Title: Nanoscience - Tiny Tinkertoys and Big Ideas

Date: May 17, 2006 02:00 PM

URL: http://pirsa.org/06050007

Abstract: Nanostructured materials continue to be the focus of intense research due to their promise of innumerable practical applications as well as advancing the fundamental understanding of these intriguing materials. From physics, to chemistry, to biology, to computer science, across the engineering disciplines and into the imagination of the general event, nanotechnology has become an extremely popular buzzword that represents both hope and hype to many people. This talk will outline and describe the exploding field of nanotechnology, including its potential for promising new applications, and for negative societal implications that cause many to fear it. Recent work in our group in the area of integration of nanoscale structures with silicon will be outlined to show the scope and approaches to building nanoscale architectures; the applications of these frameworks include molecular computing, nanoscale sensing platforms, integration of silicon with biology, and intricate structures with unforeseen properties.

National Institute For Nanotechnology

Nanotechnology: Small Science, Big Ideas

Jillian M. Buriak

Professor of Chemistry, Department of Chemistry, University of Alberta
Canada Research Chair in Inorganic and Nanoscale Materials
Group Leader, National Institute for Nanotechnology

University of Alberta

National Research Council Canada
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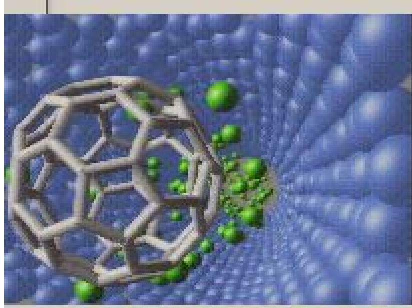
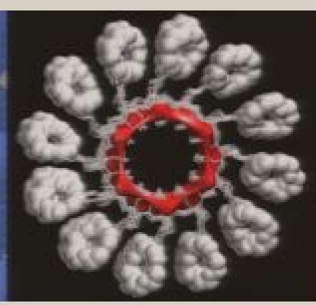
Outline

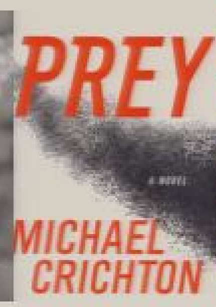
-What is nanotechnology?

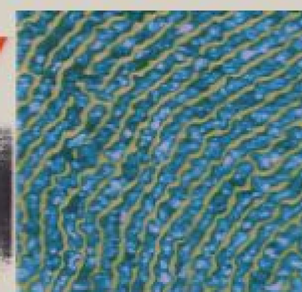
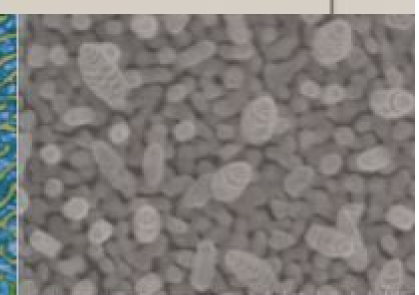
-And why nanotechnology, and why now? Moore's Law

-The potential

-Controlling nanoscale objects



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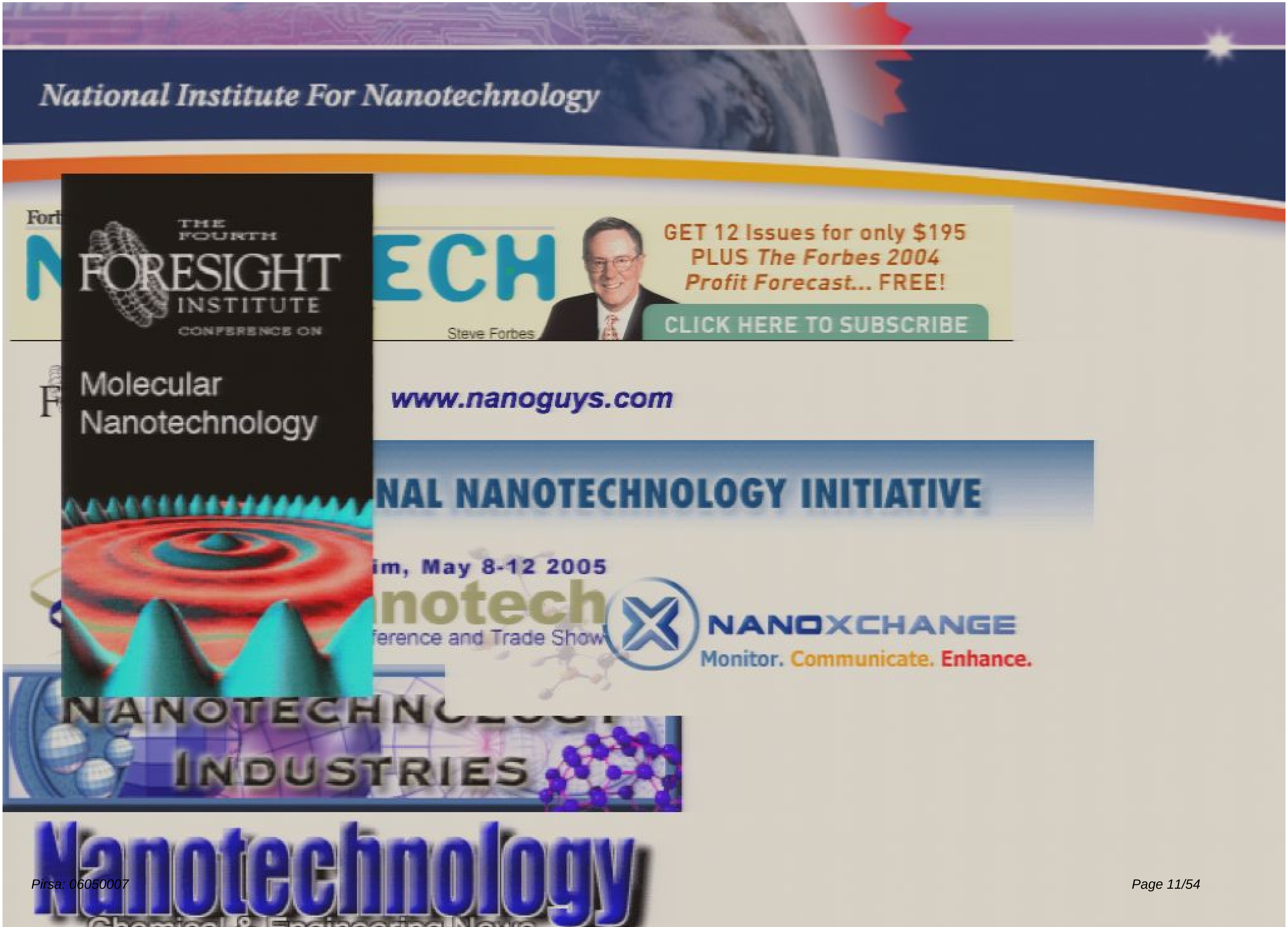
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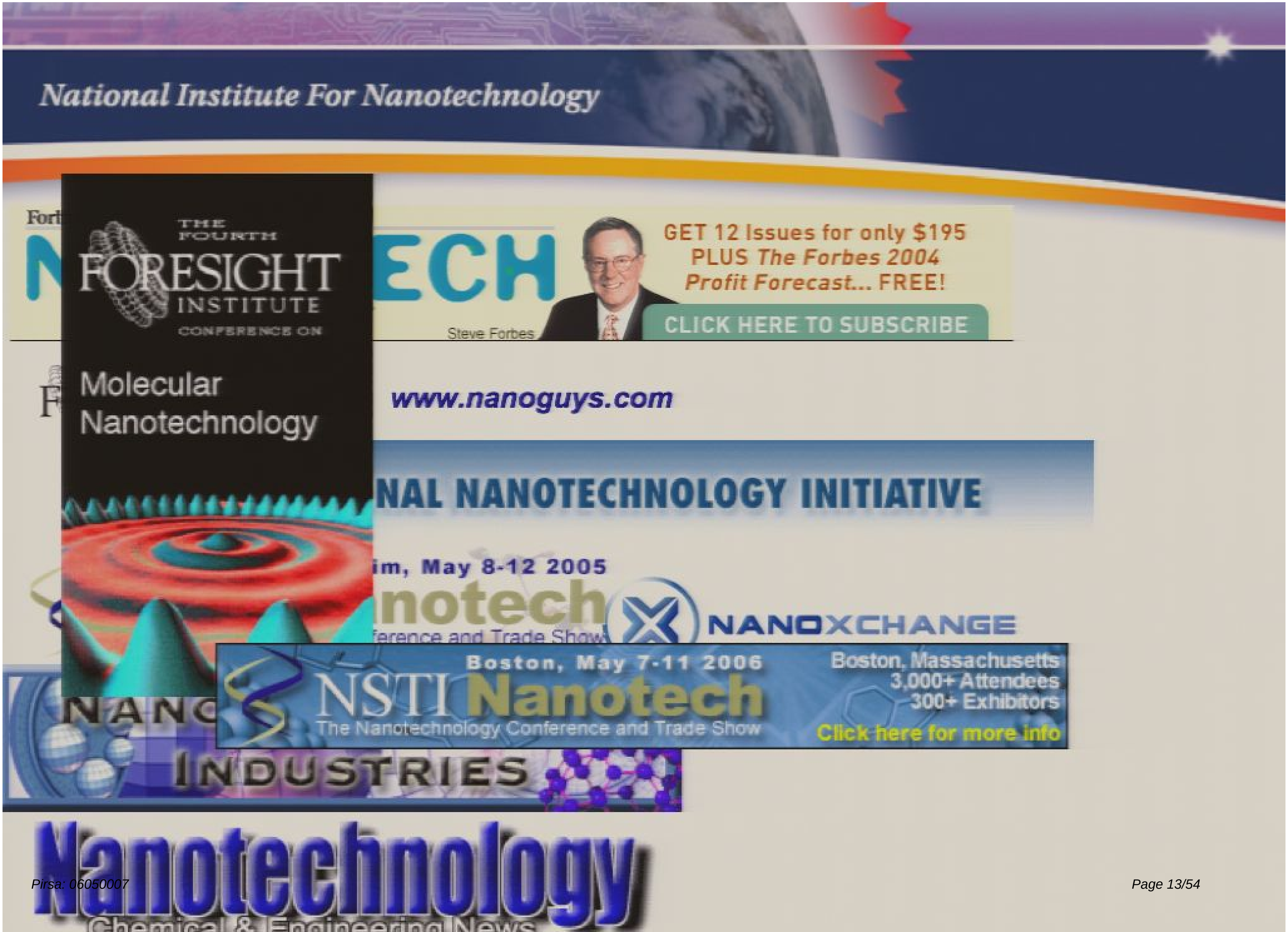
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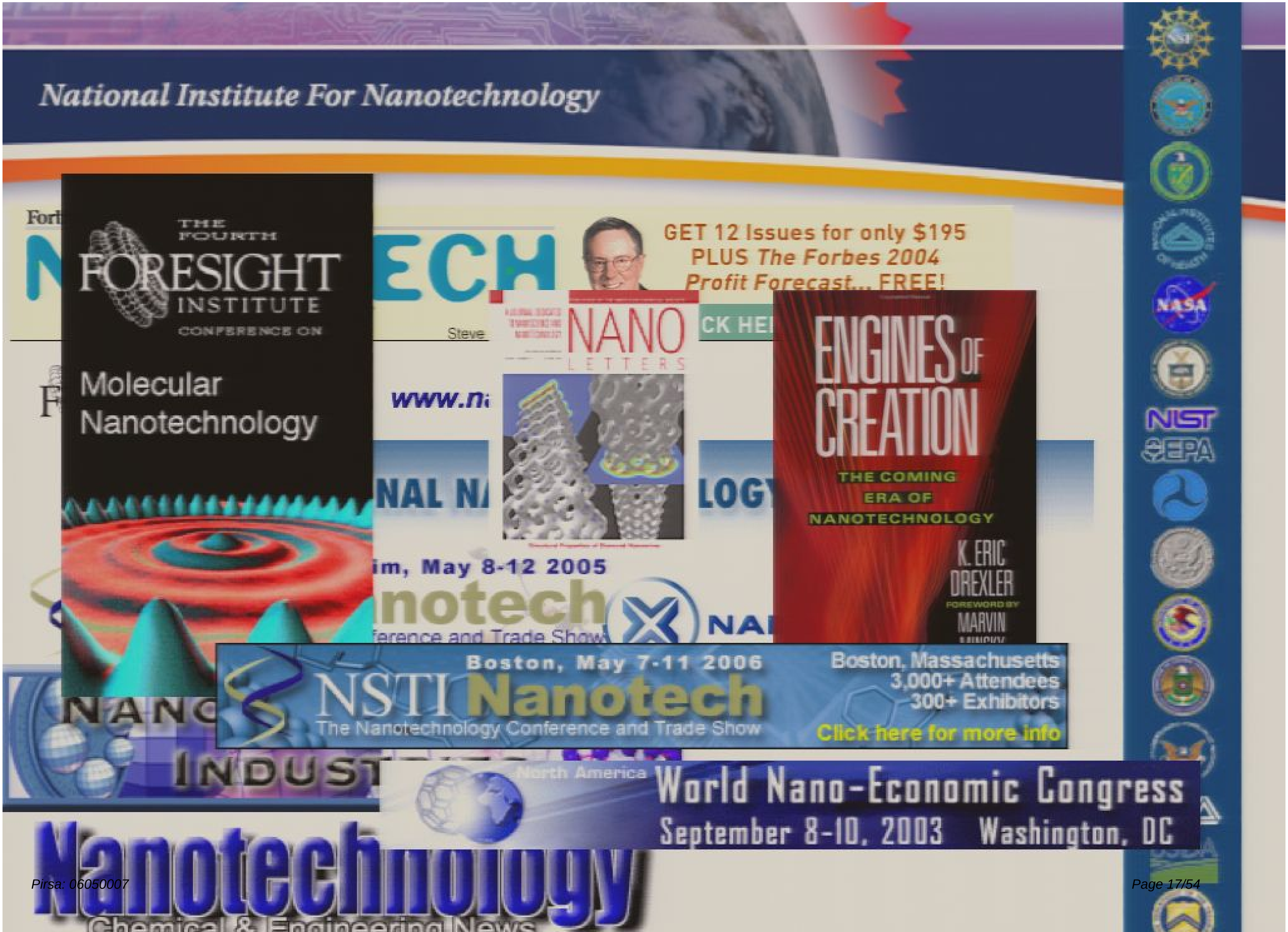
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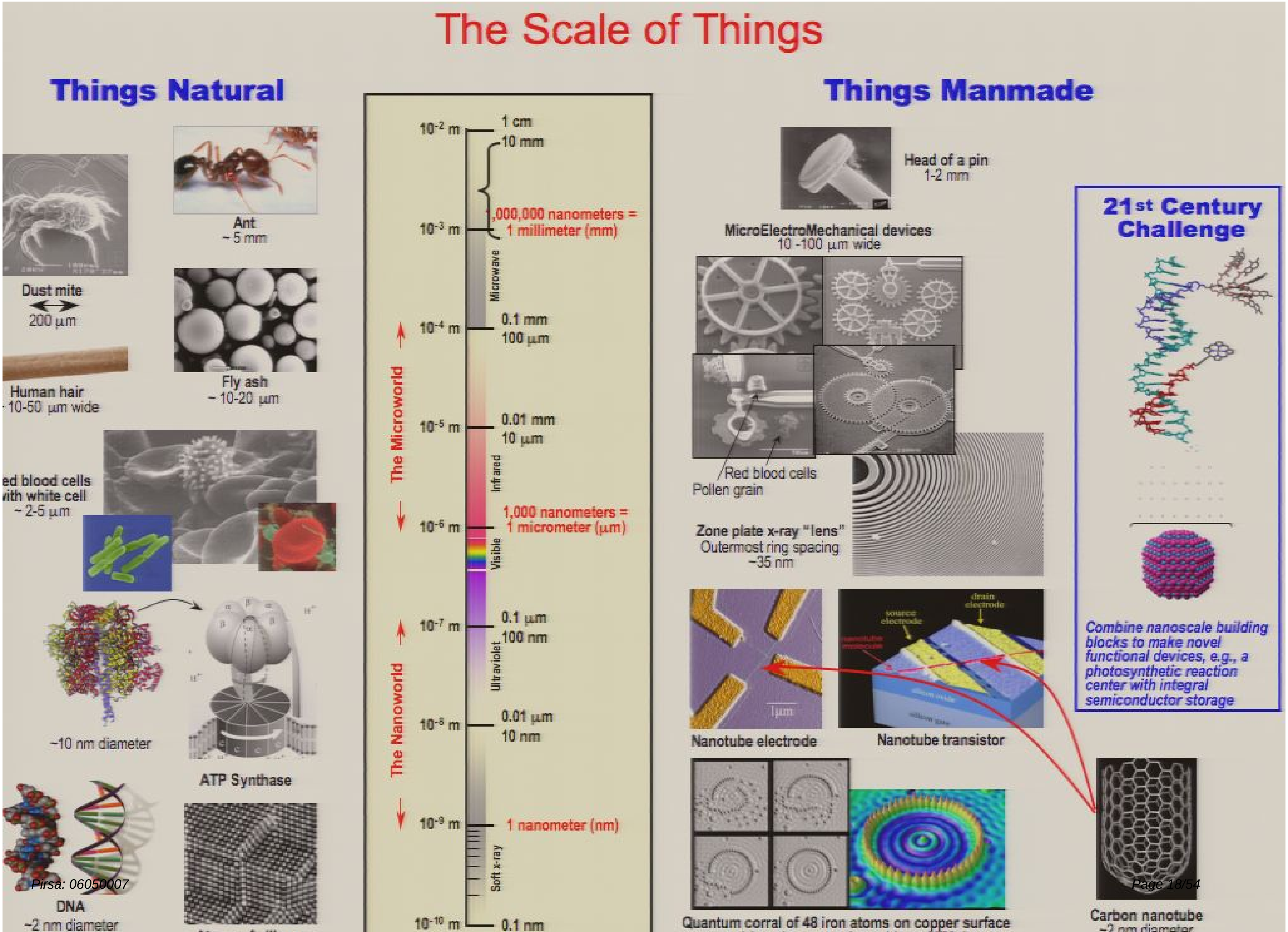

