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Advancing Beneficial Nanotechnology

Introducing Nanotechnology: Where we are & where we are going

Presented by Philippe Van Nedervelde
Executive Director, Foresight Nanotech Institute Europe

January 2006

www.foresight.org

Presentation Overview

- Foresight overview
- Nanotechnology - where are we?
- Short-term vs. Long-term
- Overview of the field
- Foresight Nanotechnology Challenges
- Roadmap Initiative
- What's Next?

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Foresight Overview - 1

- Founded in 1986 by Drexler & Peterson
- Created and popularized concept of “nanotechnology”
  - Molecular nanotechnology (MNT)
  - Molecular manufacturing (MM)
  - Molecular machine systems (MMS)
- 4 Books published, many inspired
- Foresight Guidelines
- Numerous white papers, articles, briefings, essays, …
- Top 5 “nanotechnology” Web site

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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
- Reaches 14,000+ people via email
- Staff of 10
- Think tank and public interest organization

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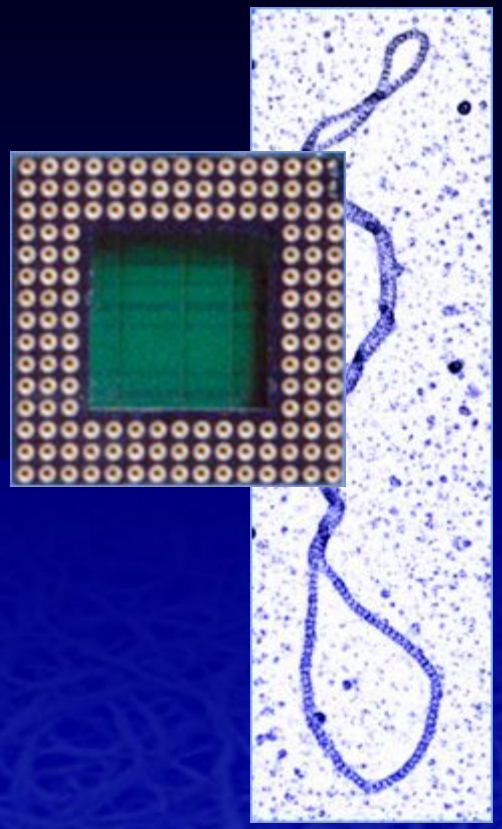
Where Are We?

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



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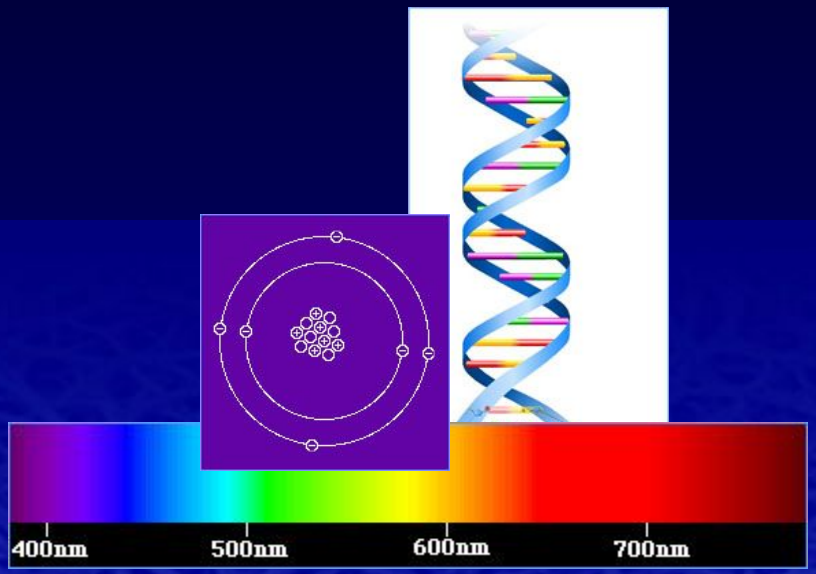
Nanotechnology Definition

- MANY definitions
- Size gives 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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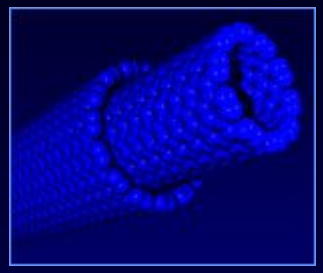
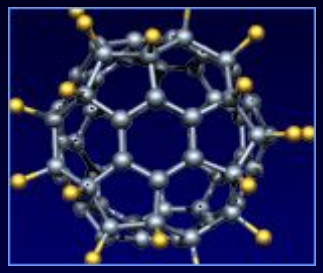
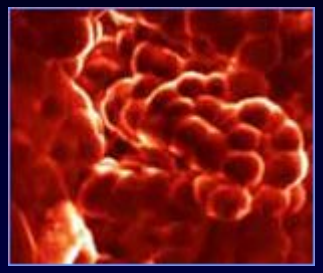
Today's Building Blocks



