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Nanotechnology & Global Security

Defense Applications & Challenges in the 21st Century

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Executive Director Europe, *Foresight Nanotech Institute*

October 31, 2005 – *Military Nanotechnology* Conference, London

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**An analytical overview
with strategic recommendations of the
global security challenges and solutions
which nanotechnology presents
for the 21st century.**

Foresight Overview - 1

- Founded in 1986 by Dr. E. Drexler & C. Peterson
- Created and popularized concept of “nanotechnology”
 - Molecular Nano-Technology (MNT)
 - Molecular Manufacturing (MM)
 - Molecular Machine Systems (MMS)
- 4 Books published, many inspired
- *Foresight Safety Guidelines for Molecular Manufacturing*
- Numerous white papers, articles, briefings, essays, ...
- Top 5 “nanotechnology” website



Foresight Overview - 2

- 54 *Foresight Update* newsletters
- 12 major conferences and Senior Associate gatherings
- Awarded 18 *Feynman Prizes*, several others
- Helped catalyze establishment of U.S. NNI
- Extensive placement in the press worldwide
- Leading public policy voice in the US
- Reaches 14,000+ people via email
- Think tank, public education, public policy development support and public interest org.



Presentation Overview

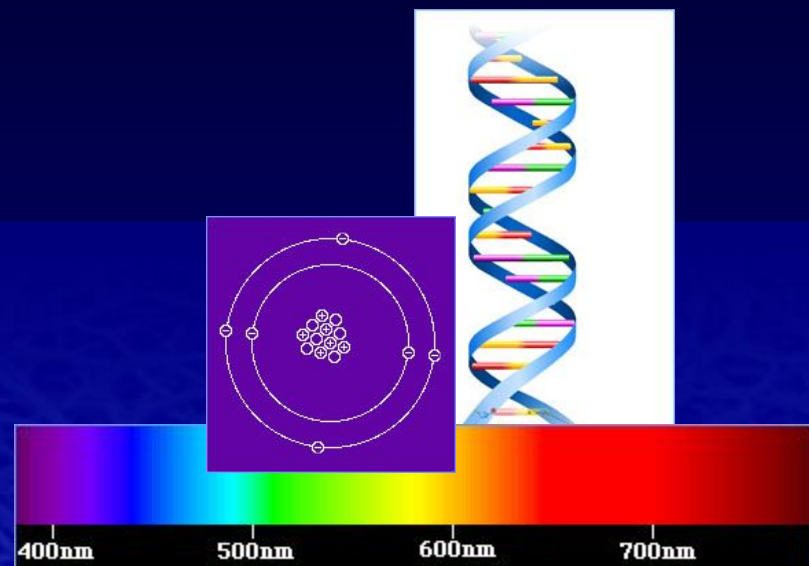
1. Military Nanotech outlook: From upgrades to potential new WMDs
2. Towards Non-lethal Warfare
3. Challenges & Opportunities for Global & Regional security
4. Challenges & Opportunities to our Institutions & Societies
5. Towards MAPPs: **M**ulti-laterally **A**ssured **P**ermanent & **P**ervasive **S**urveillance & Sousveillance
6. Perilous transition to a potentially Better New World



Nanotechnology Definition

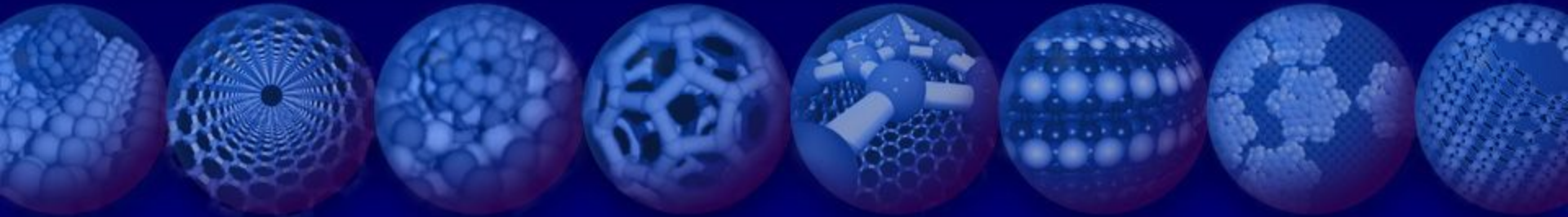
- MANY definitions
- Size/scale give rise to new properties
 - Quantum effects
 - New physical ratios/relationships
- Building systems based on new properties
- “Nanoscale Engineering”
- Near term

“The technology of structuring and controlling matter on the scale of ~100nm and below.”





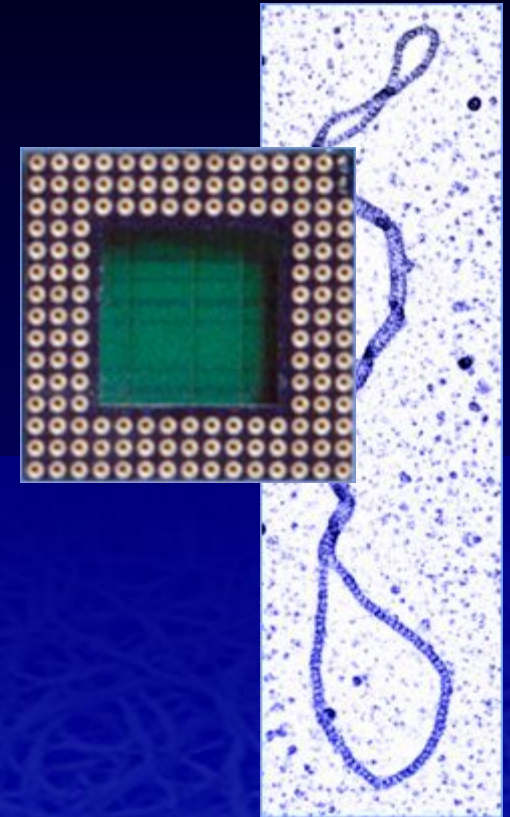
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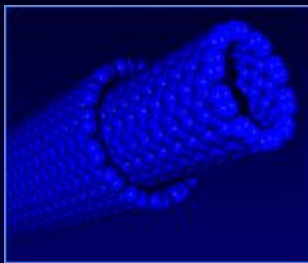
**1. Military Nanotech outlook:
From upgrades to potential new WMDs**

Where Are We?

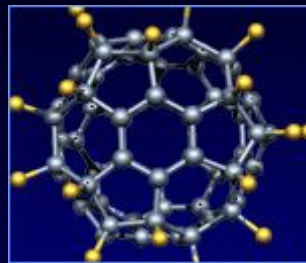
- VERY early
- IT before the integrated circuit
 - Early 60's
- Biotech before recombinant DNA
 - Early 70's
- Long term vs. short term



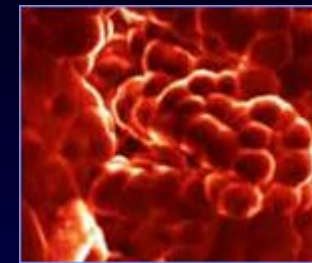
Today's Building Blocks



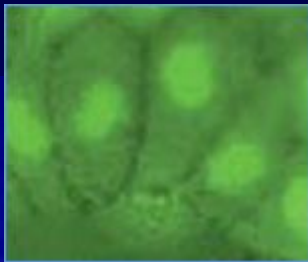
Nanotubes



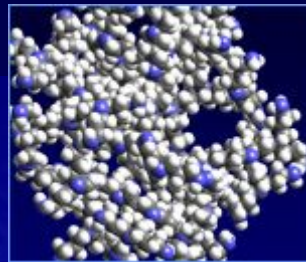
Fullerenes



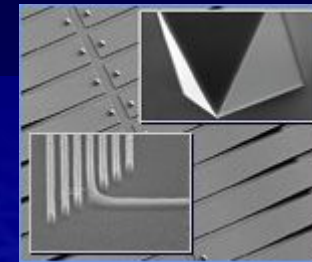
Nanoparticles



Quantum Dot



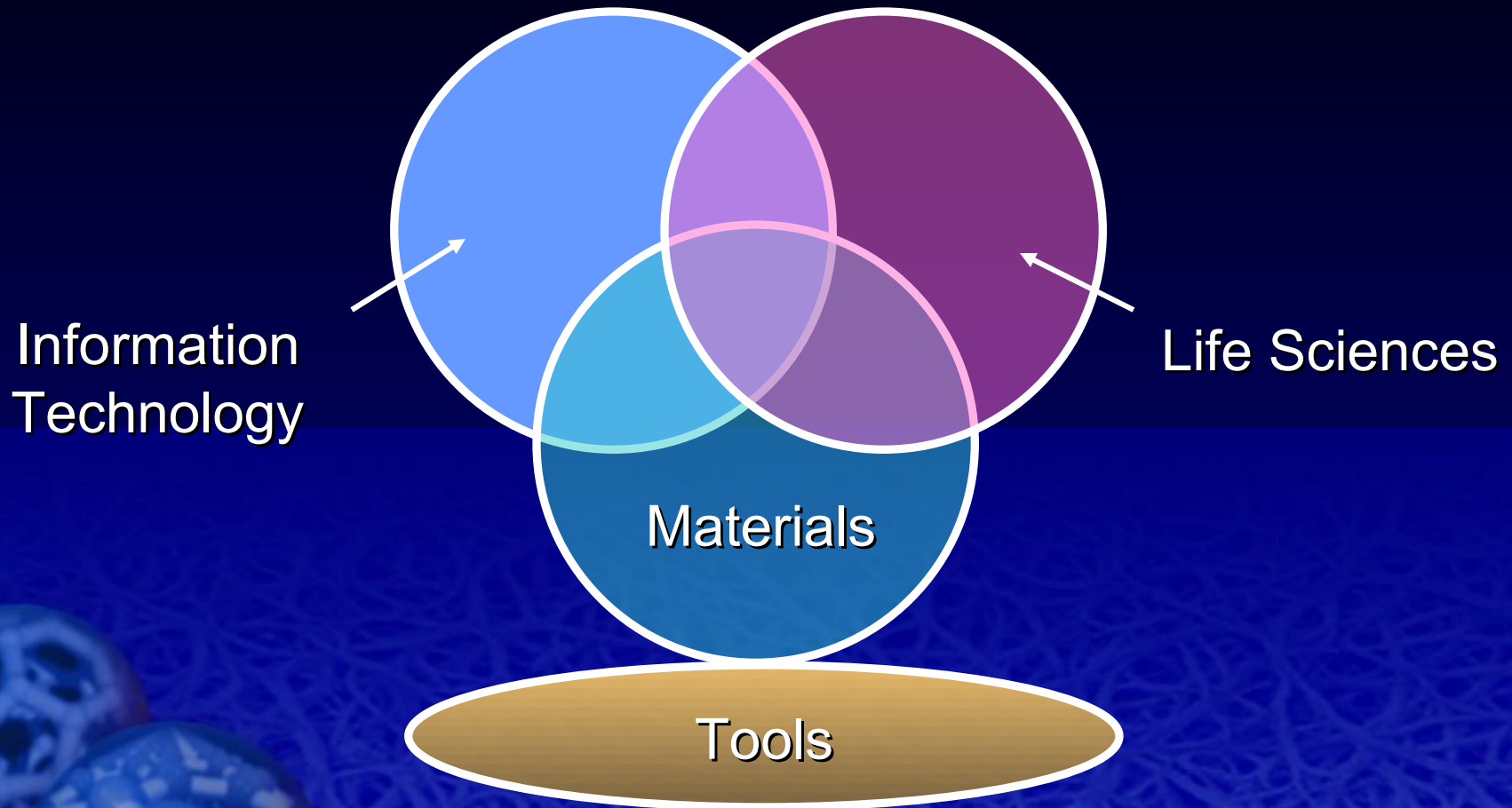
Dendrimers



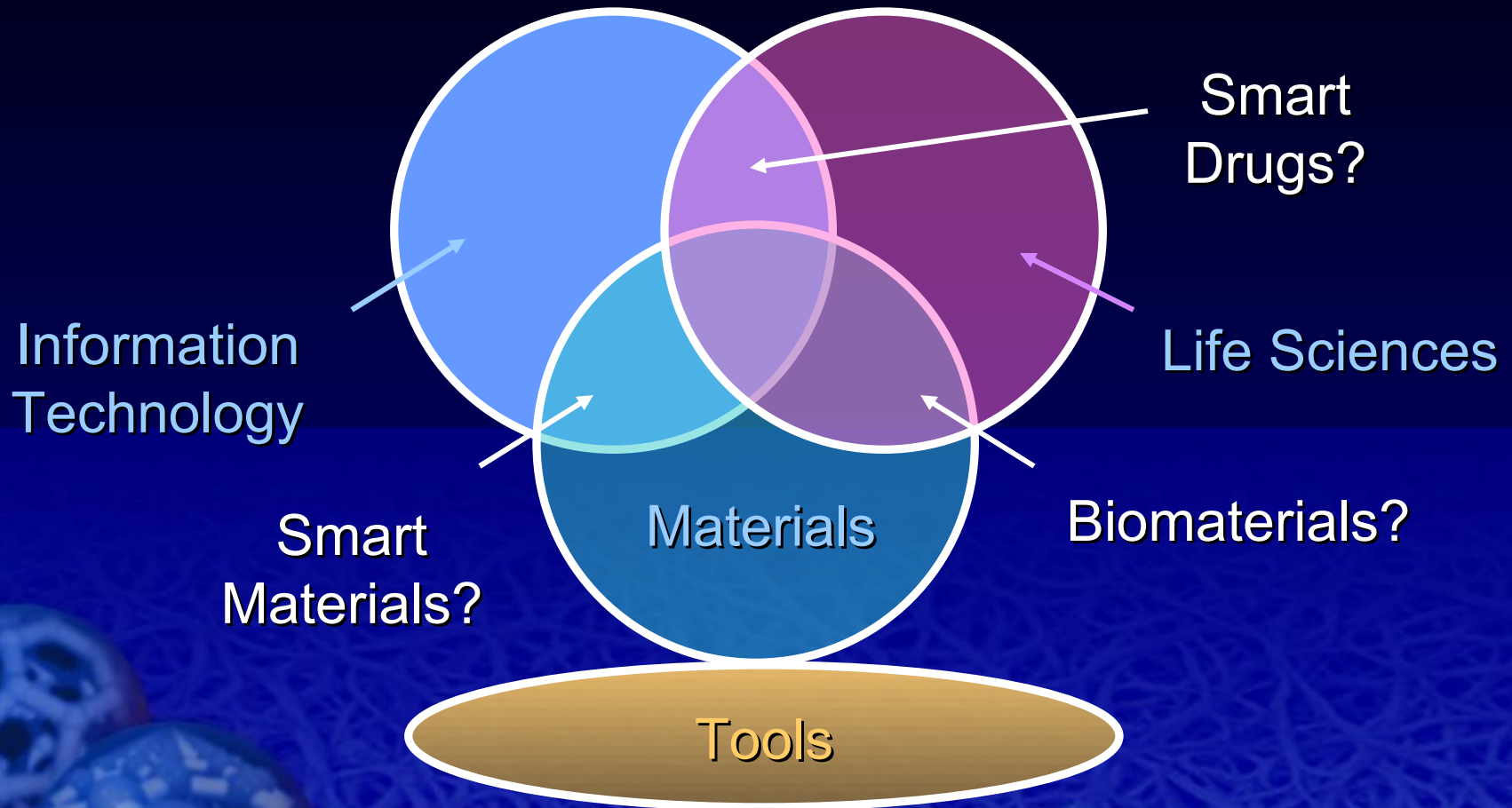
Soft Lithography
(Nano-imprinting,
Dip-pen Lithography)



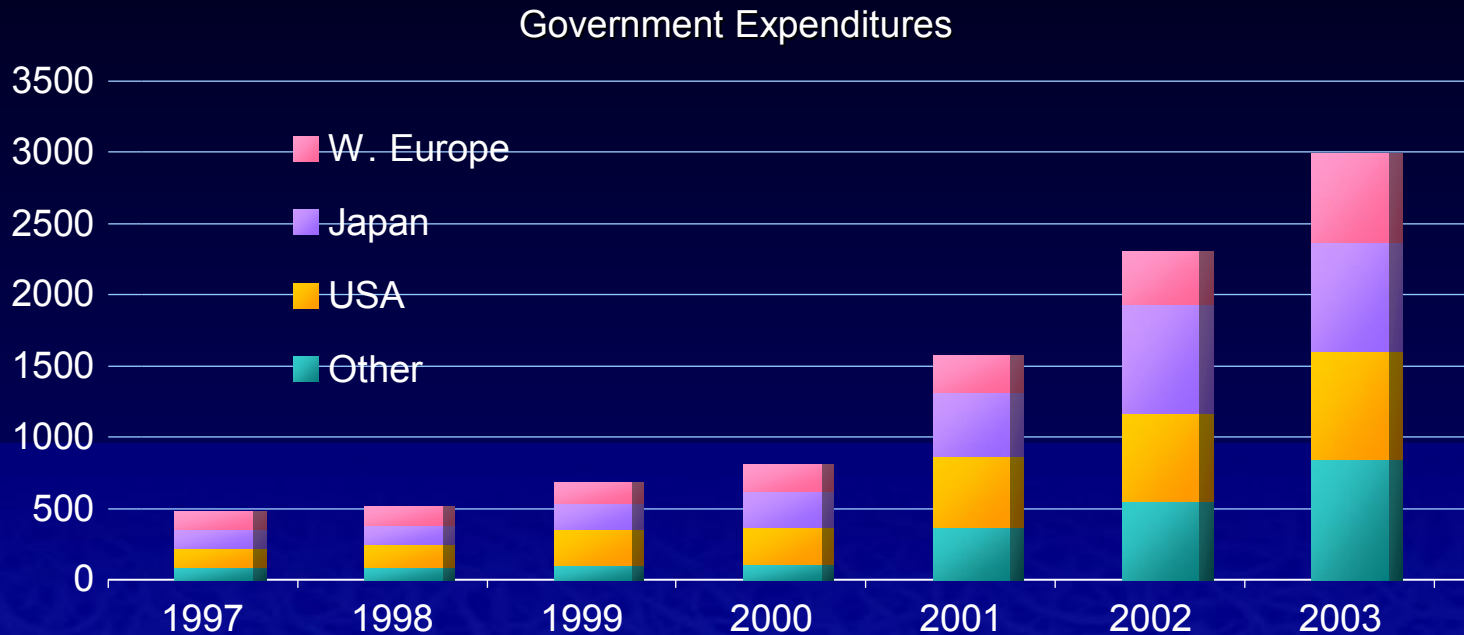
Nanomanufacturing Design Space



Nanomanufacturing Design Space



R&D Funding – 2003



Source: US National Nanotechnology Initiative

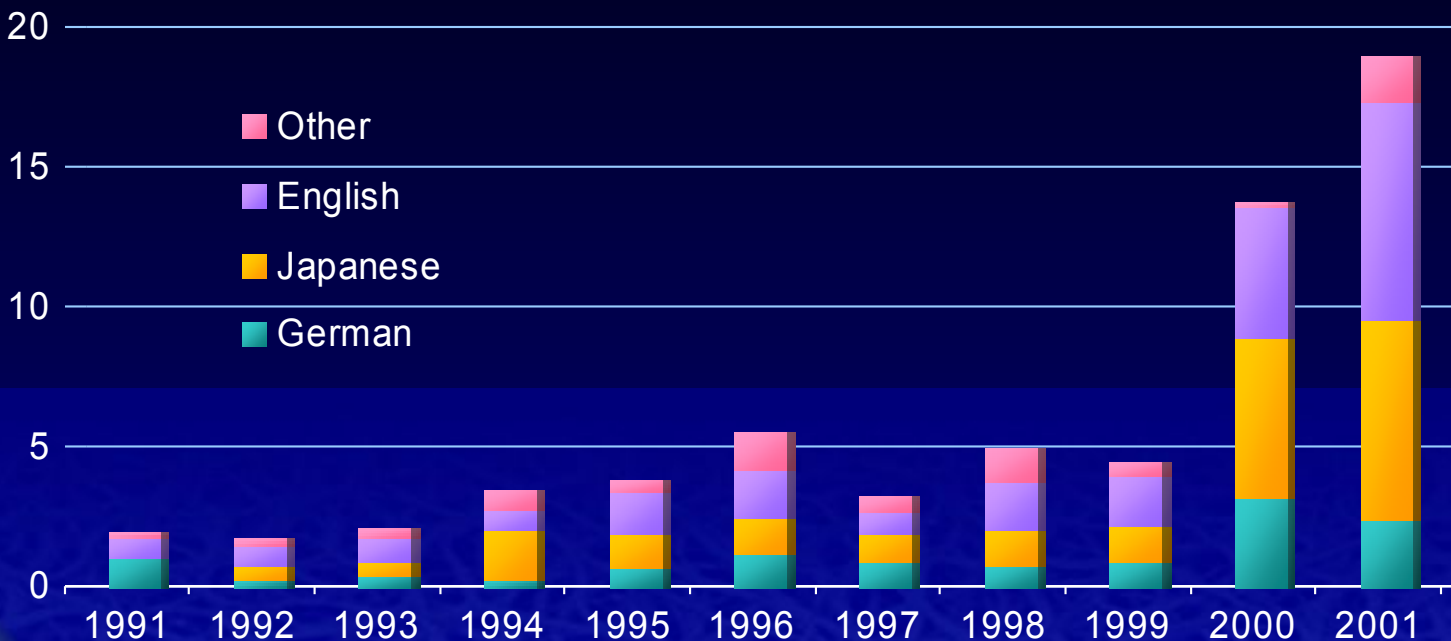
- Corporations spend approximately the same amount



