NANOTECHNOLOGY: WHAT IS IT?

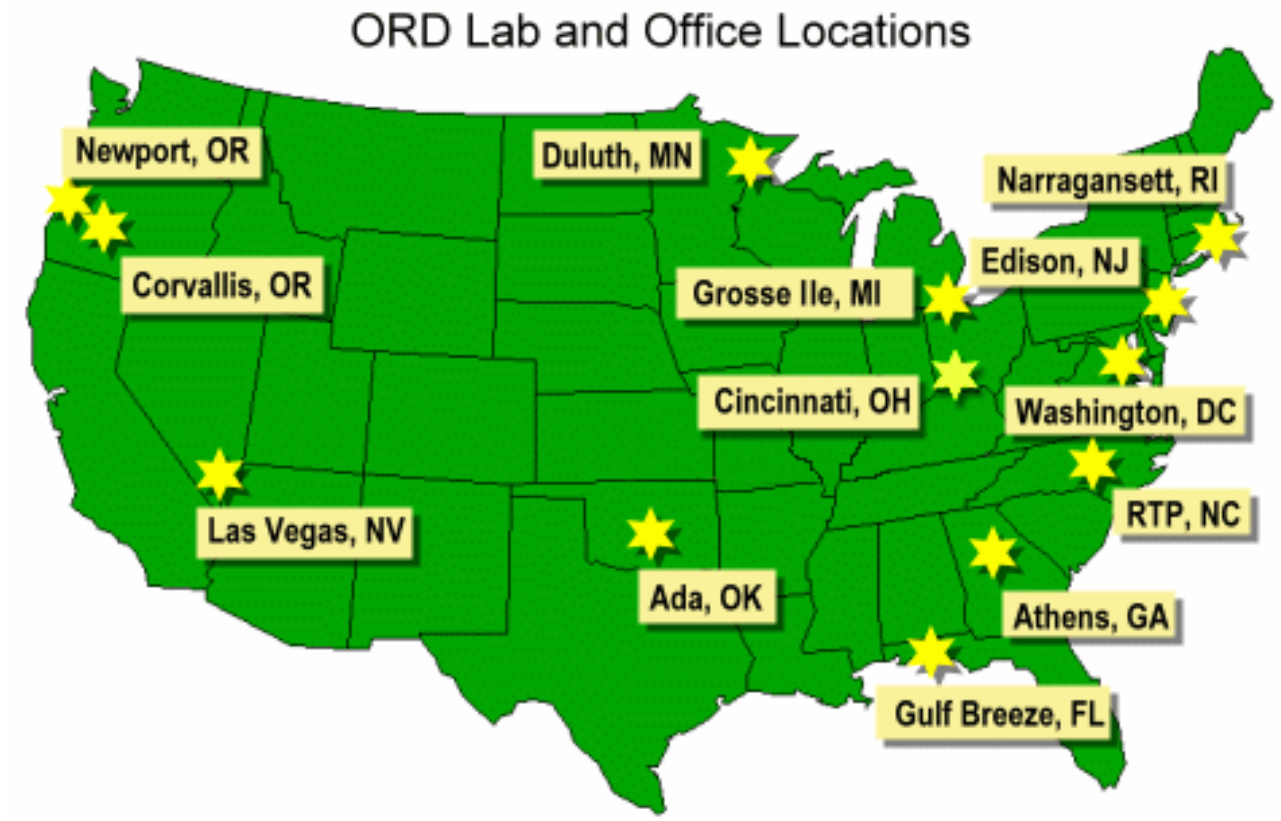
Michael D. Gill
US EPA, San Francisco

Cal EPA Nanotechnology Symposium
Sacramento, CA – March 8, 2007

Research and Development at EPA

- 1,915 employees
- $557 million* budget
- $65 million* extramural research grant program
- 13 lab or research facilities across the U.S.
- Provide credible, relevant and timely research results and technical support that inform EPA policy decisions

* FY07 Requested Levels



ORD Lab Locations:
http://www.epa.gov/ord/htm/map.htm

High Priority Research Areas

- Human Health
- Particulate Matter
- Drinking Water
- Clean Water
- Global Change
- Endocrine Disruptors
- Ecological Risk
- Pollution Prevention
- Homeland Security

Outline

1. What is nanotechnology?
2. Current Applications In Commerce.
3. Potential Environmental Implications.
4. Government Activities.
5. US EPA Regulations.
6. US EPA Research.
7. References.

Nanotechnology:

What is it?

...as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know.

Secretary Rumsfeld,
Feb. 12, 2002, ***DoD News Briefing***

http://www.dod.mil/transcripts/2002/t02122002_t212sdv2.html

What is nanotechnology?

While many definitions for nanotechnology exist, the NNI* calls it "nanotechnology" only if it involves all of the following:

1. Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range.

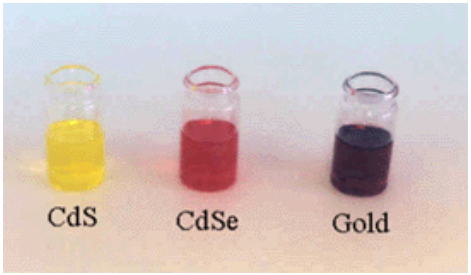
2. Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.

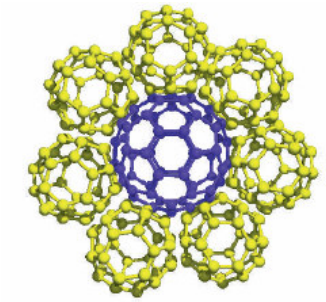
3. Ability to control or manipulate on the atomic scale.

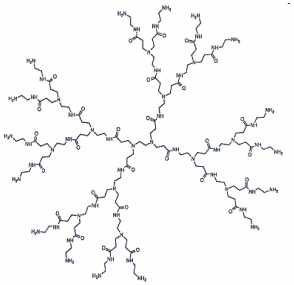
*National Nanotechnology Initiative

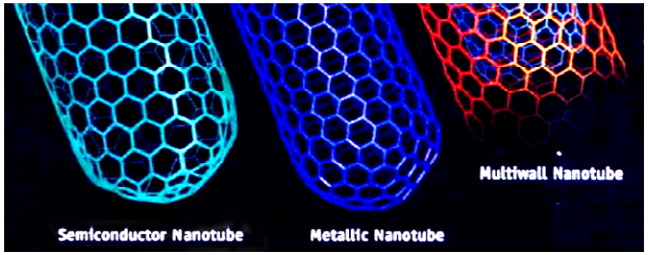
Keep in mind:

Nanotechnology does not include just a single material or class of materials

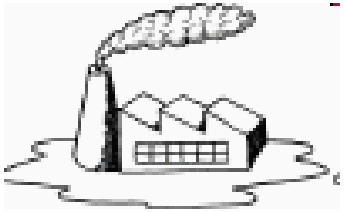




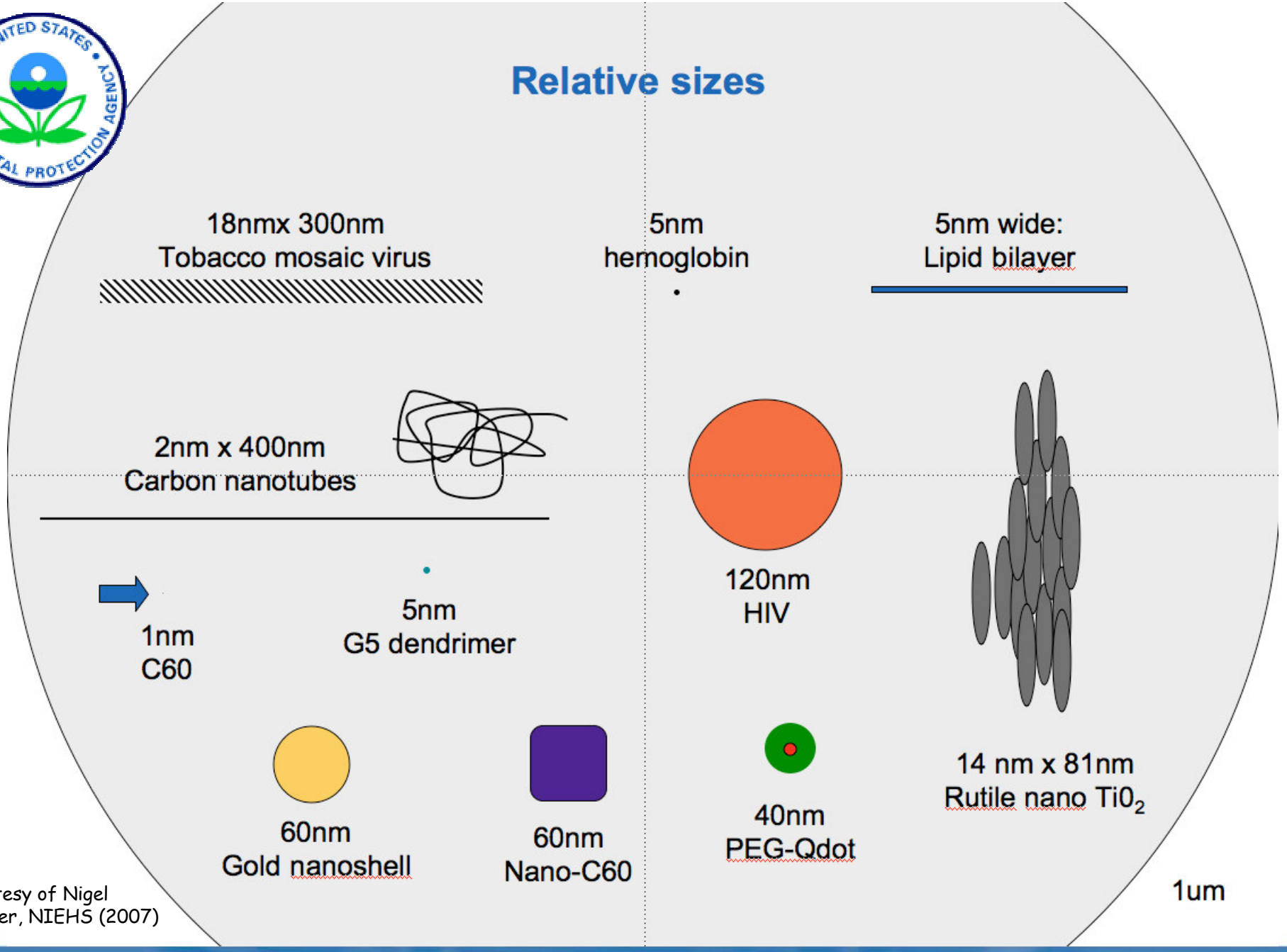




Nanotechnology does not include just a single industry or industrial sector

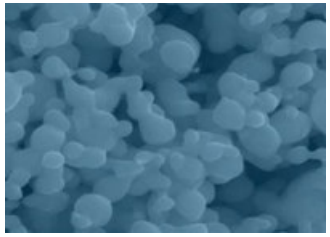


Nanotechnology converges with other technologies: biotechnology, information technology



Courtesy of Nigel Walker, NIEHS (2007)

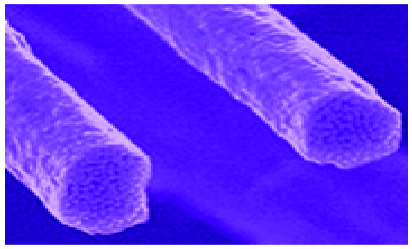
Types of Nanoscale Materials

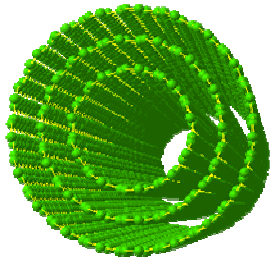
Engineered	Incidental	Natural
• Carbon-based NTs, Fullerenes • Metal Oxides • Quantum Dots • Nanotubes • Nanowires • Dendrimers	Particles from: • Combustion • Industrial Processes • Vehicles • Construction	Particles from: • Plants, Trees • Oceans, other water bodies • Erosion • Dust
		

(Courtesy of Nora Savage, EPA [2007])

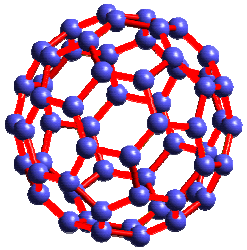
Classes of nanoscale materials

Single and multi walled nanotubes



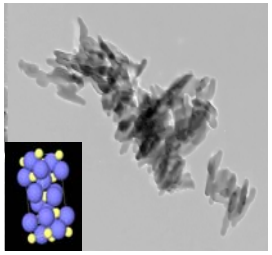


Fullerenes

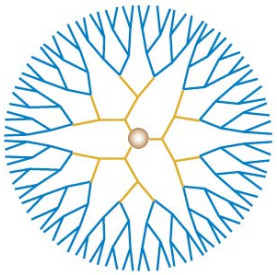


Nanoshells

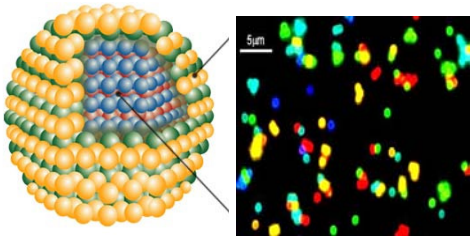
Metal oxides



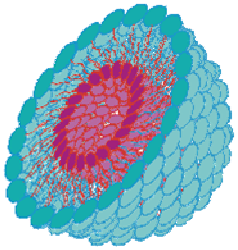
Dendrimers



Quantum dots



Nanosomes



Courtesy of Nigel Walker, NIEHS (2007)

What is nanotechnology? (non-technical definitions)

- The ability to extract large sums of money from a decreasing federal research budget?

