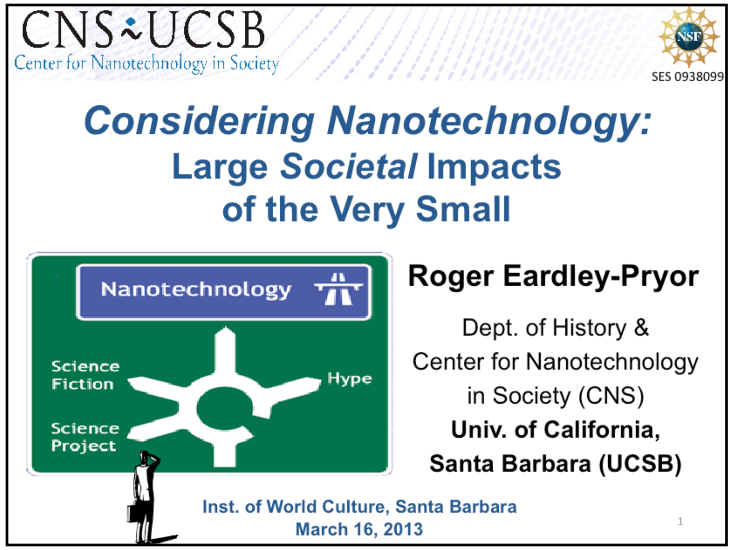



Introduction: Roger EP: PhD Candidate at UCSB; graduate this summer.

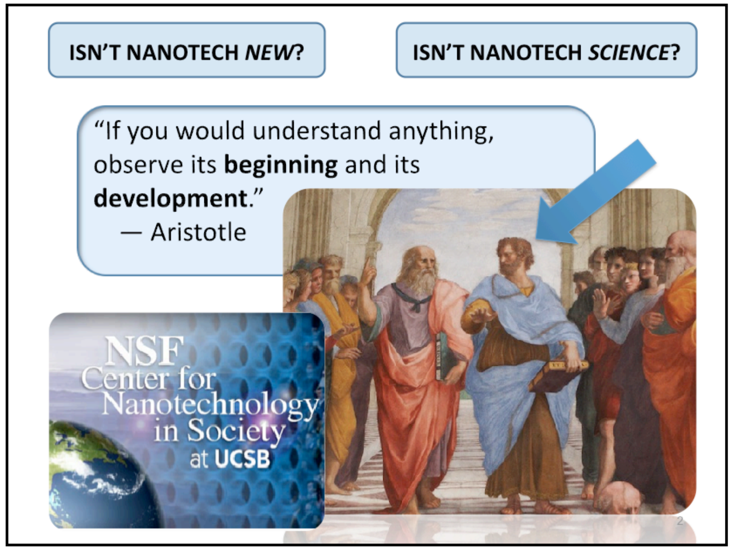
Historian: Science, Technology, & Environment; US & World

Dissertation on rise of global environmentalism, 1950s-1970s

Past 3 years (2010-2013) = Graduate Research Fellow at UCSB's Center for Nanotech in Society: NSF-funded national center for research on nanotechnology

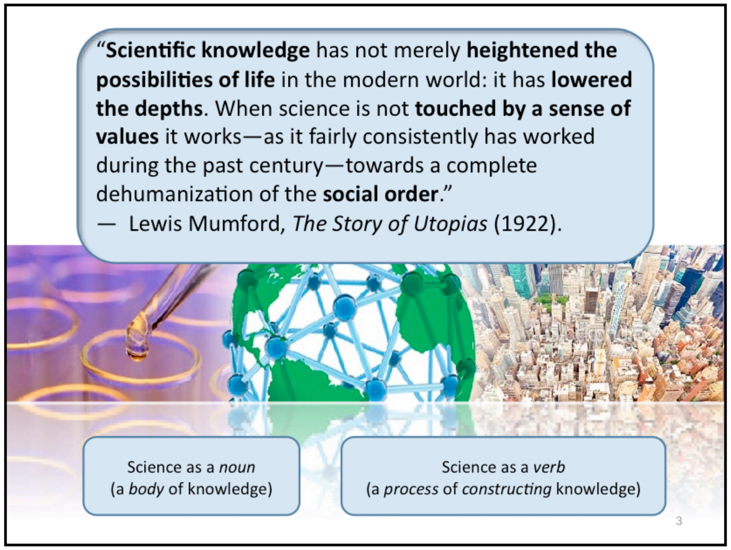
Why is the federal govt funding an historian (a *humanist*) to examine nanotech?

Isn't nano *new*? Isn't nanotech done by *scientists*?




Isn't nano *new*? Isn't nanotech done by *scientists*?

Aristotle quote: "If you would understand anything, observe its beginning and its development."

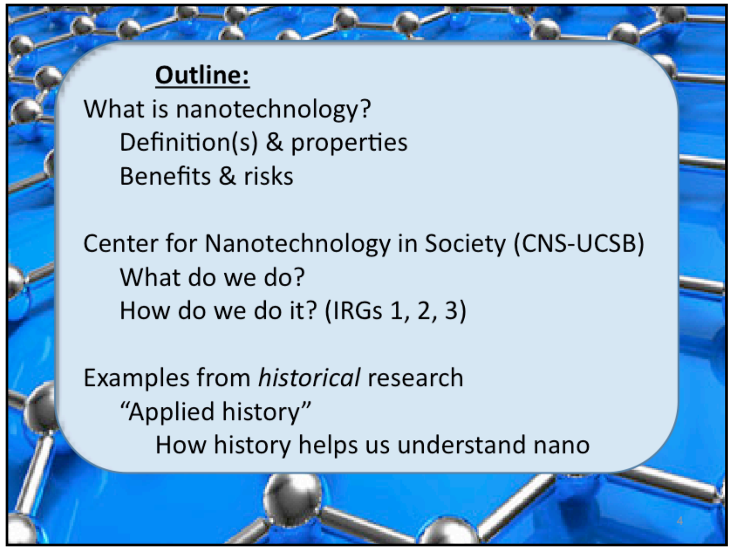



Science does not exist in a vacuum. It is *constructed* within social contexts, *conducted* within socio-cultural contexts, and it has social *consequences*.

Science Semantics (words matter; they shape our thoughts and, thus, our reality.)

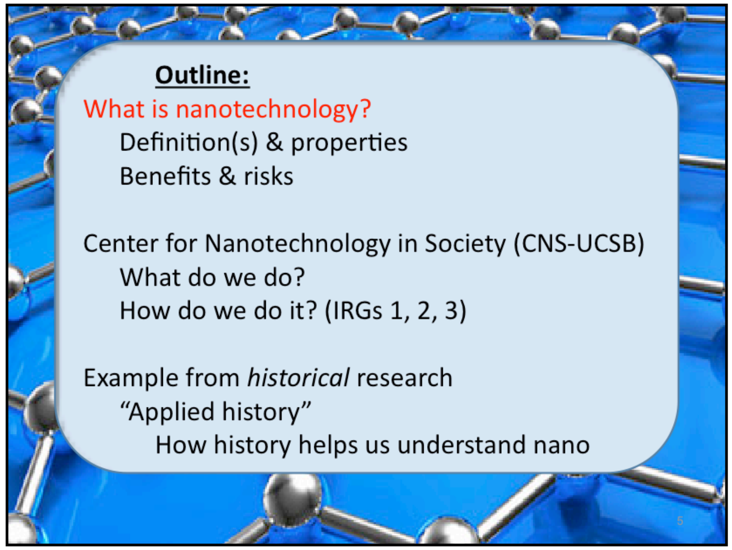
- science as a *body* of knowledge & science as a *process of constructing* knowledge.
    - relate idea of LOVE as a noun (a feeling) & LOVE as a verb (an action, a choice)
- Science = constructed by humans in social contexts.
    - Social contexts shape the process of science, and thus shape the body of scientific knowledge.