The Scale of Things
Things Natural
Things Manmade
Dust mite
200 µm
Ant
~ 5 mm
Fly ash
~ 10-20 µm
Human hair
~ 10-50 µm wide
Red blood cells
with white cell
~ 2-5 µm
~10 nm diameter
ATP Synthase
DNA
~2 nm diameter
10⁻² m
1 cm
10 mm
1,000,000 nanometers =
1 millimeter (mm)
10⁻³ m
Microwave
10⁻⁴ m
0.1 mm
100 µm
The Microworld
10⁻⁵ m
0.01 mm
10 µm
Infrared
1,000 nanometers =
1 micrometer (µm)
10⁻⁶ m
Visible
10⁻⁷ m
0.1 µm
100 nm
Ultraviolet
The Nanoworld
10⁻⁸ m
0.01 µm
10 nm
10⁻⁹ m
1 nanometer (nm)
Soft x-ray
10⁻¹⁰ m
0.1 nm
Head of a pin
1-2 mm
MicroElectroMechanical devices
10 -100 µm wide
Red blood cells
Pollen grain
Zone plate x-ray "lens"
Outermost ring spacing
~35 nm
Nanotube electrode
Nanotube transistor
Quantum corral of 48 iron atoms on copper surface
Carbon nanotube
21st Century
Challenge
Combine nanoscale building blocks to make novel functional devices, e.g., a photosynthetic reaction center with integral semiconductor storage

The Origins…

There's Plenty of Room at the Bottom

An Invitation to Enter a New Field of Physics

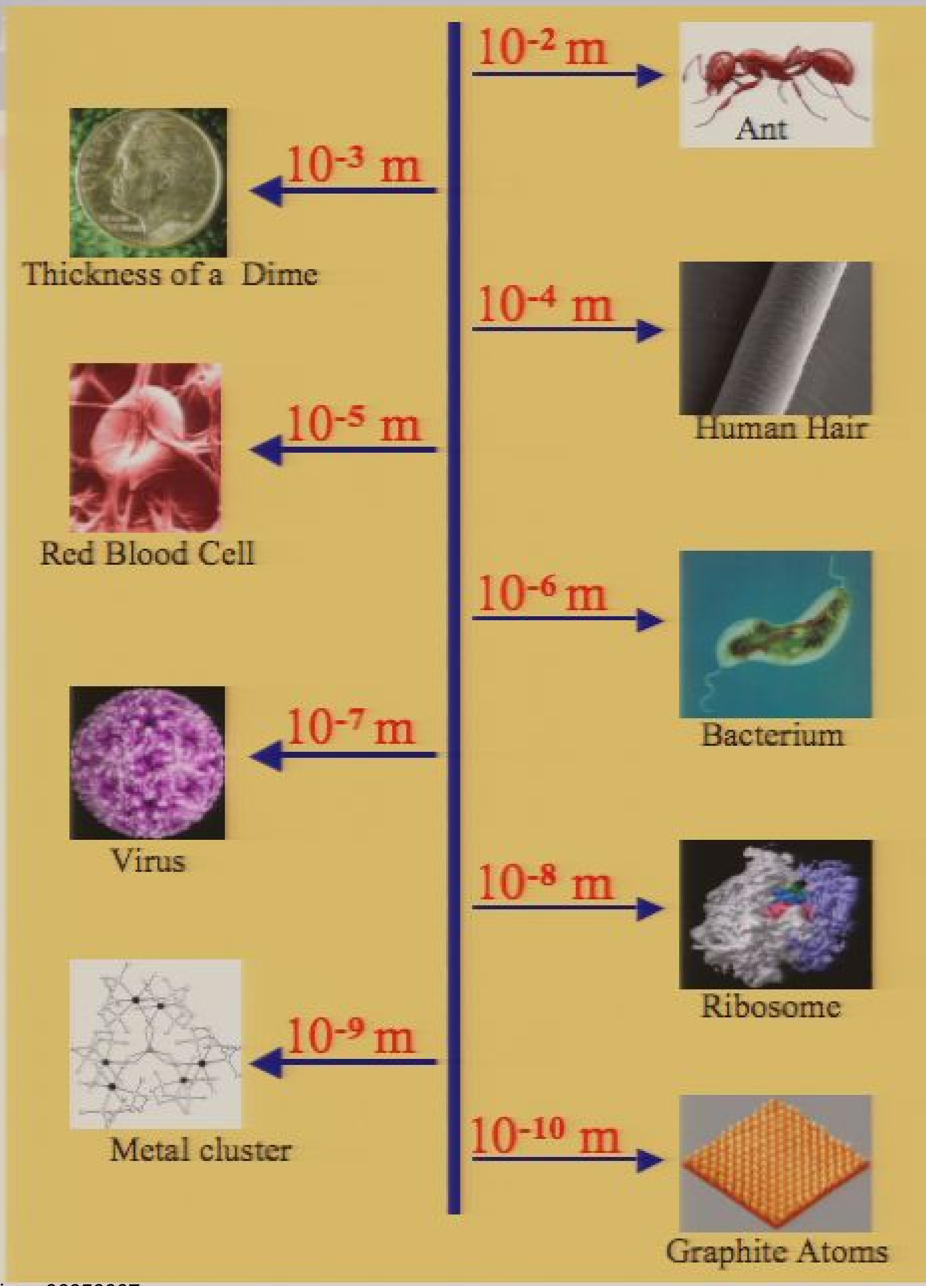
by Richard P. Feynman

This transcript of the classic talk that Richard Feynman gave on December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology (Caltech) was first published in the February 1960 issue of Caltech's *Engineering and Science*,

I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle….