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Patents by Language

Patents
in Thousands



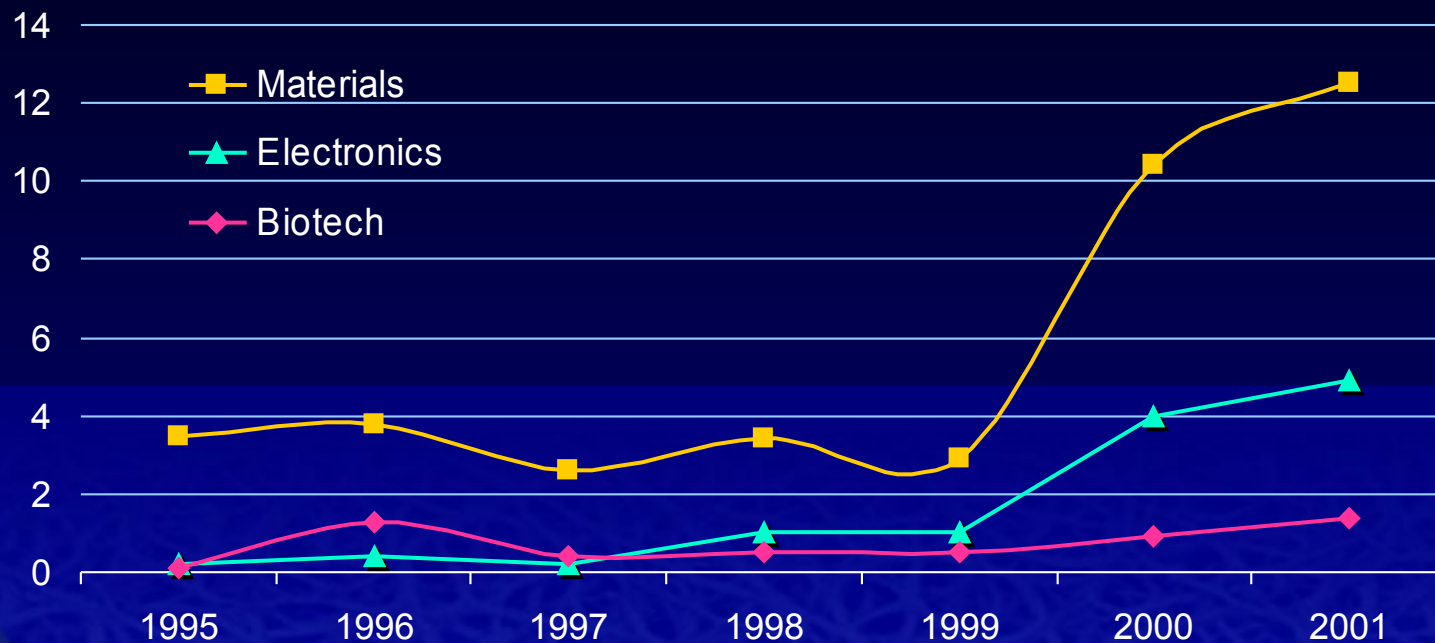
Source: Polytechnos



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Patents by Category

Patents
in Thousands



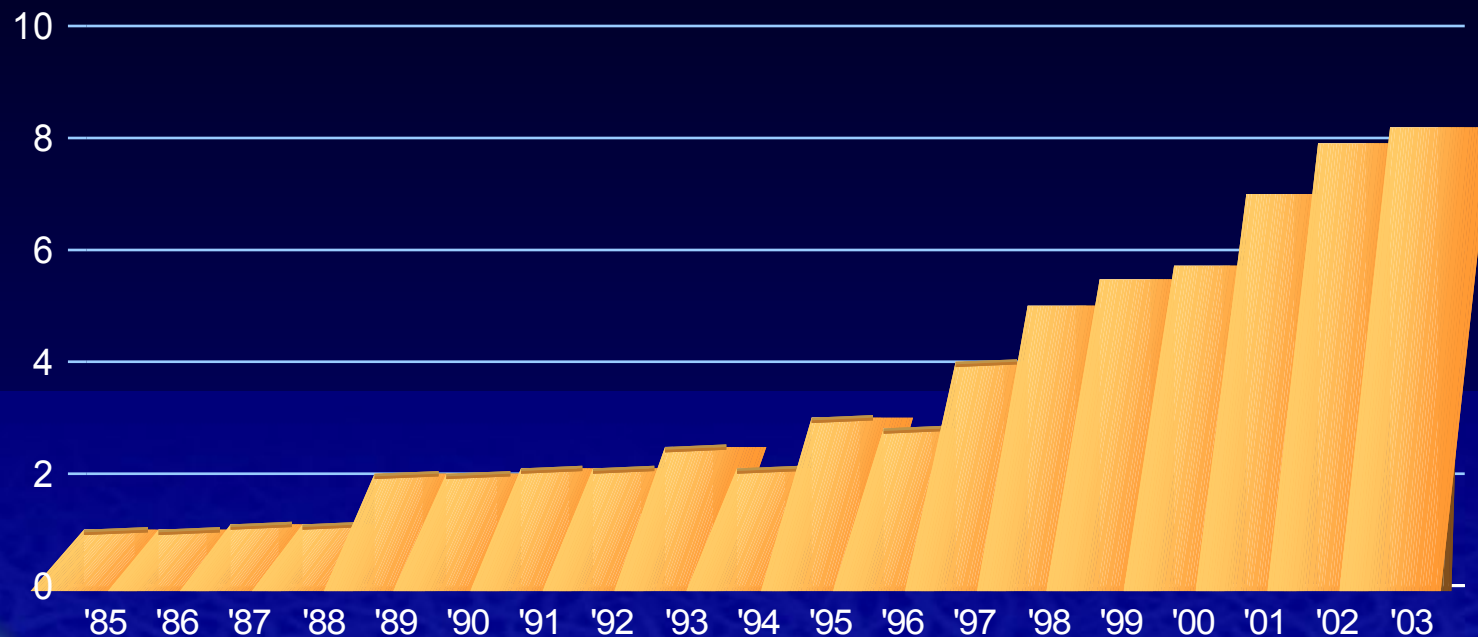
Source: Polytechnos



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US Patents

Patents
in Thousands



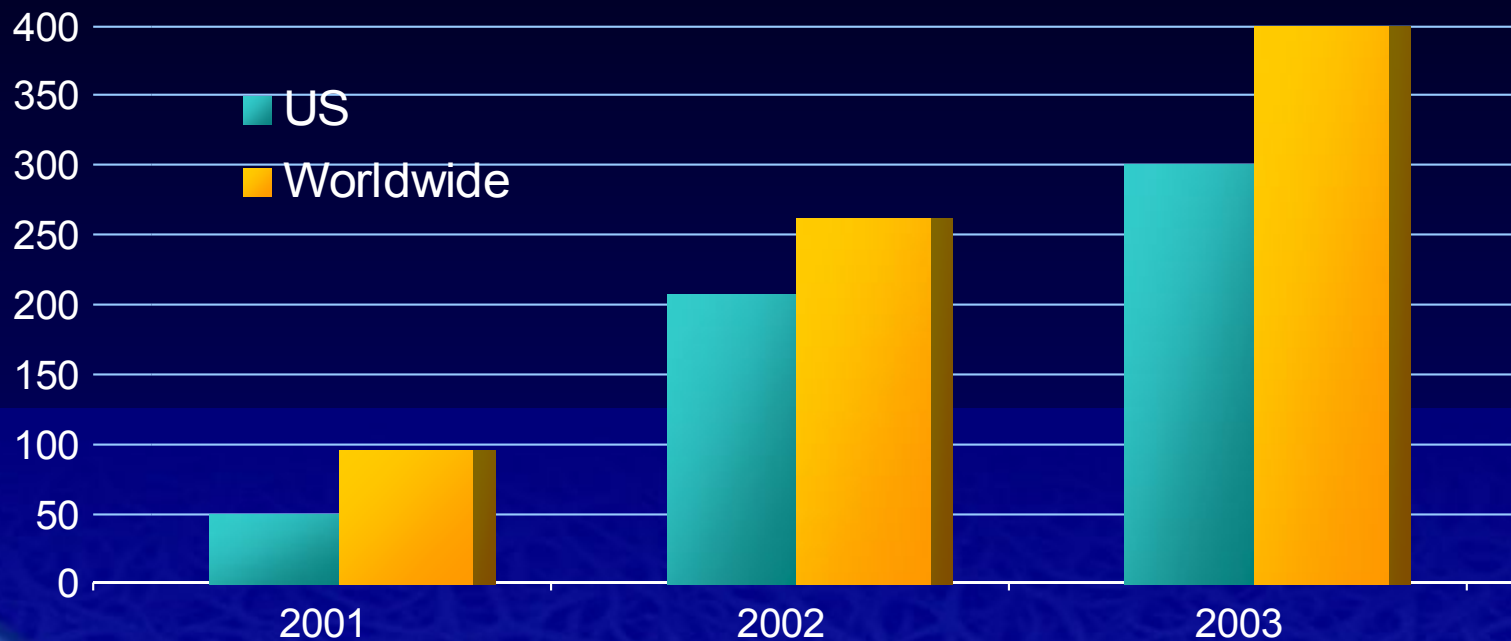
Source: Journal of Nanoparticle Research



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Venture Capital Investment

\$ Millions



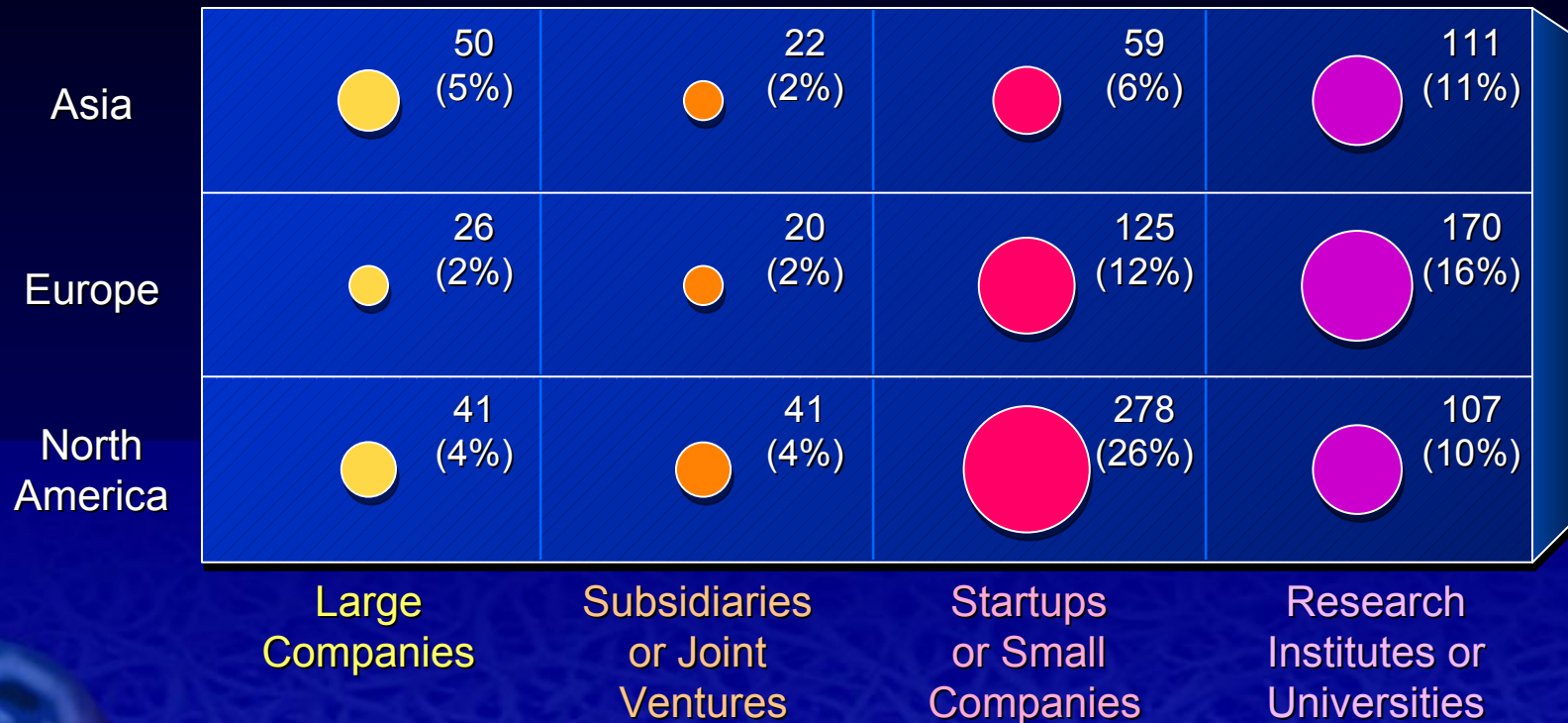
Source: Small Times



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Players by Type

Size of the Circle = Number of Actors in the Field



Source: Científica and Jaakko Pöyry Consulting, 2002



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Market Impact - Near Term

- Tools
- Composite materials
- Coatings
- Catalysts



Market Impact - Medium Term

- Aerospace
- Medicine
 - Diagnostics, drug delivery
- Memories
- Display technologies
- Energy storage & distribution
 - Batteries, fuel cells, solar power



Nanotech Giants

IBM

(www.ibm.com, IBM)

HP

(www.hp.com, HPQ)

Intel

(www.intel.com, INTC)

General Electric (
www.ge.com, GE)

Cabot

(www.cabot-corp.com, CBT)

DuPont

(www.dupont.com, DD)

BASF

(www.basf.com, BF)

Engelhard

(
www.engelhard.com, EC)

Rohm & Haas

(
www.rohmhaas.com, ROH)

Eastman Chemical

(
www.eastman.com, EMN)

Air Products

(
www.airproducts.com, APD)



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Chemicals & Materials

- Catalysts
- Membranes & filtration
- Coatings & paints
- Abrasives
- Lubricants
- Composites & structural materials



Medical & Pharmaceutical

- Detection, analysis & discovery
- Targeted drug delivery
- Prosthetics: mechanical, filtration, neural
- Anti-microbial, -viral, & -fungal agents



Automotive & Transportation

- 50 components of the automobile will be affected
- Structural materials
- Coatings
- Sensors
- Displays
- Catalytic converters
- Fillers
- Power
- Etc.

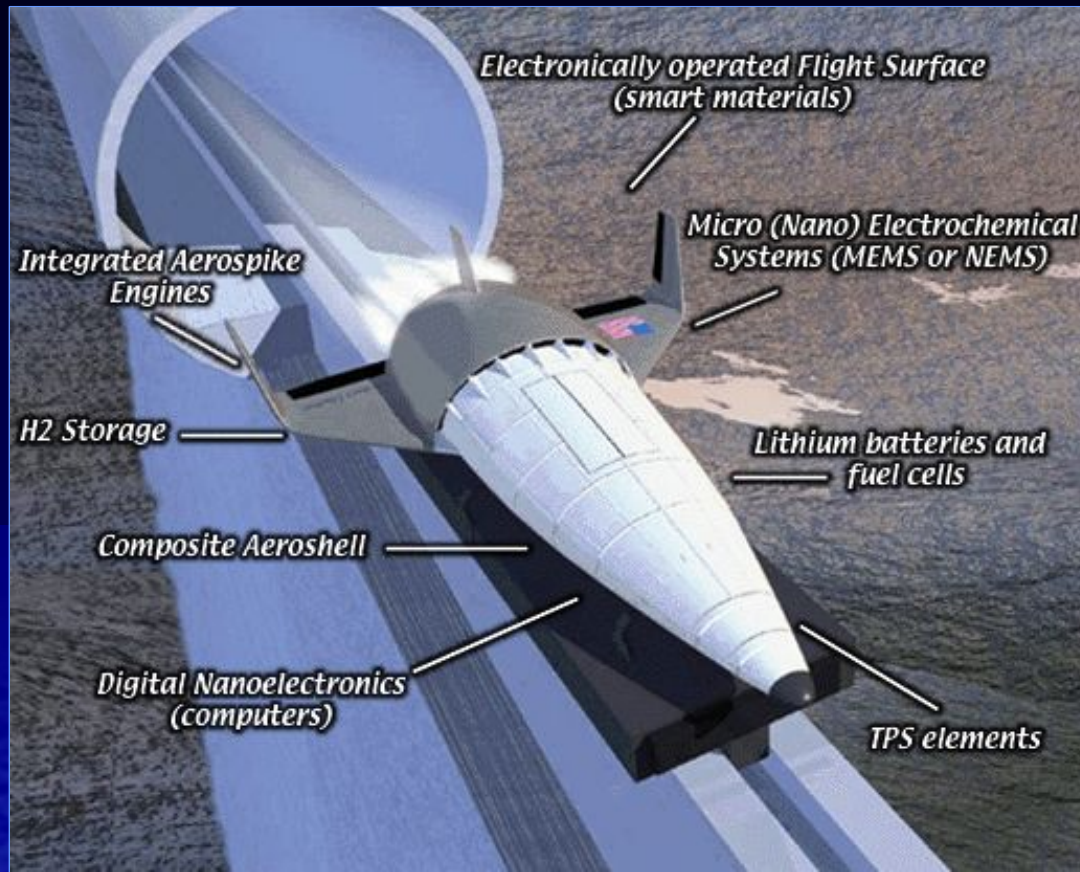


Aerospace & Defense

- Structural materials
- Coatings
- Fuel
- Electronics & electromechanical systems
- Weapons
- Surveillance
- Smart battle dress
- Life support and environmental



Impact on a Space System



Source: NASA



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IT & Telecommunications

- Photolithography
- Electronics & optoelectronics
 - Processors
 - Data storage, molecular memory
 - Display technologies
- Quantum computing
- Wireless technologies
- Optical transmission
- Optical switching



Energy

- Fuel cells
- Solar power
- Batteries
- Power transmission
- Lighting
- Higher efficiency appliances & devices



Forbes Top Products 2003

- High performance ski wax
- Breathable waterproof ski jacket
- Wrinkle-resistant, stain-repellent fabrics
- Deep-penetrating skin cream
- World's first OLED digital camera



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Forbes Top Products 2003

- Performance sunglasses
- Nanocrystalline sunscreen
- High-tech tennis rackets
- High-tech tennis balls



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Forbes Top Products 2004

- Footwarmers
- Washable mattress
- Golf balls and clubs
- Customized skin care
- Wound dressing for burns



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Forbes Top Products 2004

- Military-grade disinfectant
- Superhydrophobic spray
- Automotive glass treatment
- Joint and muscle pain cream
- Dental adhesive



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Medium-term: Global Energy Needs

Some Solutions

- Better fuel cells
- Better hydrogen storage
- Better solar cells
- Distributed energy generation and storage
 - Re-inventing the power grid
- Higher efficiency devices - lighting, appliances, etc.