- The development of novel properties for any business with "nano" prefix?

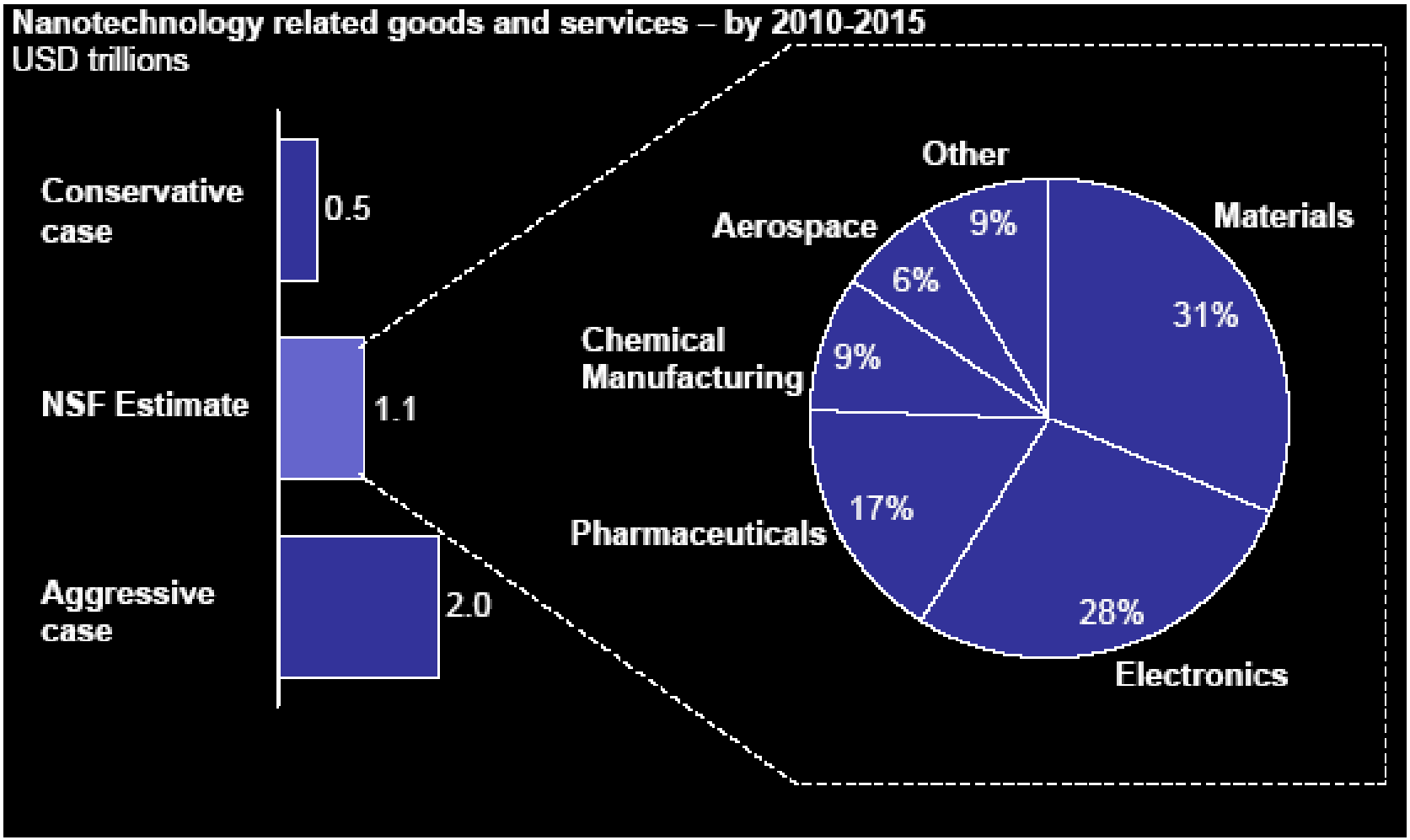
- The capacity to manipulate at the nano level to multiply exponentially the number of nano meetings?

(Courtesy of Nora Savage, EPA [2007])

Nanotechnology:

Current Applications in Commerce

What is the magnitude of nanotechnology?



(Source: NSF data, Sean Murdock presentation)

Nano-Products on the Market Now

Display Screens
Motorola (NTs)

Automobiles
(BASF's Mincor® Nanocomposite)

Nano Silver Wash
Washing Machine
Samsung (400 billion
silver ions)

Tennis Rackets
Wilson (C fibers)

(Courtesy of Nora Savage, EPA [2007])

Nano-Products on the Market Now

- Cosmetics – face creams, sunscreens, make-up
- Textiles – clothing, furniture, carpeting
- Sports Equipment – balls, bats, rackets, bicycles
- Electronics – computers, televisions
- Appliances – washing machines, refrigerators
- Cleaning Agents – household, remediation

These are NOT applications of Nanotechnology!