…*Why cannot we write the entire 24 volumes of the Encyclopedia Brittanica on the head of a pin?*..

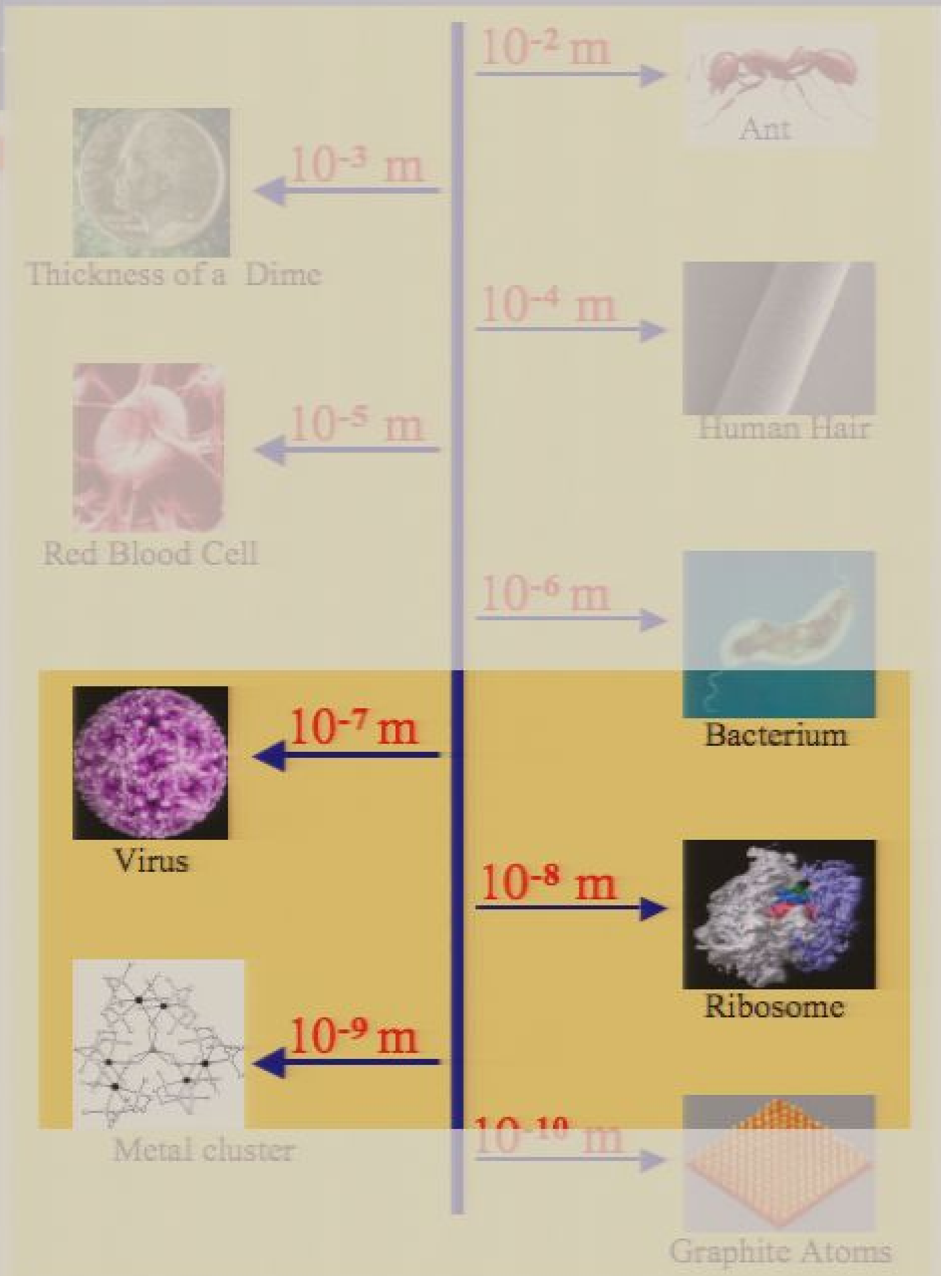
...Furthermore, it can be read if it is so written. Let's imagine that it is written in raised letters of metal; that is, where the black is in the Encyclopedia, we have raised letters of metal that are actually 1/25,000 of their ordinary size. How would we read it?



The nanometer

$1 \text{ nm} = 10^{-9} \text{ m}$

And why now?



The nanometer

$$1 \text{ nm} = 10^{-9} \text{ m}$$

And why now?

Moore's Law

Fabrication Projections

2000: 5 Billion US$

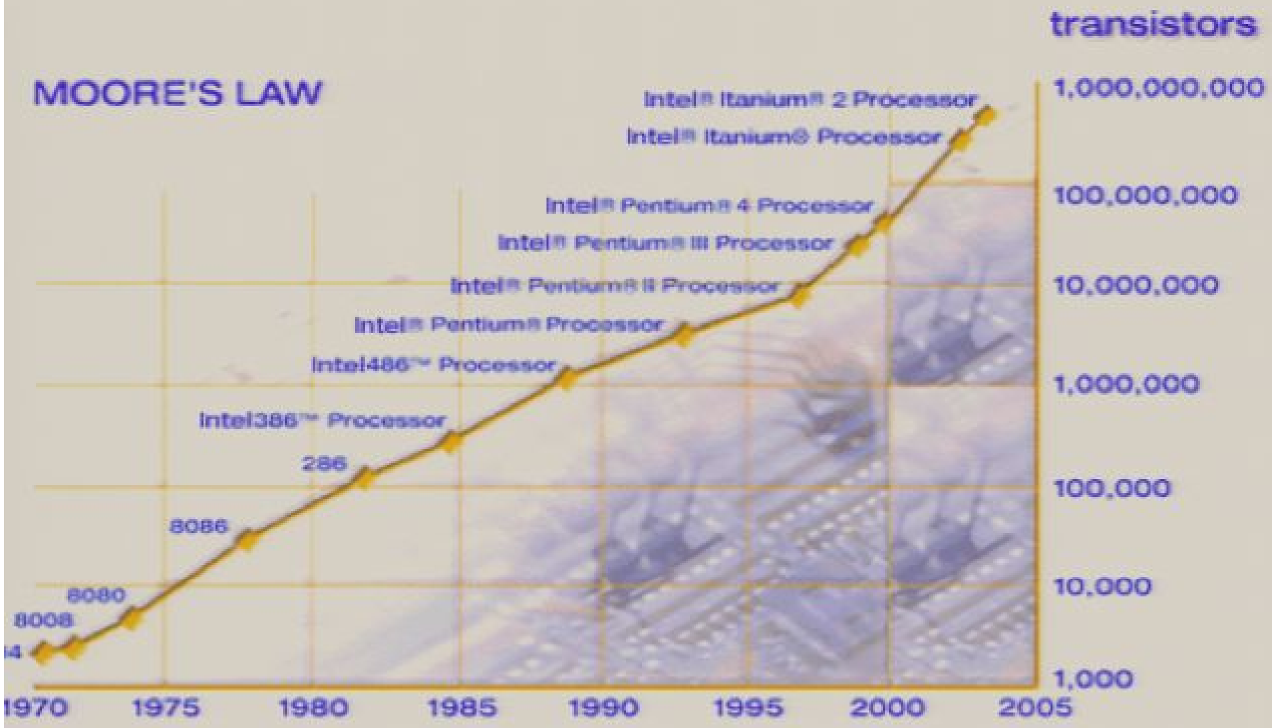
2035: Gross domestic product of the entire planet!

2017: Physical limitation of wafer fabrication

???

Moore's Law

Gordon Moore, Chairman Emeritus



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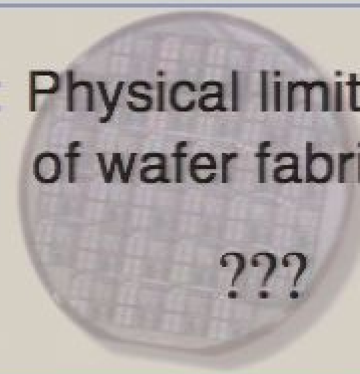

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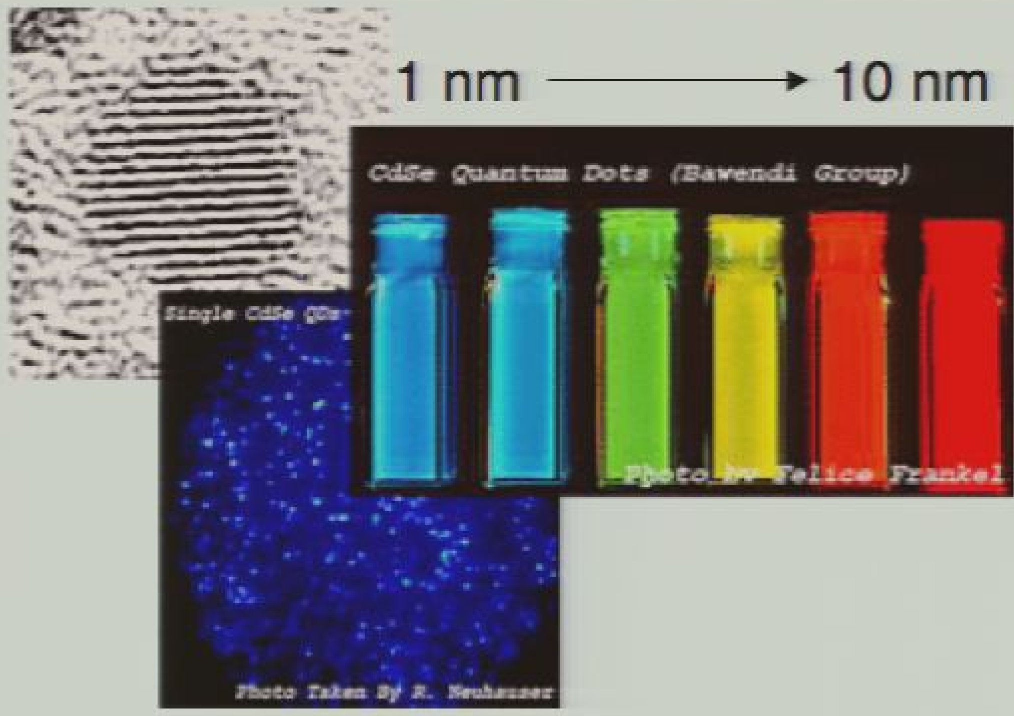
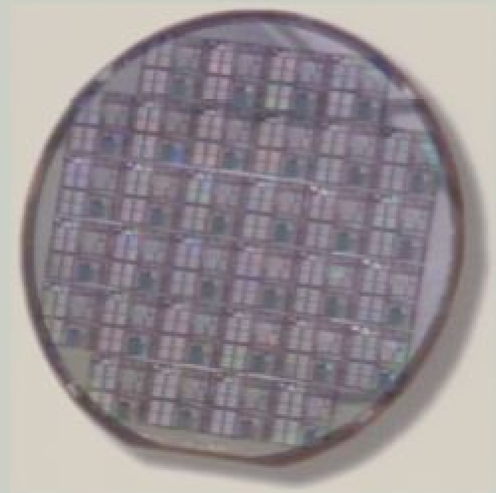
Dimensions are everything...