Medium-term: Clean Water

Some Solutions

- Inexpensive decentralized water purification
- Environmental remediation



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Medium-term: Health and Longevity

Some Solutions

- Inexpensive, rapid diagnostics
- New methods of drug delivery
- More effective anti-virals and antibiotics
 - Easier to store and administer
- Faster development of new drugs
- Customized drug therapy
- Repair of DNA/cellular damage



Medium-term: IT Everywhere

Some Solutions

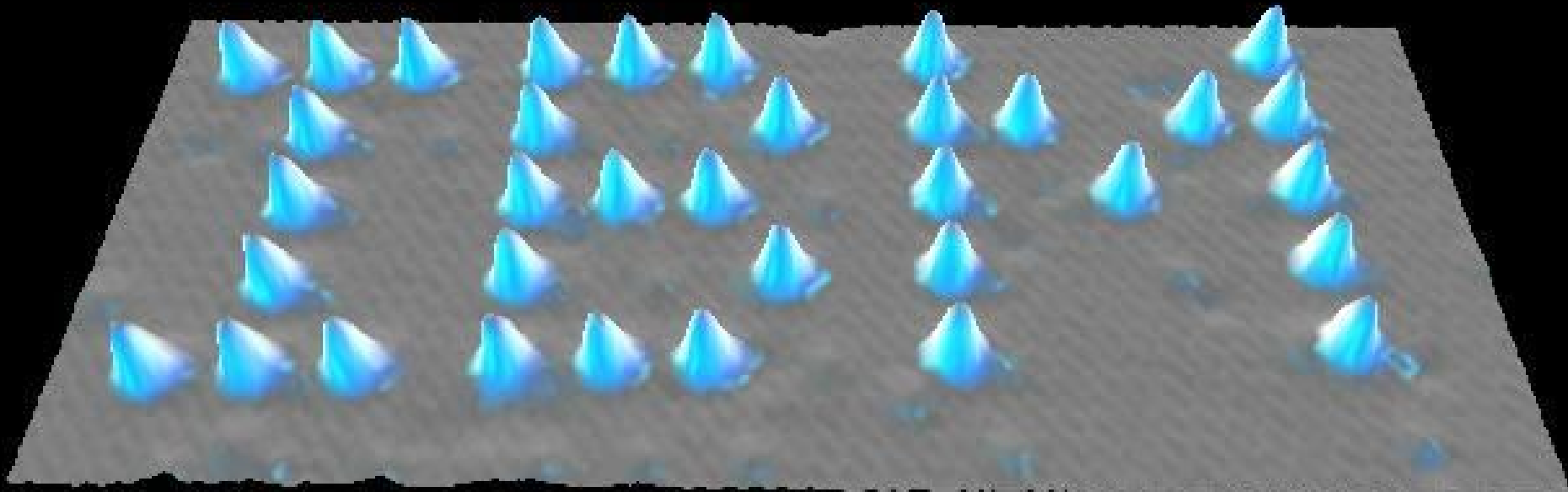
- Drastically reduced cost, increased performance
 - Memories
 - Displays
 - Processors
 - Solar powered
 - Embedded intelligence
- Distributed, pervasive, self-configuring “smart” networks
- Pervasive computing and communications
 - Increasing cross cultural understanding and cooperation



Some Key Findings & Trends

- It's NOT science fiction – it's here today
- Will affect almost everything over time
- Initial impact will be subtle and gradual
 - “Plastics”
- R&D funding is unprecedented
 - Academic, government and industrial
- Spread across globe
 - Patent filing exploding worldwide
- Accelerated pace of development
 - Advances in tools will speed acceleration

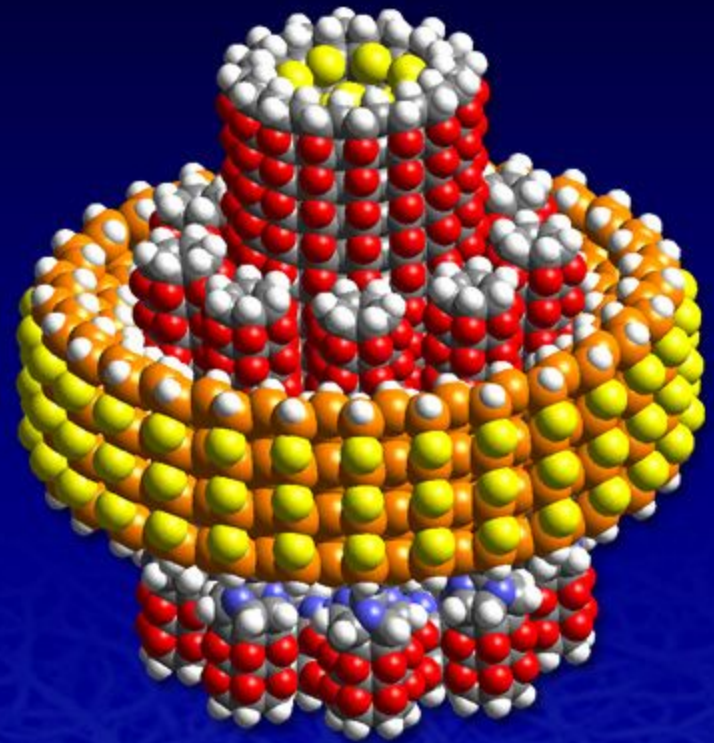




Don Eigler, *IBM Almaden Research Center*, 1990

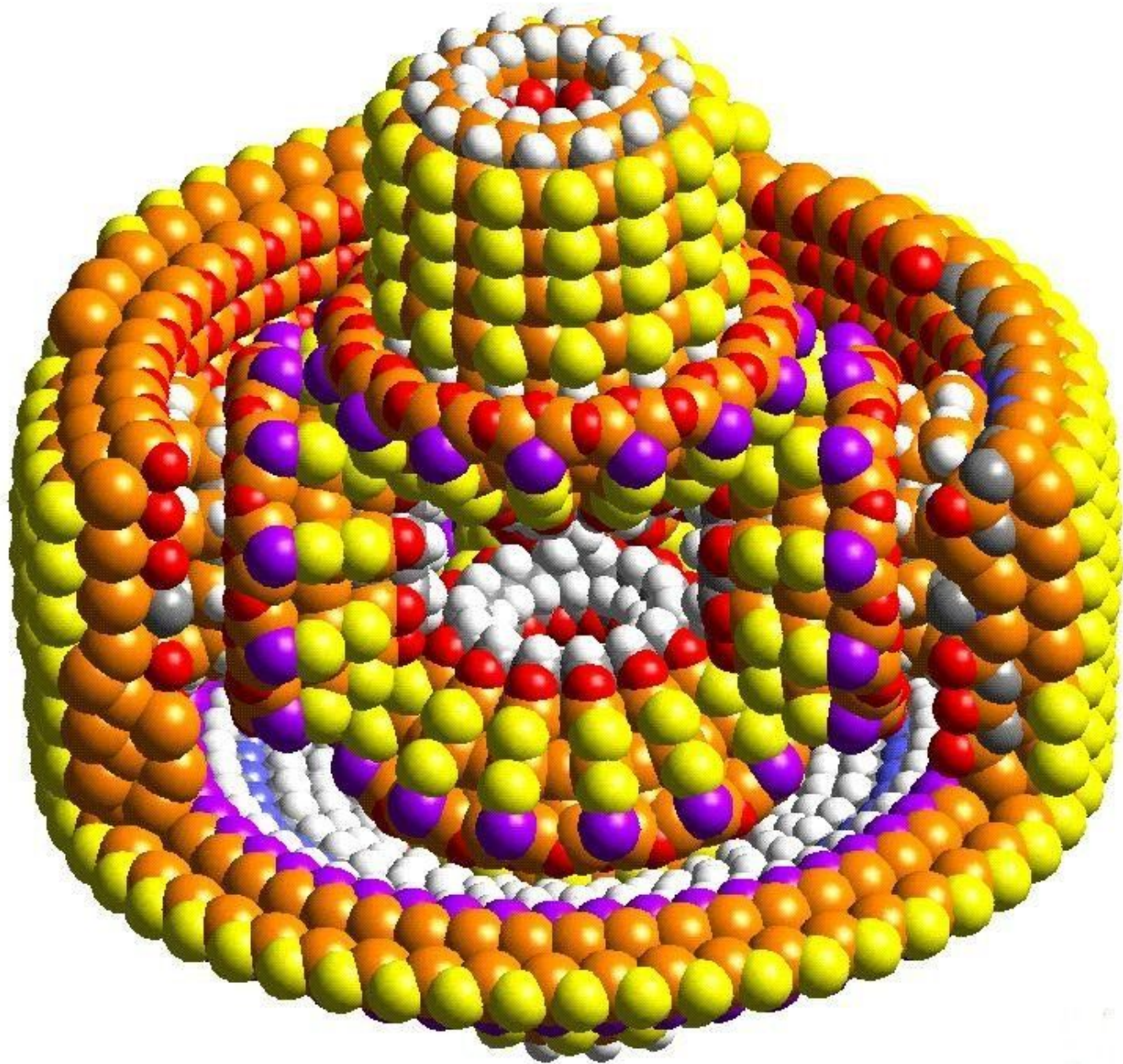
Long-term: Molecular Nanotechnology

- “Thorough, inexpensive control of the structure of matter based on molecule-by-molecule (i.e. atomically precise) control of products and byproducts of molecular manufacturing.”
 - Molecular machine systems (MMS)
 - Molecular manufacturing (MM)
- “Nanoscale Engineering” and today’s building blocks are precursors
- Productive Nanosystems applying *convergent assembly* (cf. visualization of exploratory engineering)

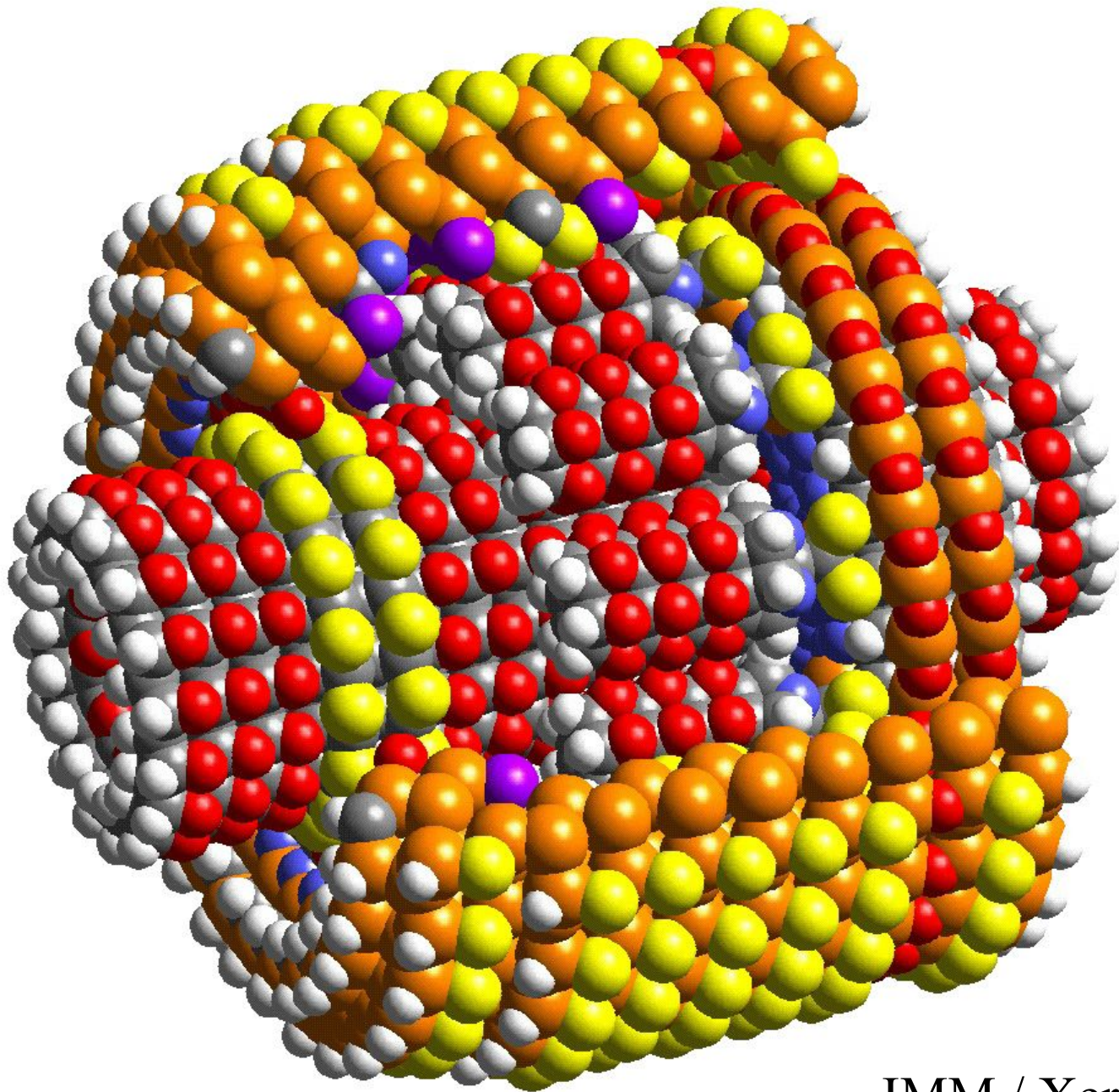




IMM / Xerox PARC

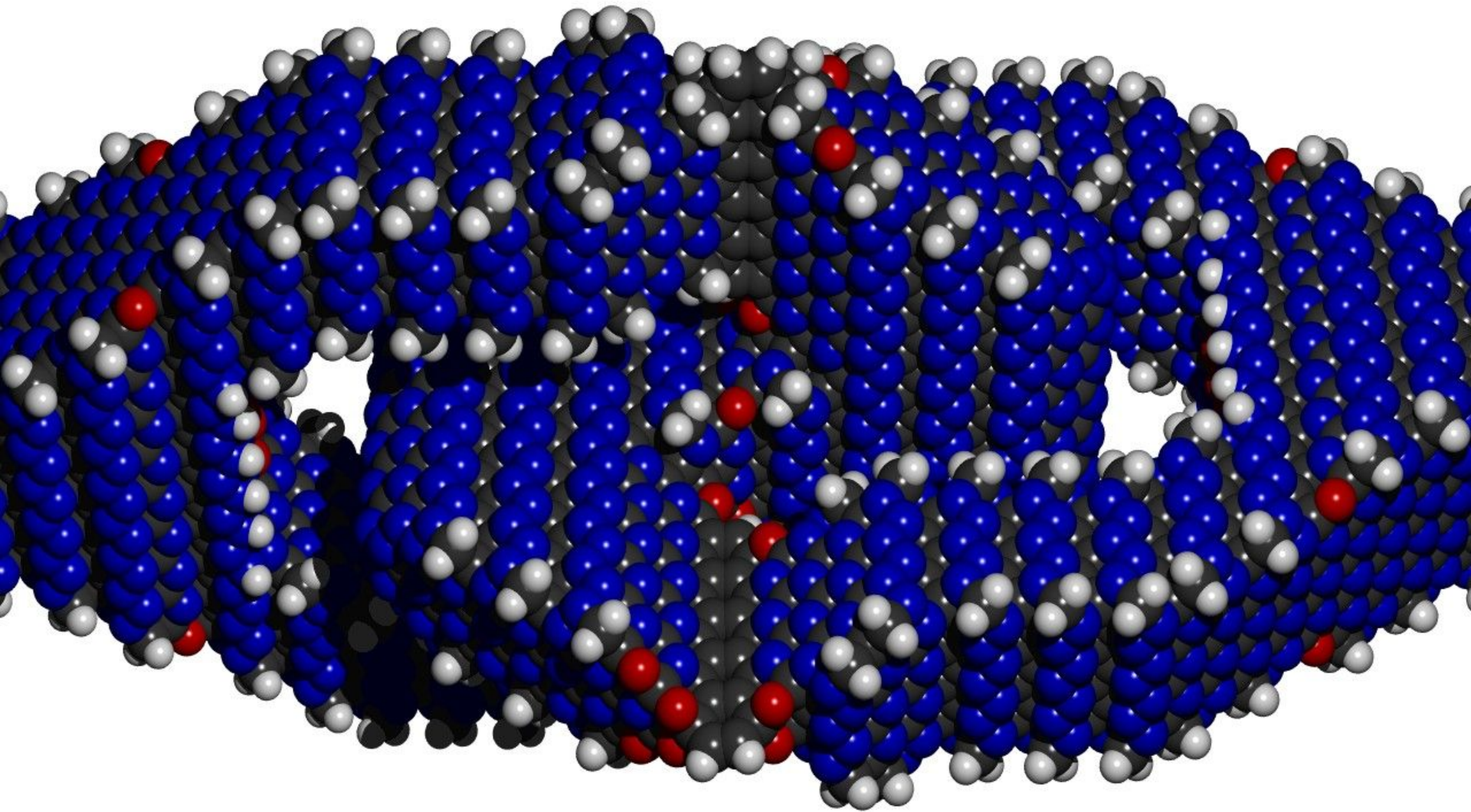


IMM / Xerox PARC

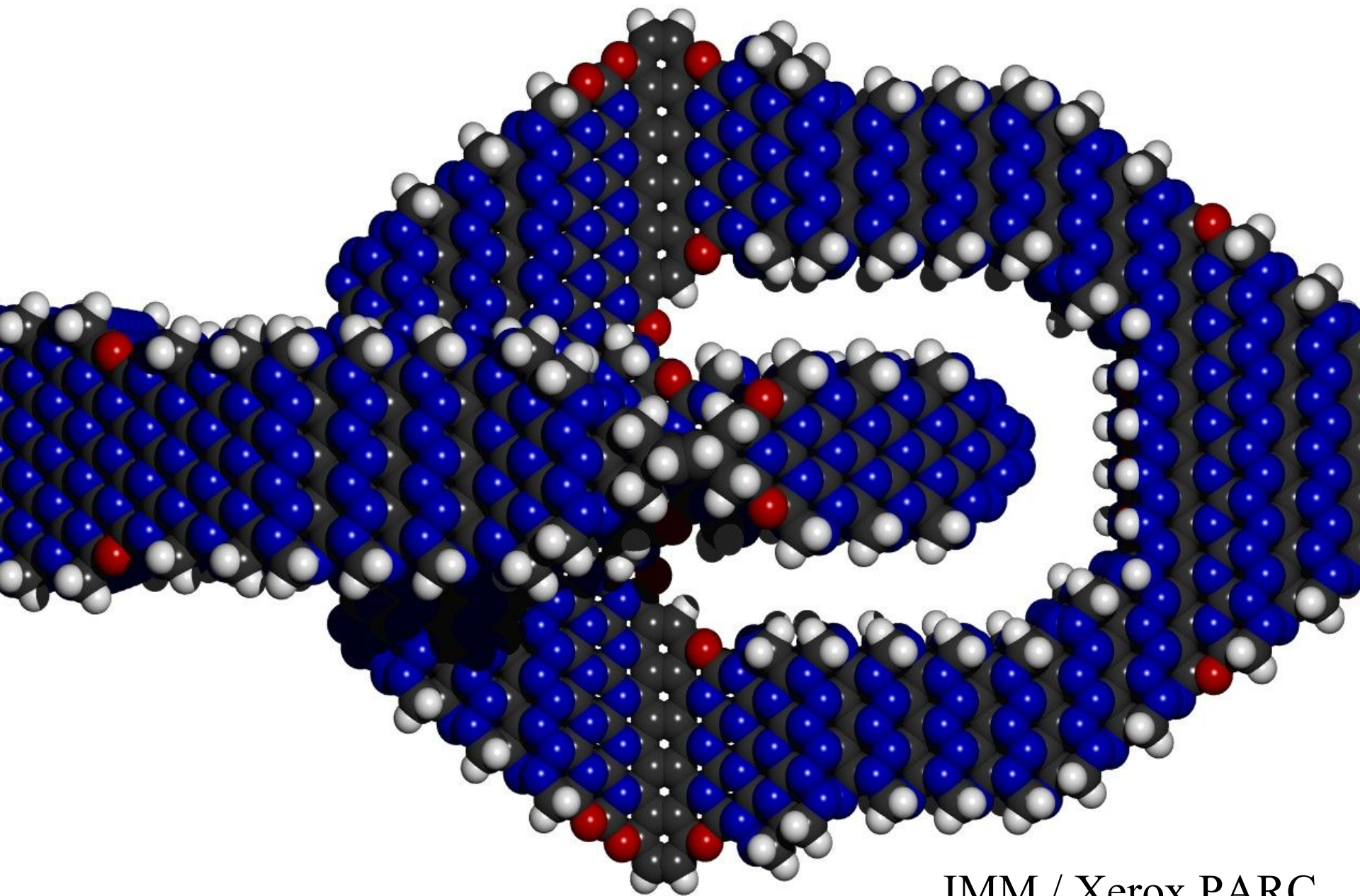


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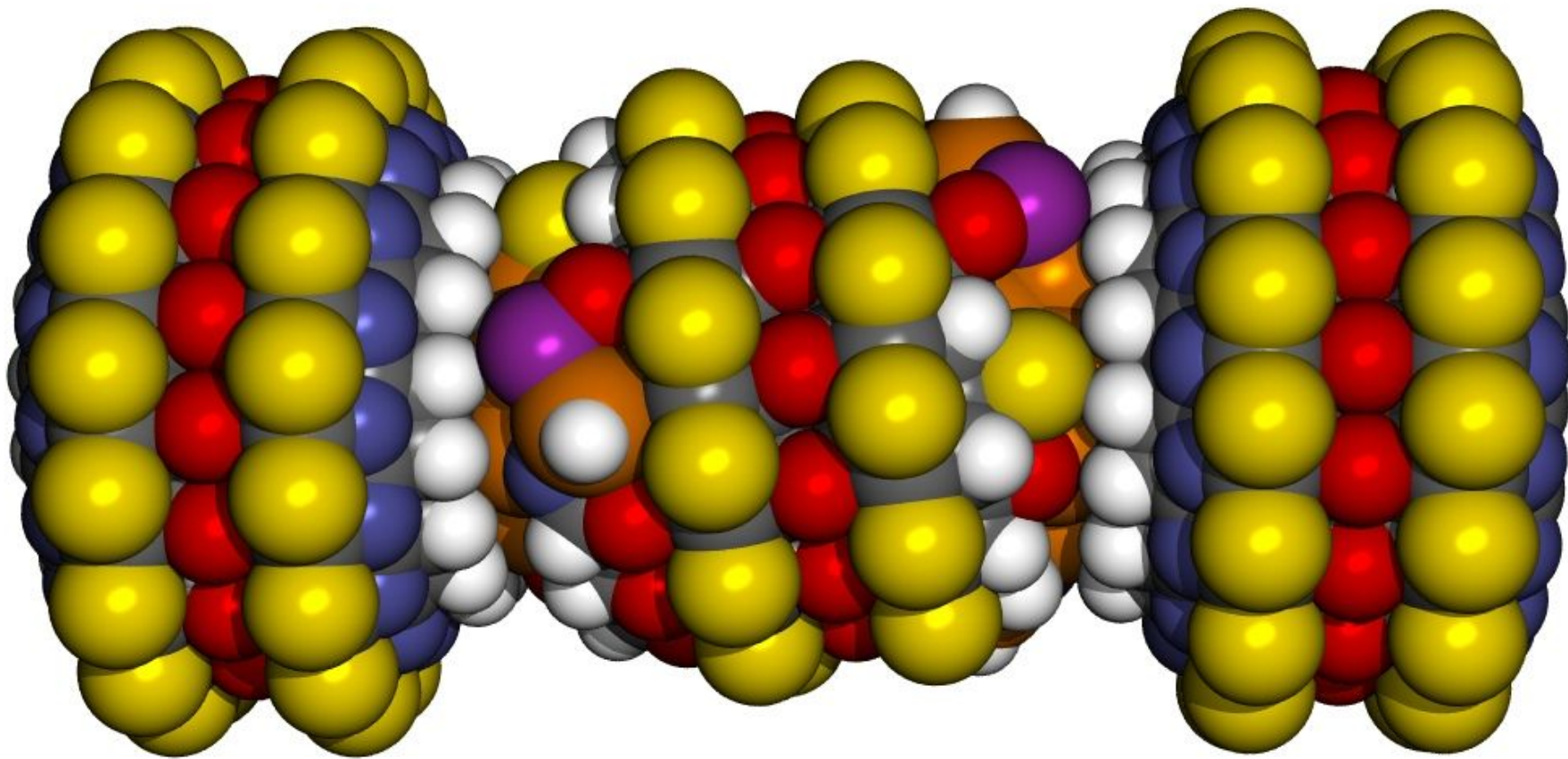
IMM / Xerox PARC