To understand Nanotechnology, we need to understand its societal contexts and implications: its origins, its diffusion, its public perceptions




Outline:

- What is nanotechnology? (Definitions & properties / Benefits & risks)
- Center for Nano in Society (CNS-UCSB) (What we do & How we do it [IRGs 1, 2, 3])
- Example from my research (Applied Hist & How history helps us understand nano)



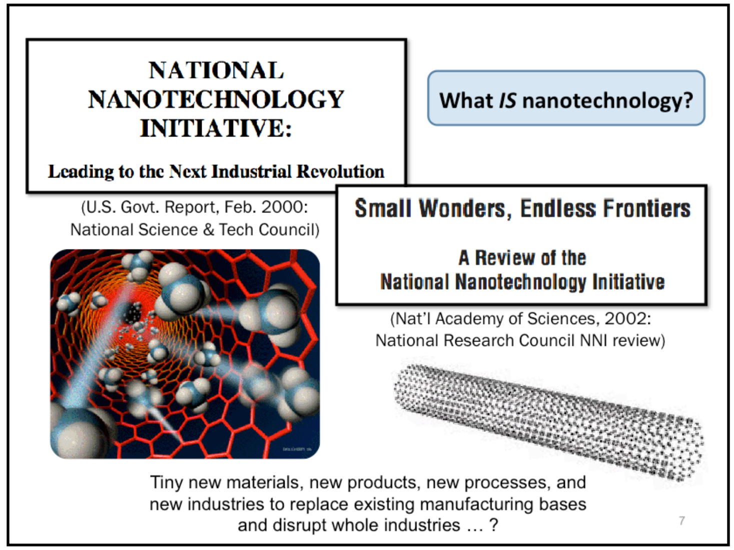

**ASK**: when hear the term 'nanotechnology', what *you* think about? What comes to mind?

What is nanotech?   Where do we see nanotech used today?   How do we expect to see nanotech used in the future?


<u>IS NANO: Science Fiction becoming science fact?</u>

Is nanotechnology about making medical micro-machines?

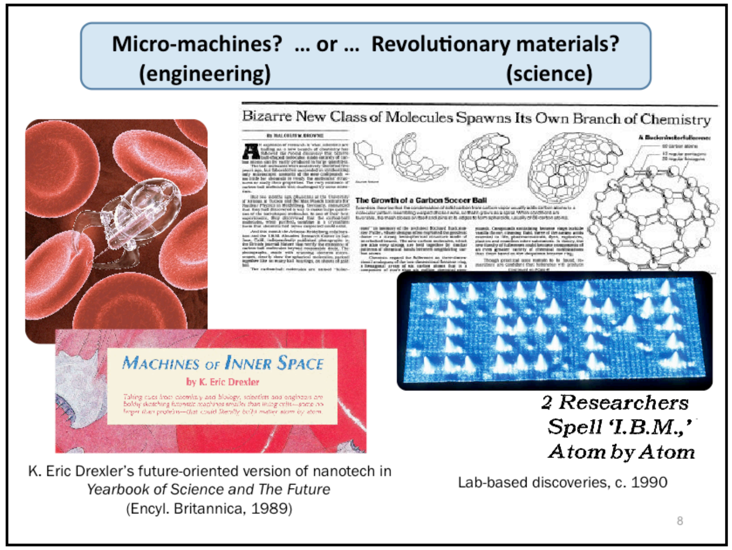
Is nanotech creating an army of self-replicating nanobots?




<u>IS NANO: New materials & industrial processes?</u>

Is nanotech the next industrial revolution?

Is nanotech the cutting edge of the science's "endless frontier?"




It seems we have several different conceptions about nanotech, from popular culture, policy makers, and journalists…

from a radical view of our technological future;

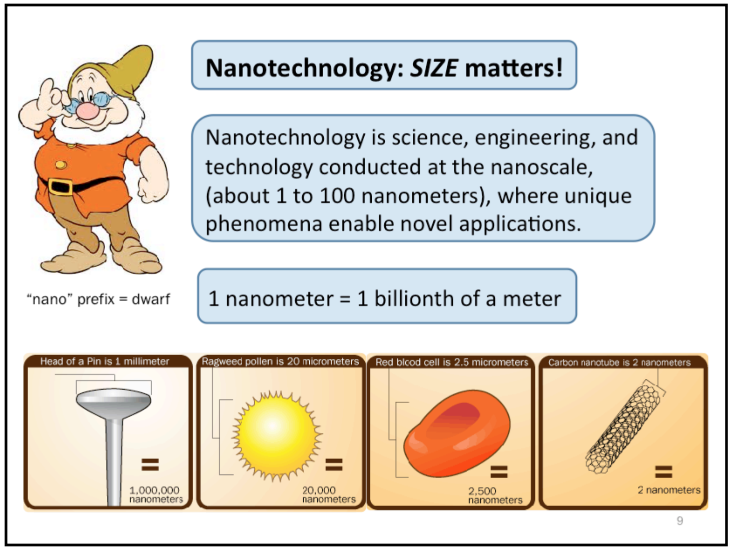
to scientific discoveries like "bucky-balls" & carbon nano;

to applications like mini-transistors, self-cleaning glass, greener energy, water filtration, carbon-capture & storage

… Will the real nanotech please stand up?

Knowing the *social* life of nanotechnology (& esp its history – how ideas about nano arose, how those ideas and scientific advances evolved over time)

helps us make sense of the various understandings about nanotech: what nanotech *IS*, where it came from, how it's used today, and where its going.