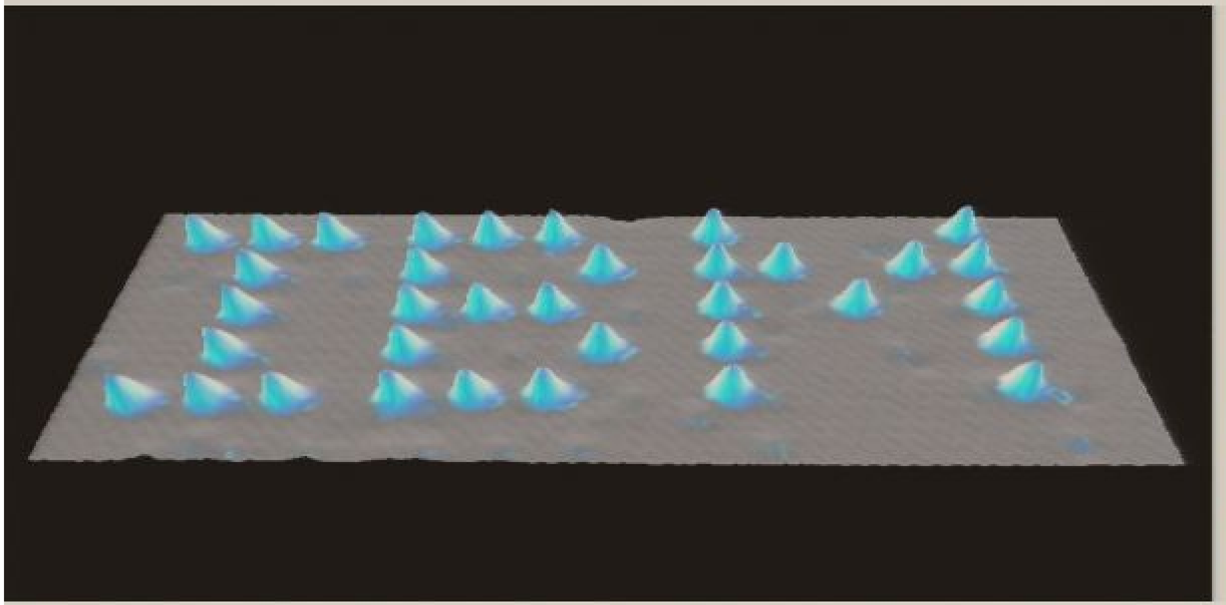


Bawendi

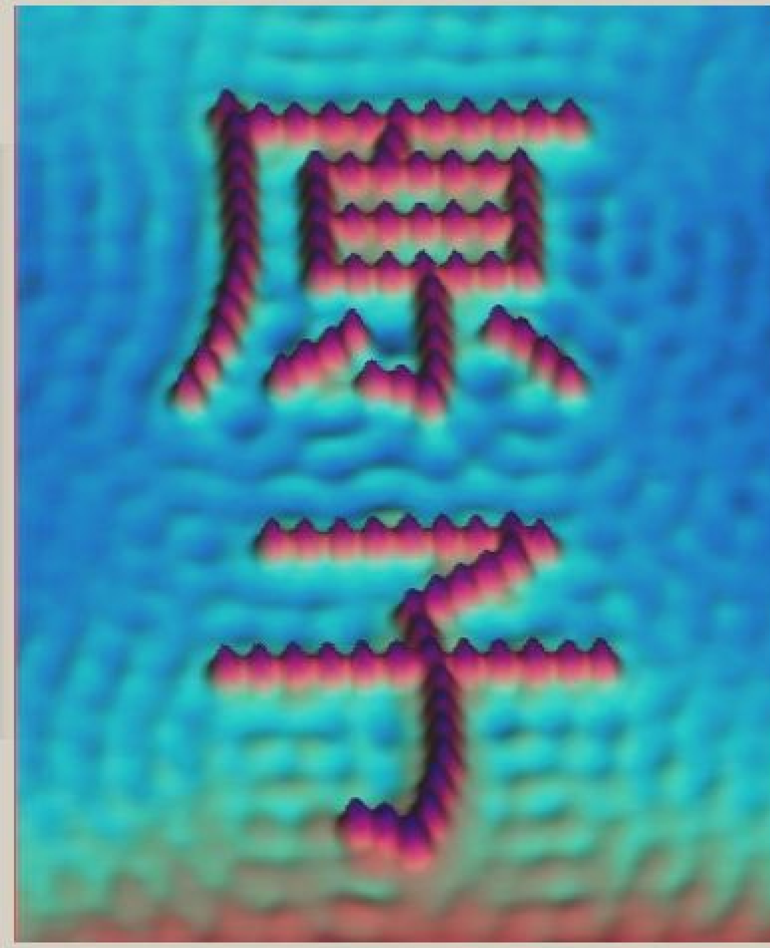


Bawendi, Alivisatos, etc.

Canham, Sailor, Fauchet, Buriak, etc.



Xe atoms



Cu atoms

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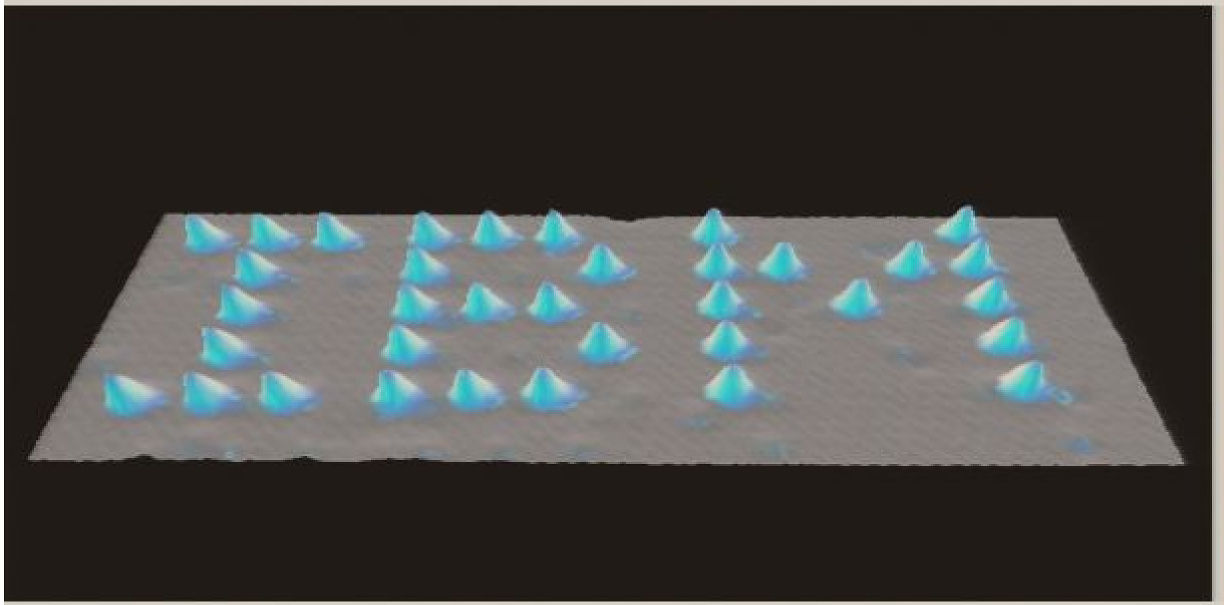

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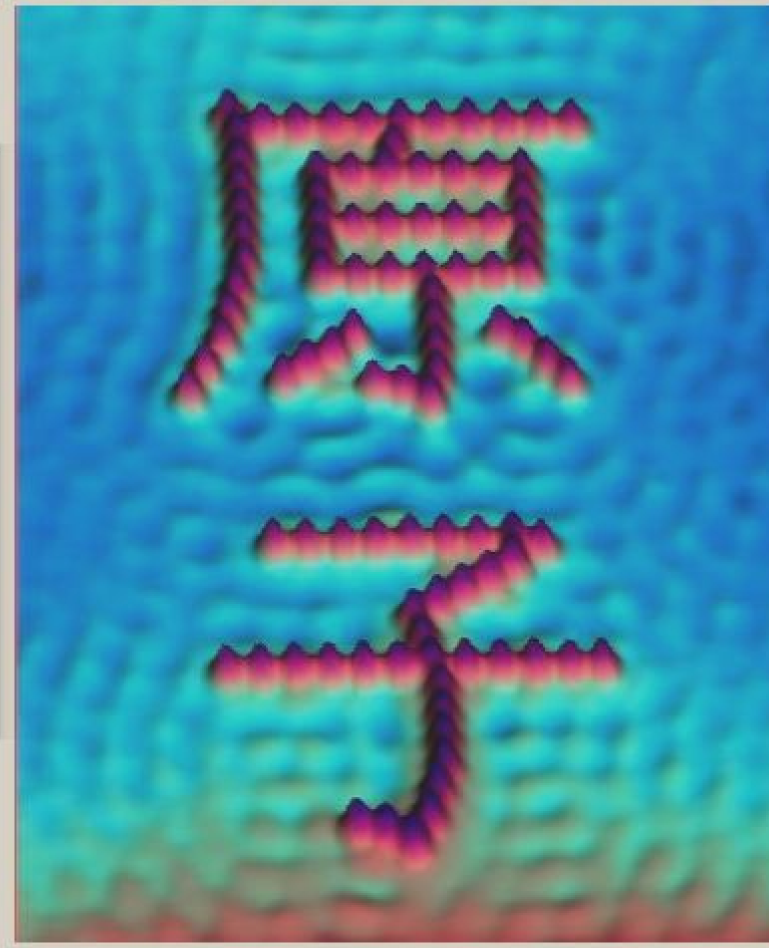