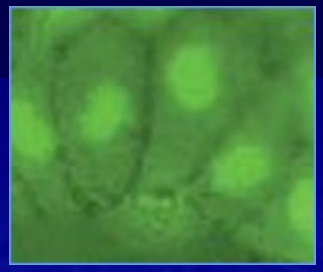
Nanotubes



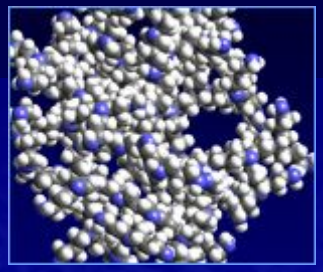
Fullerenes



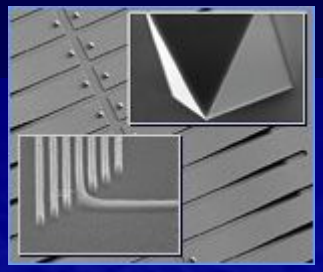
Nanoparticles



Quantum Dot



Dendrimers



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

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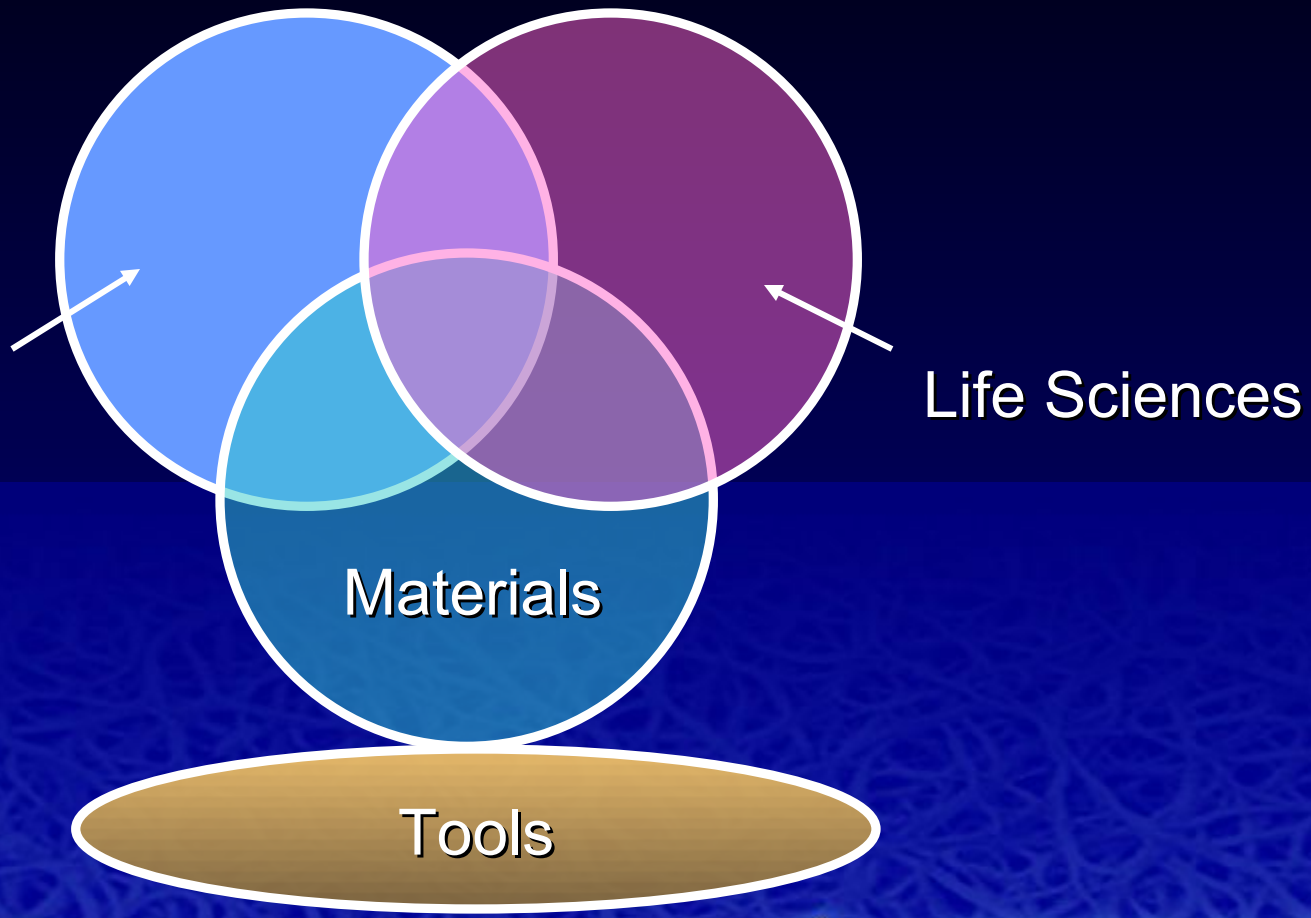
The Nanotechnology Space



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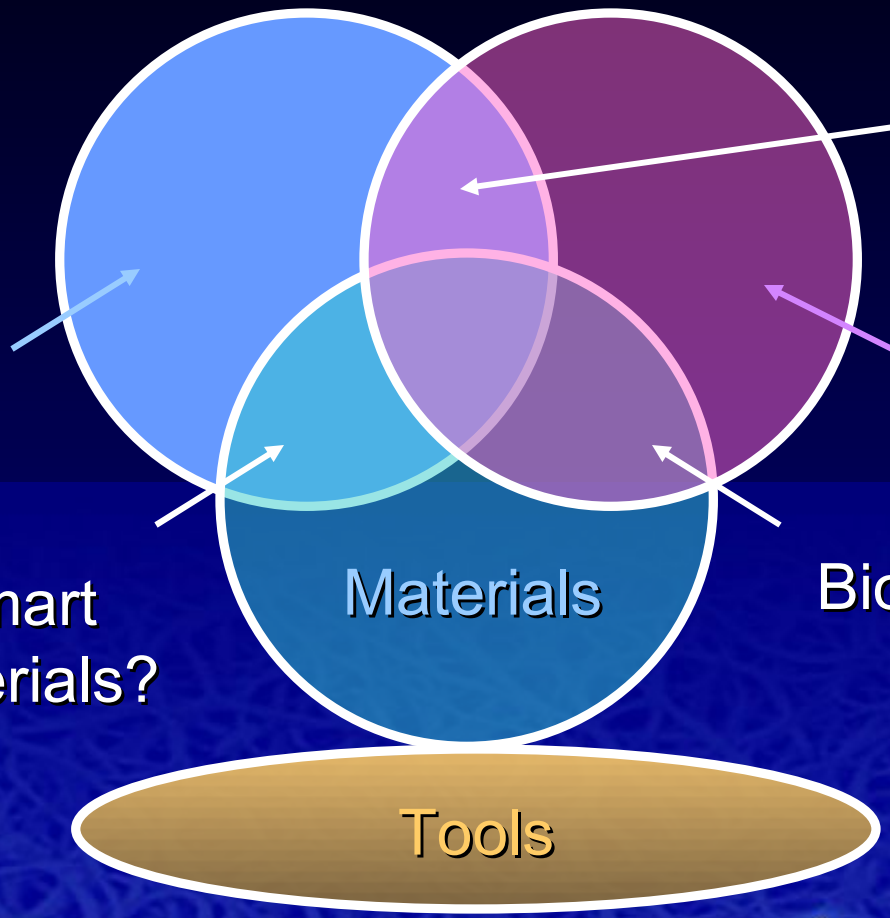
The Nanotechnology Space