<u>Nanotech: *SIZE* matters!</u>

Different national govts, scientists, and activists still debate an agreed-upon, international, science-based definition of nanotechnology, or a nanomaterial.

but, everyone agrees that *SIZE* matters

Despite 13 years of the NNI, our government has not yet established a clear regulatory definition of a “nanomaterial.” But here are some basics:

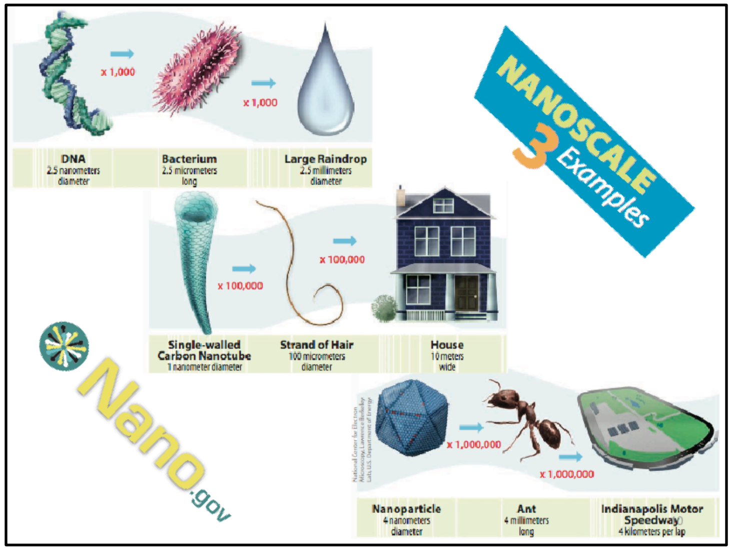
“Nano” prefix derives from the Greek word for dwarf. Nanotechnology involves the ability to see and to control individual atoms and molecules. The electron microscopes needed to see things at the nanoscale were invented only about 30 years ago: the scanning tunneling microscope (STM) and the atomic force microscope (AFM).

NNI’s Nano.gov:

“Nanotechnology is science, engineering, and technology conducted at the nanoscale (about 1 to 100 nanometers), where unique phenomena enable novel applications.

A nanoparticle can consist of any bit of matter—carbon, silver, gold, titanium dioxide, pretty much anything you can imagine.

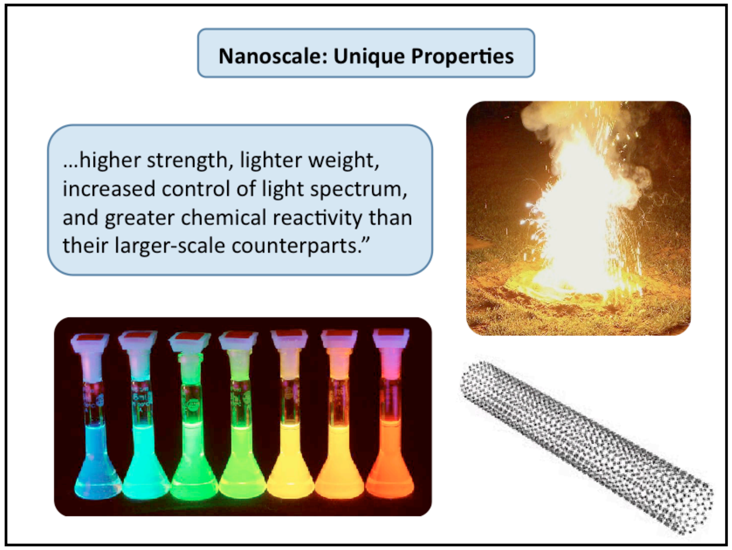
(Scientists debate the upper limits of a “nanoparticle”. Is something 101 nanometers a ‘nanoparticle?’ Similarly, if nanoparticles are use to make larger technologies, does that make the cell phone or solar panel a “nanomaterial?”)




**Nanoscale: 3 Examples**

1 nanometer is to a strand of hair, what that hair is to a 10-meter-wide home

4 nanometers is to an ant what an ant is to one lap on the Indy 500 racetrack




The nanoscale represents a transition zone between classical physics and quantum mechanics, so chemistry and physics work differently at the nanoscale.

"Today's scientists and engineers are finding a wide variety of ways to deliberately make materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts."

Examples of unique nanoscale properties:

In the nano world, the strength and melting temperature of materials change, and colors shift.

Different sized colloidal quantum dots irradiated with a UV light emit different color light.

-At 25 nanometers, spherical gold nanoparticles are red; at 50 nanometers they are green; and at 100 nanometers they're orange.

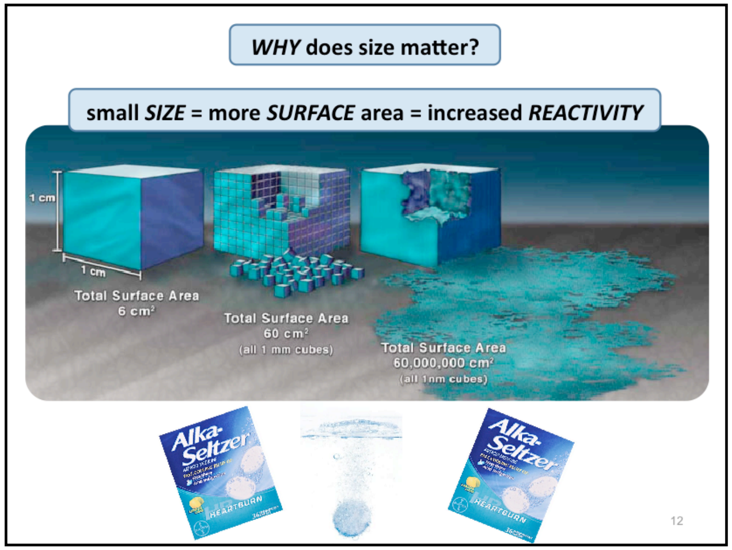
-At the nanoscale, the motion of the gold's electrons is confined. ("quantum confinement") Because this movement is restricted, gold nanoparticles react differently with light compared to larger-scale gold particles.

-- Similarly, silver is blue at 40 nanometers and yellow at 100 nanometers."

Other properties can change, too:

-Bulk carbon is soft. But at the nano level, if you superheat it, the molecules bend into a tube (carbon nanotube) that is very strong and semiconductive.

-- Aluminum is used everywhere to make soda cans. But in nanopowder form, aluminum explodes violently when it comes in contact with air.

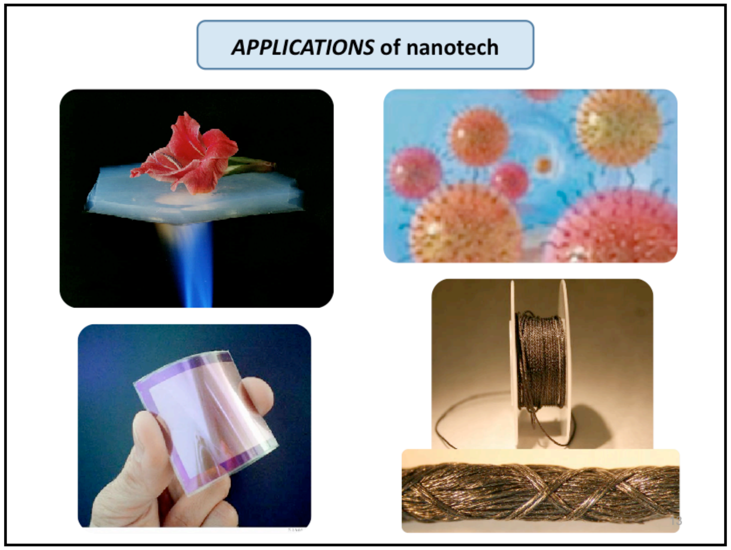



"Today's scientists and engineers are finding a wide variety of ways to deliberately make materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts."

**ASK**: Why does size matter?

- Smaller size of nanoparticles = more *surface* area = allows more reactivity

Example: Alka-Seltzer tablet in water vs. crushed Alka-Seltzer powder in water…




Applications

Researchers take advantage of these different rules by adding nanoparticles to manufactured goods to give them desired qualities.