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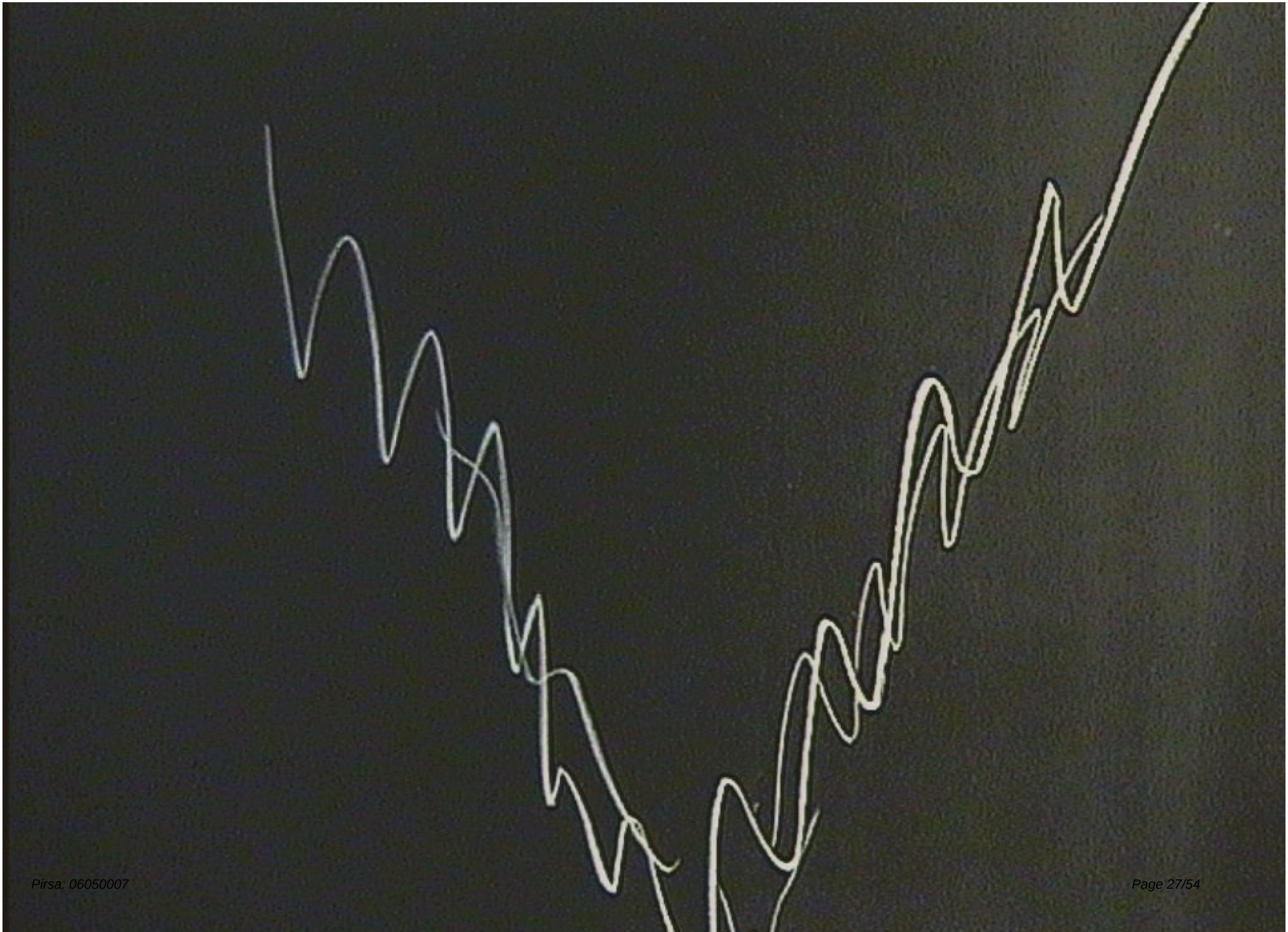
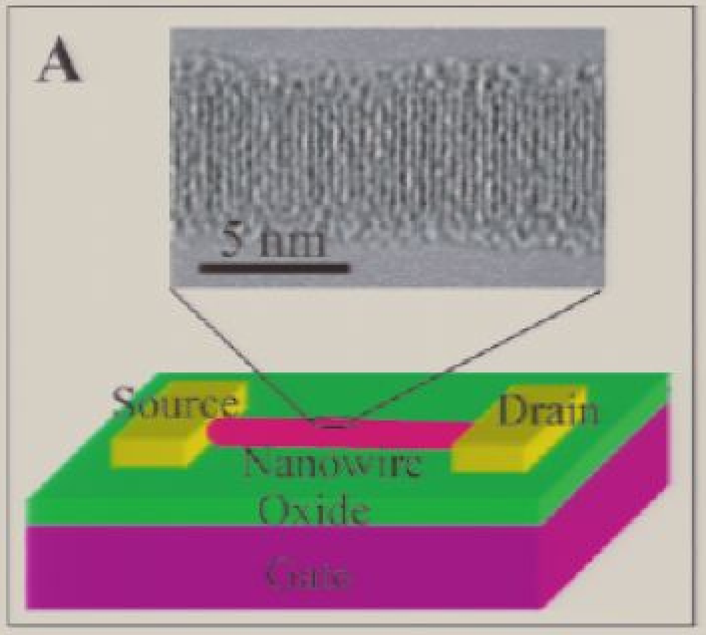
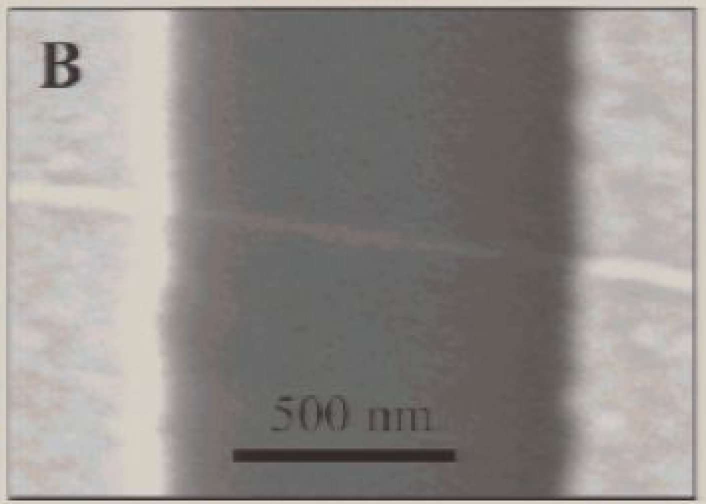
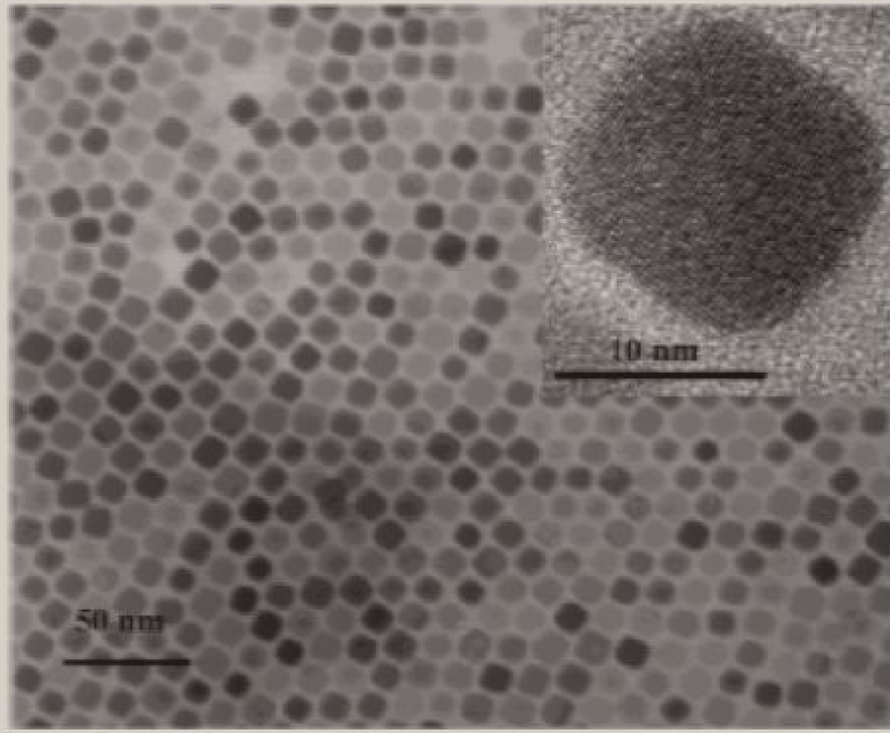
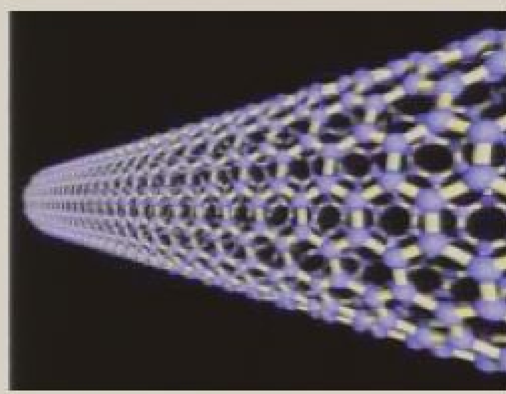


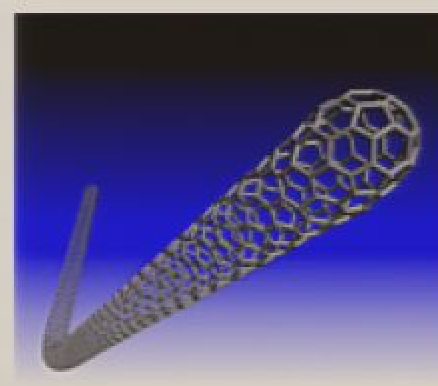
What do Nanomaterials Look Like?

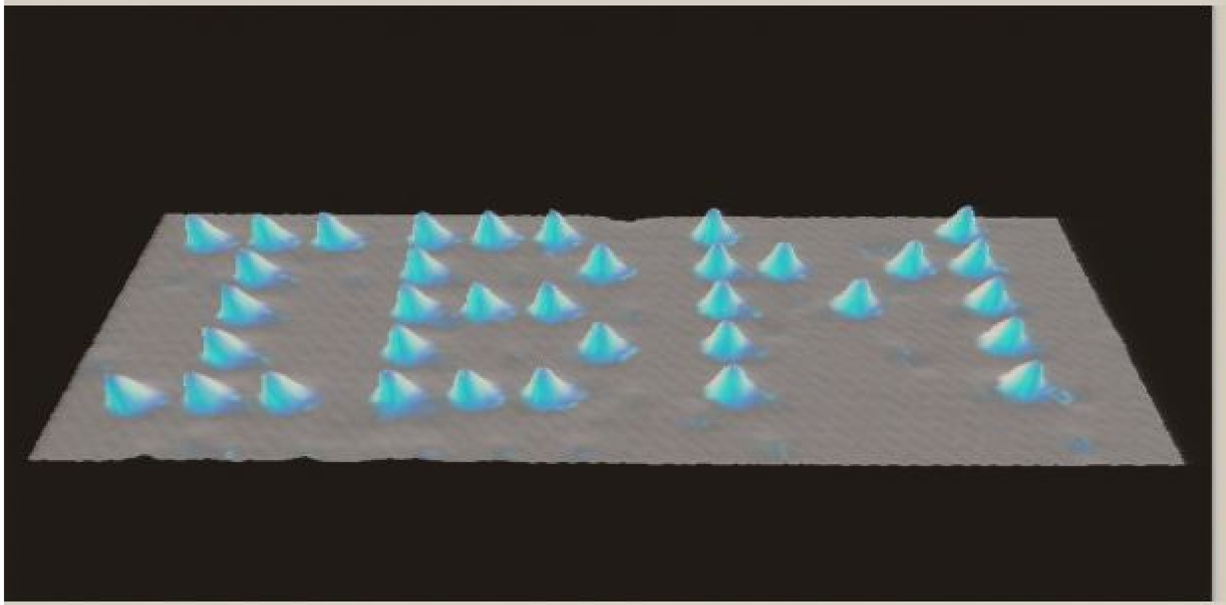












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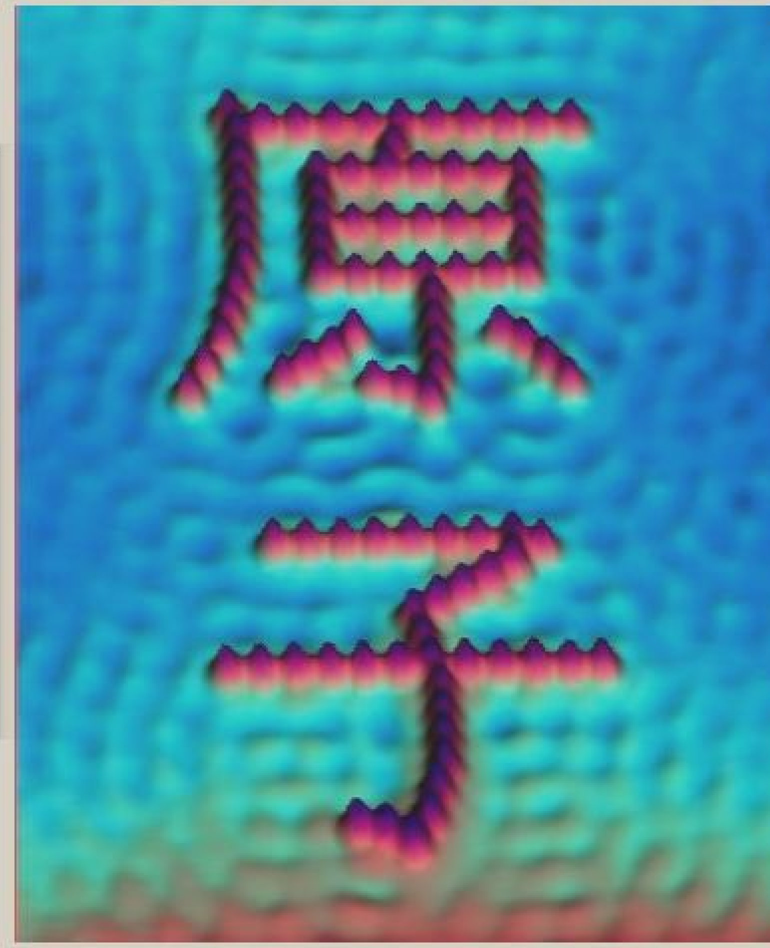