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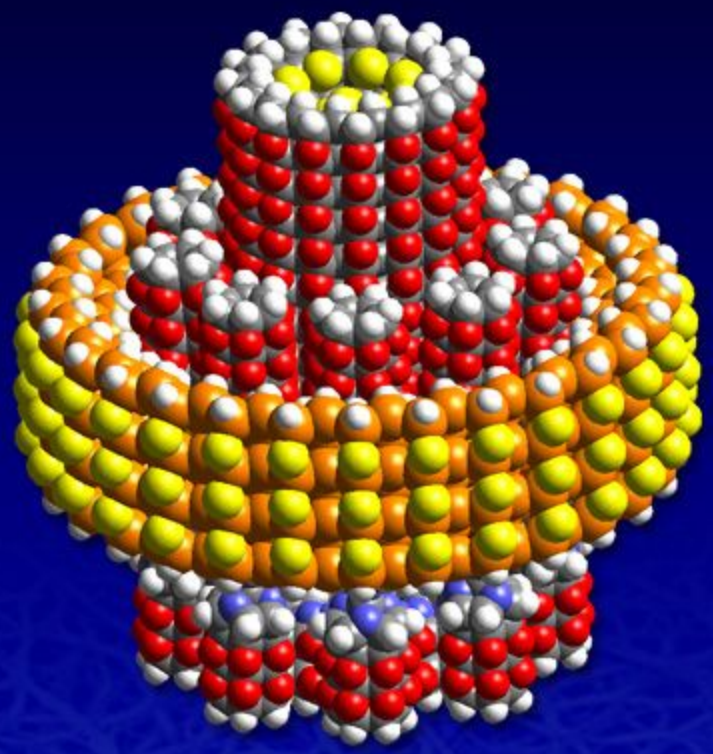
Molecular Nanotechnology

- "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
- Long term



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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

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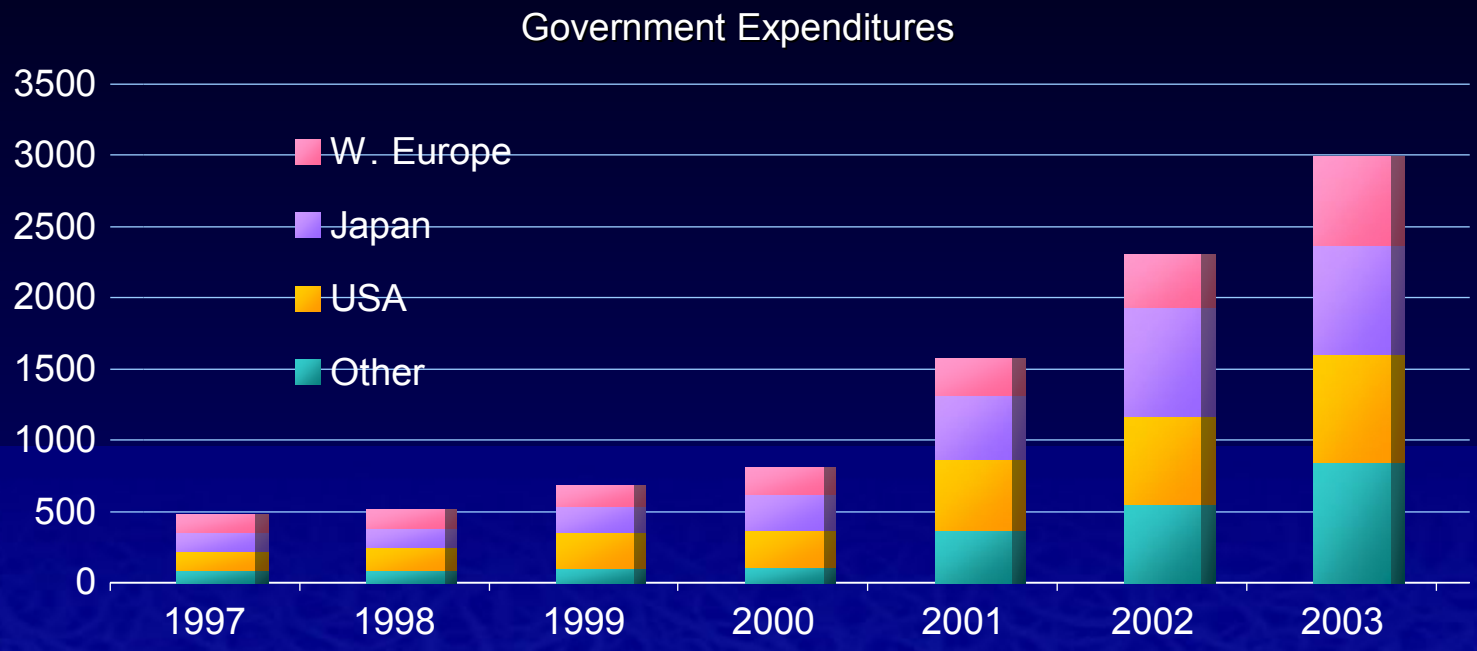
R&D Funding – 2003