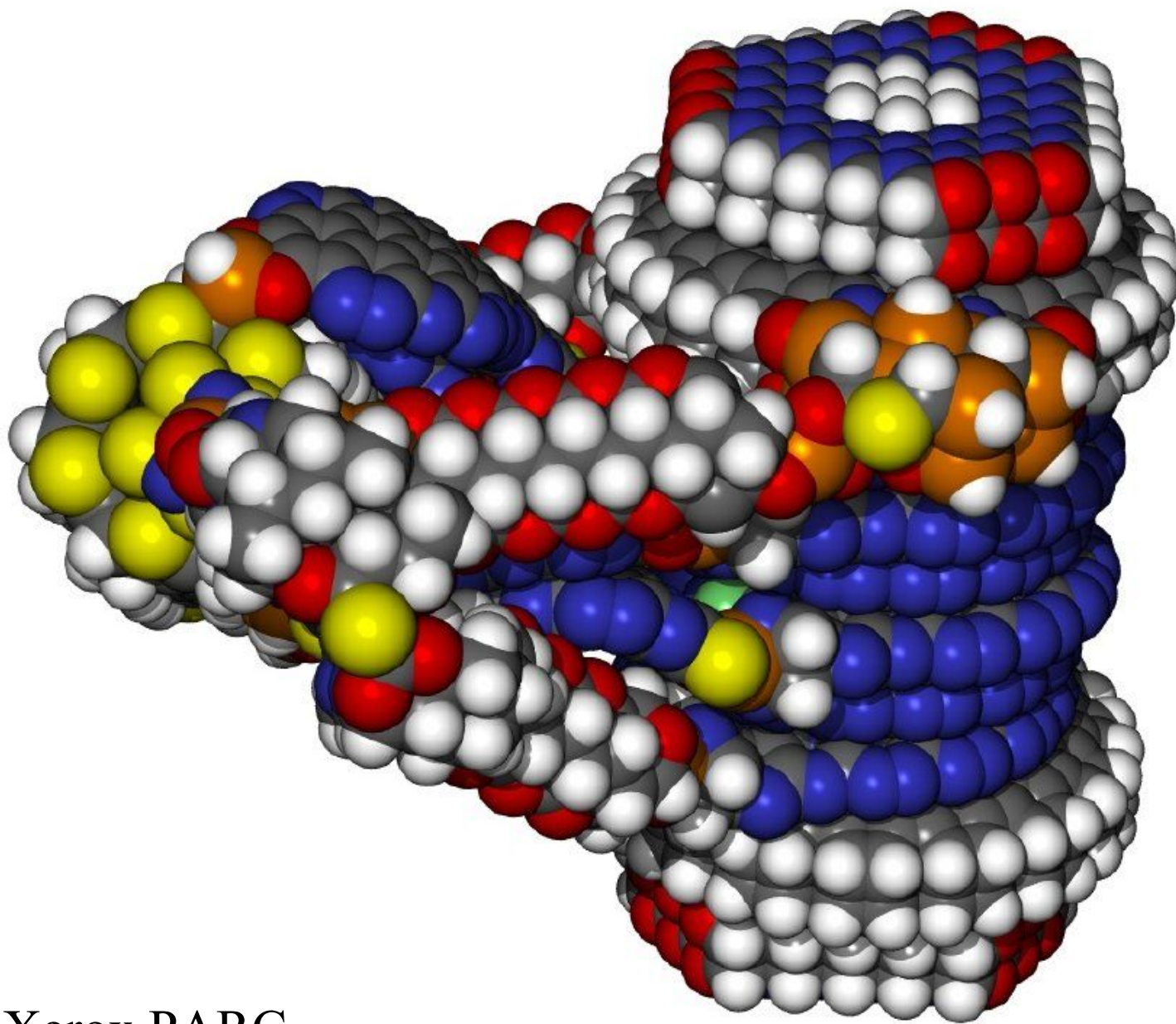
IMM / Xerox PARC



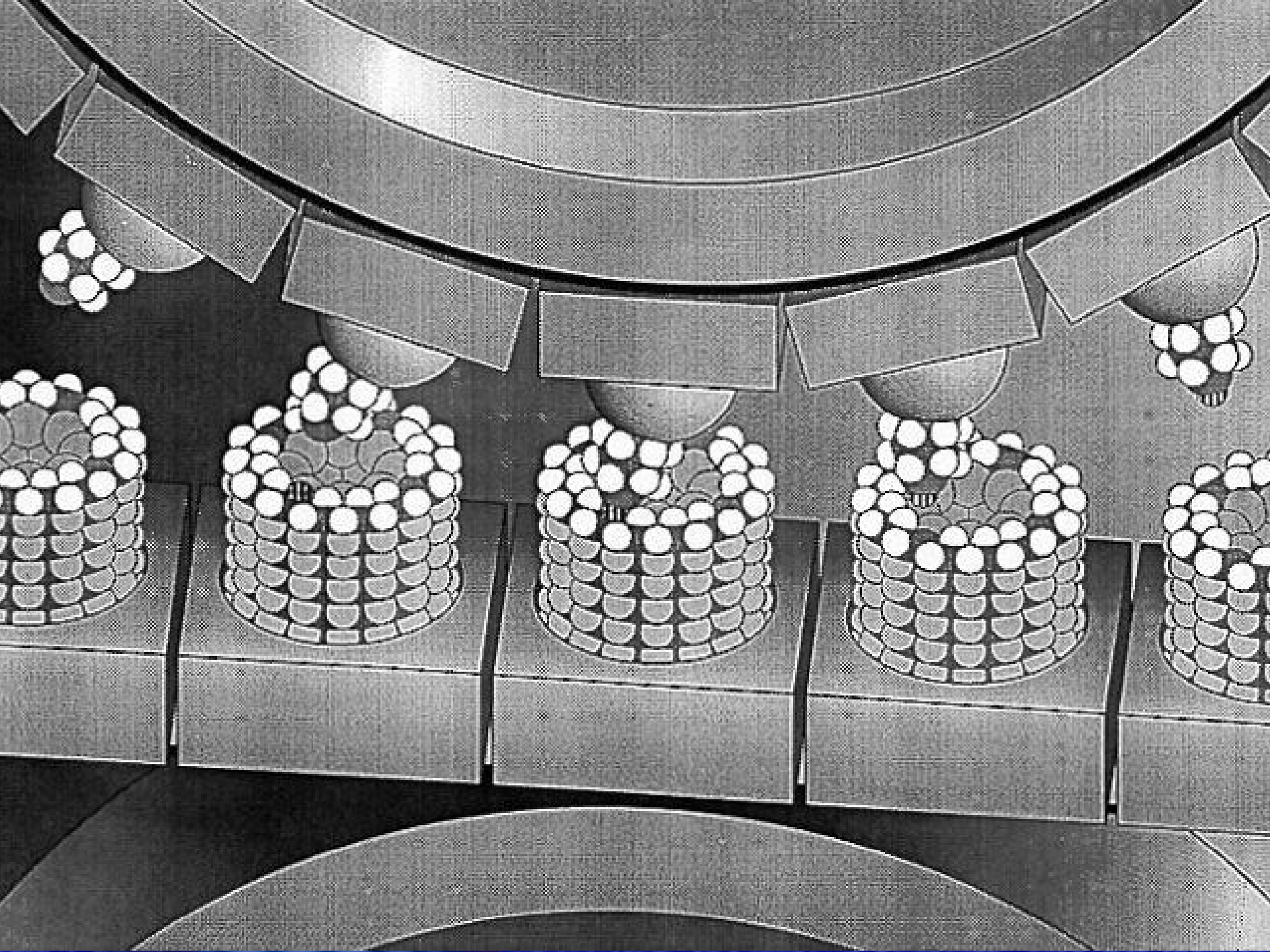
IMM / Xerox PARC



IMM / Xerox PARC

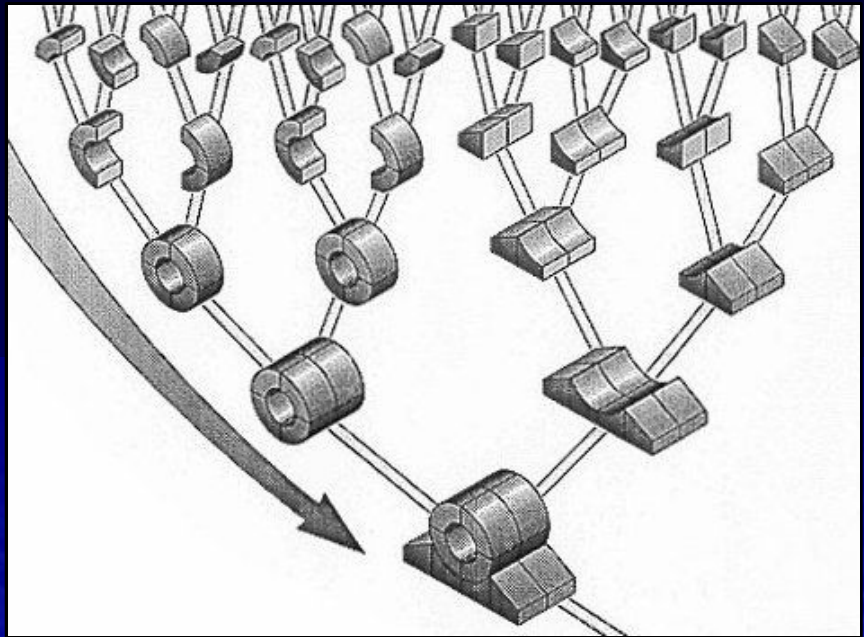


IMM / Xerox PARC

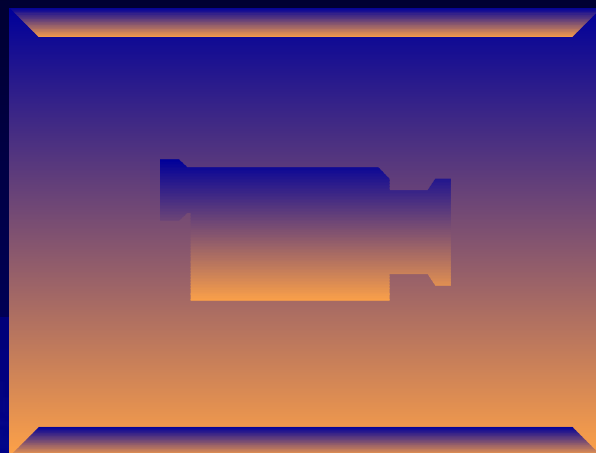


Convergent assembly

A 100-stage pairwise
assembly process
can convert
molecular-scale parts
into
ton-scale products.



Productive Nanosystems Visualization



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Science-fiction?!

“If a thirty-year projection sounds like science fiction, it may be wrong.

*If it does **not** sound like science fiction, then it is definitely wrong.”*

– Chris Peterson & Gayle Pergamit



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Science-fiction?!

“If we have learned one thing from the history of invention and discovery, it is that, in the long run – and often in the short one – the most daring prophecies seem laughably conservative.”

– Arthur C. Clarke



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EU NanoRoadMap project to cover MNT, NanoFactories

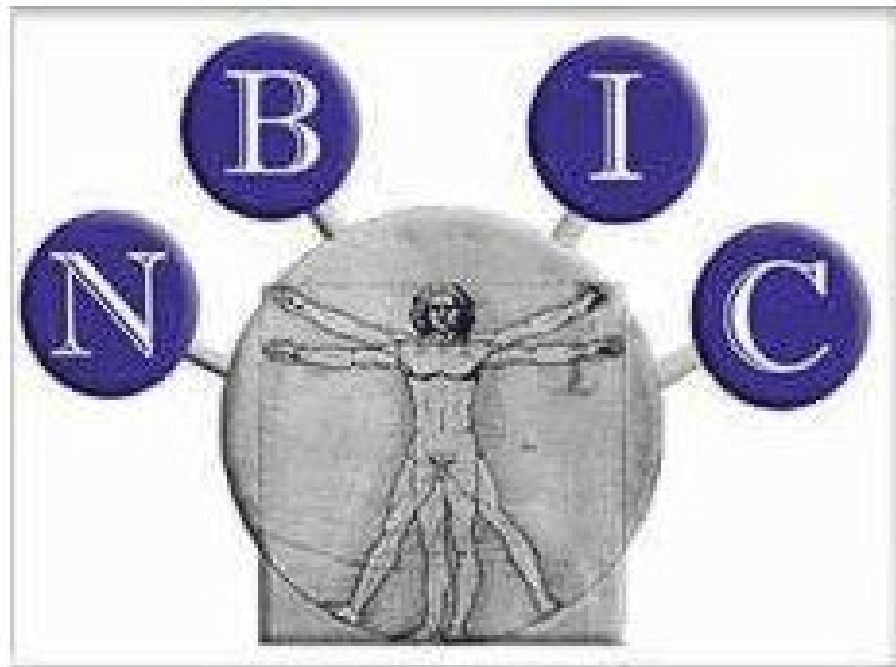
- “[...] These enormous benefits are coupled with potential dangers: molecular nanotechnology will allow the rapid prototyping and inexpensive manufacture of a wide variety of powerful products with the potential to disrupt many aspects of society and politics.”
- “In the military field, minute but powerful weapons and surveillance devices are a possibility, as is environmental damage provoked by the extensive use of inexpensive products.”
- “The control of these technologies could lead to abusive market restrictions, or create a demand for a black market almost impossible to stop as, due to the reduced size, small nanofactories could easily be smuggled, and potentially dangerous.”



NBIC Technology Convergence

- NBIC = *Nano-Bio-Info-Cogno*
- NSF / DOC Reports & conferences
- EU Commission report on NBIC
- Convergence is accelerating *exponentially*
- Implication of possible “technological singularity” ahead



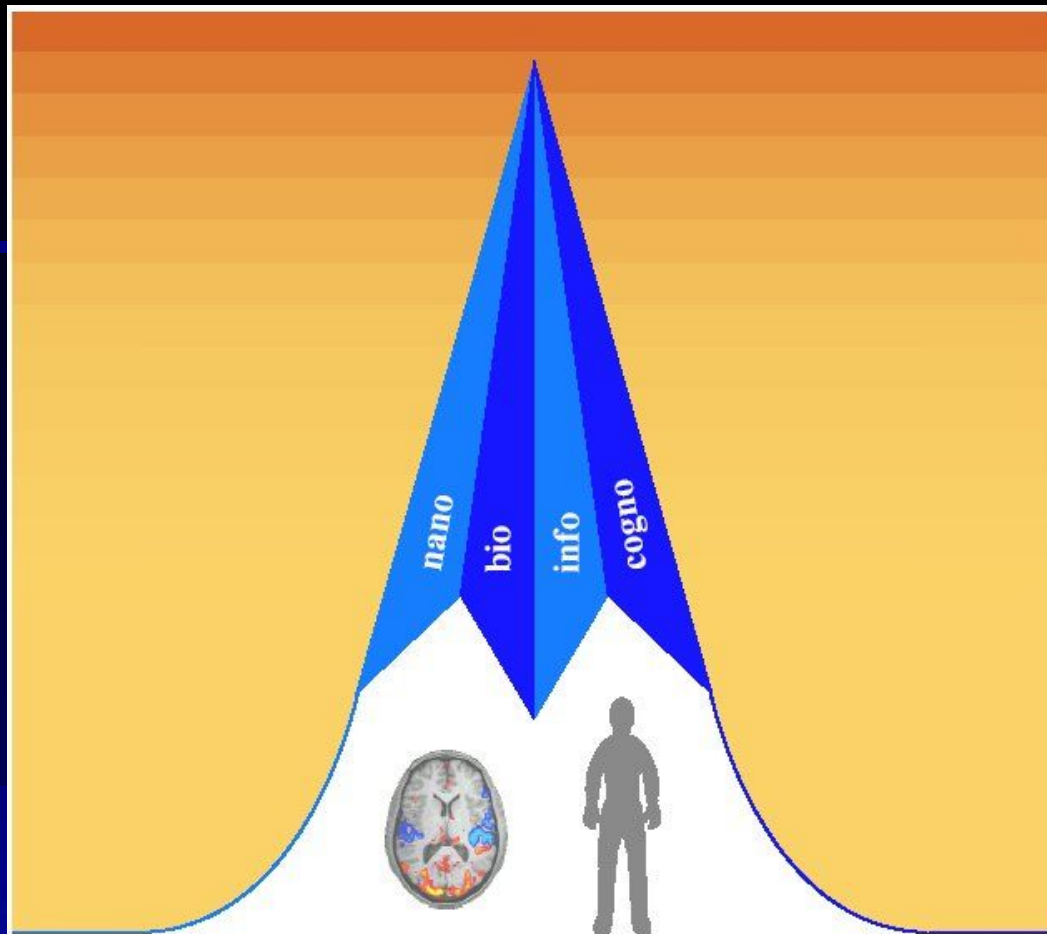


Nanotechnology, Biotechnology, Information Technology, and Cognitive Science

NBIC CONVERGENCE 2003

**Converging Technologies for
Improving Human Performance**

February 5-7, 2003 • UCLA • Los Angeles, CA



CONVERGING TECHNOLOGIES FOR IMPROVING HUMAN PERFORMANCE

June 2002

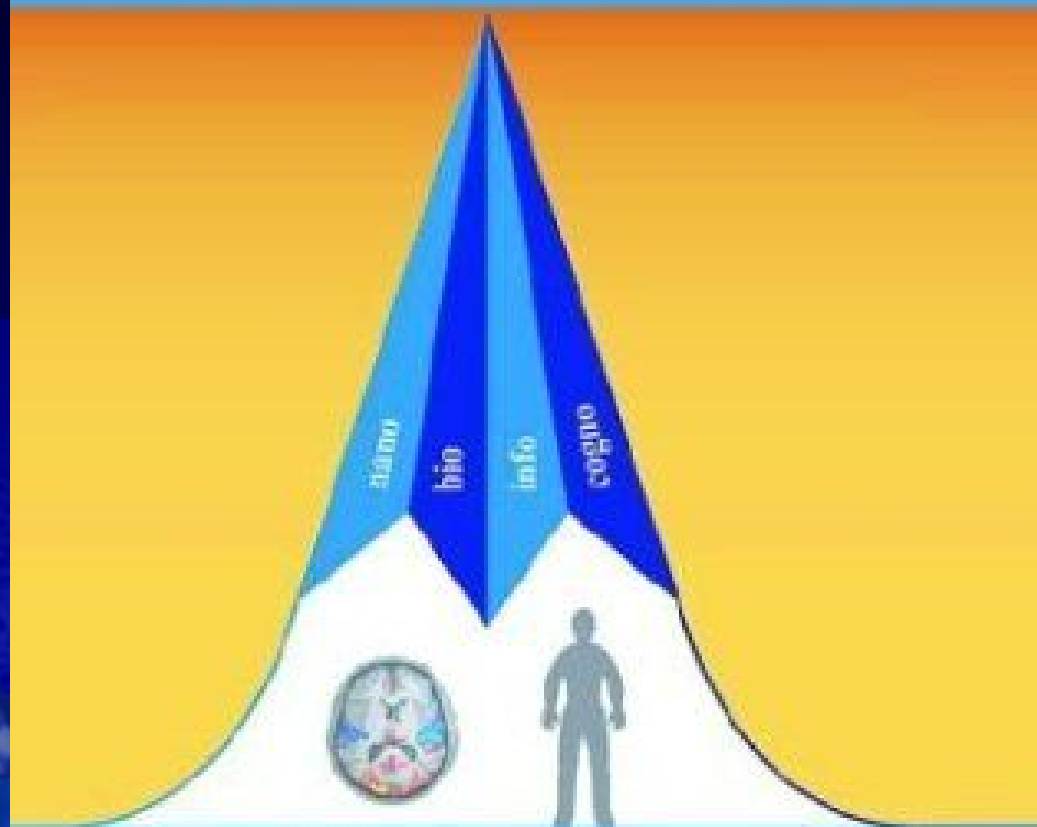


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Converging Technologies for Improving Human Performance

Nanotechnology, Biotechnology,
Information Technology and Cognitive Science

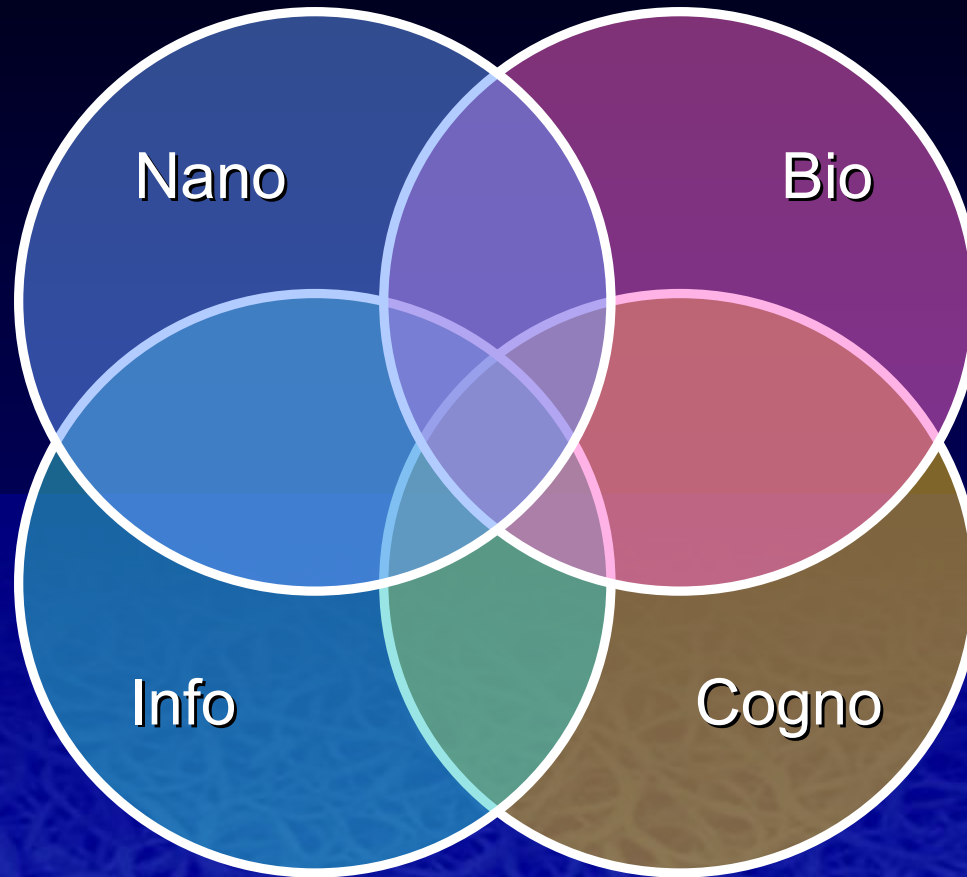
Mihail C. Roco and William Sims Bainbridge (Eds.)