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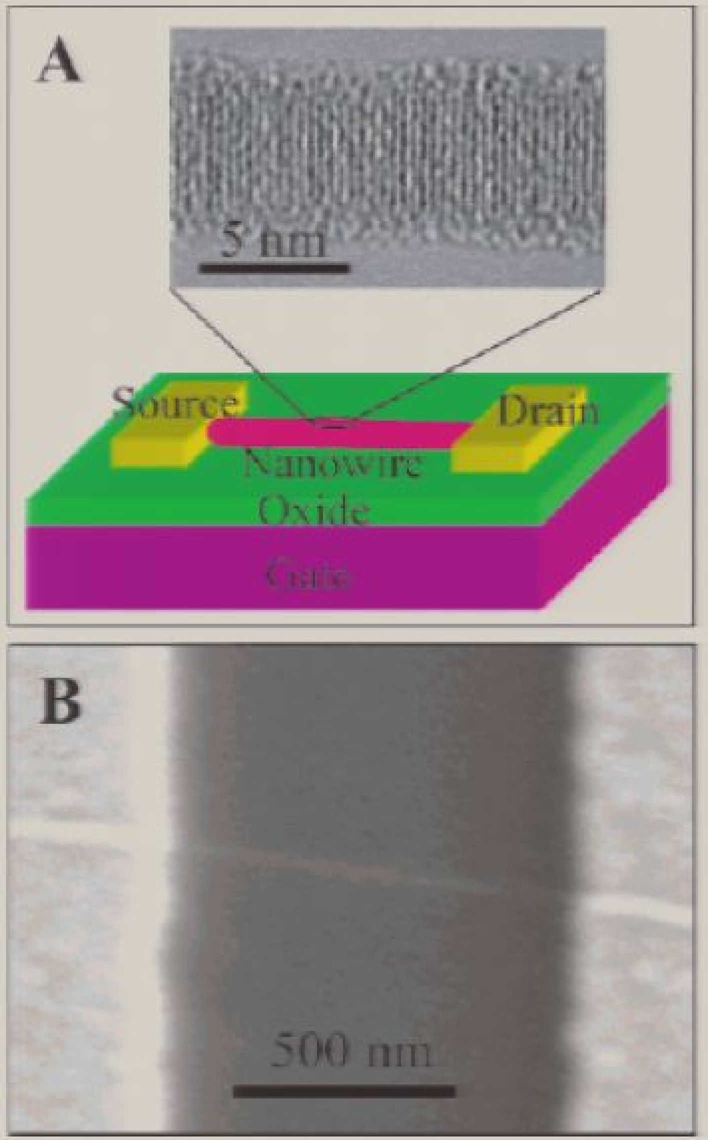
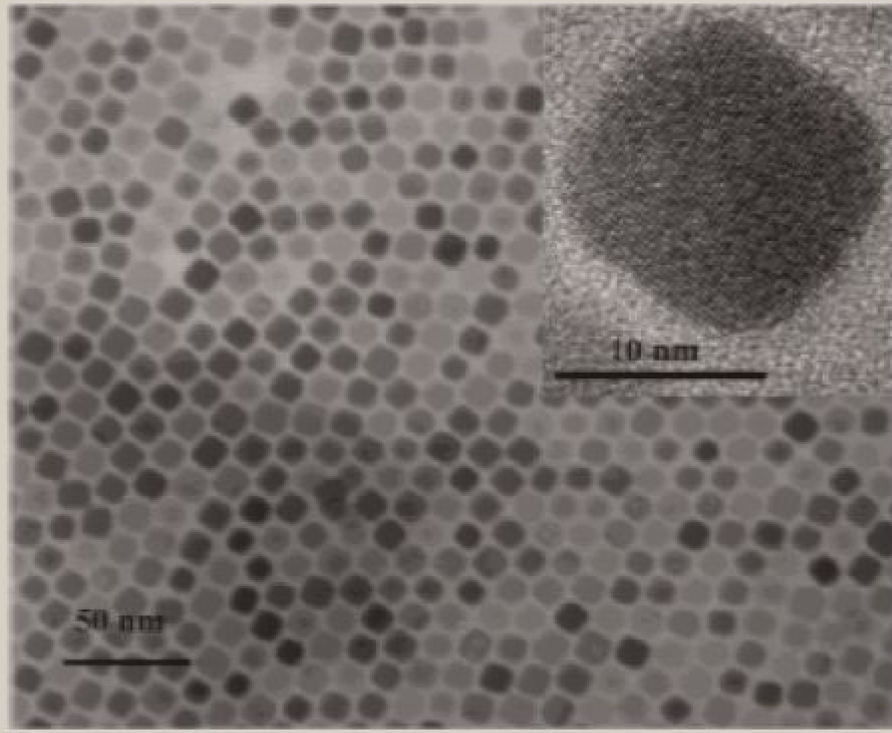
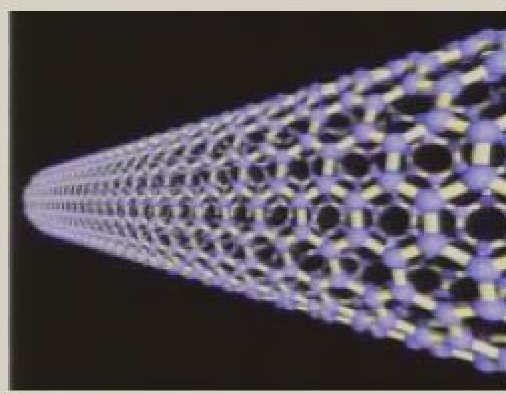
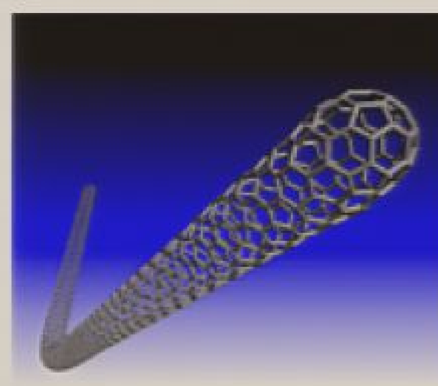






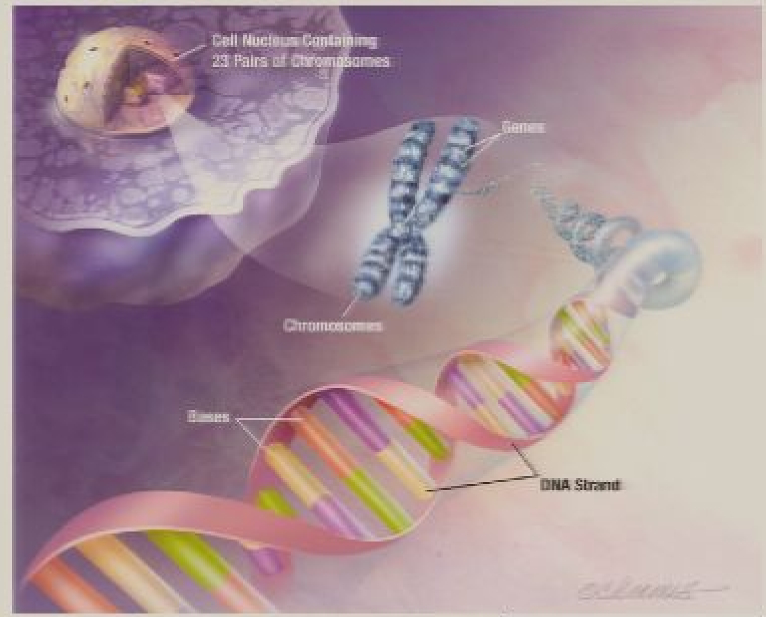


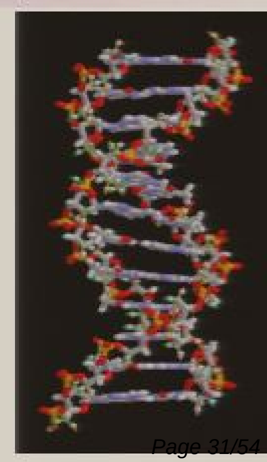
The Potential

Cleaner manufacturing (catalysts)

New approaches to energy:

Nanomedicine





Promise of Nanotechnology
(examples of societal implications)

Knowledge base: Better comprehension of nature, life
A new world of products: ~$1 trillion/year in 10-15 years
Materials: ~$340B/y in 10 years for materials and processing
Electronics: ~$300 B/y in 10-15 years for semiconductor industry, times more for global integrated circuits
Pharmaceuticals: about half of production will depend on nanotechnology, affecting **~$180B/y** in 10-15 years
Chemical plants: Nanostructured catalysts in petroleum and chemical processing, **~$100 B/y** in 10-15 years
Aerospace: ~$70B/y in 10 years
Tools: for measurement and simulations, **~22 B/y** in 10 years

Would require worldwide ~2 million nanotech workers

Improved Healthcare: extend life-span, its quality, human physical capabilities, **~$31B/y** in tools for healthcare in 10 years
Sustainability: agriculture, water, energy, **~45 B/y** in 10 years, materials, environment; ex: lighting energy reduction ~10% or **~$100B/y**

M. C. Roco, NSF, 02/05/02

THE NANOMEDICINE ROADMAP

The overarching goal is to create the *conceptual and literal interface* between biology and medical devices *at the scale* of biomolecular processes.

To achieve this goal, Nanomedicine Development Centers will:

- enable comprehensive measurements on biological molecular system components and their interactions
- combine these measurements using analytical tools to achieve fundamental understanding of biological processes
- use that knowledge to drive the design of new nanomachines and technologies to interact with living systems to improve human health.

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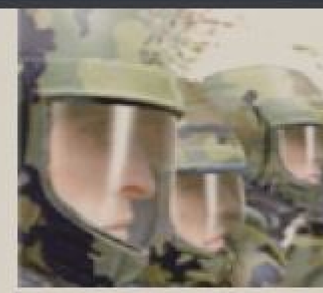
Enhancing Soldier Survivability

http://web.mit.edu/isn/index.html



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Team 2: Mechanically Active Materials and Devices
Team 3: Sensors and Chemical/Biological Protection
Team 4: Biomaterials and Nanodevices for Soldier Medical Technology
Team 5: Processing and Characterization – The Nanofoundries
Team 6: Modeling and Simulation of Materials and Processes
Team 7: Systems Design, Hardening, and Integration

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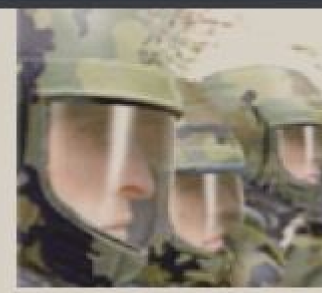

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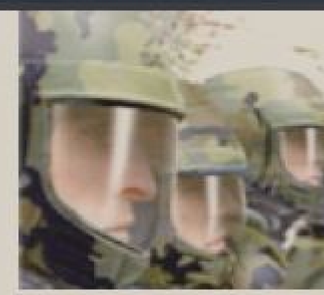

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…maybe even lends superhuman abilities.