Source: US National Nanotechnology Initiative

- Corporations spend approximately the same amount

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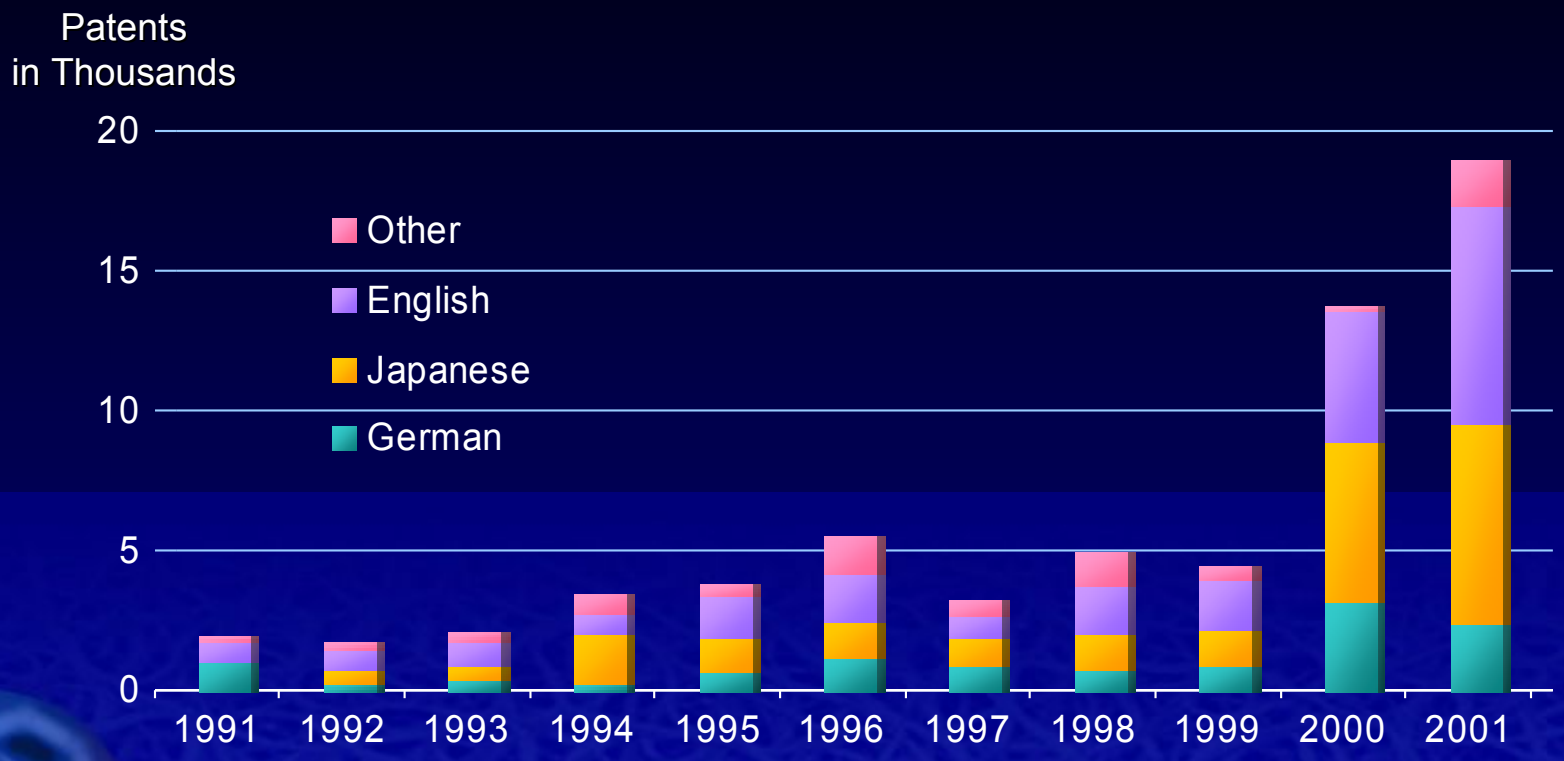
Patents by Language



Source: Polytechnos

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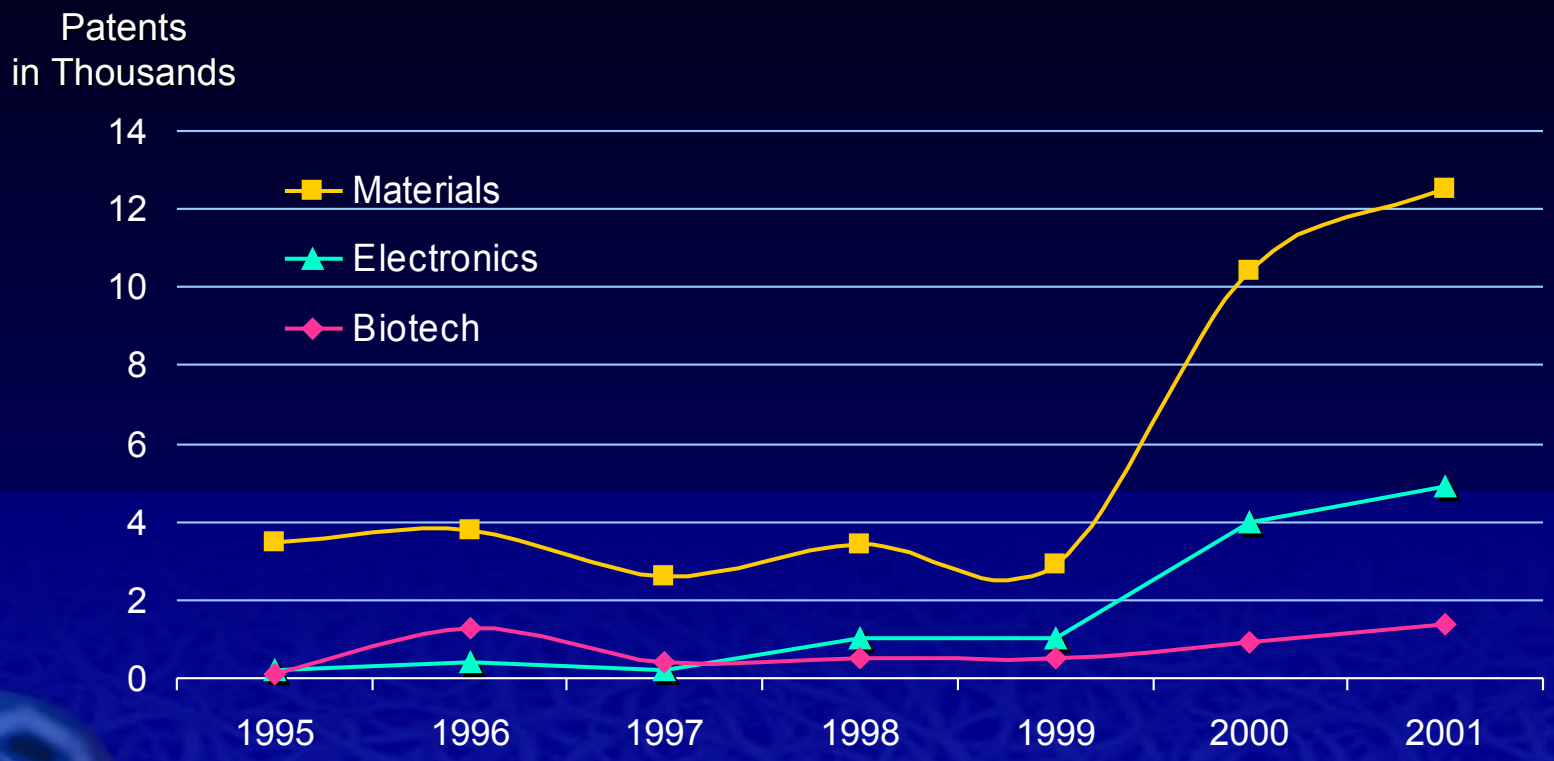
Patents by Category