With engineered nanoparticles we can

deliver drugs to specific cells

"cloak" objects to make them less visible

make solar cells more efficient

manufacture flexible electronics like e-paper

The potential of these applications inspired the US federal government to invest tens of billions of dollars into a National Nanotechnology Initiative begun in 2000.


Woodrow Wilson Center's Project on Emerging Nanotechnologies says that since 2005, nano-products have seen a 500% increase

In the household realm…

nanosilica makes house paints and clothing stain resistant

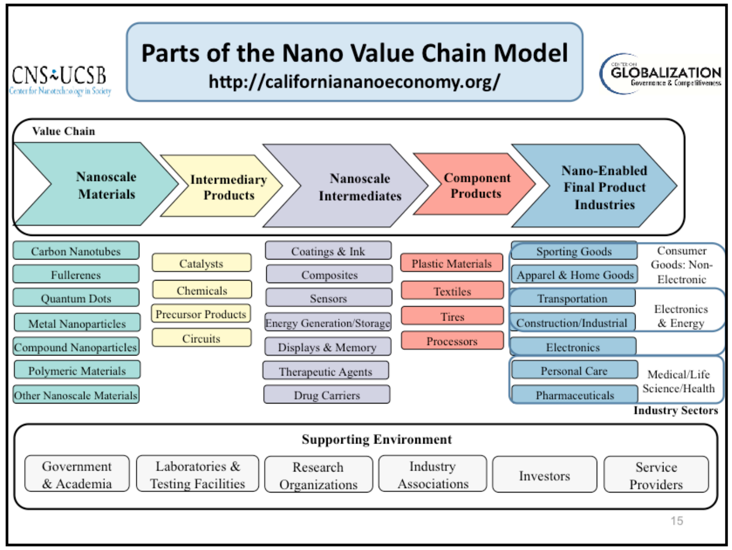
nanozinc and nano–titanium dioxide make sunscreen, acne lotions, and cleansers transparent and more readily absorbed

nanosilicon makes computer components and cell phones ever smaller and more powerful.

Various proprietary nanoparticles have been mixed into volumizing shampoos, whitening toothpastes, scratch-resistant car paint, fabric softeners, and bricks that resist moss and fungus.

Silver nanoparticles are already commonly added to many consumer products for their germ-killing properties.

Nanosilver socks, wound dressings, doorknobs, sheets, cutting boards, baby mugs, plush toys—even condoms.




Nanotechnology is an Enabling Technology.

Nano Value Chain shows how nanomaterials are used to create nano-enabled products in a global value chain for their invention, design, production, market and consumption

Nano may be small, but it received BIG funding:

Major public & private expenditures on nano research, all expecting big returns on investment:

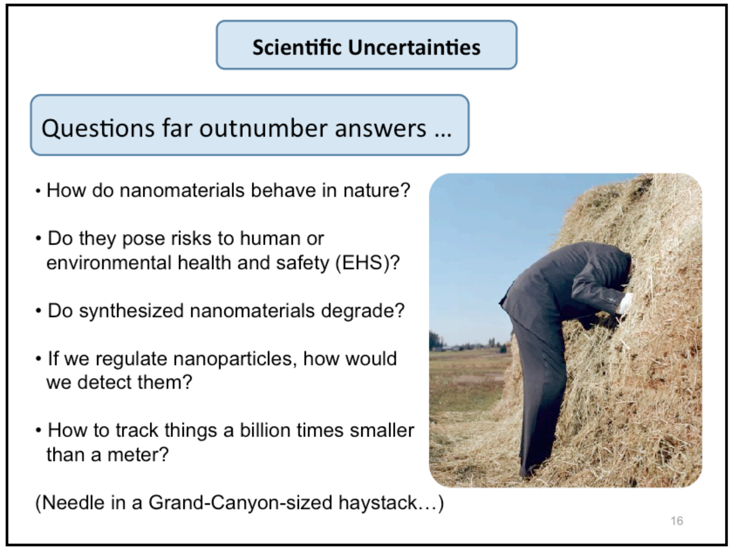
Since 2000, US govt spent over $13B, spread out across 20+ fed. agencies

2011 Lux: est total public and private investment globally approx $17.8B

2012 Congressional Research Report:

Corporate R&D $9.6B

Exceeding public $ for 1st time




Despite massive public & private investment in nanoscience research & nanotechnology applications…

Questions far outnumber the answers on how nano-materials behave and whether they pose risks to human and/or environmental health and safety

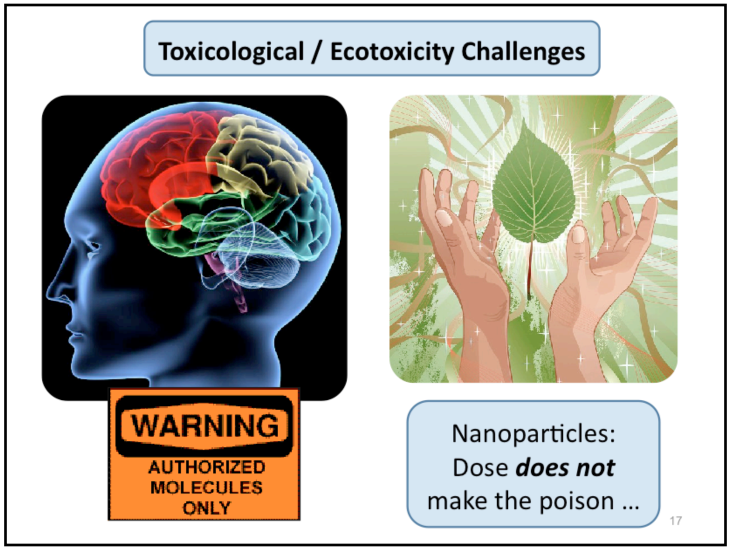
Examples of questions:

How do you track something a billion times smaller than a meter in even a modestly sized ecosystem, like a small wetland or a lake?

Do carbon nanotubes degrade? And they don't, what should we do with them? If they do, how do you tell the nanotubes from all the other carbon in your average ecosystem?

If we regulate nanoparticles, how would we detect them?

- No "nanoprobe" exists to find them today, and unlikely that there will be one any time soon.
- Finding them is like looking for a needle in a haystack, if the haystack was the size of the Grand Canyon




The tiny size and unique properties of nanomaterials presents major difficulties for traditional toxicological risk assays
methods for detecting nanoparticles in ambient environments are either highly cumbersome and expensive, or don't yet exist

Because nanoparticles are so small, they can slip past the body's various barriers: skin, the blood-brain barrier, the lining of the gut and airways
Once inside, these tiny particles can bind to many things
They seem to build up over time, especially in the brain
Some cause inflammation and cell damage. Preliminary research shows this can harm the organs of lab animals
Some published research has shown that inhaled nanoparticles actually become more toxic as they get smaller.