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Consider Computing Technologies: What's to Come?

New and wacky? **or** Continued (incredible) improvements?

Consider Computing Technologies: What's to Come?

or Continued (incredible) improvements?

BREAKTHROUGH OF THE YEAR:

Molecules Get Wired

Robert F. Service

In 2001, scientists assembled molecules into basic circuits, raising hopes for a new world of nanoelectronics

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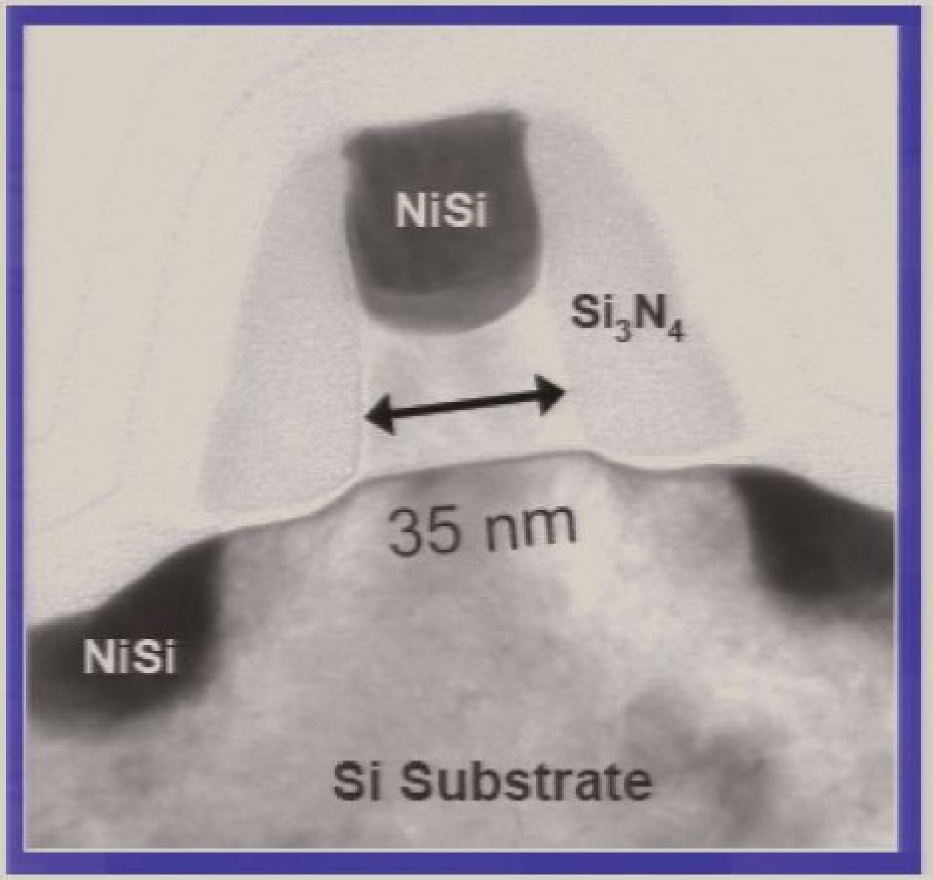
or



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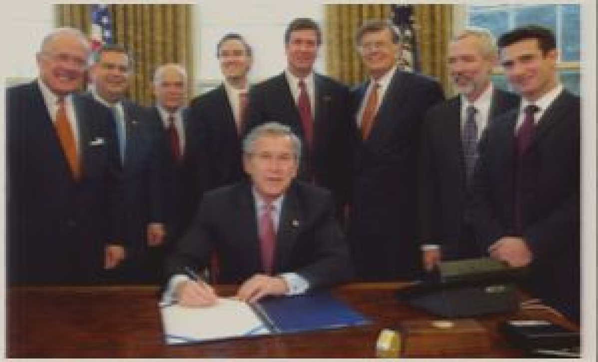
www.intel.com/technology/silicon/index.htm

Nanotechnology: The Players

Most industrialized countries are funding technology research. Japan has stated that they will spend over $700 million in their nanotechnology research program this year, up from a planned $650 million. An NNI Update meeting in April revealed that Japan might spend up to $1 billion next year where both the government and commercial sectors are making major investments in research. There are over 10 companies in Japan with nanotechnology research centers. China has publicly stated, "We can beat Japan." Korea plans to invest $1.1 billion by 2007 in nanoscience research and recently announced that they will spend about $160 million this year to accelerate nanotechnology projects.



Worldwide Nanotechnology Spending (Billions of US Dollars)

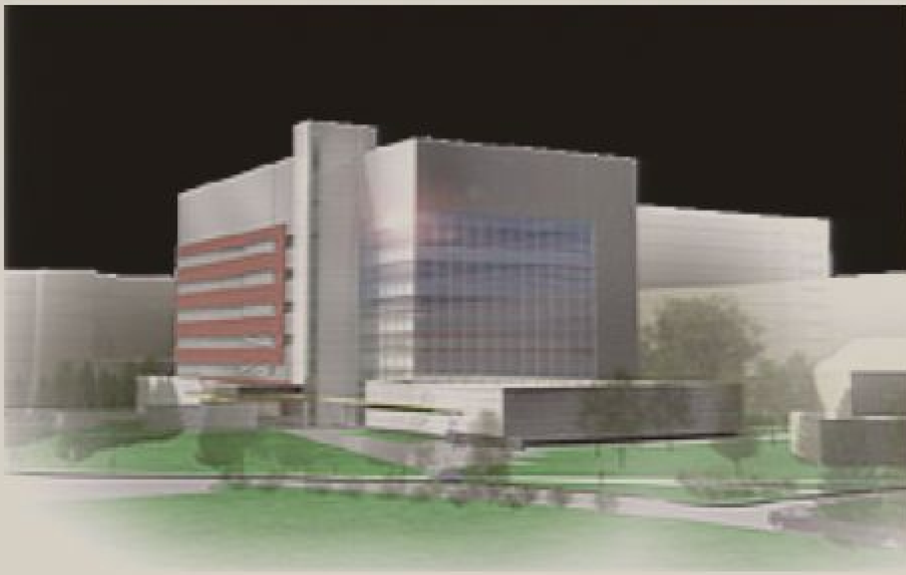
*Source: National Science Foundation

Country	2000	2001	2002	2003	2004	2005	CAGR
United States	.270	.422	.697	.774	.93	.98	30%
Japan	.245	.465	.70	.81	?	N/A	50%
Europe	.200	.225	.40	.699	1.3	N/A	50%
Asia (w/o Japan)	.110	.380	.50	.80	1.6	N/A	95%
Total World Wide	.825	1.492	2.297	3.083	8.6	N/A	55%

http://www.nanotechfoundation.org/nano_worldwide.html

National Research Council Canada | Conseil national de recherches Canada

National Institute for Nanotechnology | **Institut national de nanotechnologie**



~200,000 ft^2, 200-300 personnel (10-15 major research groups), instrumentation: EM (high res TEM, SEM), AFM/STM, XPS, SAM, ToF-SIMS, XRD, SAXS, standard array of spectroscopies, etc etc..

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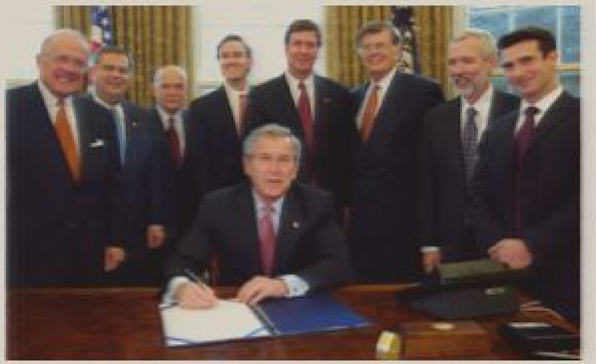

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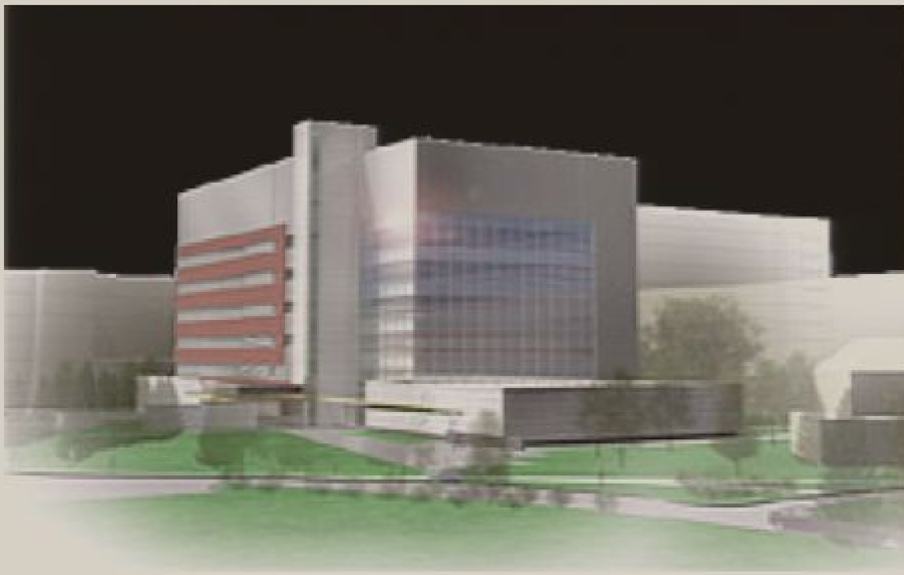

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Economist.com

SCIENCE & TECHNOLOGY

Nanotechnology

Trouble in nanoland

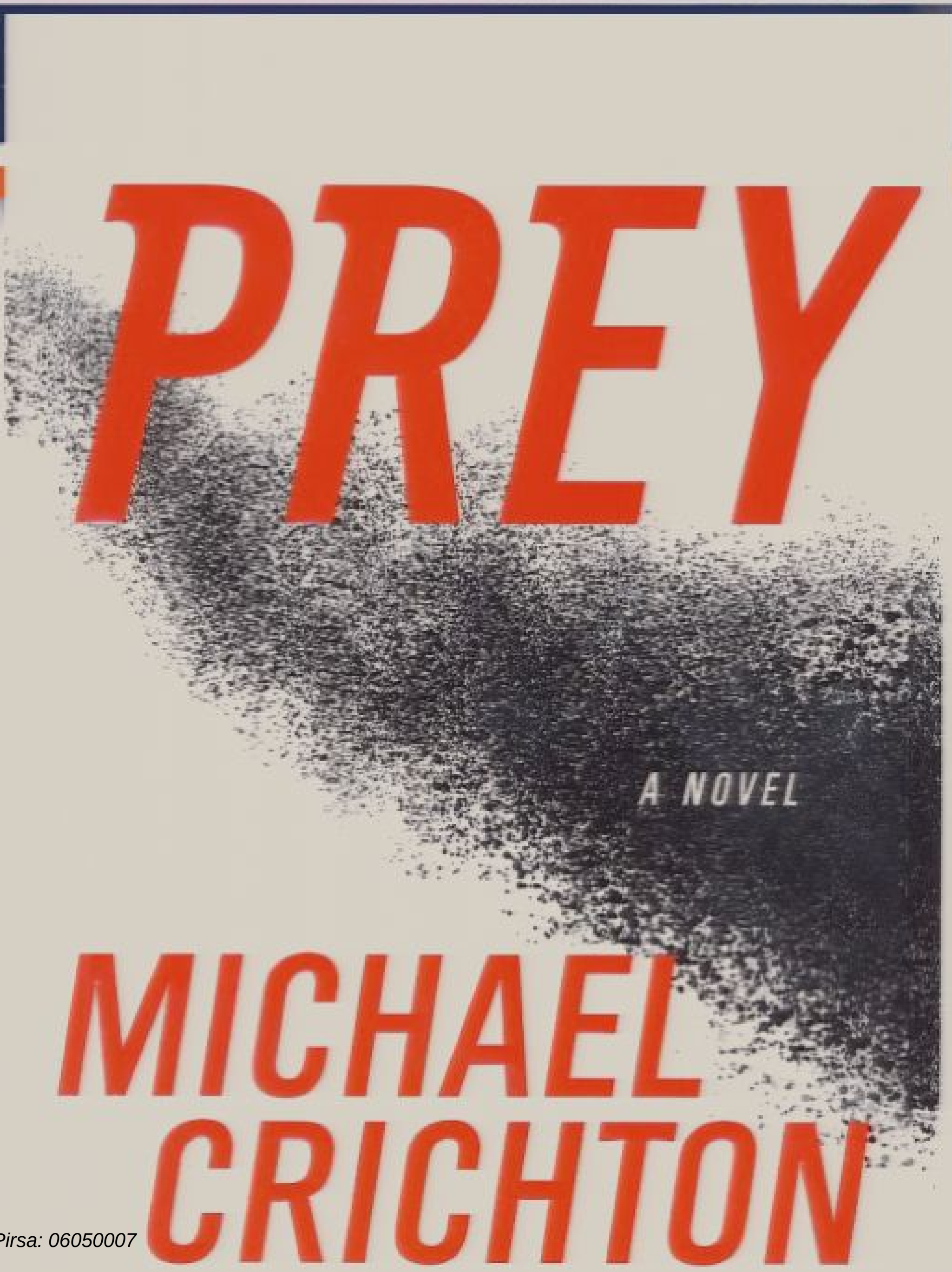
Dec 5th 2002
From The Economist print edition