Source: Polytechnos

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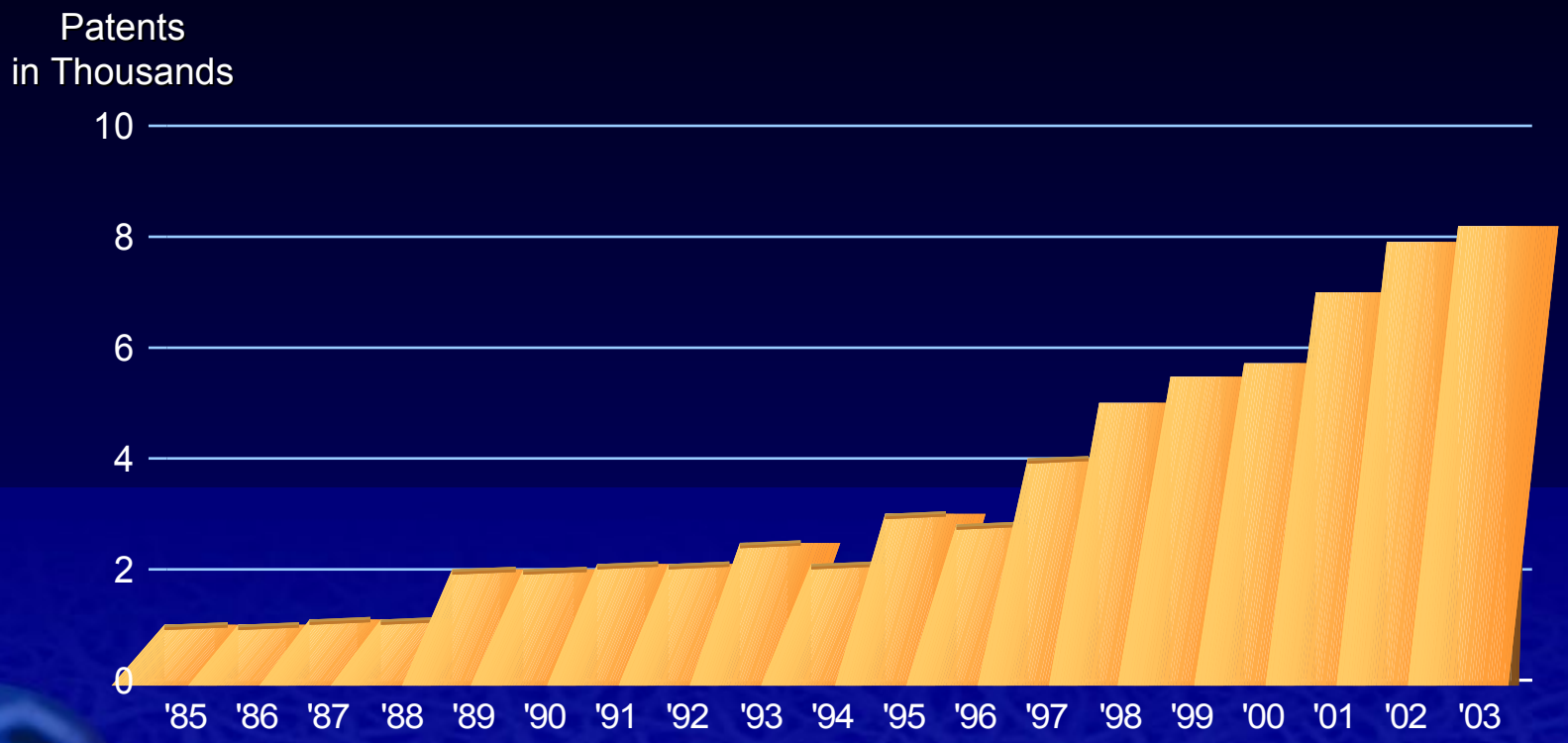
US Patents



Source: Journal of Nanoparticle Research

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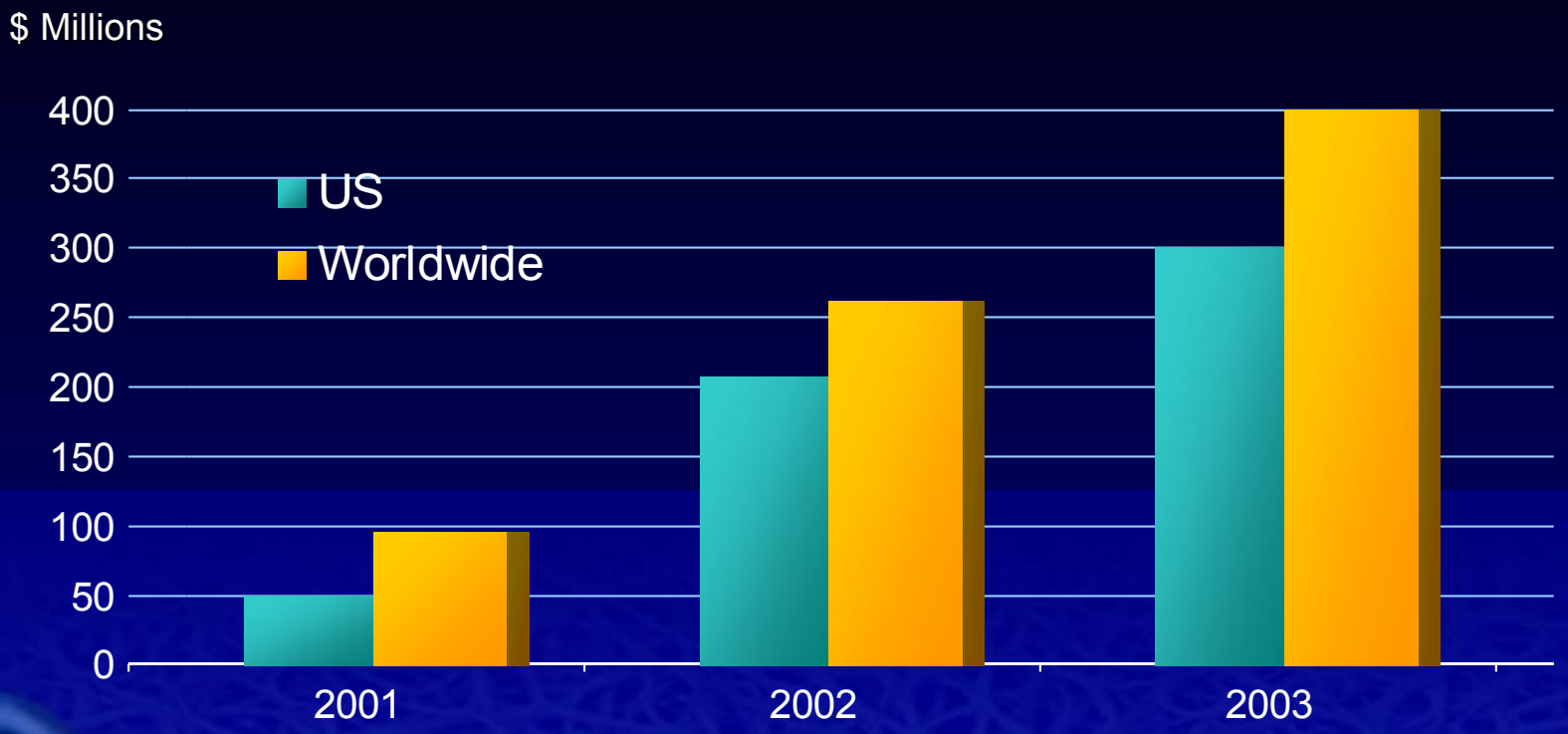
Venture Capital Investment