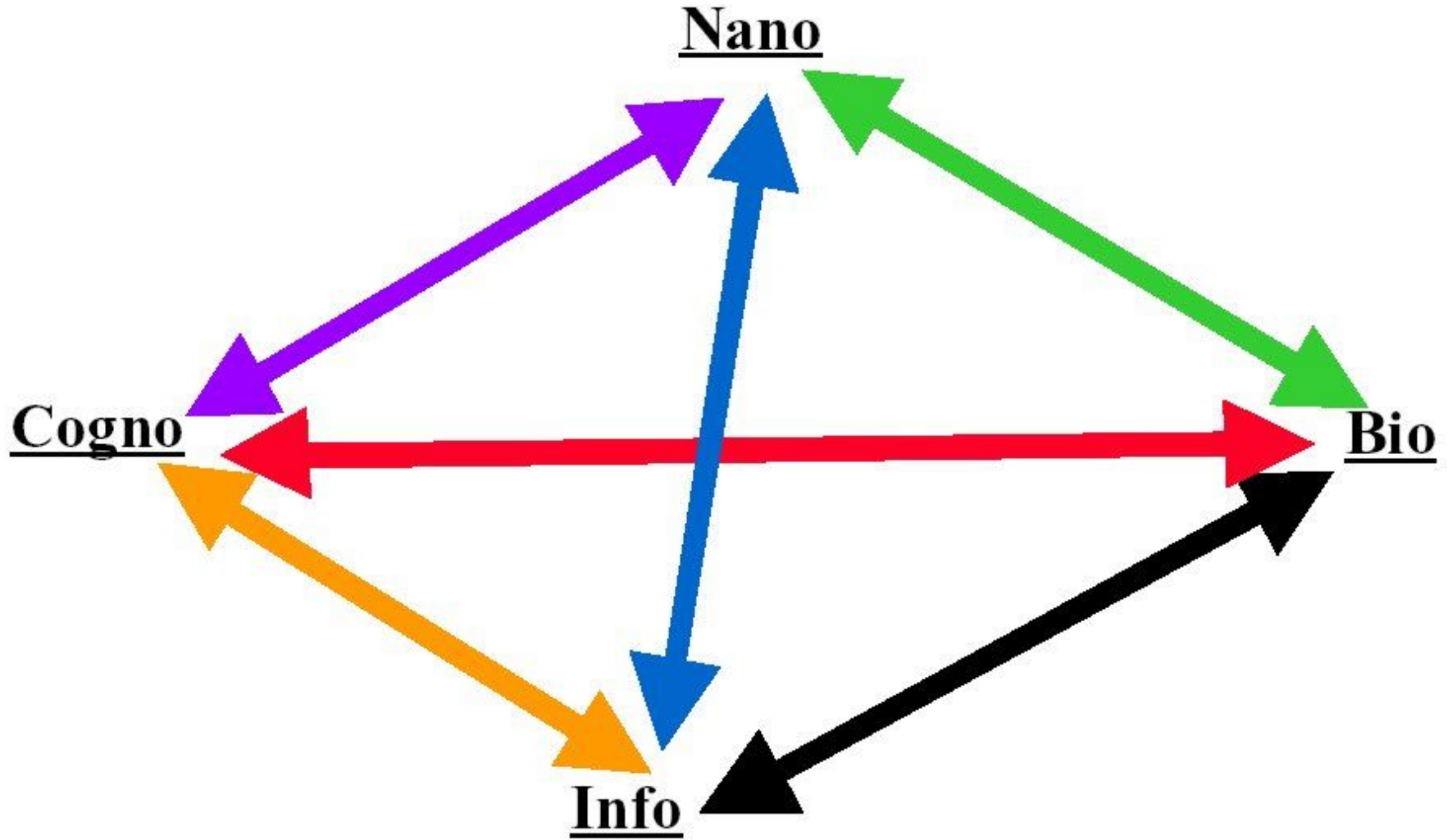
Kluwer Academic Publishers

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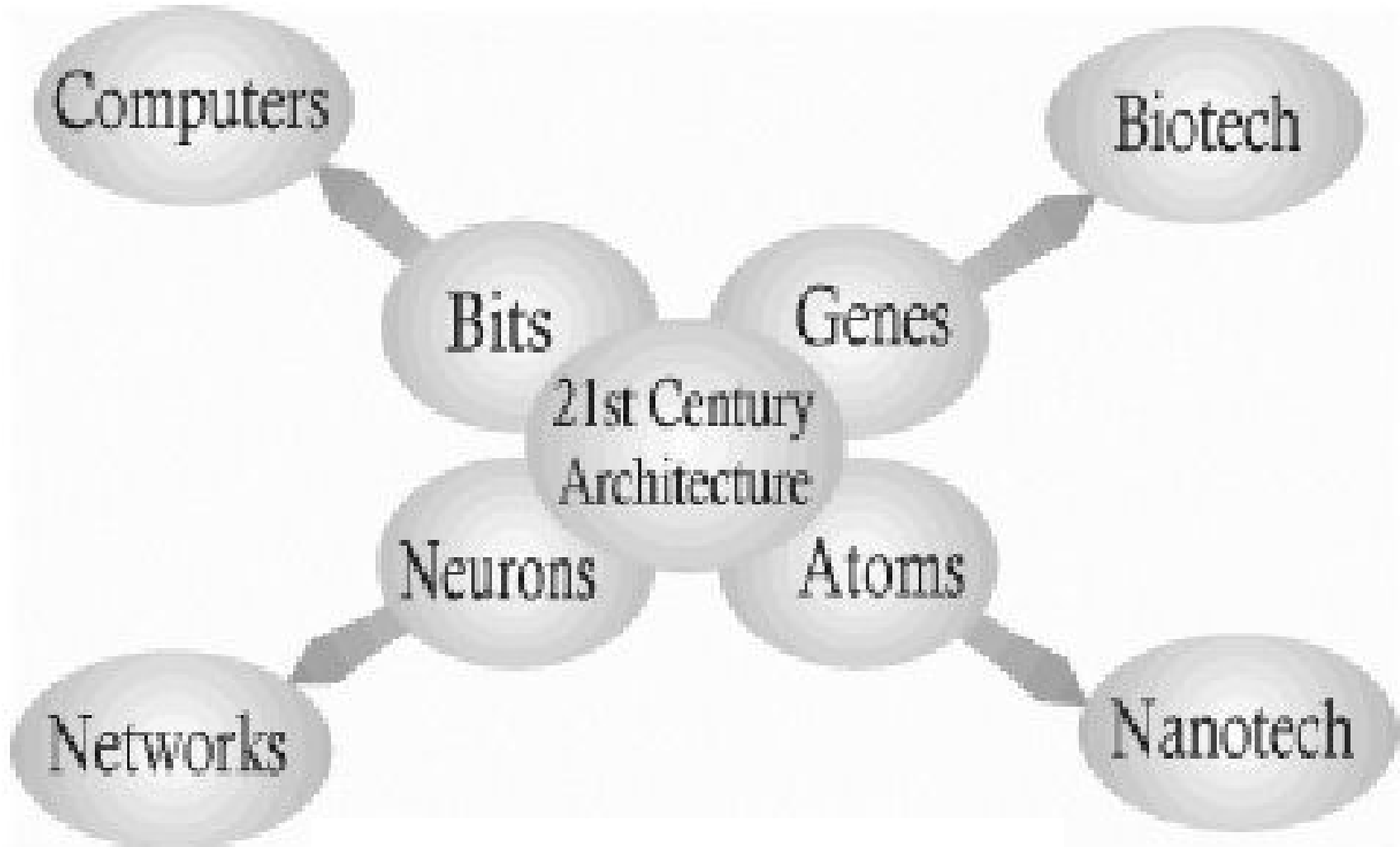
Accelerating Technological Convergence



Fundamental Interdependence



The Lay of the Converging Land



Wearable PCs for Augmented Reality



Existing & Imminent Augmented Reality



Figure B.4. "Smart environments."

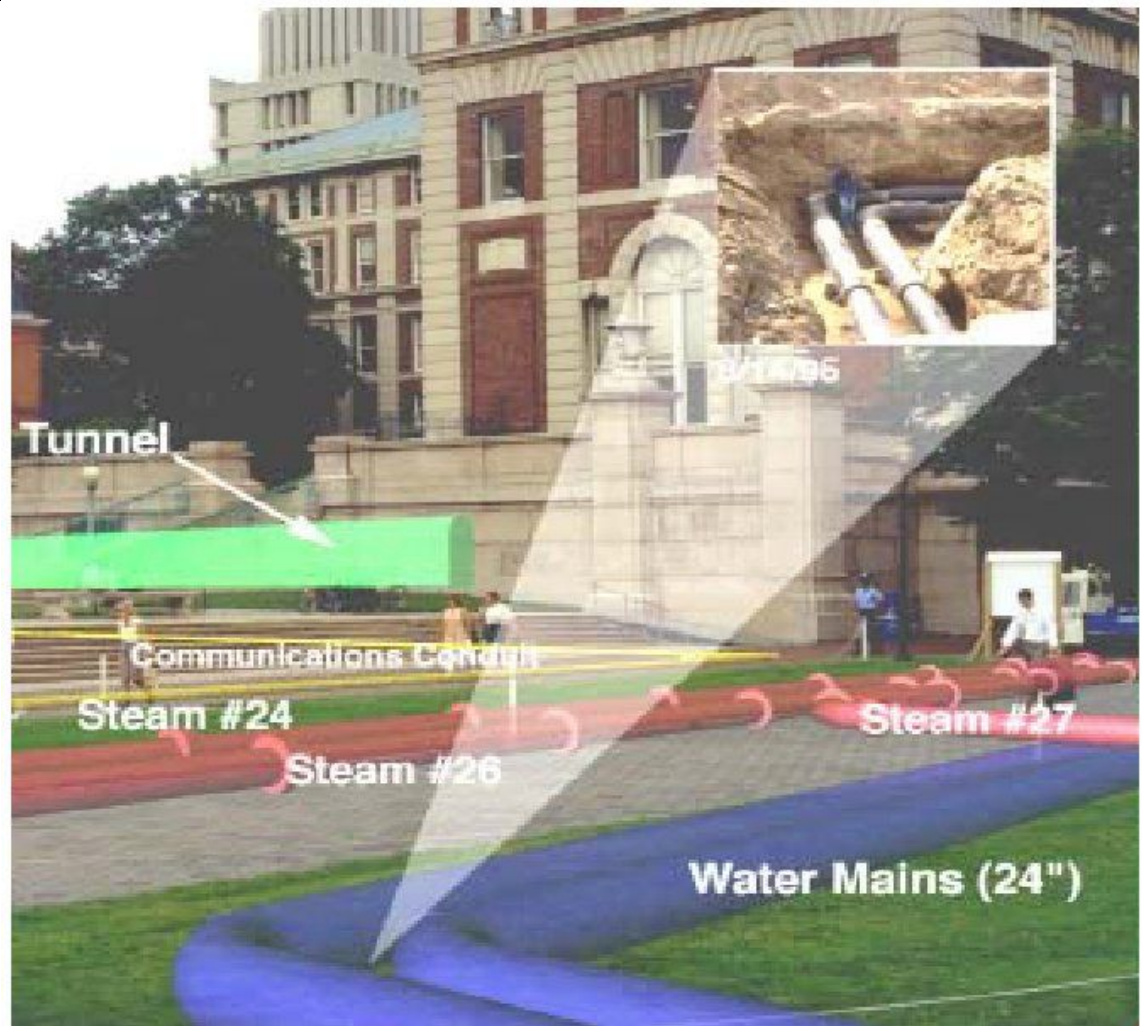


Figure E.3. Augmented reality.

Exoskeletons Augment Physical Power



ISMS's Robot Supporting Human



Motion Capture System

Figure E.9. Incorporate and advance technologies to remove the burden of mass (120+ lbs.) and increase the soldier's strength, speed, endurance, and overall combat effectiveness.

Sustained Optimal Cognitive Performance

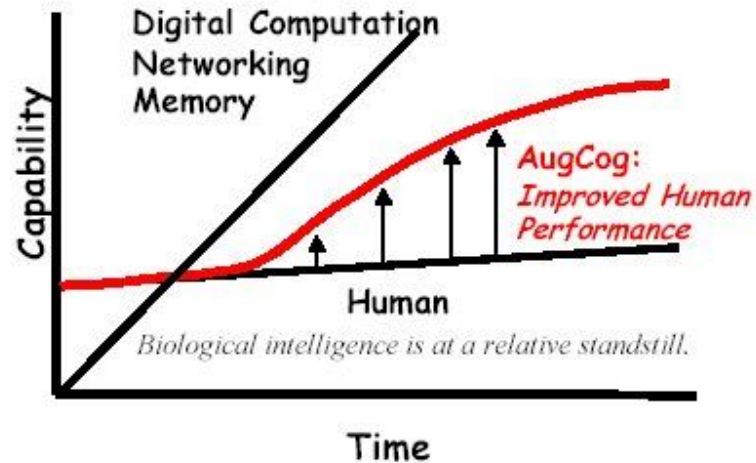


Figure E.10. Maintain a person's cognitive state at an optimal arousal level, then the person will have enhanced memory and the ability to perform optimally even under conditions of interruptions; this will improve and enhance the quality of military decisionmaking.

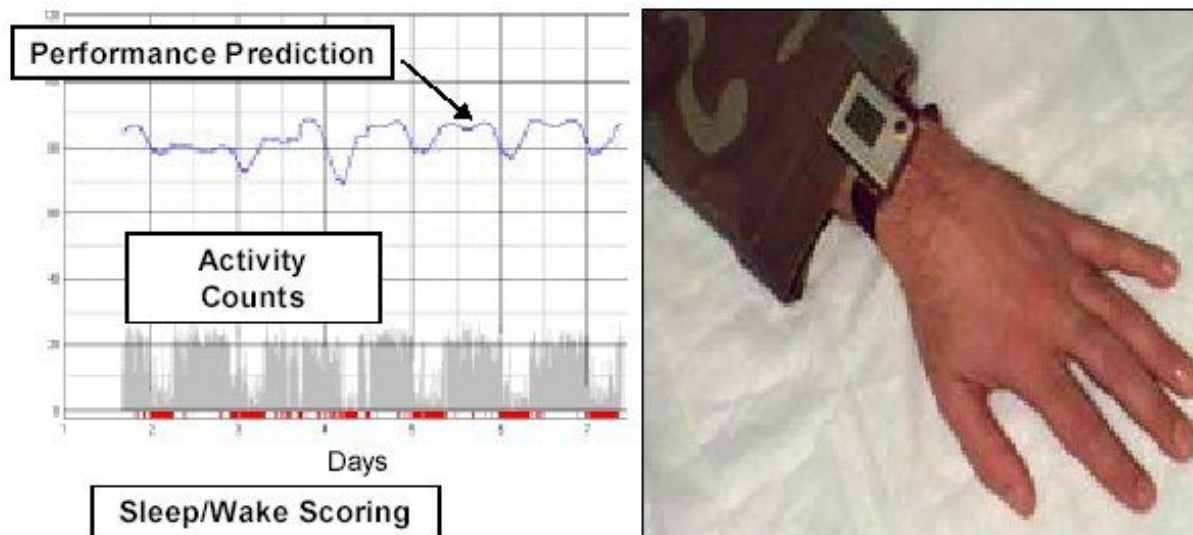


Figure E.4. Sustaining performance: managing sleep.

Brain-Airplane Interface

Brain-Machine Interface

This program uses brain-machine interfaces to explore augmenting human performance by extracting neural codes for integrating and controlling peripheral devices and systems. The program attacks the technological challenges across many disciplines and will require assembly of interdisciplinary teams to achieve the ambitious goal of having humans interact with and control machines directly from brain activity.

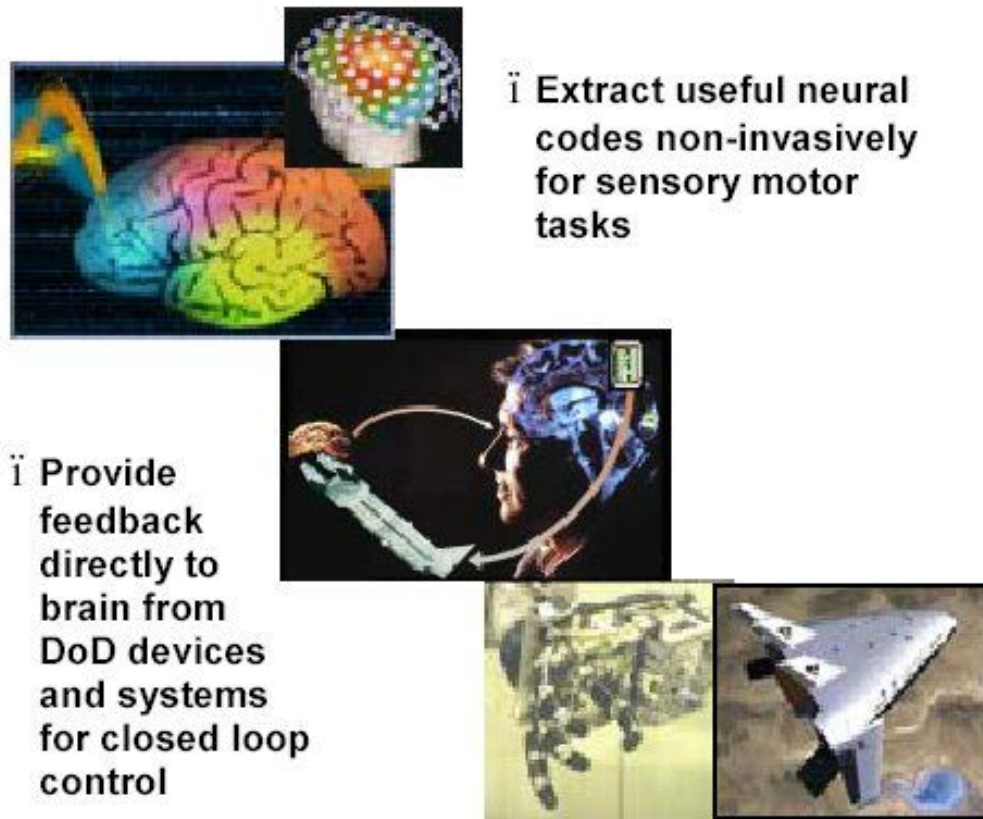
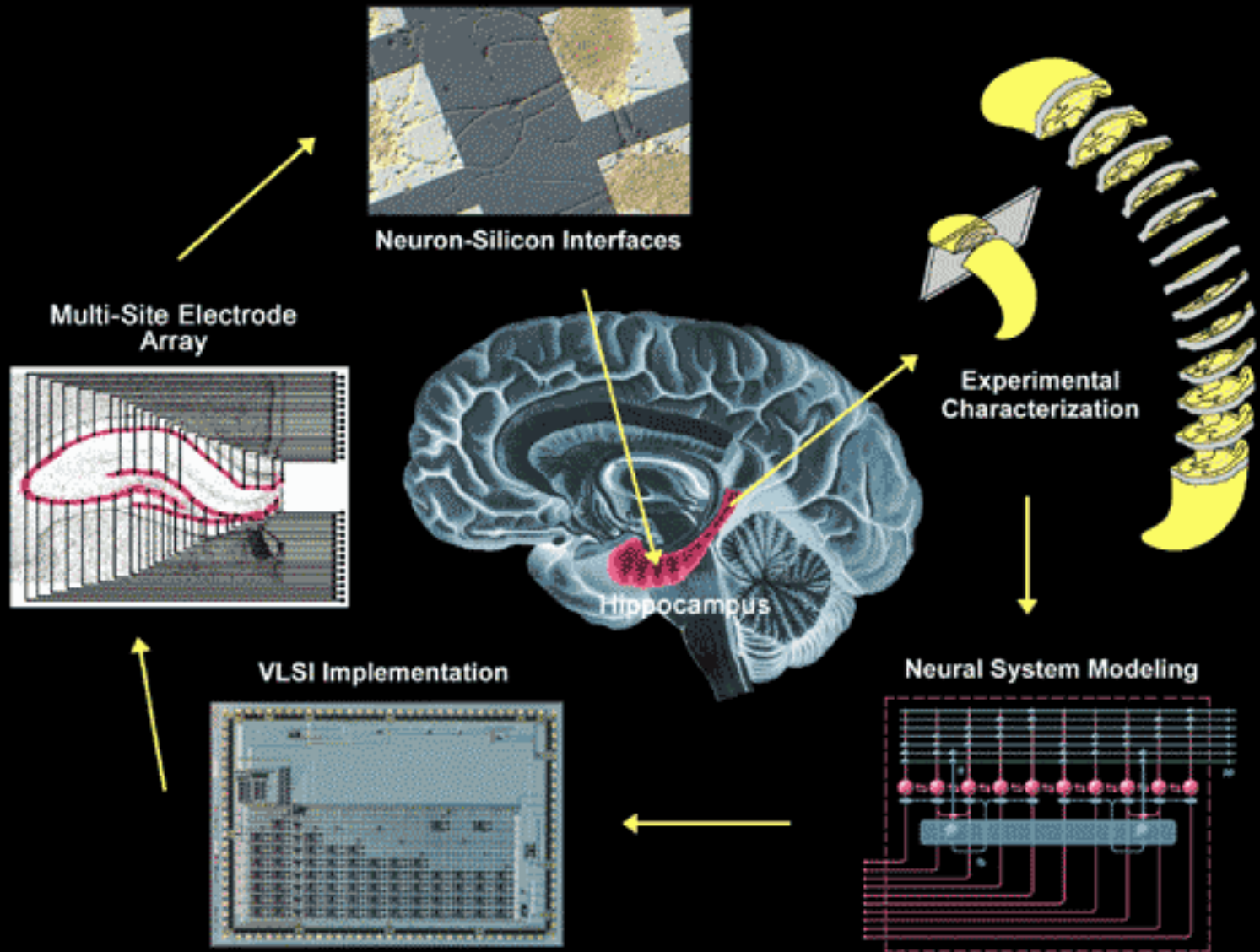


Figure E.12. Augment human performance by harnessing brain activity to command, control, actuate, and communicate with the world directly through brain integration and control of peripheral devices and systems.

