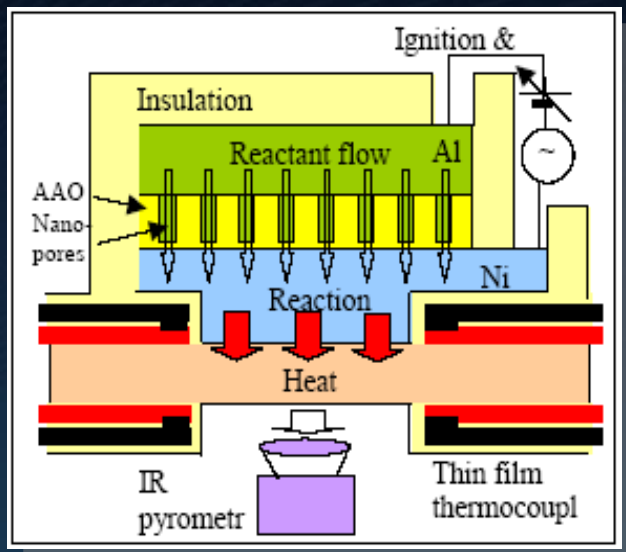


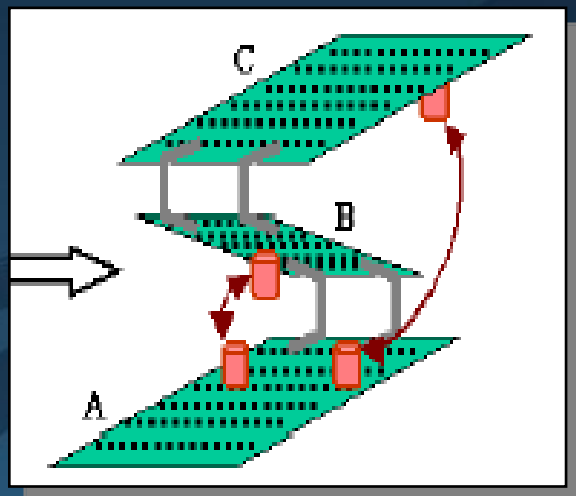
* Center for Hierarchical Manufacturing *(CHM, J. Watkins, UMass Amherst)*
  - -nanoscale polymer materials & processes
  - -nanoelectronics, magnetics, photonics
  - -bio-directed assemblies and devices

(e.g. Kramer B, Chen SC, Doumanidis C, NSF Programs in Nanomanufacturing, *Proc 6th ISNM*, 2008)

Nanomanufacturing Research Issues

* Manufacturing scalability in the nanoworld
* Continuous, parallel processing for production
* Multi-scale integration in 3D/2D space
* Modeling and feedback control in ns-fs time
* Metrology, sensing and actuation in real time
* Hybrid deposition-ablation-assembly processes
* Multi-domain, bottom-up/top-down technologies
* Patterning, templating - positioning, alignment

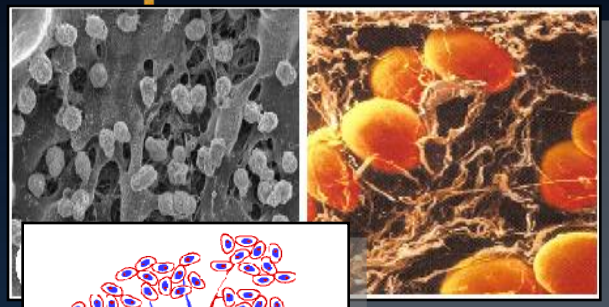




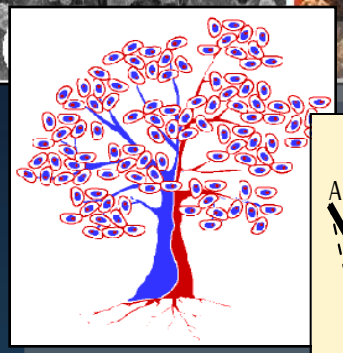
(G. Barbastathis, MIT)