Source: Small Times

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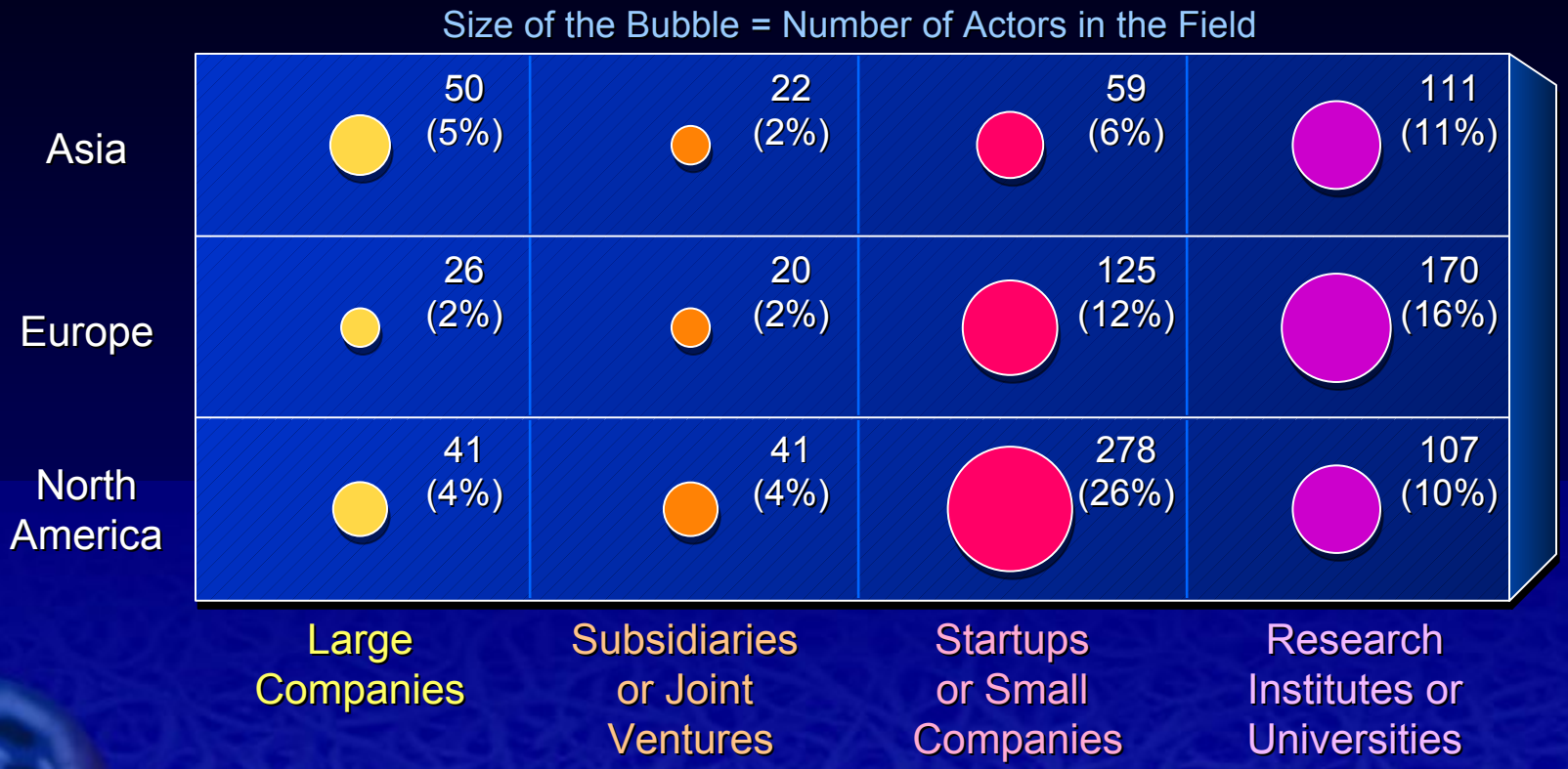
Players by Type



Source: Científica and Jaakko Pöyry Consulting, 2002

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Market Impact - Near Term

- Tools
- Composite materials
- Coatings
- Catalysts

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Market Impact - Medium Term

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

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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

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Medical & Pharmaceutical

- Detection, analysis & discovery
- Drug delivery
- Prosthetics
- Anti-microbial, -viral, & -fungal agents

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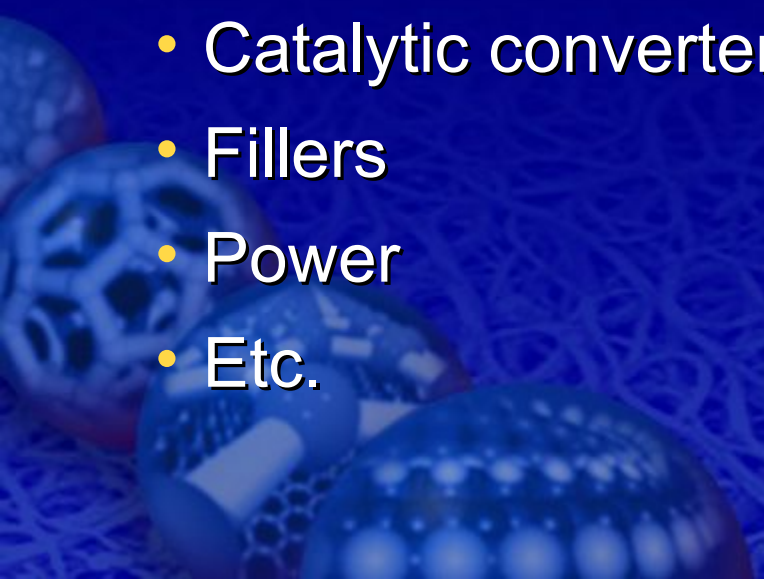
Automotive & Transportation