Elvis on a pinhead…

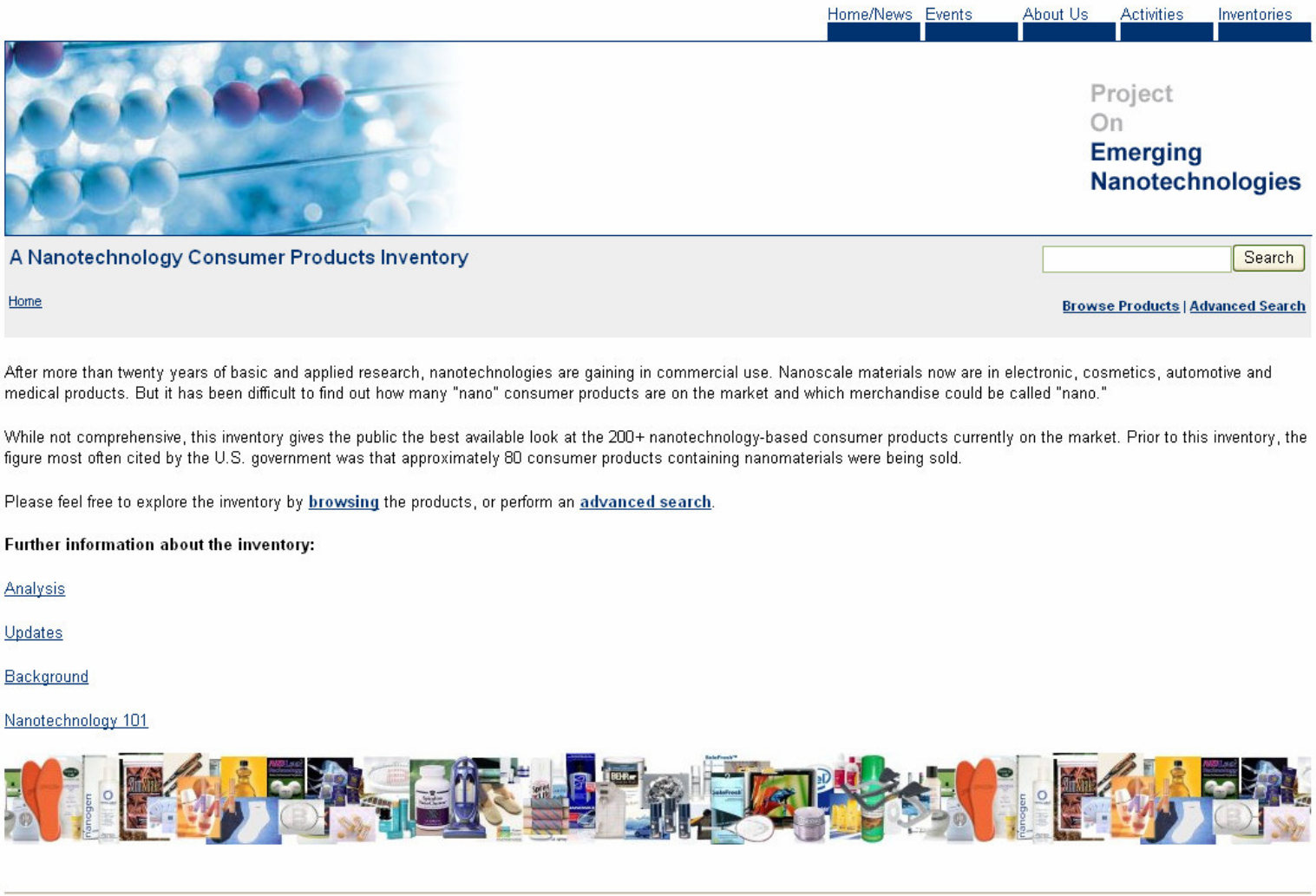
(Courtesy of artist Willard Wigan, http://www.willard-wigan.com/)

(Courtesy of Apple)

Wilson Center Nanotechnology Consumer Products Inventory

(http://www.nanotechproject.org/index.php?id=44)

(381 items as of Feb 16, 2007)



ENVIRONMENTAL APPLICATIONS OF NANOTECHNOLOGY

SENSORS - improved monitoring and detection capabilities, better controls

TREATMENT / REMEDIATION - Cleaning up waste streams of contaminants, particularly those substances that are highly toxic, persistent within the environment, or difficult to treat

GREEN MANUFACTURING - Use of environmentally friendly starting materials and solvents, improved catalysts, and significantly reduced energy consumption in the manufacturing process

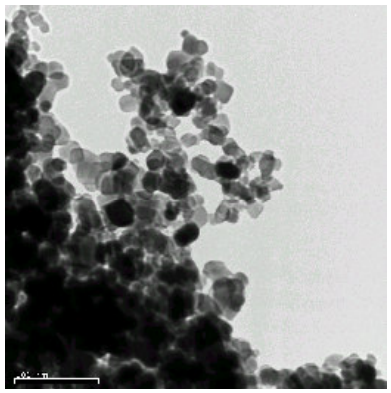
GREEN ENERGY - Nano products such as Solar and fuel cells could lead to commercially viable alternative clean energy sources. Energy savings via light weight composites, embedded systems.

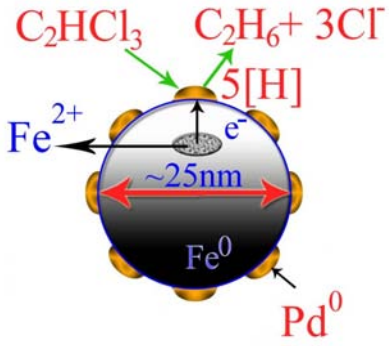
Applications: Treatment/ Remediation

(ES&T, March 2006)

Wei-xian Zhang, Lehigh

Remediation of Groundwater





TCE reduction with nano Iron

- Oxidation of pollutant enhanced by coupling with other metals (Fe/Pd)* on the nanoscale.
- Smaller size makes it more flexible -- penetrates difficult to access areas.

ENVIRONMENTAL APPLICATIONS

Two EPA Workshops –
October 2005 – Washington, DC / September 2006 – Chicago, IL
"Nanotechnology for Site Remediation"

Covered site remediation research and application:

- nZVI, EZVI, nano-porous ceramic sorbents
- Nano-sensors
- Case studies

Also covered potential implications:

- Fate and Transport issues
- Nanotechnology Life-Cycle Analysis
- Environmental Health and Safety
- Risk Assessment of Nano-Scale Metal Particles