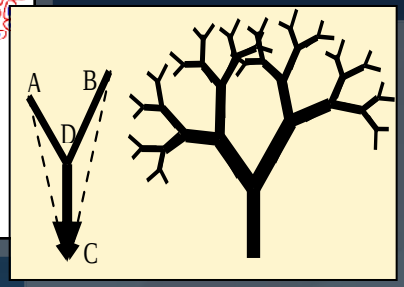
* Systems approach, nano-design for manufacturing
* Software for CAD/CAM/CAE in the nanoworld
* Process simulation: combined atomistic-continuum
* Industrial layout, supply chain, process planning
* Instrumentation and automation in the nanoworld
* Tech transfer, commercialization, entrepreneurship
* Health and safety aspects in nanomanufacturing
* Environmentally benign nanomanufacturing

Naturalist Manufacturing: Random 3D Fractals

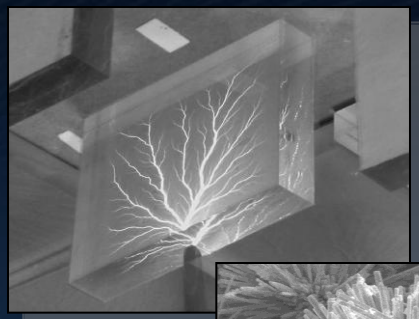


* Natural rivers, snowflakes, dendrites, plants, corals, plant chloroplast structures
* Animal tissue –alveolar, circulatory, lymphatic, nervous systems



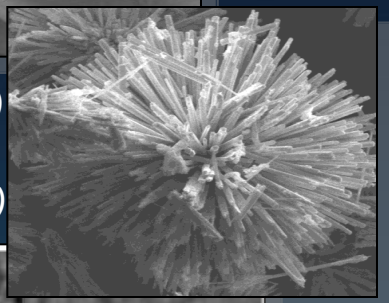


•Optimal mass/ energy/information perfusion, transport and transduction

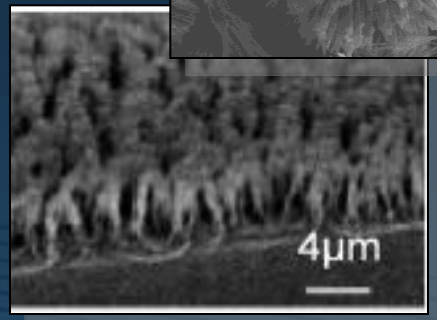


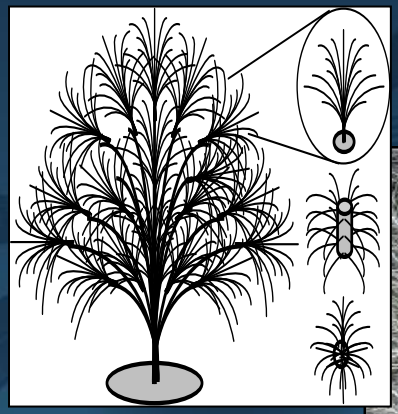
(T. Grey)

(S. Aouadi, SIU)



(E. Gogolides)





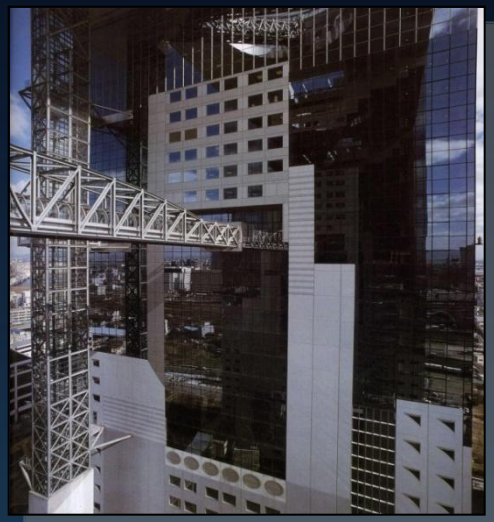
*Organic & hybrid photoelectrodes

*Photocatalysis and advanced oxidation

* Engineering networks, transport, information, antennae, scaffolds and vasculatures in tissue eng

(e.g. Doumanidis C, Nanomanufact. Random Branching Material Arch, *J Microelectronic Eng* 86, 2009)