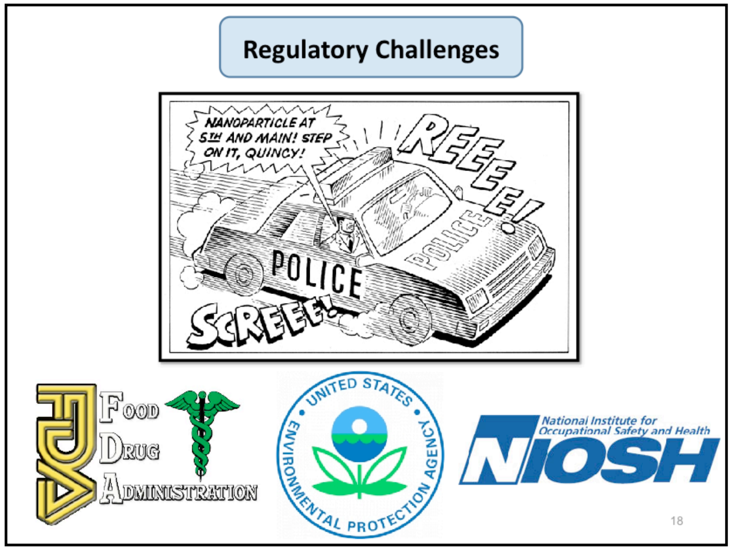
- Nano–titanium dioxide, one of the most commonly used nanoparticles (found in Pop-Tarts, M&Ms, powdered doughnuts, sunblock), has been shown to damage DNA in animals and prematurely corrode metals
- Carbon nanotubes seem to penetrate lungs even more deeply than asbestos.

Environmental effects / Ecotoxicology:
Limited but unsettling knowledge about environmental effects of nanoparticles
Nanoparticles from consumer products have been found in sewage wastewater, where they can inhibit bacteria that help break down the waste
They've been found to accumulate in plants and stunt their growth.
Another study has shown that gold nanoparticles become more concentrated as they move up the food chain from plants to herbivores.

OECD report on nano risks, March 2012:
"The nanomaterial properties determining its toxicokinetics and toxicodynamics are currently not known with confidence."
"These uncertainties mean that methodologies to permit extrapolation between different types of nanomaterials and different species are not available, implying that assessments often have to be made *de novo*, on a case-by-case basis."

The old toxicology maxim "Dose makes the poison" does not apply
nanomaterial-assessment includes significantly more variables to consider.

- For instance, the mass of a nano-particle is likely not the most important metric of toxicity
  - This has serious consequences for our current regulatory system in which mass is the primary and most legally binding measure for toxic exposure.



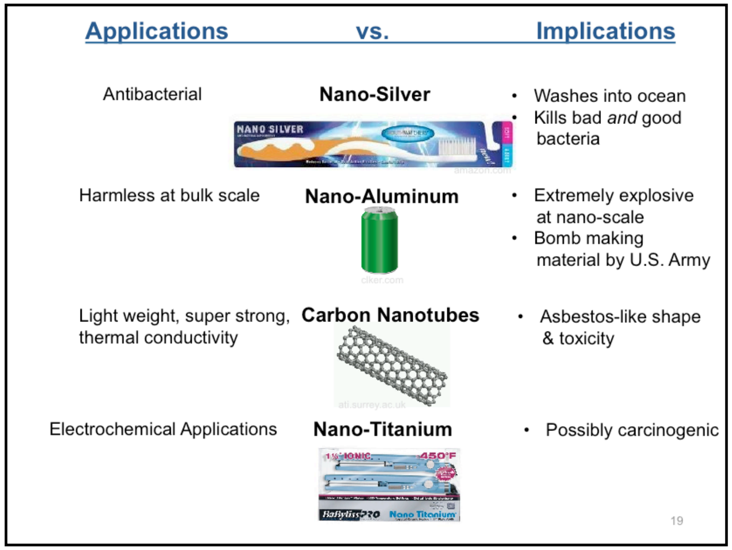

Regulation:

The regulation of nanoparticles has been recommended for more than a decade, but there's no agreement on exactly how to do it. Regulatory structures, both here and abroad, are completely unprepared for this onslaught of nanoproducts, because nanoparticles don't fit into traditional regulatory categories.

Meanwhile, the use of man-made nanoparticles has spread into almost every area of our lives: food, clothing, medicine, shampoo, toothpaste, sunscreen, electronics, and thousands of other products.

Additionally, companies often shield details about them by labeling them "proprietary"; they're difficult to detect; we don't have protocols for judging their effects; and we haven't even developed the right tools for tracking them.

Our inability to precisely quantify the toxicity of nanomaterials means regulators must make decisions to mitigate the risks of nanotechnology based on incomplete information.




Applications vs Implications:

Nanotechnologies have costs, risks, and benefits that affect our lives in powerful ways, many of which we cannot always predict.

To best understand what nano is doing (where it came from, what it is, where its going), we must to study the social & environmental implications of nanotechnology

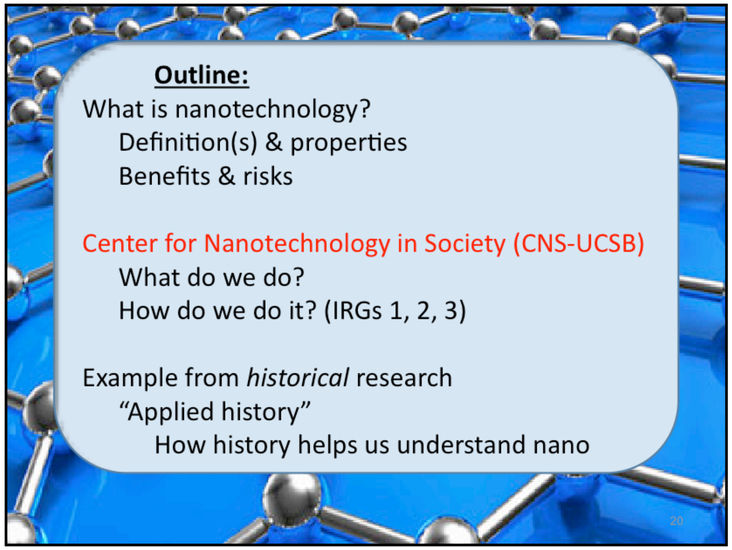
(not just research its new properties and applications)

Some social science researchers label this type of "up-stream" attempt to manage technological development as "Anticipatory Governance"

Anticipatory Governance

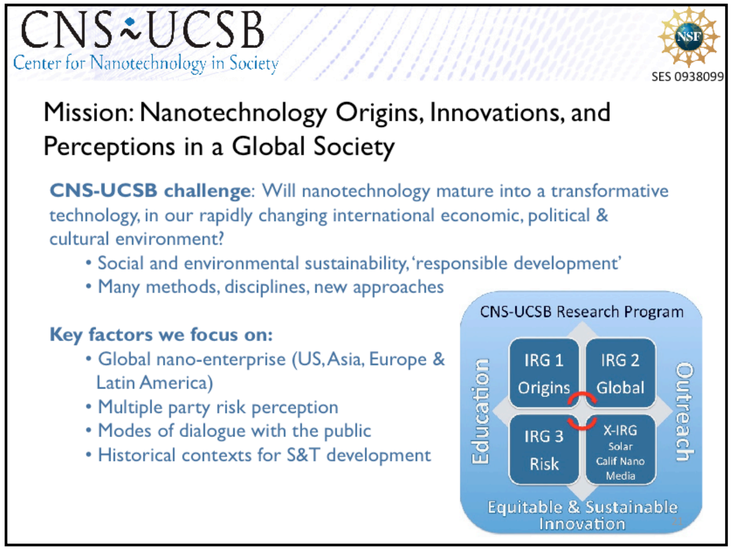
similar to 1960s ideas by Buckminster Fuller:

> Buckminster Fuller claimed that "Humanity on Earth teeters on the threshold of revolution. It has to be success for all or none. If the revolution is a bloody one, humanity is through. The alternative is a **design-science revolution**." Buckminster Fuller called for a "comprehensive **anticipatory design science**." Design science, he said, was "the effective application of the principles of science to the conscious design of our total environment in order to help make the Earth's finite resources meet the needs of all of humanity without disrupting the ecological processes of the planet."