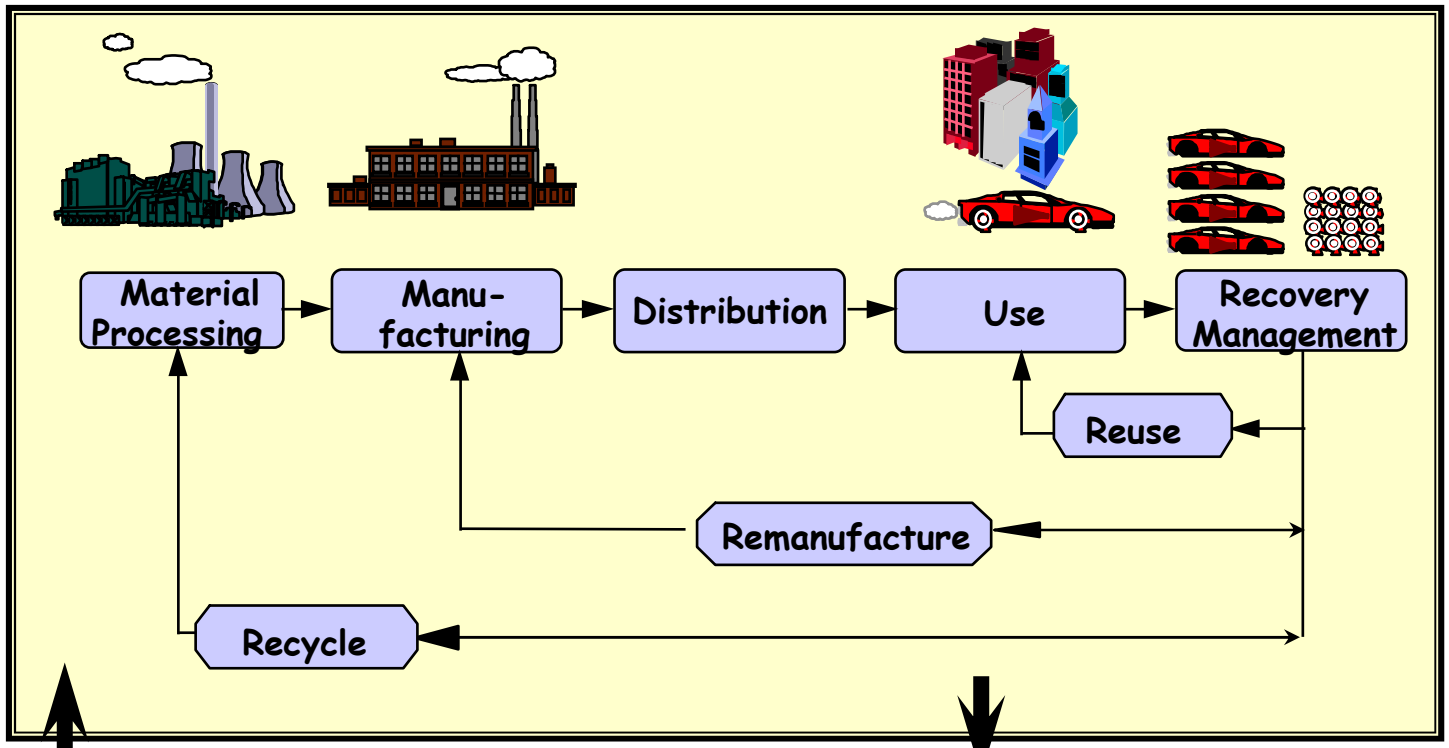
MESSAGES:

- Due to unknowns, need to consider both effects and mobility
- Public perceptions can "sink" an industry, whether true or not
- Precautionary Principle should be considered (take it slow until data gaps filled)

Nanotechnology:

Potential Environmental Implications

Nanotechnology must involve a **Systems Approach** to Environmental Protection: Life Cycle Assessment, Materials Flow Analysis



Raw Materials
(Energy, Renewable Resources, Nonrenewable Resources)

Disposal
(Air Emissions, Liquid and Solid Wastes)

J. Golden

The opportunity exists right now for doing nano right in the first place!

Environmental and Health Implications of Nanotechnology

Knowledge Gaps

- Exposure/Detection
- Toxicology of Nanomaterials
- Worker Protection
- Fate/Transport/Transformation
- Waste Generated
- Production Volume
- Nomenclature

Public Concern about Nanomaterials

Molecular FOUNDRY
A NANOSTRUCTURES USER LABORATORY

-Lawrence Berkeley Lab's Molecular Foundry

-Offers support to nanoscience research (industry, gov't, academia)

-For the study of synthesis, characterization and theory of nanoscale materials

Berkeley Daily Planet

Matthew Artz: Protestors gathered at the entrance to the Lawrence Berkeley Naitonal Laboratory Thursday to protest today's planned groundbreaking for the Molecular Foundry.

Molecular Foundry Foes Protest Groundbreaking

About 30 protesters withstood steady drizzle early Thursday morning, worried that once Lawrence Berkeley National Laboratory (LBNL) completes its newest laboratory complex, far smaller, more dangerous particles could rain down on them. FULL STORY

(January 30, 2004)

Public Concern about Nano-Products

Nanotech is a new no-no this holiday season

By Gina Solomon and Jennifer Sass

If you're a holiday shopper on the cutting edge, you may have considered nanotechnology gifts this year. If so, you found a wide array of new products made with nanoparticles, microscopic materials that are one-millionth the width of the head of a pin.

For fashionistas, there are fleece jackets, gloves and hats that resist static cling, lint and pet hair. For the younger set, there are nano plush toys. For sports aficionados, there are tennis rackets that the manufacturer says are 100 times more rigid than steel and 10 times stiffer than graphite. And for romantics, there's a wide range of cosmetics and beauty creams, and even synthetic diamonds.

That's just a handful of the more than 350 products now made with nanoparticles – a 70 percent jump since March, according to the Project on Emerging Technologies at the Woodrow Wilson International Center. Last year, $30 billion in manufactured products included them, and by 2014, an estimated $2.6 trillion in manufactured products around the world will feature nanotechnology.

This explosion in nano products has raised concerns among scientists and health experts that too little is known about nanotechnology's potential health risks. While such advances hold the promise of breakthroughs in biomedical treatments, energy efficiency and many other fields, the risks posed by nanoparticles to human beings, wildlife and the environment are largely being ignored.

Animal studies suggest that some nanoparticles can cause inflammation, cell damage and precancerous lesions resembling asbestos disease.

Even so, there are no adequate federal or state regulations governing their use, and the Environmental Protection Agency is moving much too slowly to ensure that they are safe. We need to know about the short- and long-term risks, especially because we're already wearing stain-resistant nanoparticle clothing, applying nanoparticle cosmetics and sunscreens, and swabbing our babies' bottoms with nanoparticle baby wipes.

The most prevalent nanomaterial in consumer products is nanosilver, used as a germ-killer. Nanosilver is found in at least 47 products – nearly double the number from just eight months ago, according to the Wilson Center.

Samsung sells a washing machine that releases nanosilver ions during the wash and rinse cycles to kill germs. Sharper Image is marketing nanosilver-treated slippers, socks that reduce germs and odors, and nanosilver food storage containers that keep food fresher longer. And Motorola recently began marketing two "germ-free" cell phones coated in nanosilver.

Last month, the EPA announced that it plans to regulate only nanosilver products that claim to kill germs, ignoring those companies that couch their marketing claims in less obvious language. In a recent letter to the agency, the Natural Resources Defense Council urged the EPA to review all consumer products containing nanosilver and require manufacturers to register such products as a pesticide.

Members of the House Science Committee have criticized the Bush administration for moving too slowly to develop a research program on nanotechnology.

So before you choose to give nano gifts this year, you may want to consider whether the old-fashioned, non-nano version would be equally appreciated. Why add to what amounts to an uncontrolled experiment on the public?

Gina Solomon is a physician and senior scientist, and Jennifer Sass is an environmental toxicologist and senior scientist, at the Natural Resources Defense Council. Contact us at insight@sfchronicle.com.