Computer Chip Models of Neural Function as Brain Implants for Neural Prostheses

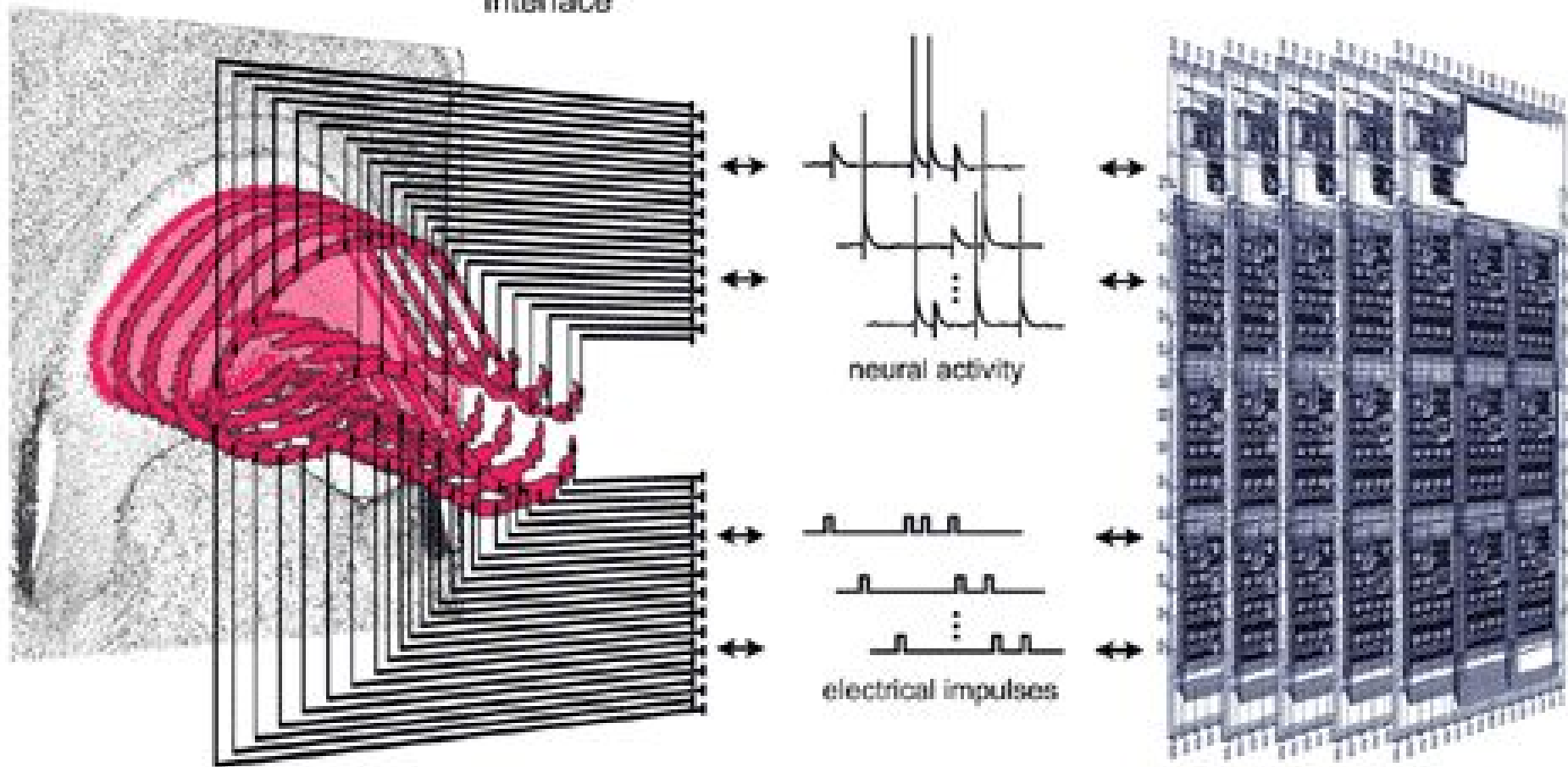


Hardware Models of Neural Networks as Brain Prostheses: Neuron-Silicon Interface Devices Connect Multi-Chip Modules to Existing Neural Tissue

Intact Brain

Neuromorphic
Neuron-Silicon
Interface

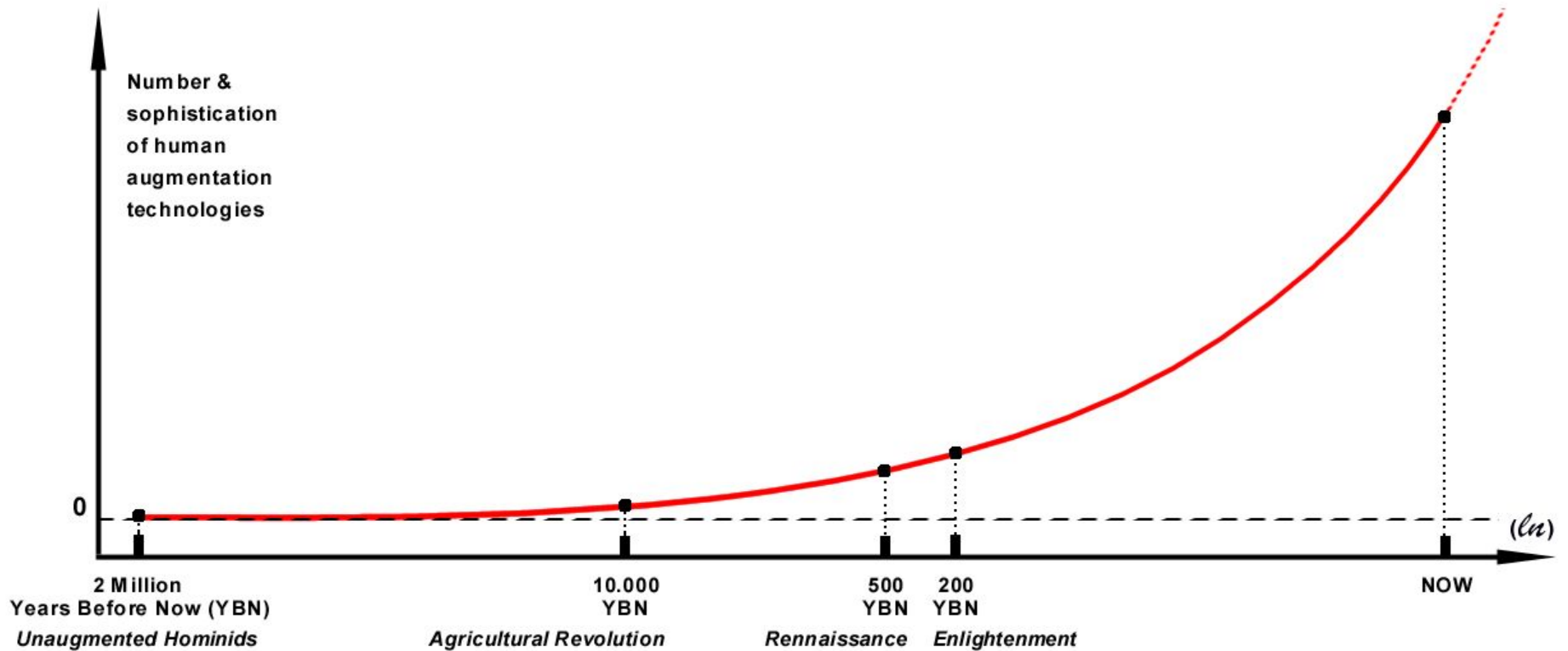
Neurocomputational
Multi-Chip Module



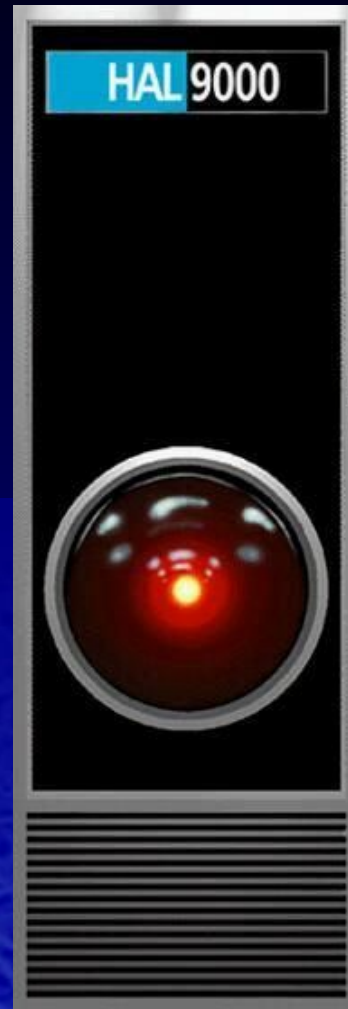


President Clinton presented Ray Kurzweil with the National Medal of Technology, the nation's highest award for technological achievement.

Technological Singularity Ahead



Tech Singularity \cong real A.I. finally emerges



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WHEN HUMANS TRANSCEND BIOLOGY



THE
SINGULARITY
IS
NEAR

**RAY
KURZWEIL**

AUTHOR OF *THE AGE OF SPIRITUAL MACHINES*

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Take *Exponentially Accelerating Convergence* Seriously Enough

Accelerating Change 2004

Physical Space, Virtual Space, and Interface

Stanford University
Palo Alto, California
November 5 - 7



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Forsighted Pres. Kennedy?

“Most of the scientists that the world has ever known are alive and working today. [...] This nation’s own scientific manpower is doubling every 12 years at a rate of growth more than three times that of our population as a whole.”

– President John F. Kennedy

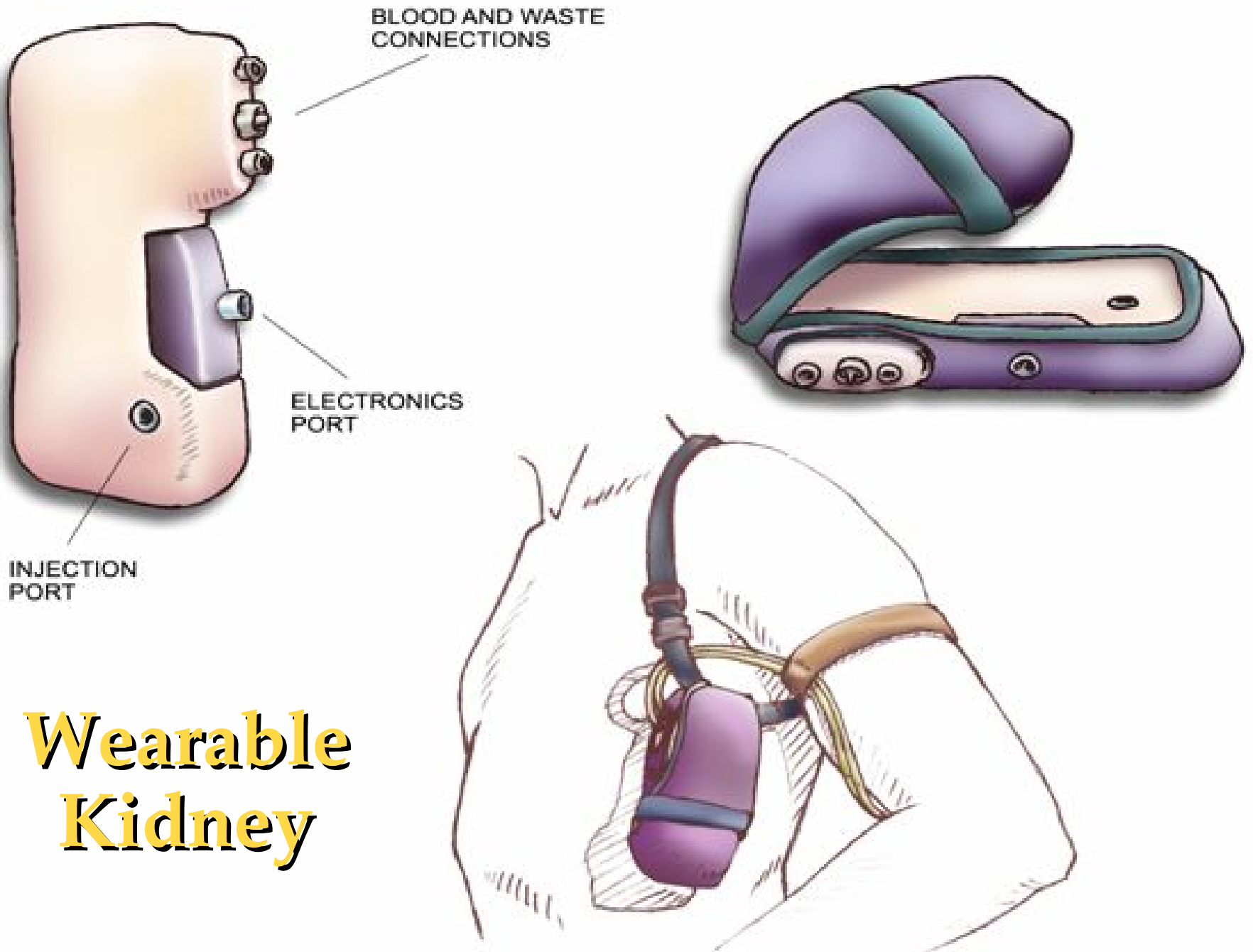


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Near-term military apps: upgrades to existing weapons & support systems

- Nanomaterials
- Nanoscale filtration membranes – Chemically and mechanically tunable pores up to single atom precision (Cf. *Covalent Ind. Technol., Inc.*)





Nanoscale Filtration Applications

- Wearable Kidney (= Bye-bye dialysis sessions)
- Water desalination
- Water purification
- Breathable NBC-protection clothing
- Wearable anti-dehydration systems -- “still-suits”
- Advanced rebreathers for indefinite-length underwater presence – “artificial gills”
- Superior gas masks



High-performance Warfighter

- “Augmented Warrior”
- “Nanosoldier” / “NanoWarrior”
- “Supersoldier”
- “Human Tank”

→ Major military nanotech
applications nexus





Nanotech-based Bulletproof Clothing



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Institute for Soldier Nanotechnologies (ISN)

“The soldier of the future will be protected by an impregnable exoskeleton. This 21st century armor will also impart superhuman strength, reflexes and endurance. It will sense its environment with molecular precision and administer chemicals, pharmaceuticals and other potions directly to the human inside based on pre-programmed stimuli or other command and control signals...”



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The "Human Tank"

Nano-Technology for the Future Warrior

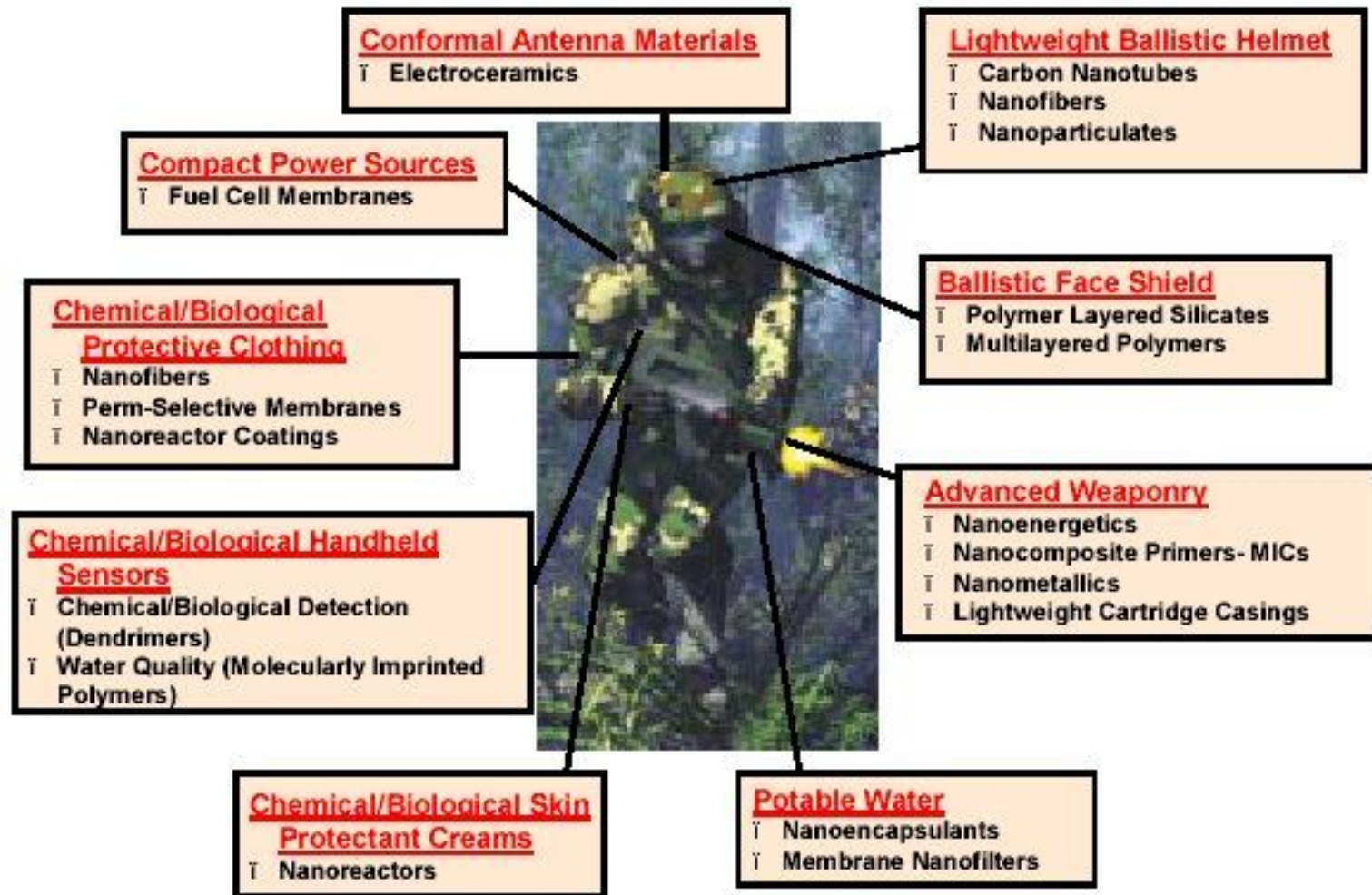
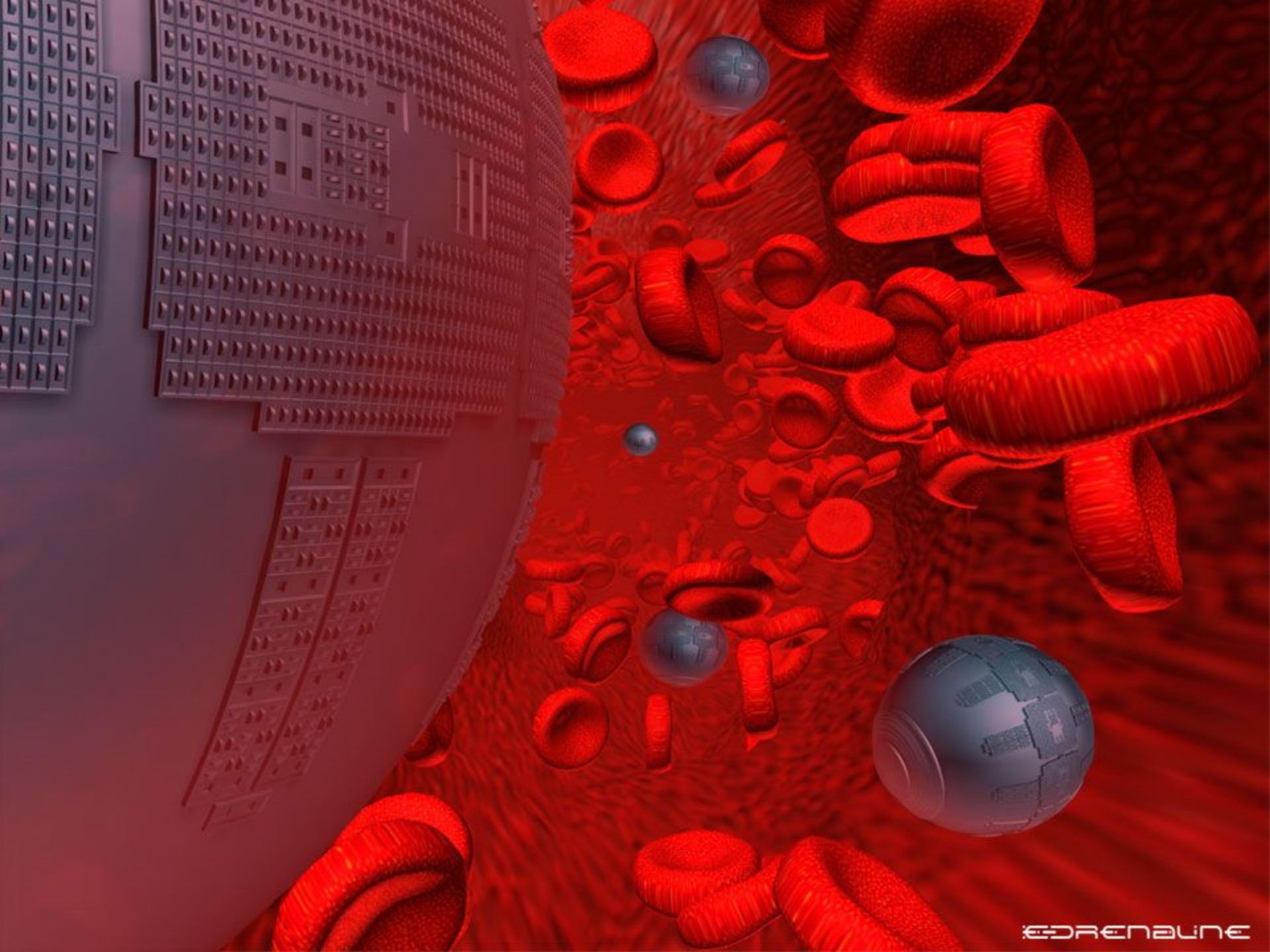