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



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Aerospace & Defense

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

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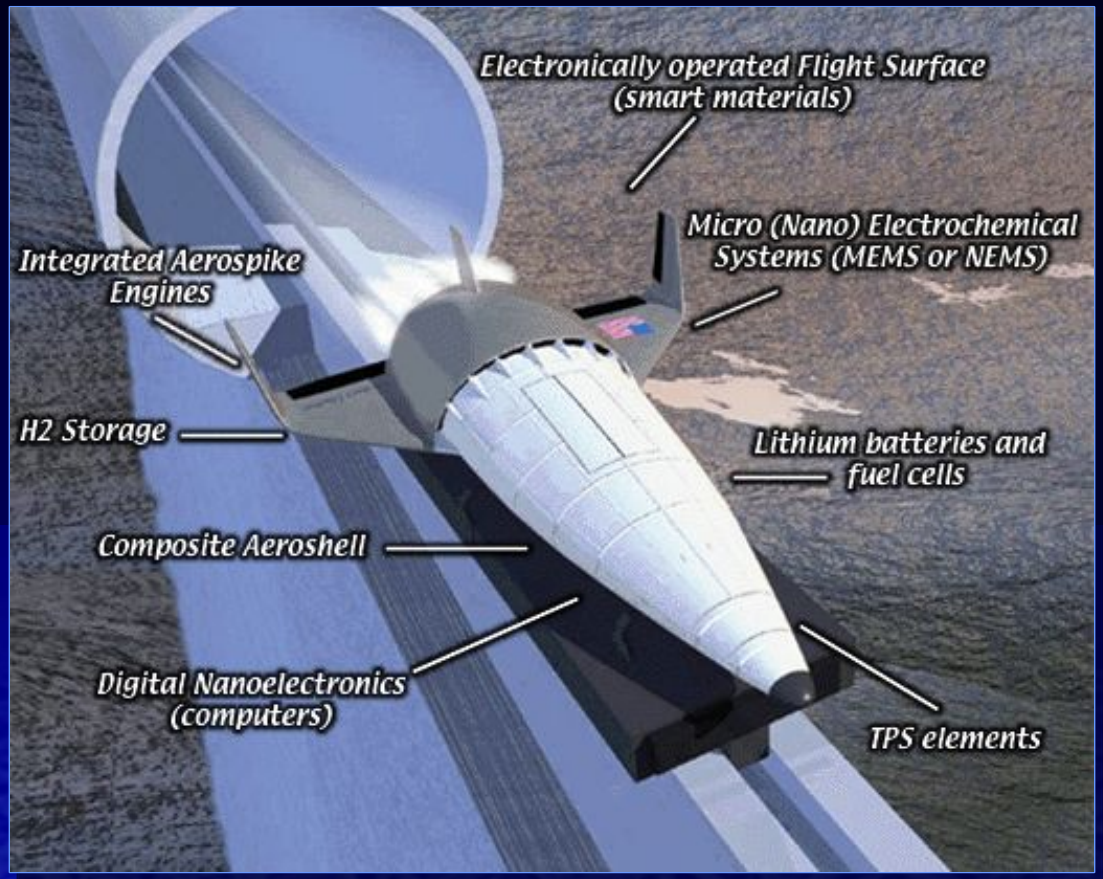
Impact on a Space System



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

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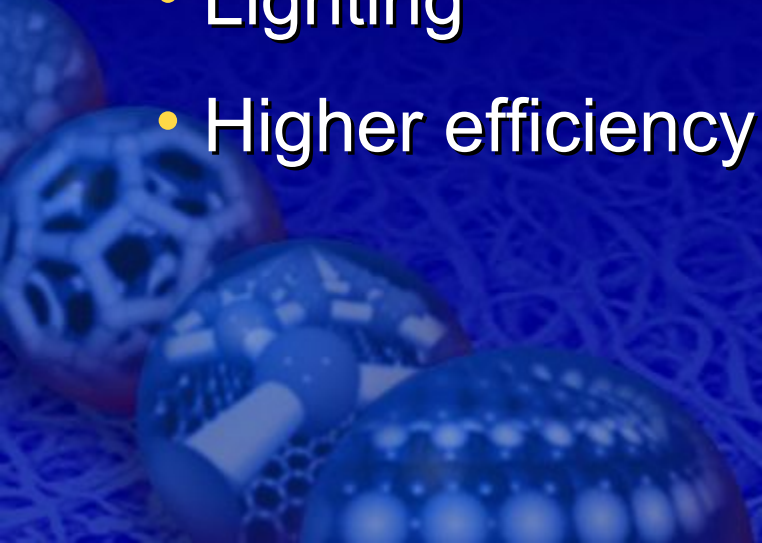
Energy

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



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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

- Nanotech DVD and book collection
- 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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Focusing on Big Challenges

- Big Problems = Big Markets (most of the time)
- Focuses societal investments in R&D
- Significant incentive for financial investors
- Basis for diverse alliances of mutual interest
- What are the BIG problems/challenges?

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The "Millennium Challenges"

- Developed by ACUNU
- Millennium Project
- 1650 experts worldwide over 8 years
- 15 Global Challenges
- Other similar lists
- Effort to focus humanity on big problems
- How can nanotechnology contribute?

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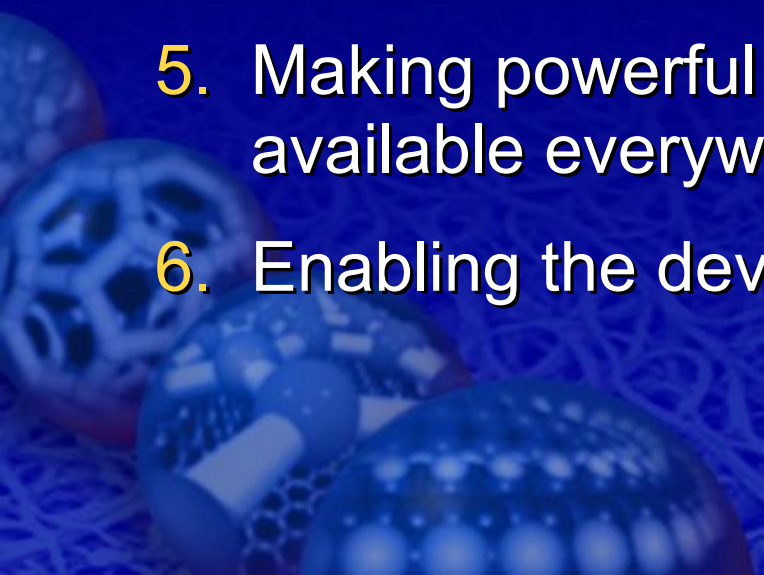
Foresight Nanotech Challenges