Outline:

•Center for Nano in Society (CNS-UCSB) (What we do & How we do it [IRGs 1, 2, 3])




CNS-UCSB, is a NSF center for interdisciplinary research on nano in society

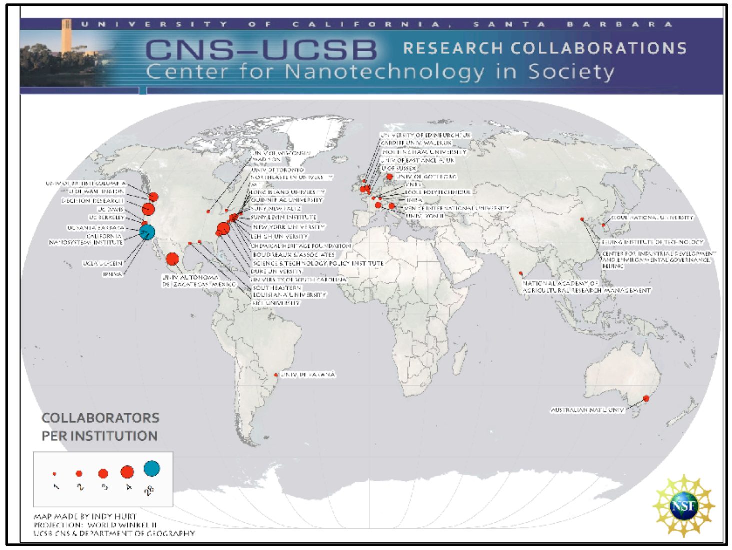
In a recent presentation, CNS Director Barbara Herr Harthorn explained:

"CNS is dedicated to understanding the relationship of technological innovation and social change. It does so by focusing on: the individual; on institutions & policy; and on global issues. CNS does this by drawing from many academic disciplines. CNS's work is motivated both by the desire to advance interdisciplinary social science and humanities, and the desire to partner with Science & Engineering to advance equitable and sustainable technological innovation around the world."

"The NSF Center for Nanotechnology in Society at UCSB serves as a national research and education center, a network hub among researchers and educators concerned with societal issues concerning nanotechnologies, and a resource base for studying these issues in the US and abroad."

The CNS has three primary research groups, each with a particular focus:

Origins \
Innovations > all in a GLOBAL SOCIETY
Perceptions /

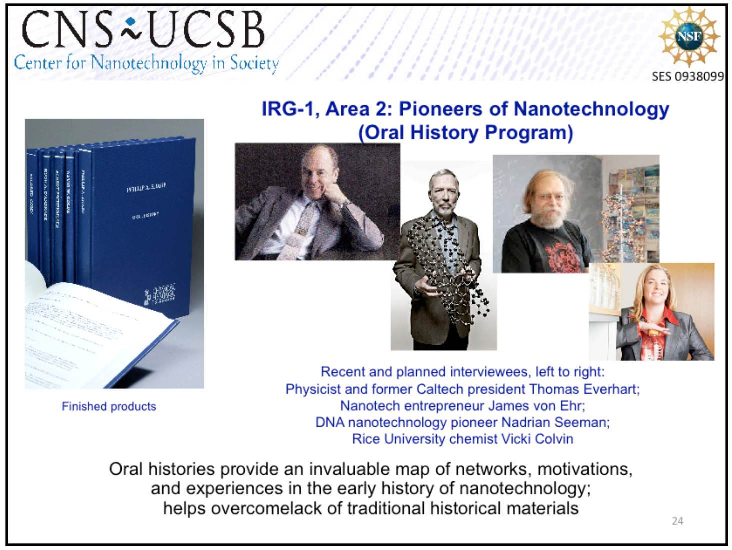



CNS-UCSB Research Collaborations across the globe


Our groups past and future research is based on the belief that understanding nanotechnology's social and economic implications must be based on a robust understanding of its historical contexts.

Our work continues to examine these historical underpinnings at multiple levels – scientists' careers, research institutions, instrumentation, national and state policy, and the public's evolving perception of nanotechnology. The result is a "deep history" will ultimately allow us to understand how these resources constrained and enabled aspects of today's nano-enterprise.

Our GRAND goal – perhaps after 10 years – is a comprehensive and holistic narrative of nanotech's trajectory. This would trace it from research in the 1950s and 60s in materials science to the discoveries of the buckyball and STM in the 1980s to the creation of a vast transnational infrastructure for doing interdisciplinary research.




I want to highlight one aspect of our work:

Since our group was formed in 2006, we have been exceptionally active in collecting oral histories. These help us and other scholars understand people’s career paths and preserve their recollections of key events. We have selected individuals from several  communities including university and corporate scientists as well as policy makers.

To date, over two dozen oral history interviews have been carried out; finished interviews are archived at the Chemical Heritage Foundation and/or the Center for History of Physics.

IRG 1 leverages its research through partnerships with CHF and AIP, allowing CNS to do more with the resources it has. Also, note that these interviews are available for use by the wider scholarly community.

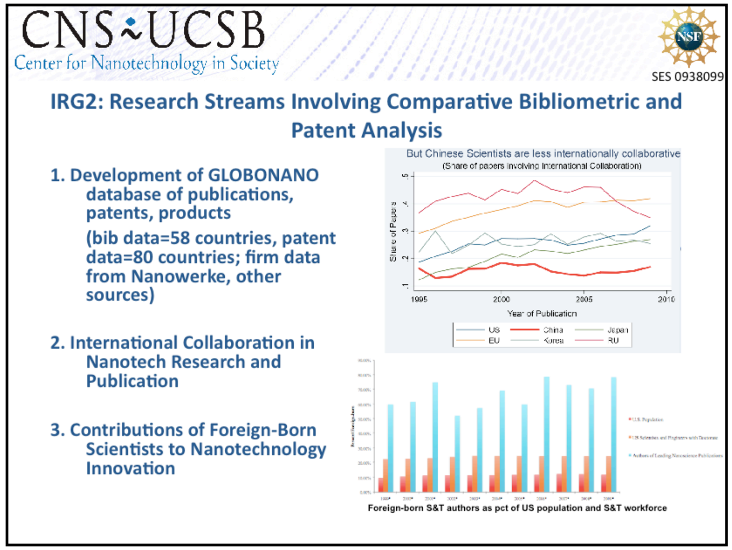

IRG2 Goal: to better understand the importance of state policies and international collaboration in fostering nanotechnology R&D and commercialization, and contribute to more sustainable and equitable development, through comparative studies of the U.S., China, Japan, India, Korea, and selected Latin American countries.