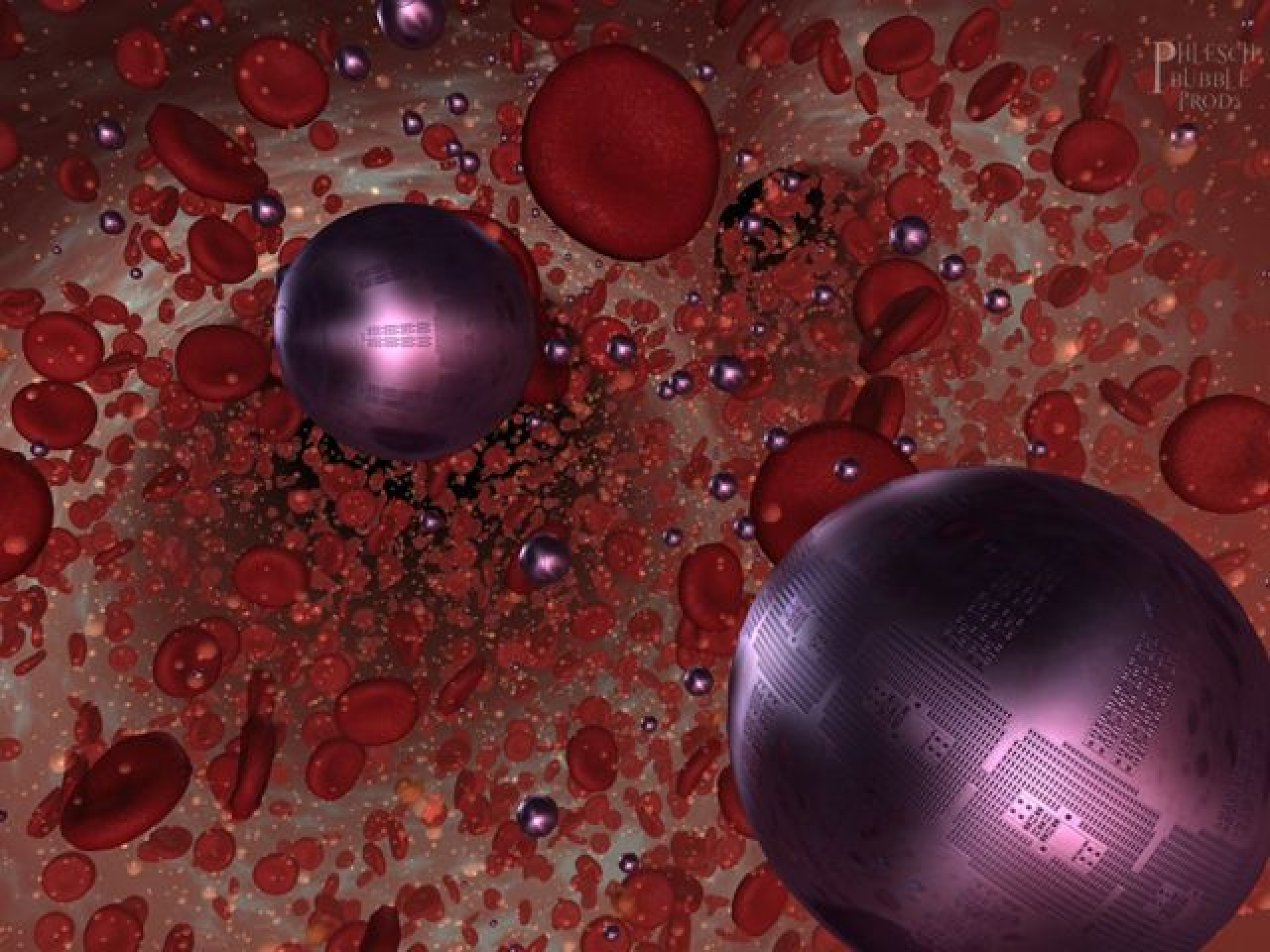
Figure E.13. Soldier system of the future (courtesy Dr. Andrzej W. Miziolek, U.S. Army Research Laboratory, AMSRL-WM-BD, Aberdeen Proving Ground, MD).

ISN Research Teams Focus:

- Energy Absorbing Materials
- Mechanically Active Materials and Devices
- Sensing and Counteraction
- Biomaterials and Nanodevices for Soldier Medical Technology
- Processing and Characterization – “Nanofoundries”
- Modeling and Simulation of Materials and Processes
- Systems Design, Hardening, and Integration







New Nano-enhanced Chemical Weapons

- Development of new chemical weapons banned by majority of nations
- Future techniques adoptable by remaining countries with chemical weapons programmes and terrorist groups
- Nano-enhanced chemical such as cyanide could be synthesised in far smaller amounts
- Design of new agents to attack specific organs like Central Nervous System would enable far smaller amounts of the chemical to be made without detection and would require only small, low-level facilities
- Other nanotechnology-based weapons might emerge from otherwise benign fields such as law enforcement in the creation of 'non-lethal weapons' for riot control and other policing operations
- Some currently permitted under Chemical Weapons Convention
- New delivery mechanisms to make incapacitating substances target more selectively could be adapted to more lethal uses



Nanotech weapons described in Jane's

- Excerpt 1: *“As with many technologies, the medical applications may be adapted for offensive purposes. Manipulation of biological and chemical agents using nanotechnologies could result in entirely new threats that might be harder to detect and counter than existing CBWs [chemical and biological weapons]”*
- Excerpt 2: *“Other nanotechnology-based weapons might emerge from otherwise benign fields such as law enforcement in the creation of ‘non-lethal weapons’ for riot control and other policing operations. Some of these are currently permitted under the Chemical Weapons Convention. New delivery mechanisms to make incapacitating substances target more selectively could be adapted to more lethal uses...”*



Nanotech a high priority for Pentagon

- *"Nanotechnology is one of the highest priority science and technology programs in the Defense Department."*
 - Clifford Lau, Senior science adviser
Pentagon Office of Basic Research
- Spent \$315 million in fiscal 2004 on nano R&D.
- The specific projects cited are all near-term nanoscale science projects, mostly materials, like lightweight, radar-resistant nanocomposite materials for airframes and coatings to eliminate barnacle buildup on submarines.



White House endorses NNI; Emphasizes Anti-terror Uses

- *“Bush Administration OKs Report Making Nano a Terror War Priority” Small Times, August 22, 2002*
- NNI report for FY 2003 introduced a new "grand challenge": *“Nanotechnology for bio-chem-radiological-explosive detection and protection -- expanded and refocused Bio-Nanosensors”*
- White House signed off on NNI report including a heightened commitment to using nanotech to fight weapons of mass destruction.
- Better-security-through-smaller-sensors



Longer term: Intentional Global Ecophagy / Ecocide Threat

“Perhaps the earliest-recognized and best-known danger of MNT is the risk that self-replicating nanobots capable of functioning autonomously in the natural environment could quickly convert biomass into replicas of themselves – “nanomass” – on a global basis, a scenario usually referred to as the “grey goo” but perhaps more properly termed “global ecophagy.”

Robert Freitas



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Longer term: potential new WMDs; Early Nano-WMD concepts (R. Freitas):

- **Aerovores** (Grey Dust) – Worldwide blanket of airborne replicating copier-toner-like dust which blots out all sunlight. 100% atmospheric opacity in 2 days. 72 days later, 100% conversion of atmospheric carbon mass into nanomass.
- **Grey Plankton** – Seabed-grown replicators eat up land-based carbon-rich ecology.
- **Grey Lichens** -- Ecophagic destruction of land-based biology by a maliciously programmed noncarbon epilithic replicator population.
- **BioMass Killers** -- Malicious ecophagic attack directly aimed at biomass.



ADC – *Asymmetric Destructive Capability*

- ADC = Little needed to destroy a lot
- Large-scale destruction with small-scale resources
- NBIC convergence reveals *exponentially increasing* asymmetry



Resources needed for Nano-WMD production & deployment

- Mastery of self-replicating nanobot tech
- 4 mediocre PhDs
- 4 off-the-shelf supercomputers
- About 4 months development time, possibly less
- Standard nanofabrication equipment capable of creating seed replibots
- Global seed replibot dissemination network (4 dispersion points probably minimum)

→ ADC on steroids



Power of Nanotech-based Weapons of Mass Destruction

*“Somewhere in the back of my mind I still have this picture of five smart guys from Somalia or some other non-developed nation who see the opportunity to change the world. To turn the world upside down. **Military applications of molecular manufacturing have even greater potential than nuclear weapons to radically change the balance of powers.**”*

Admiral David E. Jeremiah, US Navy (Ret.),
Former Vice Chairman, *Joint Chiefs of Staff*
November 9, 1995



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US Congress Thinks Along Similar Lines

"The greatest danger of another catastrophic attack in the United States will materialize if the world's most dangerous terrorists acquire the world's most dangerous weapons."

9/11 Commission Report
US Congress



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... and Britain's Astronomer Royal

"Biotechnology is advancing rapidly, and by 2020 there will be thousands—even millions—of people with the capability to cause a catastrophic biological disaster. My concern is not only organized terrorist groups, but individual weirdos with the mindset of the people who now design computer viruses. Even if all nations impose effective regulations on potentially dangerous technologies, the chance of an active enforcement seems to me as small as in the case of the drug laws."

– Sir Martin Rees, UK Astronomer Royal
Author of *Our Final Hour: A Scientist's Warning: How Terror, Error, and Environmental Disaster Threaten Humankind's Future In This Century—On Earth and Beyond*



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... and the White House

"We are menaced less by fleets and armies than by catastrophic technologies in the hands of the embittered few."

– White House

US National Security Council

"It is inevitable that terrorists will obtain weapons of mass destruction, and that they will use them against us."

– Donald H. Rumsfeld

U.S. Secretary of Defense



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Some Encouraging News too:

In Freitas' paper "***Some Limits to Global Ecophagy by Biovorous Nanoreplicators, with Public Policy Recommendations***"

→ Precautions, Prevention, Early Warning & Effective Defensive Countermeasures
possible



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2. Towards Non-lethal Warfare

- Life is precious, not only the lives of one's own troops and civilians who happen to be in a war-zone, but also the lives of enemy troops. (cf. downwards trend of war casualties)
- Effective intervention with zero lethality & zero collateral damage



3. Challenges & Opportunities for Global & Regional security

- Nanotech-based threats from terrorist assassinations to the deployment and usage of nanotech-based WMDs (ADC)



4. Challenges & Opportunities to our Institutions & Societies

- Central challenge: allow and enable societies to benefit from the exponentially accelerating technological convergence which is underway,
- ... while applying existing as well as the newest means for safeguarding them from existing and new threats as these are being subjected to the exponentially accelerating increase of Asymmetric Destructive Capability.



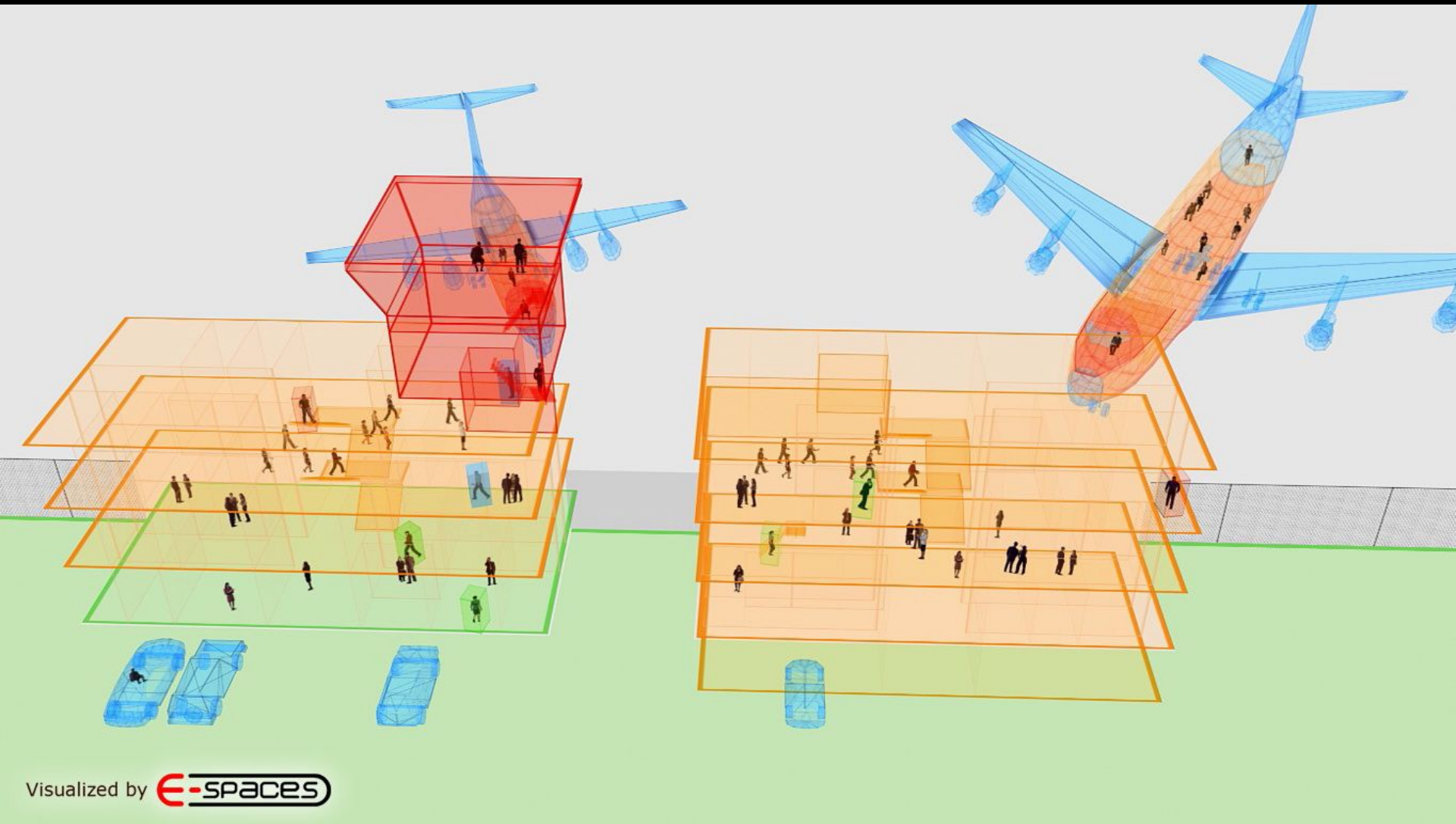
5. Towards MAPPS: *Multi-laterally Assured Permanent & Pervasive Surveillance & Sousveillance*

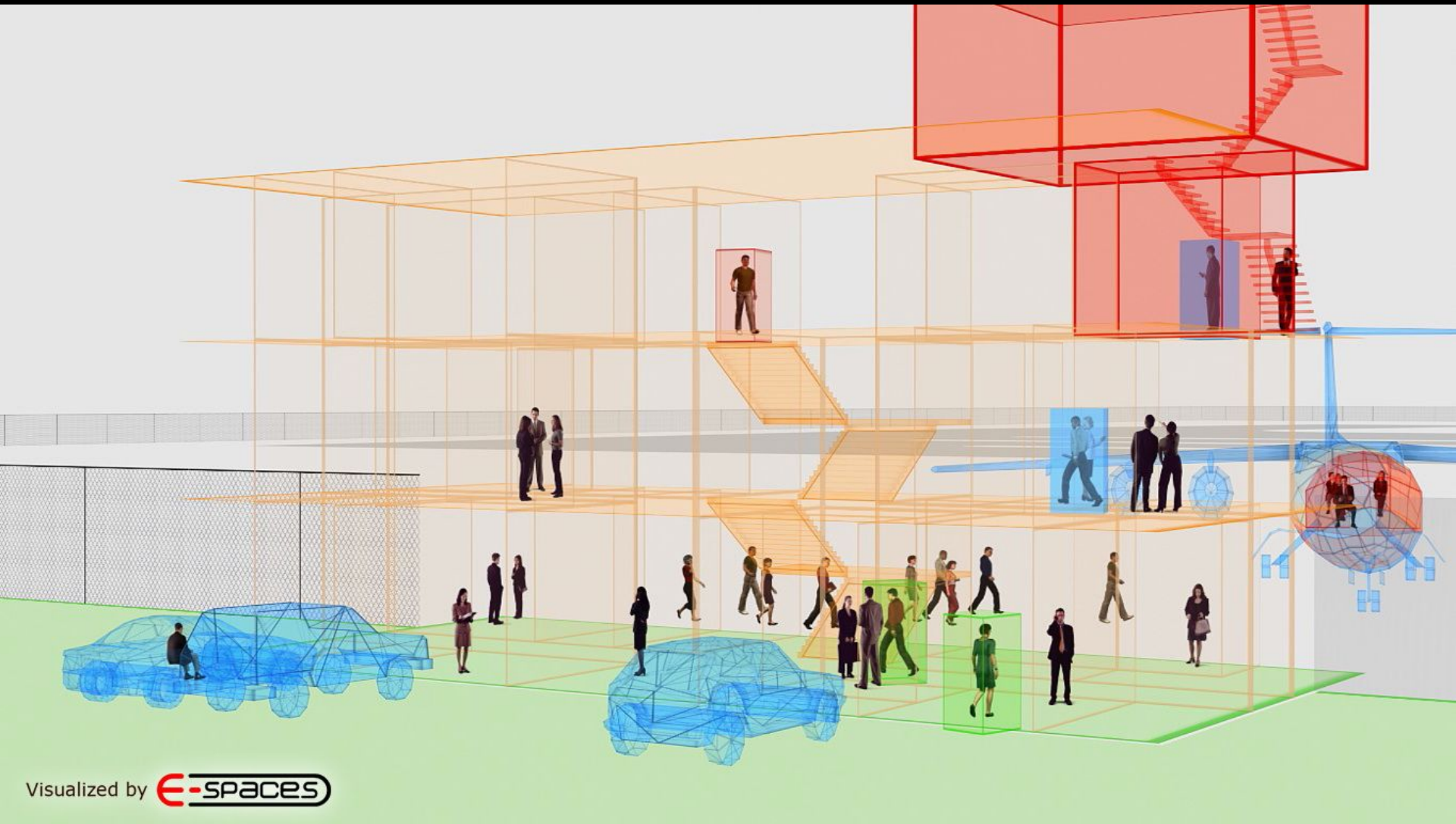
- What would the world look like if we could really & fully know what our opponents are doing all the time and in real-time?
- Nanotech, together with NBIC convergence will enable unprecedented highly fine-grained pervasive surveillance & sousveillance capability
- *Already paving the way:*
 - *C-Thru Surveillance technology by Panoptic Systems, Inc.*
 - *Aetherwire, Inc.*
 - *Dust Networks, Inc.*
 - *ORB by Physical Optics Corporation, Inc.*
 - *People's P2P Panopticon*