SF Chronicle 12/24/06

"…too little is known…"

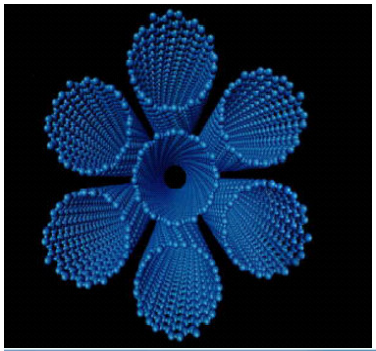
"…uncontrolled experiment…"

"…no adequate regs…"

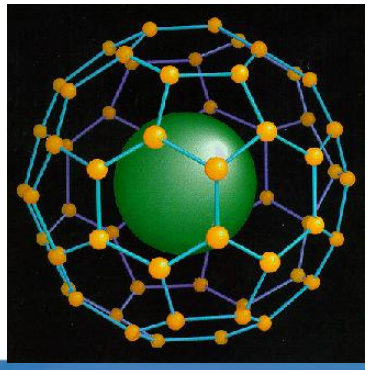
Lessons Learned:
Can They Be Applied to Nanotoxicology?

- Recent Paper assessed the risks of nanomaterials
- EPA learned lessons from PCBs, MTBE, asbestos cases

- Lifecycle perspective is important
- Byproducts may be more problematic than primary substance
- Human health is not the only concern
- Use caution in generalizing from limited empirical data
- The public deserves to be well informed
- Everything has tradeoffs – some are acceptable, others not
- Even with limited info, technical experts may be able to anticipate risks
- An adaptive risk management strategy is important



(J. Michael Davis [EPA], *Journal of Nanoscience and Nanotechnology, Vol 7, 402-409, 2007*)



Nanotechnology:

Government Activities

The US Government institutionalized Nanotechnology Dec. 3, 2003

108TH CONGRESS
1ST SESSION

S. 189

AN ACT

To authorize appropriations for nanoscience, nanoengineering, and nanotechnology research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "21st Century Nanotechnology Research and Development Act".

National Nanotechnology Initiative

http://www.nano.gov

NNI goals:

- Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology;
- Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit;
- Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and,
- Support responsible development of nanotechnology

US Gov't Spending on Nanotechnology Research

Fiscal Year	Federal Funds
FY2007 (requested)	$1287 M
FY2006 (estimated)	$1303 M
FY2005	$982 M
FY2004	$961 M
FY2003	$774 M
FY2002	$604 M
FY2001	$422 M
FY2000	~ $270 M
FY1999	$232 M
FY1998	$116 M

(Lynn Bergeson, 5/9/05, and NNI Presidential Budget document, July 2006)

Federal NNI Research: Environment, Health and Safety: 07 Request (Million)*

• NNI total	$1,278.0
• NNI EHS research	**44.1**
▪ NSF	25.7
▪ EPA	8.0
▪ NIH	4.6
▪ NIOSH	3.0
▪ DOC (NIST)	1.8
▪ DOD	1.0

*Includes only efforts whose primary purpose is to understand potential risks to health and the environment.

(NNI Presidential Budget document, July 2006)

Nanotechnology:

US EPA Regulations

First EPA Nano Regulation: Nanosilver

TESTING SILVERCARE'S METTLE

Samsung's SilverCare Washer WF316LAW ($1,200; *www.samsung.com*) promised lower water and energy use and less wear on clothes when it made its debut earlier this year. But the intriguing feature on this front-loader is its SilverCare setting, which the maker claims will sanitize your wash by releasing a trace amount of silver from two small bars into the water during washing. The setting is designed to remove or kill 99.9 percent of "tested bacteria" with cold water but without chlorine bleach. The washer is part of a wave of products inspired by nanotechnology, which involves engineering materials at the molecular level. (A nanometer is a billionth of a meter.)

DON'T HOLD YOUR NOSE **Samsung's SilverCare setting made sweaty shirts less smelly than in a regular washer.**

How we tested. We washed T-shirts 10 times using the SilverCare setting, drying the shirts between each wash. Next, we cut the shirts in half and sewed them together with halves of shirts cleaned in a conventional washer. Volunteers wore those shirts while exercising, then tore them in half and stowed each section in separate zip-top bags. We let the shirts "ferment" over a weekend.

What we found. The Samsung performed very well overall, and T-shirt halves washed on its SilverCare setting were less malodorous than those washed normally, so clothes should smell fresher longer. But SilverCare adds 6 to 24 minutes per load, and you must replace the silver bars after 10 years or 3,000 washes (about $50 to $75 per pair). We're also concerned about potential health and environmental impacts of silver on clothes and wastewater.

CR's take. This Samsung is fairly pricey. You can get a washer with comparable ability to remove dirt and stains, such as the Kenmore HE2, for less.

(Consumer Reports, October, 2006)

- In Nov, 2006, EPA decided to regulate "nanosilver particles" as a pesticide

- Nanosilver contains bacteria-killing particles of silver

- There are unknown effects to aquatic environments

- The regulation will affect items designed to eliminate odors, such as shoe liners, washing machines, food storage containers

- This is the only nanoparticle affected and is somewhat of a test case

(Washington Post, Nov 23, 2006)

Why Only One Regulation So Far???

Prior to writing a regulation, one must:

- develop consistent terminology (ANSI)
- be able to classify the compound(s) in question
- be able to monitor them ...and...
- determine their environmental impacts (human health/eco)

Much more research needed before regs can be written

Is TSCA Applicable?

Toxic Substances Control Act - TSCA

- Passed in 1976

- Gave EPA the power to regulate chemicals in commercial use with risk or potential risk to the environment, with concern given to economic and societal impacts (Precautionary Principle in mind)

- TSCA seems to be the best regulation, at least as a model, for nanotechnology and nanoparticles.

- UK has no existing laws either, but similar process has been proposed, that is to modify existing laws for nanotech and be flexible as more is learned (Royal Society Report- "Nanosciences and Nanotechnologies" - July '04)

Where is EPA going wrt nanotechnology?

- EPA "Science Policy Council" White Paper released Feb 15, 2007) (available at http://www.epa.gov/OSA/nanotech.htm)

- Purpose is to **inform EPA management of the science needs associated with nanotech, support program office needs and communicate these issues to stakeholders and the public.**

- Suggestions include:

1. Consider pollution prevention, stewardship and sustainability
2. Support environmental research on nanomaterials:
   - -Detection and analysis
   - -Environmental fate and transport
   - -Identification
   - -Exposure and health effects (human/eco)
   - -Technology applications
3. Encourage collaboration within and outside EPA on nanotech issues

Voluntary Program For Nanomaterials

An EPA Stewardship Program has been established within the Office of Pollution Prevention and Toxics (OPPT)

Encourage companies notify EPA of the manufacture, import or use of nanoscale materials, even though TSCA normally allows entry into commerce without such notification