IRG2 China research:

1. China's Developmental State: Becoming a 21st Century Nanotech Leader

2. The Implications of China's Move to High-Tech Innovation for U.S. Policy

3. Drivers of Nanotechnology Commercialization in China: Patent Analysis



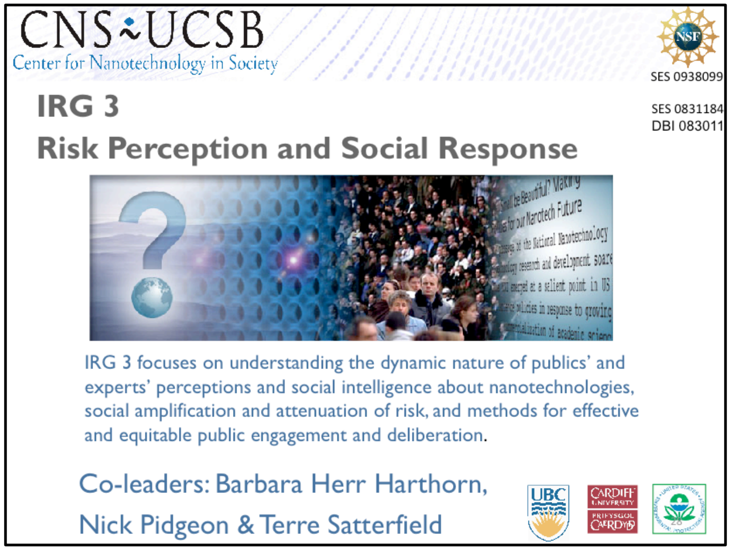

**IRG 2 Bibliometric & Patent Analysis research**

1. Development of GLOBONANO database of publications, patents, products

(bib data=58 countries, patent data=80 countries; firm data from Nanowerke, other sources)

2. International Collaboration in Nanotech Research and Publication

3. Contributions of Foreign-Born Scientists to Nanotechnology Innovation




**IRG 3, Risk Perception and Social Response**

IRG 3 asks: Will nanotechnologies experience public backlash and stigma when they are developed and disseminated that could limit the realization of their potential economic and/or social benefits?

To help answer this question, IRG 3 conducts sociological research on the public perceptions of nanotech risk and benefit. They use mixed qualitative and quantitative social science research methods to study multiple parties' views and beliefs about nanotechnology.

Multiple Parties means people in various social locations and positions

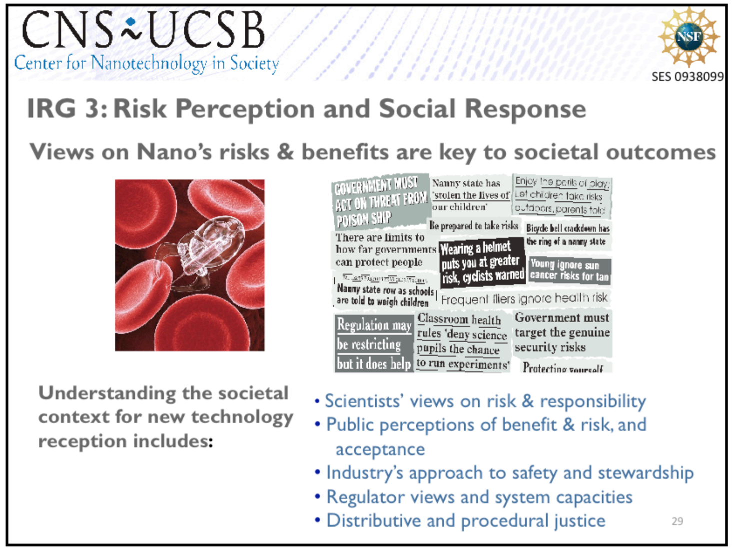
> This includes nanoscale scientists and engineers, nano risk assessment experts, regulators, industry leaders, insurers, NGOs or other social action and special interest groups, journalists, and members of the public who differ by gender, race/ethnicity, class, occupation, education, and age, as well as nation.

Quantitative methods used in IRG 3 include

- in-person, phone, and web surveys of demographically diverse US publics, including various "experts" like scientists and engineers, regulators, and industry leaders.
- tracking of print and internet media coverage of nanotechnologies

Qualitative methods help validate quantitative results and include

- mental models interviewing, expert interviews, ethnographic interviews
- deliberative public engagement workshops and focus groups on risks and benefits of specific nanotech applications

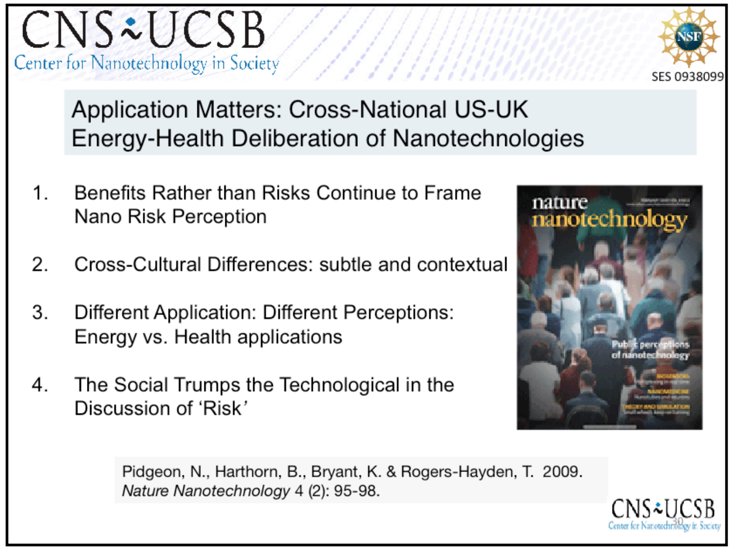



**Risk Perception and Social Response**

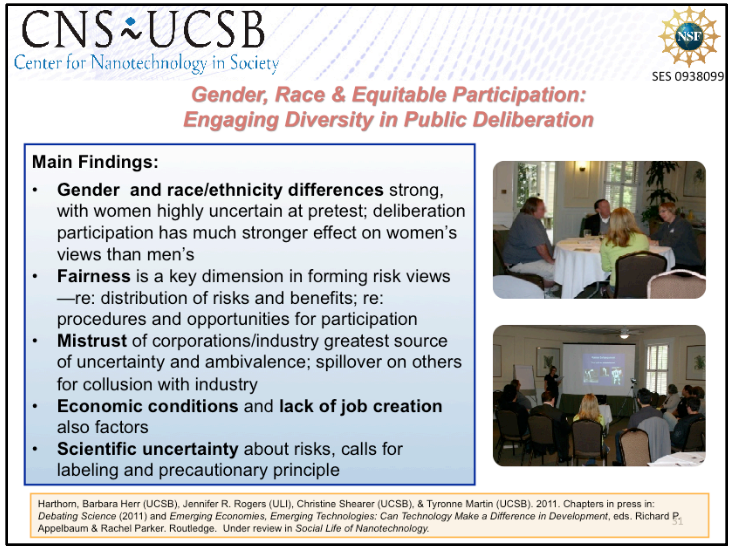
Views on Nano's risks & benefits are key to societal outcomes