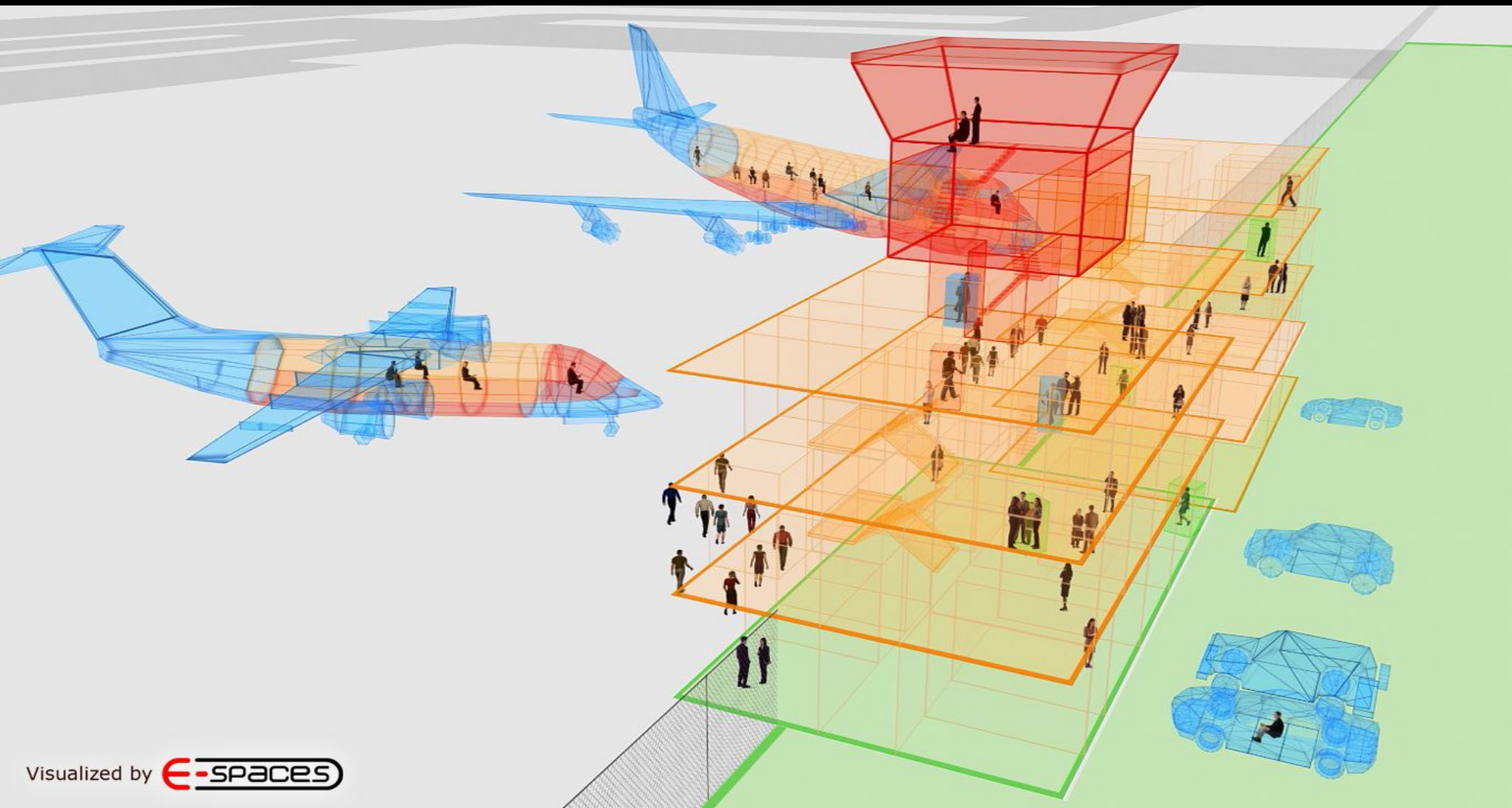






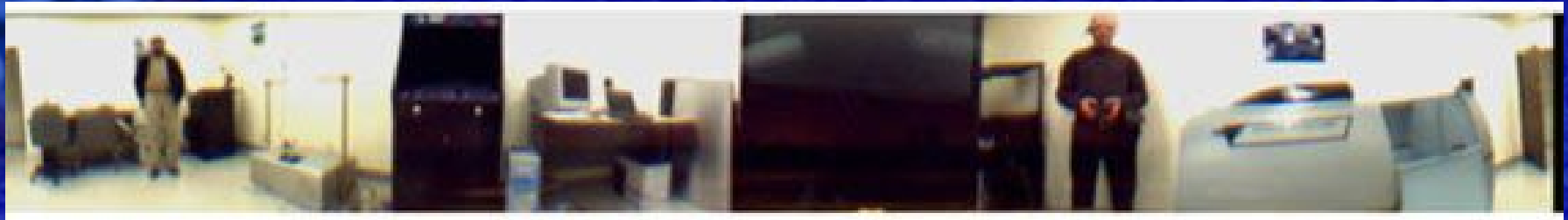
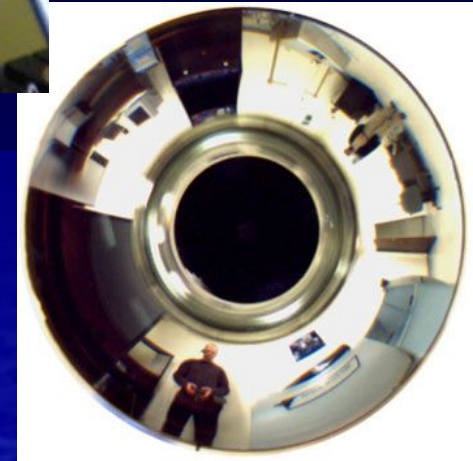


Visualized by **E-SPACES**



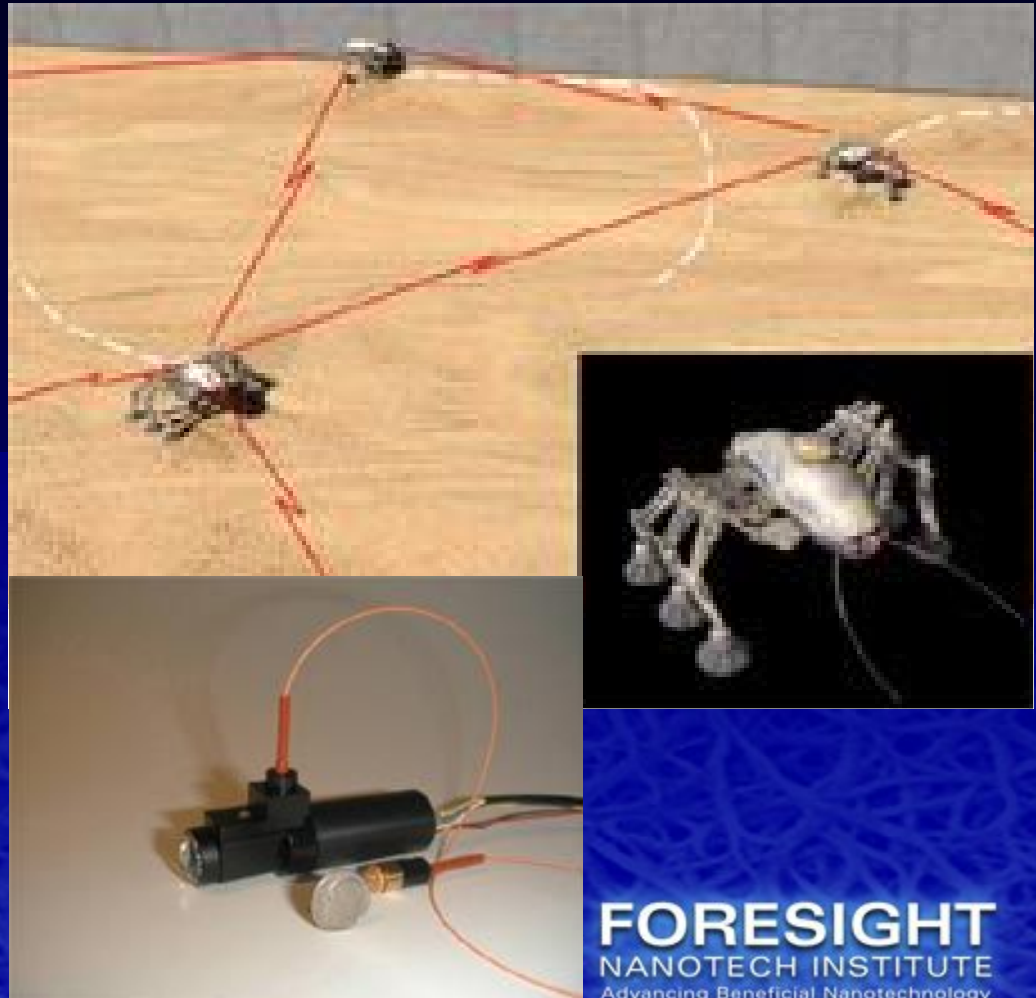
RT 360° OmniView Camera

- OMNIVIEW camera system provides real-time 360 degree panoramic video monitoring.
- Adaptive system can be tailored to the internet, compression, wired or wireless systems. Patent Pending.



Towards Smart NEMSbot "Swarms"

- Omnidirectional Robotic Beacon Eye (ORB) -- ORB is a wireless optical communication system with a 360° field-of-view and at a 15° elevation. This line of sight, near-infrared ORB with light modulation, transmits an optical, personal signature and survey information. ORB is miniaturized, requires low battery power and can not be jammed.
- **Application:** Semi-autonomous Robotic surveillance, common knowledge communication and wireless optical communication network.
- **Availability:** Proof of concept completed. In-house demo available. Commercialization-ready since 2003.
- http://www.poc.com/tech_summary/hom



6. Perilous transition to a potentially Better New World

- Dangers-fraught transition from a pre-singularity to a post-singularity world
- Transition: few years up to about two decades
- Danger due to multiple parallel disruptions:
 - Societal disruption
 - Economic disruption
 - ADC-based disruptions of local to global military & security equilibria
- Needed: planning and coordination with civil society so that we may all proceed through the transition period as safely as possible.



Given the Writing on The Wall...

*"Predicting rain doesn't count,
building arks does."*

– Warren Buffett



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Foresight Institute Roadmap Initiative

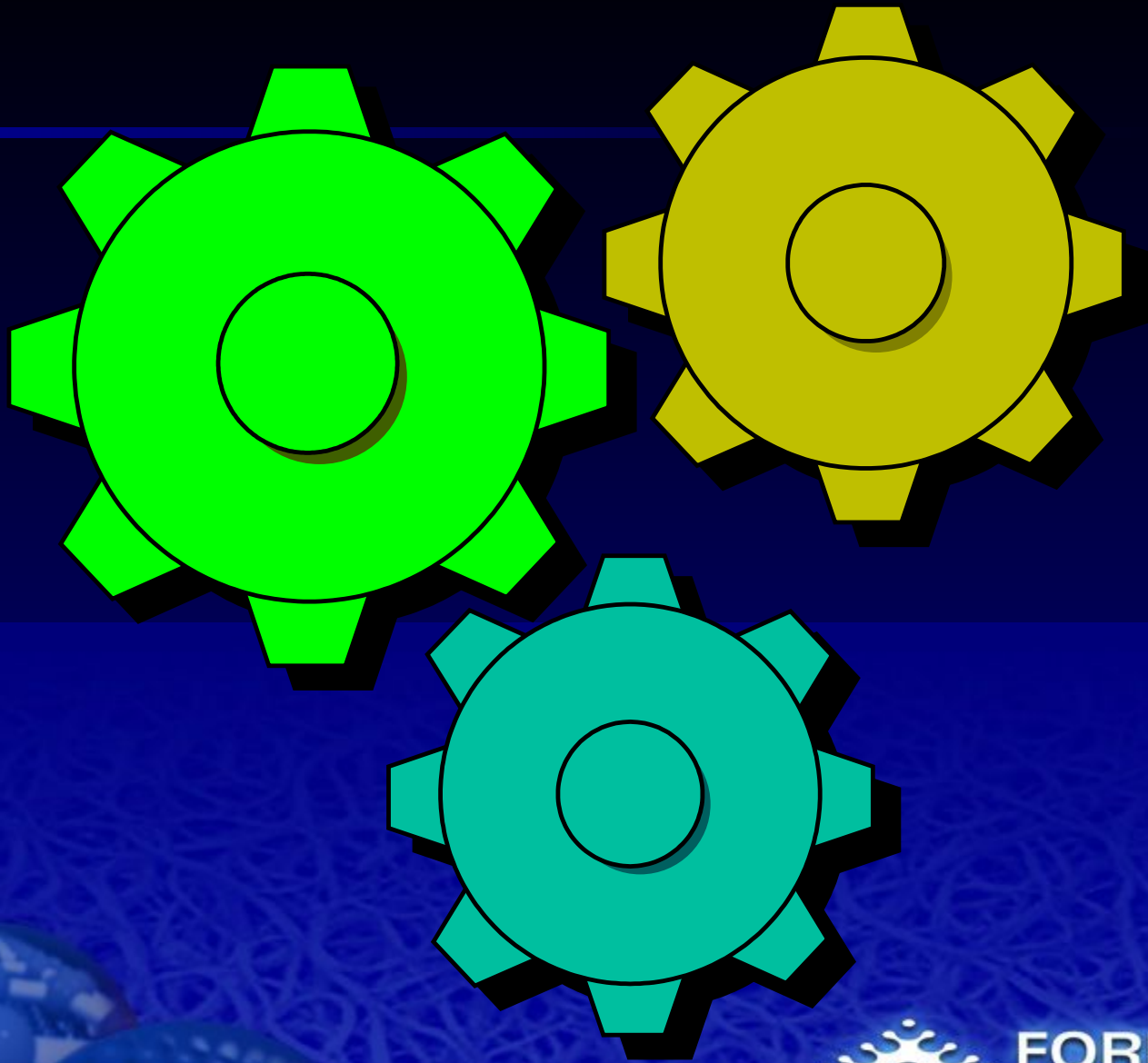
- Established method for coordinating stakeholders
- Vision for future end state(s)
- Articulates steps from current state to end state
- Illuminates what to focus on today
- Basis for R&D and usage agenda
- Deeply understand *offensive* capability in order to develop *defensive* capability



What's Next?

- Collaboration of all stakeholders
- Roadmapping of possible solutions
 - Basis for R&D and usage agendas
- Accelerated integration & synergizing of technological and non-technological solutions





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Presentation Overview

1. Military Nanotech outlook: From upgrades to potential new WMDs
2. Towards Non-lethal Warfare
3. Challenges & Opportunities for Global & Regional security
4. Challenges & Opportunities to our Institutions & Societies
5. Towards MAPPs: **M**ulti-laterally **A**ssured **P**ermanent & **P**ervasive **S**urveillance & Sousveillance
6. Perilous transition to a potentially Better New World





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Questions & Answers

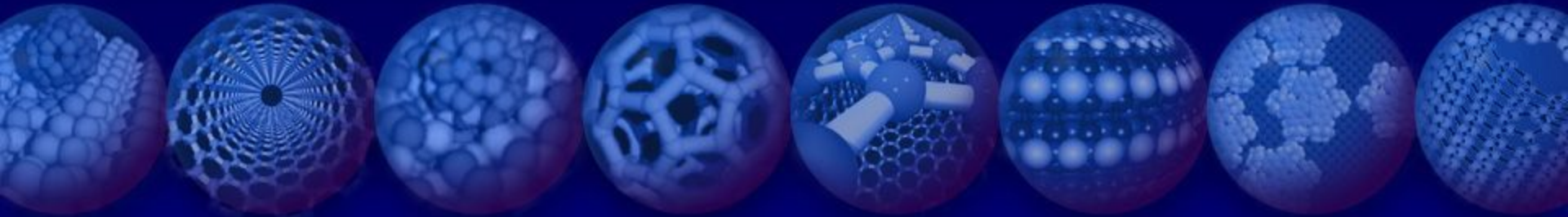
Resources

- Foresight Institute
 - www.foresight.org
- Nanotechnology Opportunity Report™
 - www.foresight/store
- Vision 2020 Roadmap for Nanomaterials
 - <http://chemicalvision2020.org/nanomaterialsroadmap.html>
- International Technology Roadmap for Semiconductors
 - <http://public.itrs.net>
- National Institutes of Health Roadmap
 - <http://nihroadmap.nih.gov>





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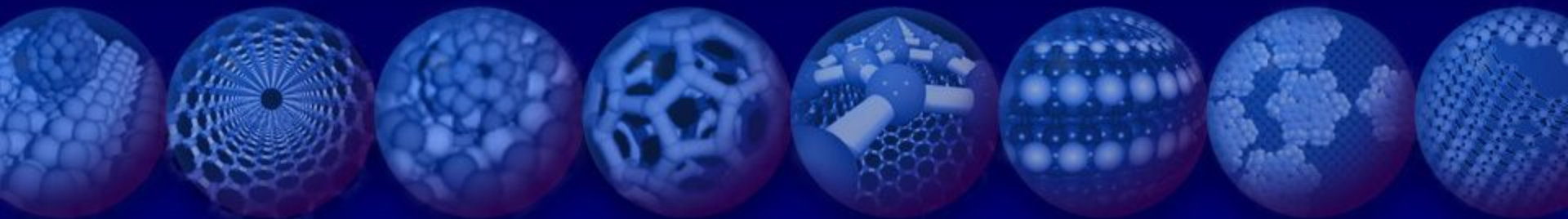
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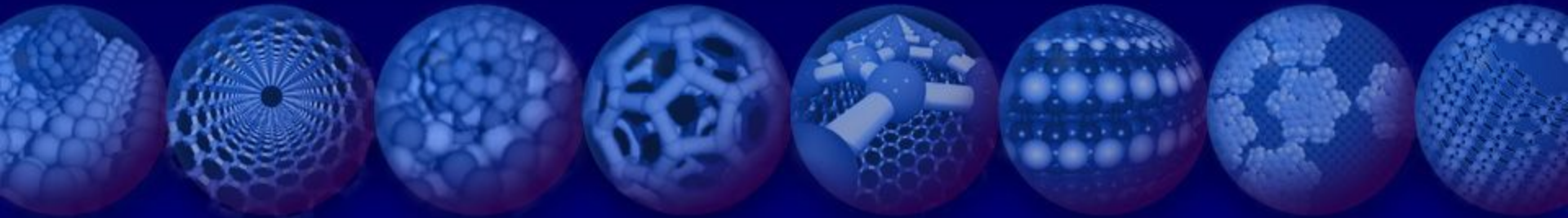
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Additional Slides for Q & A

A few 100 years ago, who would have thought?...

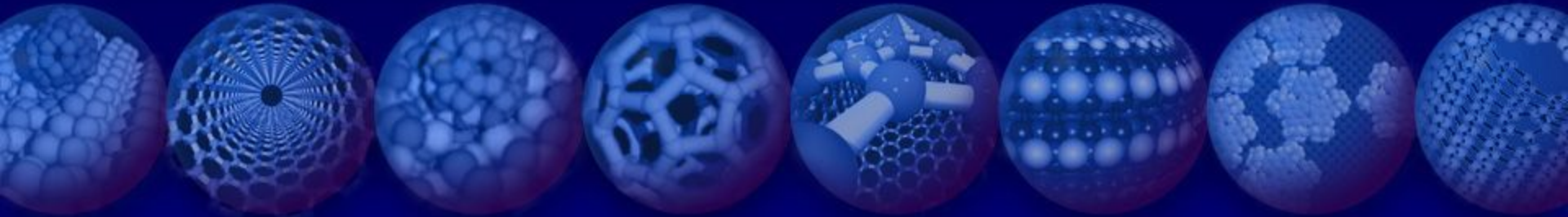
Table A.1. Greatest Engineering Achievements of the Twentieth Century

1. Electrification	11. Highways
2. Automobile	12. Spacecraft
3. Airplane	13. Internet
4. Water Supply	14. Imaging
5. Electronics	15. Household Appliances
6. Radio and TV	16. Health Technologies
7. Agricultural Mechanization	17. Petroleum Technologies
8. Computers	18. Laser and Fiber Optics
9. Telephones	19. Nuclear Technologies
10. Air Conditioning & Refrigeration	20. High-performance Materials





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**Predicting the future used to be
more guesswork than science...**

Lessons in how to *miss* the ball

Be careful what you predict. It may come back to haunt you... or laugh at you.

- *"Heavier-than-air flying machines are impossible."*
-- Lord Kelvin, president, Royal Society, 1895.
- *"Computers in the future may weigh no more than 1.5 tons."*
-- Popular Mechanics, forecasting the relentless march of science, 1949
- *"This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us."*
-- Western Union internal memo, 1876.
- *"I think there is a world market for maybe five computers."*
-- Thomas Watson, chairman of IBM, 1943
- *"There is no reason anyone would want a computer in their home."*
-- Ken Olson, president, chairman and founder of Digital Equipment Corp., 1977
- *"640K ought to be enough for anybody."*
-- Bill Gates, 1981



- *"Airplanes are interesting toys but of no military value."*
 - Marechal Ferdinand Foch, Professor of Strategy, Ecole Superieure de Guerre.
- *"Who the hell wants to hear actors talk?"*
 - H.M. Warner, Warner Brothers, 1927.
- *"Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools."*
 - 1921 New York Times editorial about Robert Goddard's revolutionary rocket work.
- *"The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?"*
 - David Sarnoff's associates in response to his urgings for investment in the radio in the 1920s.
- *"Drill for oil? You mean drill into the ground to try and find oil? You're crazy."*
 - Drillers who Edwin L. Drake tried to enlist to his project to drill for oil in 1859.



- *"We don't like their sound, and guitar music is on the way out."*
-- Decca Recording Co. rejecting the Beatles, 1962.
- *"The abdomen, the chest, and the brain will forever be shut from the intrusion of the wise and humane surgeon".*
-- Sir John Eric Ericksen, British surgeon, appointed Surgeon-Extraordinary to Queen Victoria 1873.
- *"But ... what is it good for?"*
-- Engineer at the Advanced Computing Systems Division of IBM, 1968, commenting on the microchip.
- *"So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said, 'Hey, we don't need you. You haven't got through college yet.'"*
-- Apple Computer Inc. founder Steve Jobs on attempts to get Atari and HP interested in his and Steve Wozniak's personal computer.



- *"Stocks have reached what looks like a permanently high plateau."*
-- Irving Fisher, Professor of Economics, Yale University, 1929.
- *"Everything that can be invented has been invented."*
-- Charles H. Duell, Commissioner, U.S. Office of Patents, 1899.
- *"Louis Pasteur's theory of germs is ridiculous fiction".*
-- Pierre Pachtet, Professor of Physiology at Toulouse, 1872
- *"\$100 million dollars is way too much to pay for Microsoft."*
-- IBM, 1982



One of the lessons learned:

Predictions about the future of technology
tend to be tainted by *macromyopia*:

the tendency to overestimate the short-term
effects and at the same time to
underestimate the long-term effects of an
innovation.



Futurism Today

Thanks to the work of Alvin Toffler and many others over the last three decades, the accuracy of predictions has dramatically improved.

“Futurism” has become a science, taught and practiced at universities and beyond. The discipline is forging ahead to intelligently identify, analyze, and extrapolate trends into likely future scenarios.

Which is not to say that we are now completely shielded from making prediction mistakes...