Also encourages use of risk management practices

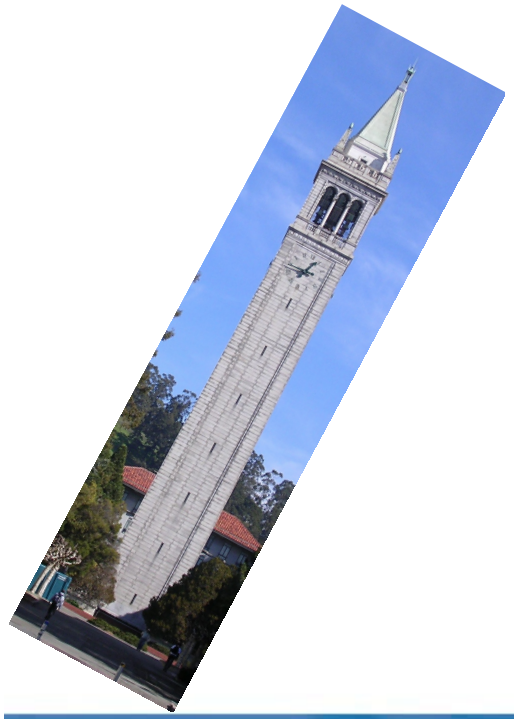
http://www.epa.gov/oppt/nano/

UK launched voluntary reporting system for engineered nanoscale materials in Sept 2006

Local Regulation of Nano-Products

San Francisco Chronicle, December 6, 2006:

"The Berkeley City Council has unanimously approved new rules requiring handlers of nanomaterials to make annual disclosures to the city's toxics manager."



Section 1. That Berkeley Municipal Code Section 15.12.040 is amended to add Subsection I to read as follows:

15.12.040 Filing of disclosure information.

I. All facilities that manufacture or use manufactured nanoparticles shall submit a separate written disclosure of the current toxicology of the materials reported, to the extent known, and how the facility will safely handle, monitor, contain, dispose, track inventory, prevent releases and mitigate such materials.

Nanotechnology:

US EPA Research

Extramural Research at EPA

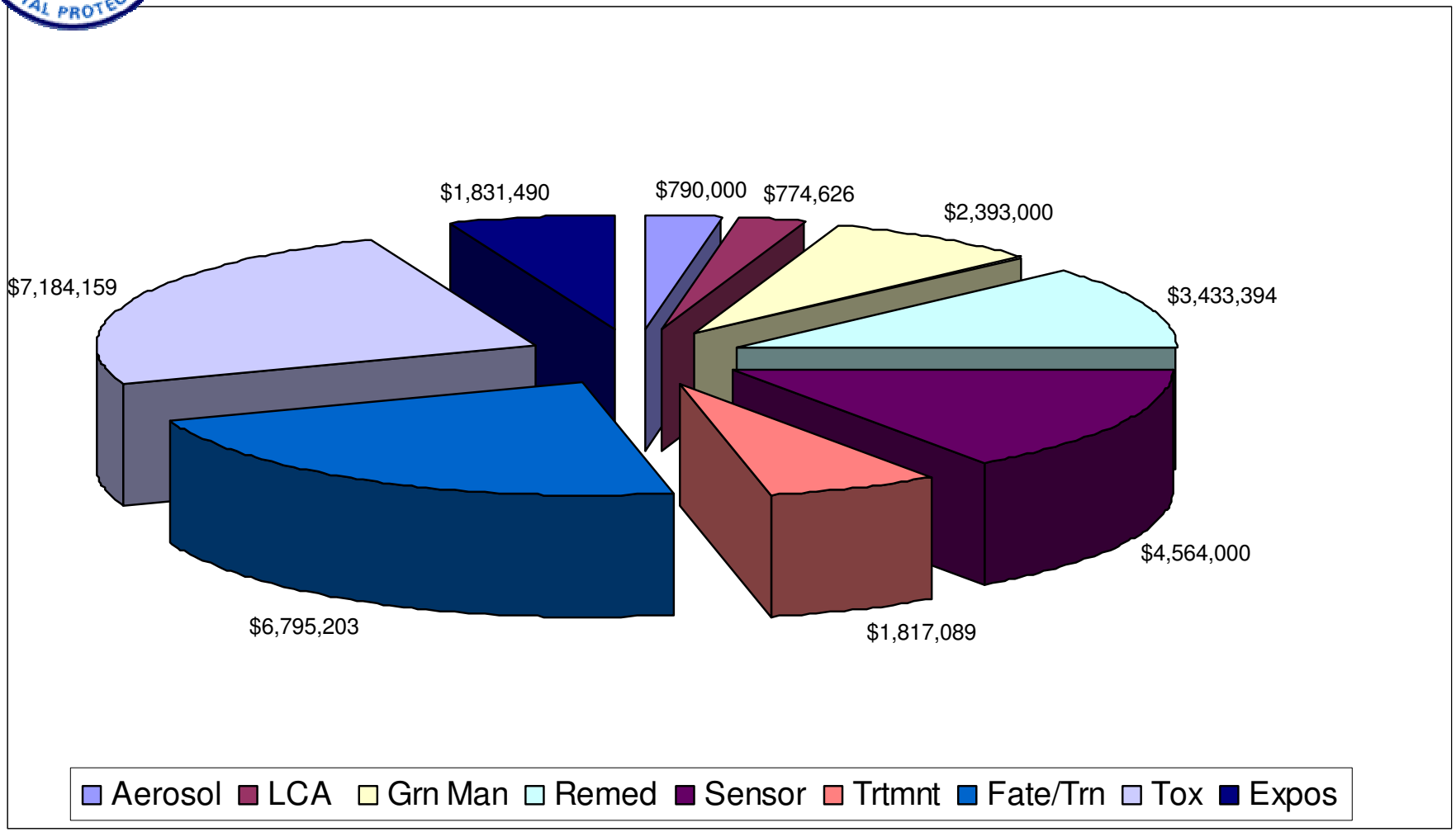
($$ for Grants)

Applications address existing environmental problems, or prevent future problems (Approx. $15.6 M to date)

Implications address the interactions of nanomaterials with the environment, and any possible risks that may be posed by nanotechnology (Approx. $17.6 M to date, excluding ultrafine)