1. Meeting global energy needs with clean solutions
2. Providing abundant clean water globally
3. Increasing the health and longevity of human life
4. Maximizing the productivity of agriculture
5. Making powerful information technology available everywhere
6. Enabling the development of space



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Global Energy Needs

The Problem

- Global Warming
  - CO2 concentrations have nearly doubled
  - 3 of the last 5 years hottest in recorded history
  - Glaciers receding worldwide
- Energy Demand
  - 1.6 billion have no access to electricity
  - 2.4 billion rely on burning of biomass
  - Demand will increase approximately 50% by 2025
  - $16 trillion required to meet demand by 2030
  - On track for only 10% renewable energy by 2025
  - Fossil fuel consumption could double by 2030
  - Developing world will surpass developed world

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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.

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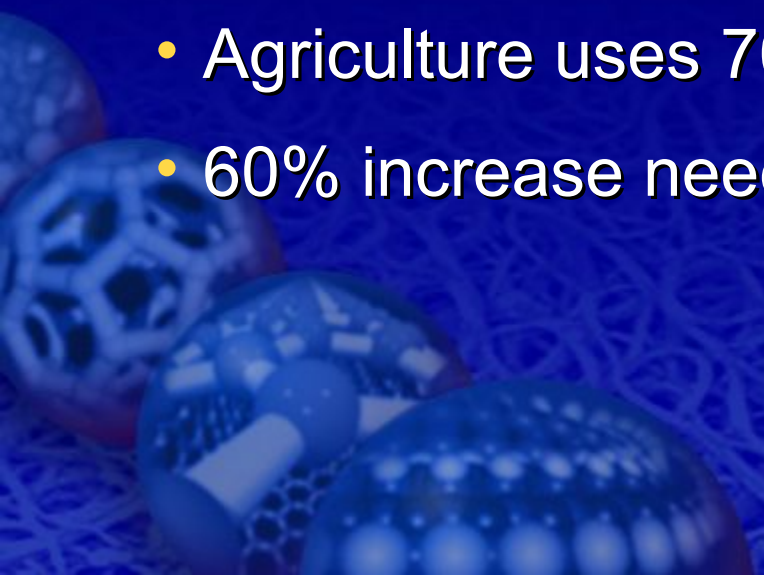
Clean Water

The Problem

- Water tables falling on every continent
- 1.1 billion don't have access to safe water
- 2.4 billion lack sanitation
- 80% of developing world diseases are water-borne
- Agriculture uses 70% of water
- 60% increase needed to feed 2 billion more by 2030



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Clean Water

Some Solutions

- Inexpensive decentralized water purification
- Environmental remediation

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Health and Longevity

The Problem

- Infectious disease
  - Cause of 30% of deaths worldwide
  - 30 new highly infectious diseases in last 20 years
  - HIV/AIDS, SARS, Ebola, Avian Flu
  - Reappearance and resistance to antibiotics
  - Globalization has increased exposure
  - HIV/AIDS is most critical threat
    - 22 million killed, 42 million infected
    - Leading cause of death in sub-Saharan Africa
- Cancer
  - Over 500,000 U.S. deaths annually
  - Over $1.5 million U.S. cases annually
- Life expectancy from 65 now to 75 in 2050
  - Could be significantly longer with anti-aging advancements
  - 2 billion people over 60

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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

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Agricultural Productivity

The Problem

- Increasing demands for nutrition, shelter, water
- World grain harvest fell short last four years
- Biodiversity being destroyed worldwide
  - 1,000,000 more species extinct by 2050
  - 1/2 of forests and 1/4 of coral reefs are gone
  - 9.4 million hectares of forest lost annually
- 8.9 billion population by 2050 (now 6.4 billion)
  - 40% in India and China today
  - 98% of growth in poorer countries
  - 5 billion city dwellers by 2030

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Agricultural Productivity

Some Solutions

- Inexpensive decentralized water purification
- Plant gene therapy
  - Pest-resistant
  - Require less water
  - Higher yield
- Pest nanocides
- Precision farming - nanosensors

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IT Everywhere

The Problem

- Need for “planetary nervous system”
- Widespread lack of access to:
  - Communications
  - Information
  - Services and resources
- Lead to insurmountable barriers to:
  - Education
  - Democratization
  - Economic Growth
- Need to coordinate collective action

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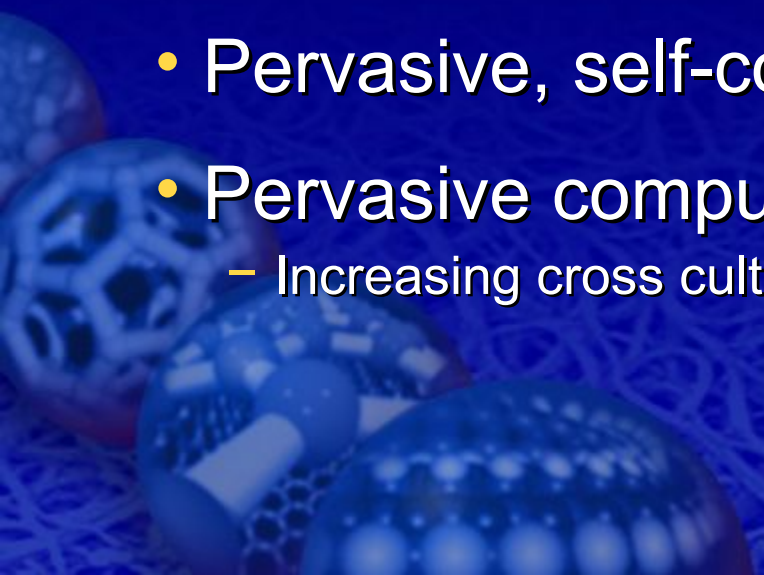
IT Everywhere

Some Solutions

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



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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 research and commercialization agenda
- First roadmap on Productive Nanosystems

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What's Next?

- Collaboration of all stakeholders
- Focus on technology solutions mentioned
- Roadmapping of possible solutions
  - Basis for research and commercialization agendas
- Synergizing of technological and non-technological solutions

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Resources

- Foresight Institute
  - www.foresight.org
- Millennium Project Global Challenges
  - www.acunu.org/millennium/challeng.html
- 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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