Plagued by both pessimism and hype, can nanotechnology grow up?

...Given that the well-organised and influential biotechnology industry has suffered some serious setbacks at the hands of such activists, some worry that the embryonic nanotechnology industry will be a pushover...

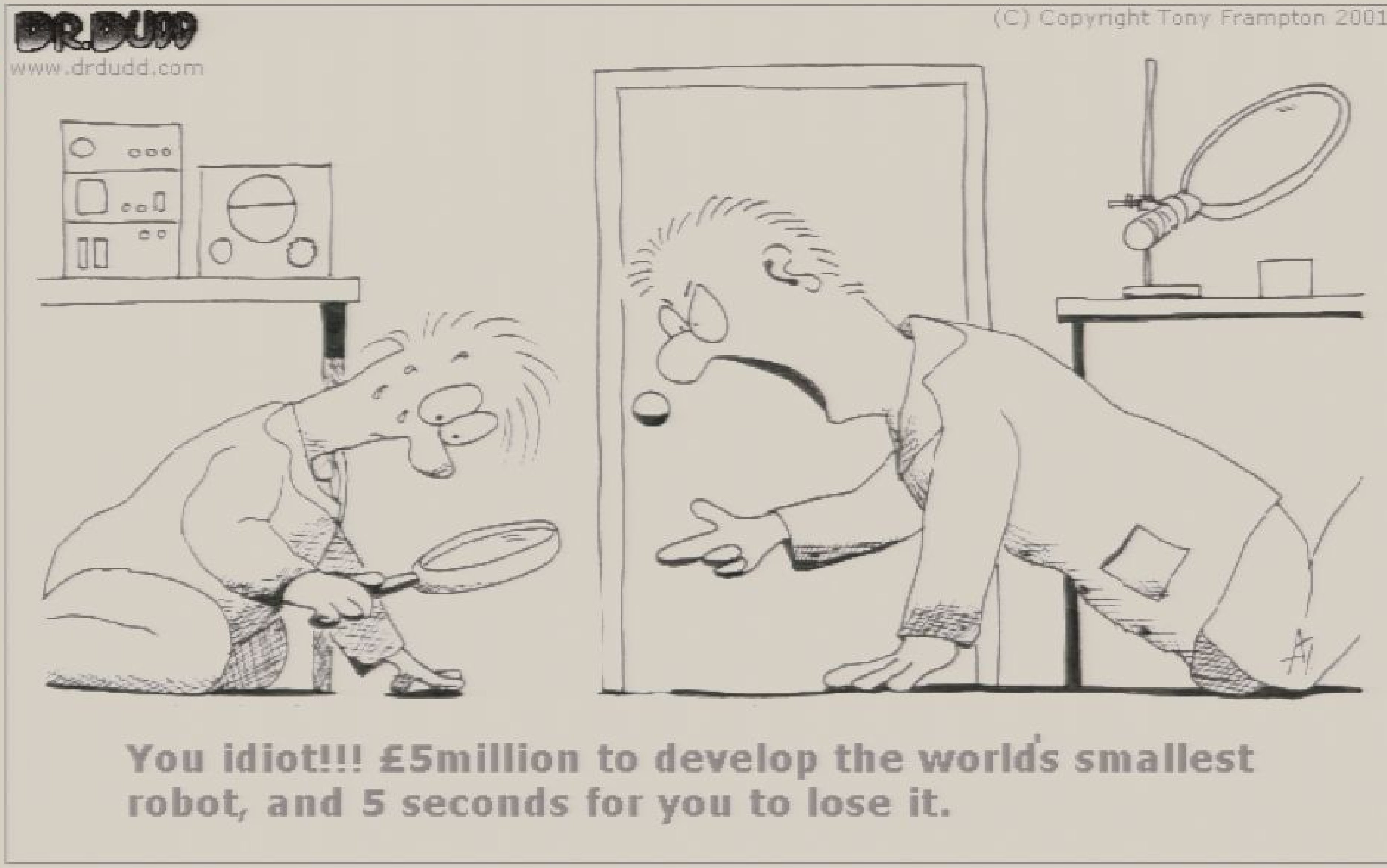
...At the opposite end of the spectrum are the nano-enthusiasts, who are recklessly setting impossibly high expectations for the economic benefits of nanotechnology.

In many new technologies, it is common to overestimate what can be done in five years' time, and to underestimate what can be done in 50 years' time.... However, there is a huge technological gap between molecular cascades and fully-functional nanobots. The rest of the world, then, should not hold its breath.



The New York Times ON THE WEB

Best seller list - 4 weeks at number 1 in 2003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You idiot!!! £5million to develop the world's smallest robot, and 5 seconds for you to lose it.


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ENGINEERING


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MR BLAIR DO YOU DARE
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WHO WANT BRITAIN GMO FREE


Kellogg's
Genetically Modified
FROSTED FAKES
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Hey Kids!
Get Your
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Splicer!


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Cereal City
U·S·A
Kellogg's
Stop Feeding
Frankenfood to
America's Kids

Why Worry?

Equity- enormous benefit for world's poor:
-environmental remediation, cleaner energy production, medical diagnosis, biomaterials, etc.

Privacy and Security - nano tracking devices, surveillance, military applications (and misuse)

Environmental Issues - what happens when nanomaterials enter the environment

Biomaterials - implants, modification of organisms

Anisa Mnyusiwalla[1,2,3], **Abdallah S Daar**[1,2,3] **and Peter A Singer**[1,2,3]

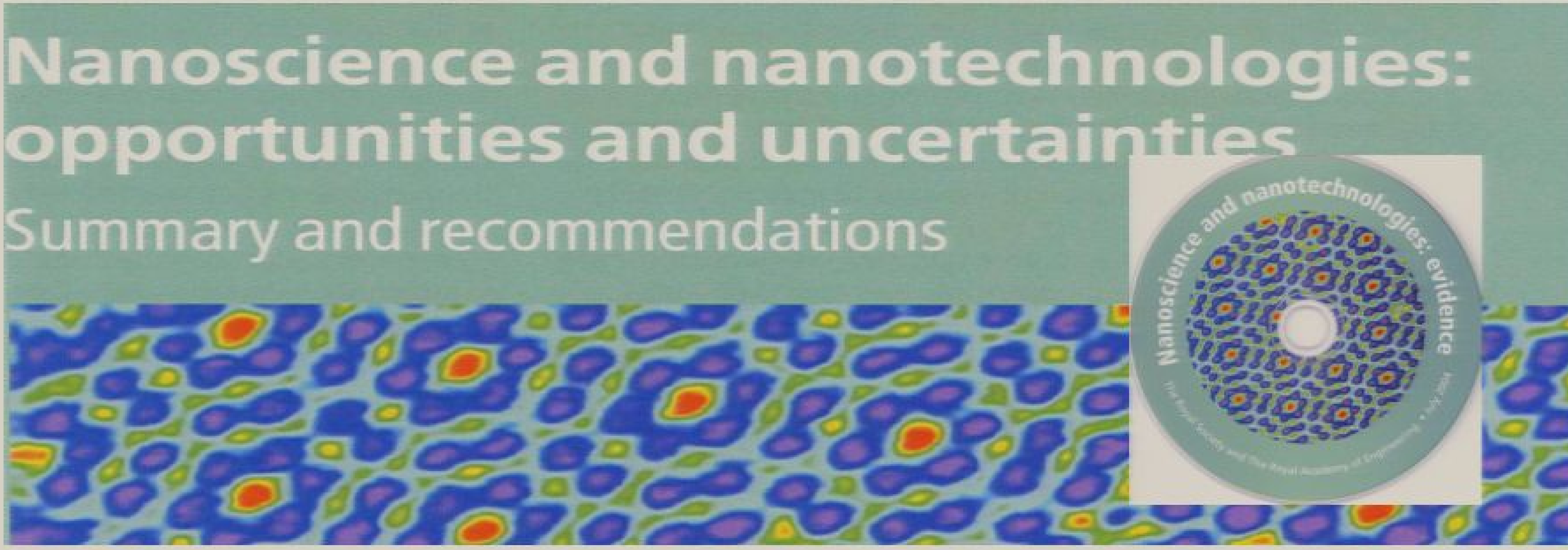
[1] University of Toronto Joint Center for Bioethics, Canada
[2] Faculty of Medicine, University of Toronto, Canada
[3] Program in Applied Ethics and Biotechnology, University of Toronto Joint Center for Bioethics, Canada
[4] Departments of Public Health Sciences and Surgery, University of Toronto, Canada
[5] Department of Medicine, University of Toronto, Canada

Future Technologies, Today's Choices

Nanotechnology, Artificial Intelligence and Robotics; A technical, political and institutional map of emerging technologies.

- Less radical approach than the ETC Group.
- The impact of nanotechnology will be gradual.
- A moratorium would be impractical and harmful.
- **Industry must take the issue of public acceptance of nanotechnology seriously**.
- Failure to do so will result in self-imposed moratorium.

(Greenpeace Environmental Trust, 2003)



- Social and ethical concerns are similar to those encountered for other technologies.
- Past experience demonstrates that these issues should be taken seriously, even though many are not unique to nanotech.

(Royal Society & Royal Academy of Engineering, 2004)

And the Researchers Themselves…

MEDICAL NEWS
& PERSPECTIVES

Researchers Size Up Nanotechnology Risks

(Reprinted) JAMA, October 19, 2005—Vol 294, No. 15

CBEN
Center for Biological and Environmental Nanotechnology

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NSERC
CRSNG

Funding individual scientists/groups

Cover Story

May 1, 2006
Volume 84, Number 18
pp. 10-18

CHEMICAL & Engineering News

Chance Of A Lifetime

As they steward their products into the market, nanomaterial producers have the opportunity to address environmental, health, and safetv concerns from the start

ISOLATED To ensure worker safety, Arkema's carbon nanotube pilot plant is completely automated and contained.

Arkema Photo