Extreme Manufacturing: Macro-Construction & Transportation



* Umeda Sky City – Osaka, Japan (*H. Hara*)
* Reusable Launch Vehicles-PathFinder (*NASA*)

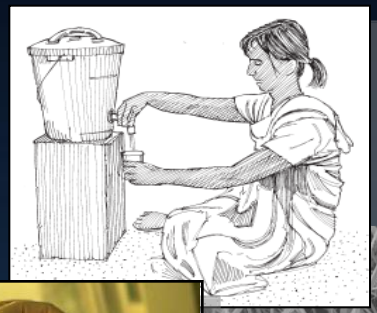
* Buildings,towers,bridges,pipelines
* Air/Spacecraft, ships, submarines
* Solar parks, power/info grids

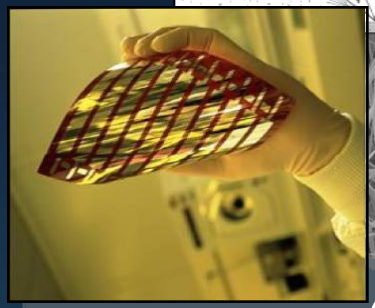
* Large size (10 m - 10,000 km)
* In-situ, out-of-plant manufacture
* Scale effects and disturbances
* Macro-manufacturing process:
  - Use of nano-materials
  - Macroscale self-assembly
  - Climbing robotic construction

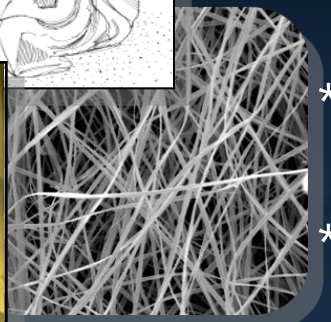
* Space Elevator (*NASA*)

* Polymer OPV panels (*NanoSys*)

Humanitarian Engineering Via Nanomanufacturing







(S. Choulis, Konarka)

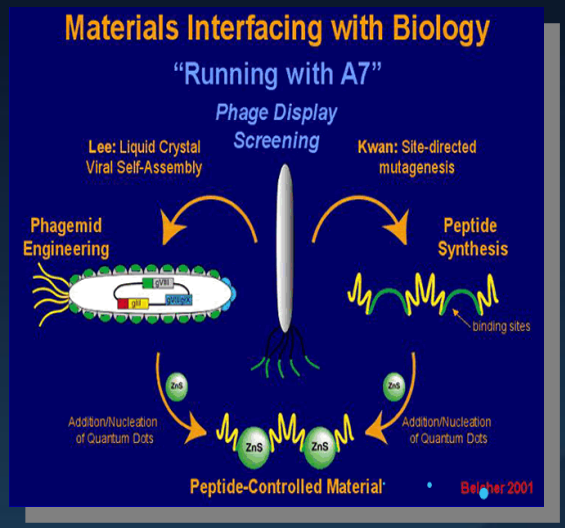
* Point-of-use water filtration and purification by electrospun nanofiber membranes, dendrimers
* Low-cost micro/nano-porous sanitation materials with antibacterial/germicidal coatings
* Temporary solar power by disposable, low-lifetime organic and hybrid flexible photovoltaic panels
* Solar-powered tandem photovoltaic-Peltier thermoelectric foils for self-cooling packaging

* Low-cost natural nanocomposite/nanoporous construction materials (including random fractal and bio-materials)
* Small biomass processors for local biofuel generation
* Transdermal medication delivery bandages with drug-loaded electrospun fibers
* Affordable, robust biomedical materials and instrumentation for deployment in emergency ICUs

(Engineers Without Borders in Africa- www.ewb.gr)

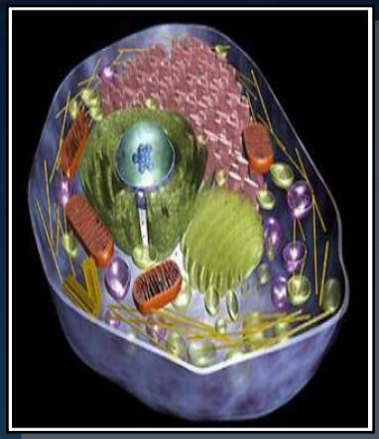
Bio-Manufacturing: Imitating Manufacture in Nature