EPA "STAR" Nano Grants

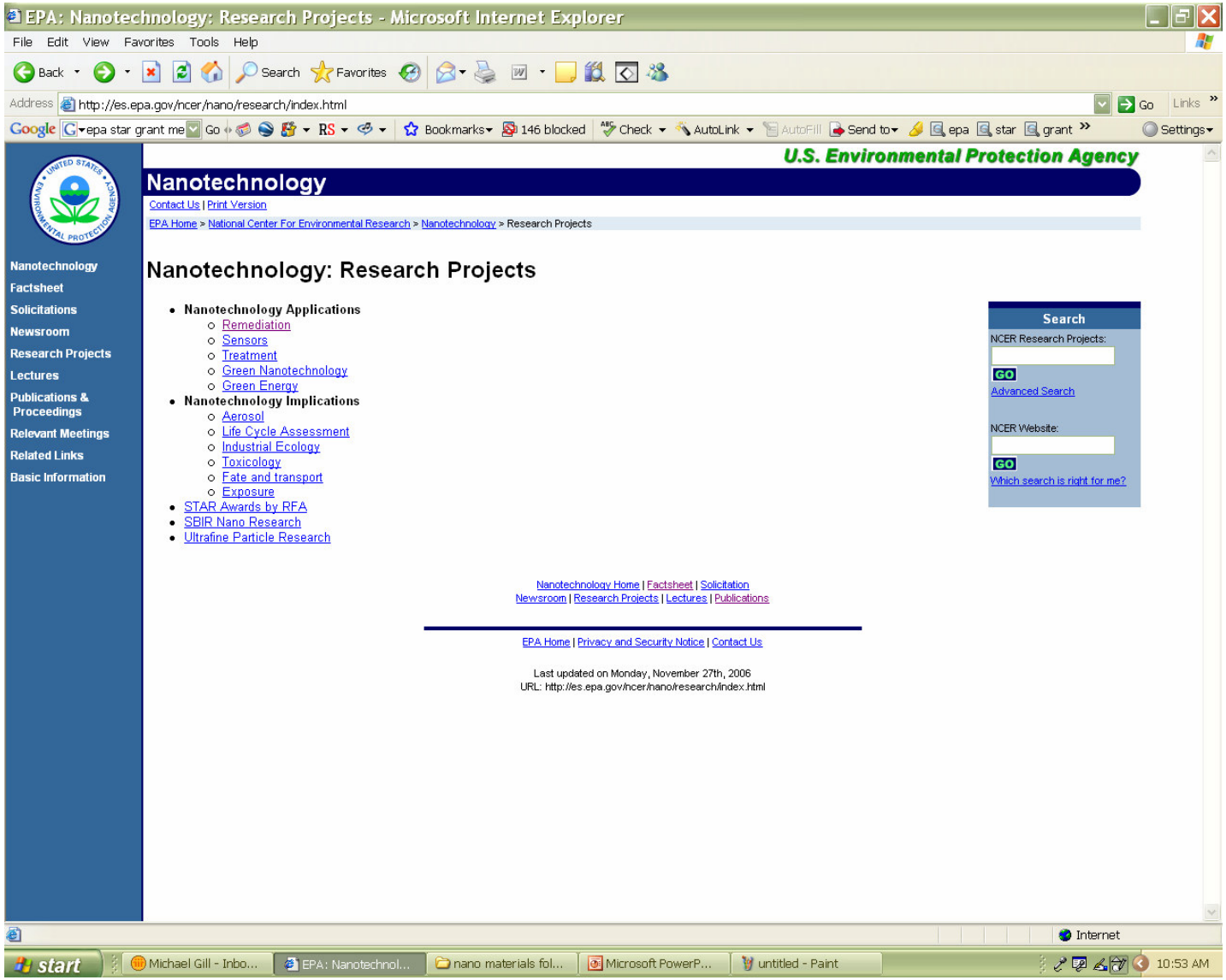
"Science to Achieve Results"



(Courtesy of Nora Savage, EPA [2007])

EPA Research Online

(www.epa.gov/ncer/nano/research)



Nanotechnology Research Strategy

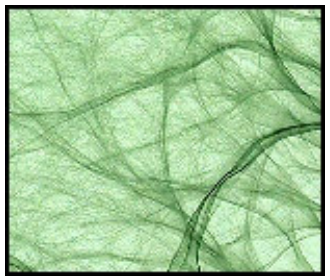
In fiscal years 2007 and 2008, EPA will focus on the following high priority areas:

- Environmental fate, transport, transformation
- Exposure
- Monitoring and detection methods
- Effects assessment methods consistent with and derived via exposure information.

Coming Soon:
EPA's New Nano Web Page

NOW.....

Nanotechnology Home



Nanotechnology has both applications and implications for the environment. EPA is supporting research in this technology while evaluating its regulatory responsibility to protect the environment and human health. This site highlights EPA's research in nanotechnology and provides useful information on related research at EPA and in other organizations.

Nanotechnology

Factsheet

Solicitations

Newsroom

Research Projects

Publications & Proceedings

www.epa.gov/ncer/nano

Coming Soon EPA-wide Website!!

FUTURE US EPA NANOTECHNOLOGY EVENTS

NIEHS 2007 Nanotechnology Seminar Series
(http://www.cluin.org/live/)

EPA Training for Remedial Project Managers on Nanotechnology
(May 2007)

International Conference on Remediation by Nanotechnology
(Chicago – Fall 2007)

Take Home Messages:

Nanotechnology is a very powerful new mixture of disciplines that is changing our industries and our lives.

Applications are currently being developed and marketed throughout the world and investments continue to climb worldwide.

Environmental implications are still for the most part unknown. Application-based research investments far outstrip implications research.

EPA is still reviewing the issues surrounding the regulation of nanomaterials; voluntary reporting program exists.

Others outside US have suggested that industry take slower steps (the Precautionary Principle); UK has similar voluntary reporting program as US EPA.

(Modified from B. Karn, 2004)

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EPA OPPTS: Jim Willis

King Features Syndicate, September 22, 2004

The field of Nanotech has many challenges……
Where does EPA stand with regard to handling them?

Nanotechnology:

References

Useful Nanotechnology Resources

- NIOSH's nanotechnology website
  (http://www.cdc.gov/niosh/topics/nanotech)
- National Nanotechnology Initiative (NNI)
  (http://www.nano.gov/)
- EPA nanotechnology website
  (http://es.epa.gov/ncer/nano/index.html)
- Compilation of US gov't funded implications research
  (http://www.wilsoncenter.org/nano)
- Swiss Re:Nanotechnology Small Matter, Many Unknowns
  (http://www.swissre.com/)
- International Dialogue on Responsible Nanotechnology
  (http://www.nsf.gov/home/crssprgm/nano/dialog.htm)
- Royal Society Report
  (http://www.nanotec.org.uk/finalReport.htm)

(Lynn Bergeson, 5/9/05)

Useful Nanotechnology Resources (cont'd)

- Foresight Institute

  http://www.foresight.org/Nano/
- Nano Science and Technology Institute

  http://www.nsti.org
- The EU's Community Research and Development Information System (CORDIS)

  http://www.cordis.lu/nanotechnology
- OTHERS

  http://www.nanotechnologyinstitute.org
  http://cben.rice.edu
  http://www.environmentalfutures.org
  http://www.nanoforum.org (European Nanotechnology Gateway)
  http://www.hse.gov.uk/research/rrhtm/rr274.htm

(Lynn Bergeson, 5/9/05)

Questions??

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