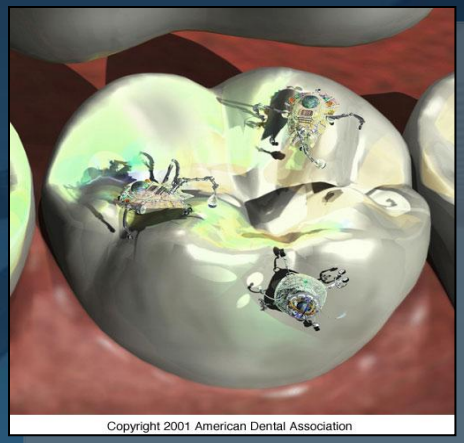
- Biotechnological manufacture of complex biomolecular structures by design



(A. Belcher, MIT)

- *The live cell as ultimate production plant:*
  synthetic biology
  +systems engineering:
  -Genetic engineering via bioinformatics
  -Mitotic multiplication (cancer research)
  -In-time/In-situ/In-vivo manufacture

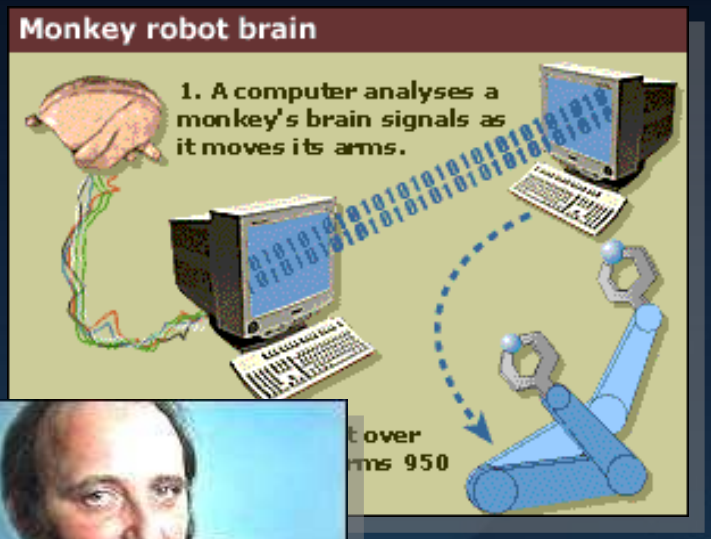




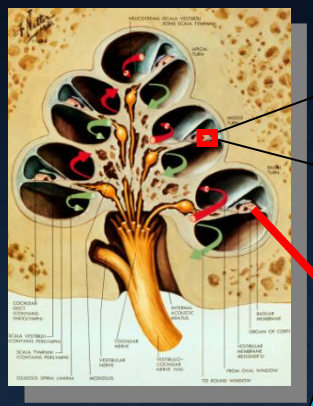
* *Biomolecular manufacture machinery*:

* Material diversity	*Environment adaptation
* Multi-functionality	* Evolution and learning
* Redundancy	* Self-repair
* Synergy, symbiosis	* Self-replication
* Autonomous sustain	* End-of-life cycle

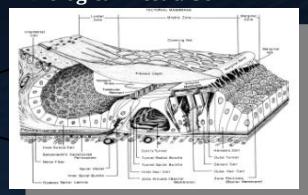
Brain-Machine Interfacing

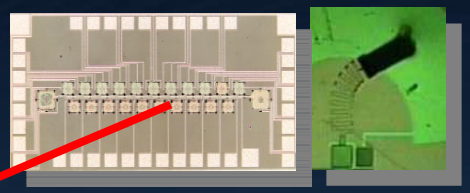


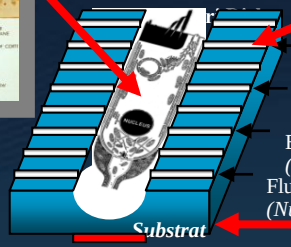
(M. Nicolelis-Duke Univ, M. Srinivasan-MIT)

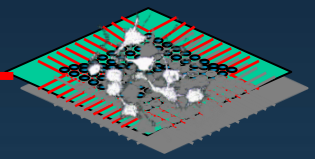


NASA URETI
On CMISE
(UCLA)

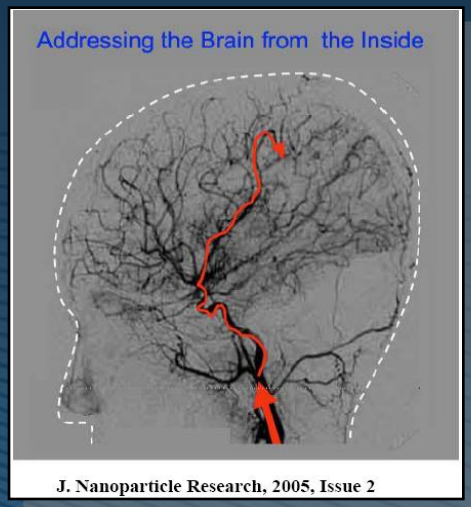








- Neural synaptic interfaces
- Non-invasive imaging (MEG etc)
- Neuron status model & monitoring
- Central motion control-cerebellum
- Prostheses, exoskeleta
- Robotic and manufacturing control



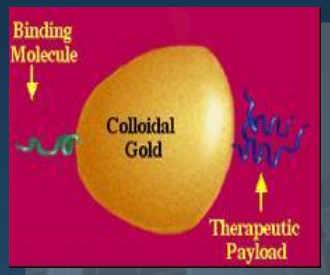
Design and Manufacturing in the 21st Century

(Babolat Co)

* *Product Customization vs Mass Production*:
user-centric, shifting weight to customer preferences, design alternatives, optimization and decision making, and flexible, lean, high-tech, trendy manufacturing

* *Service vs Product Engineering*:
eventual deliverable, focusing on function vs platform, integrating customer-tailoring, soft/human elements, operation, maintenance, replacement, multi-product flexibility

(3M-ESPI)



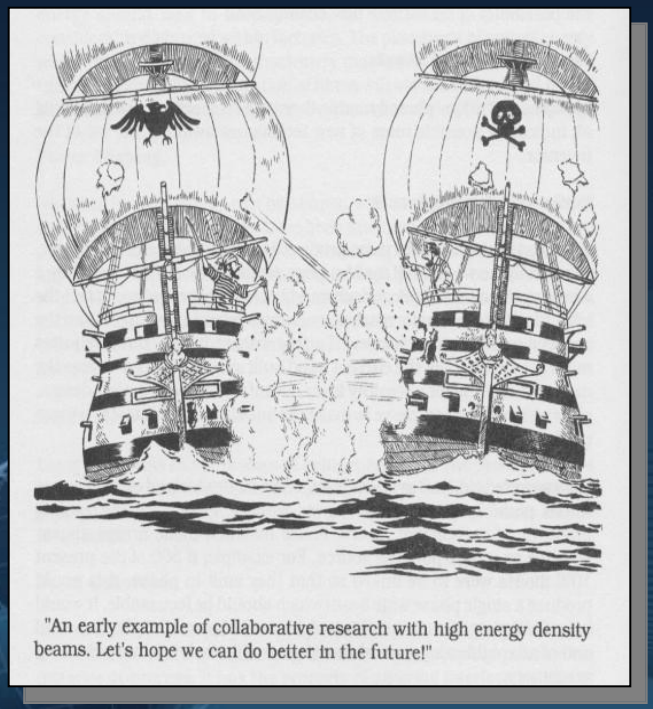
(CytImmune)

* *Professional Inventorship vs Manufacturing*:
entrepreneurship founded on cultural/experiential diversity, vertically integrating market analysis, product conceptualization, design, prototyping, testing, manufacturing & enterprise aspects

* *Elite Education vs Workforce Training*:
capitalizing on unique national expertise and premier facilities, world-leading academe, federal resources and mobility for an exclusive education, pre-empting world research & innovation

Epilogue

- Unprecedented international competition
- Intellectual drive and application markets
- Nano/Bio-Manufacturing research booming



"An early example of collaborative research with high energy density beams. Let's hope we can do better in the future!"

- Nanotechnology products emerging
- New nanomanufacturing ideas and jobs
- Educational and collaboration needs

THANK YOU FOR YOUR ATTENTION!