Understanding the societal context for new technology reception includes:

- Scientists' views on risk & responsibility
- Public perceptions of benefit & risk, and acceptance
- Industry's approach to safety and stewardship
- Regulator views and system capacities
- Distributive and procedural justice




IRG3 Research Example 1:
Public Deliberations in UK & USA on Energy & Health applications of nanotech: (published recently in *Nature*)
These comparative analyses have found:
•even in the UK (where risk controversies have littered the landscape) benefits frame nano risk perception (with focus on constraints on benefits, rather than tech risk).
•US/UK differences were far less salient than expected—nuances rather than large effects
•Surprisingly: responses in both countries sharply different between enthusiastically received energy apps and more problematic health technologies
•AND In spite of considerable effort to provide accessible and valid scientific expertise about technologies and risks, these discussion in these veered strongly toward social implications rather than discussion of risk




**IRG3 Research Example 2:**

2009 Public Deliberations on Gender, Race & Equitable Participation re: Nano

Main Findings:

- Gender and race/ethnicity differences strong, with women highly uncertain at pretest; deliberation participation has much stronger effect on women's views than men's
- Fairness is a key dimension in forming risk views—re: distribution of risks and benefits; re: procedures and opportunities for participation
- Mistrust of corporations/industry greatest source of uncertainty and ambivalence; spillover on others for collusion with industry
- Economic conditions and lack of job creation also factors
- Scientific uncertainty about risks, calls for labeling and precautionary principle

## IRG 3: NGOs and Tomorrow's Nanotechnologies

| Organization | Description | Funding | Action | Target | Goal |
|---|---|---|---|---|---|
| etc group | **Erosion, Technology, & Concentration Group** *Issues*: Consumer safety & equitable development | Donations | Publications | International Governments | Moratorium |
| GREENPEACE | **Greenpeace** *Issues*: Environmental | Members | Publications | Nanotech Industry | Moratorium |
| EDF Environmental Defense Fund | **Environmental Defense Fund** *Issues*: Environmental and consumer health and safety | Members | Publications & Partnerships | US Government & Industry | Regulatory Change |
| Friends of the Earth | **Friends of the Earth** *Issues*: Public and environmental health and safety | Members | Publications | Government & Industry | More EH&S Research |
| Project on Emerging Nanotechnologies | **Project on Emerging Nanotech** *Issues*: Environmental and consumer | Donations | Conferences & Publications | US Government | Regulatory Change |
| Soil Association Organic Standard | **Soil Association** *Issues*: Consumer health and safety | Donations | Publications & Organic Std. | Food Industry & Farmers | Regulatory Change |
| SVTC | **Silicon Valley Toxics Coalition** *Issues*: Consumer, environmental, occupational health and safety | Donations | Publications | Nanotech Industry | Regulatory Change |

*Engeman, Earl & Harthorn, in progress*

**<u>IRG 3 Research Example 3:</u> <u>NGOs & Nanotech</u>**

Creating an expanding global database of over 140 NGOs, distinguishing between NGOs that are actively engaged in nanotechnology-related issues and NGOs that endorse the actions of other NGOs but do not take independent action.

NGOs are well-positioned to influence public perceptions and the future governance of nanotechnology. In comparison to unorganized individuals, NGOs have better structural and financial resources to conduct research, issue reports, and communicate their views to the media, policymakers, and industry. NGOs can disperse their messages to publics by attracting media attention or using their communication and social media networks to reach individual members directly. In the current context of low public awareness of nanotechnology, public perceptions of nanotechnology-related risks are particularly susceptible to how organizations and the media frame nanotechnology issues.

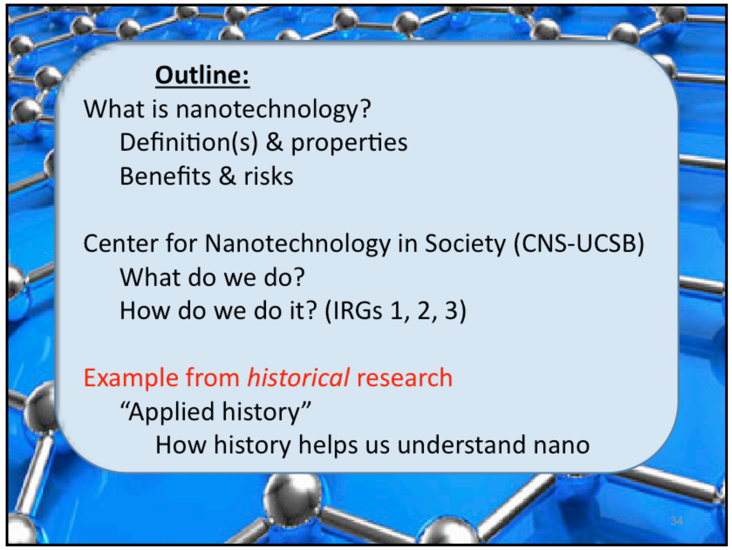
This project contributes to understandings of how organized groups construct and disseminate their particular understandings of social problems with respect to emerging technologies in contexts of low public awareness and lacking in disruptive events that often trigger large-scale social response.


**Research Challenge: evaluating public perceptions before they've formed**

Thus far, nano R&D has evolved with little evidence of significant public awareness, amplified risk perception, or media attention

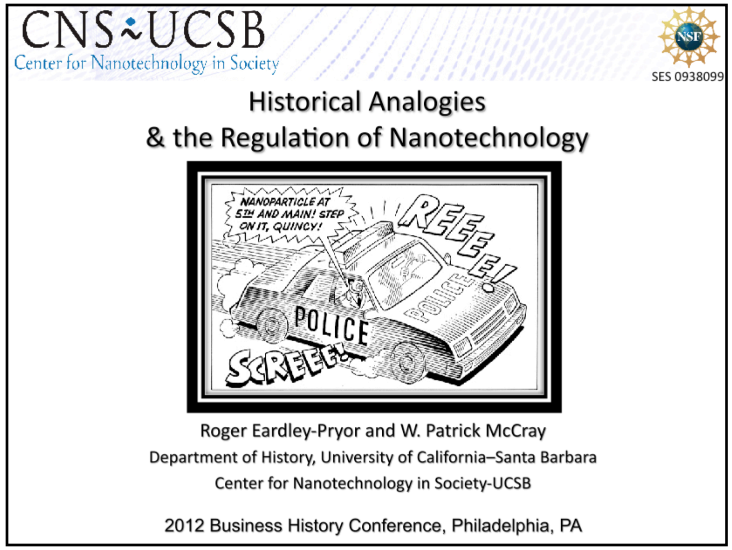
in other words, the public has formed few ideas about nano yet; limited public knowledge

As a result, IRG 3 research has moved into more research on how regulatory actions could impact perceived risk



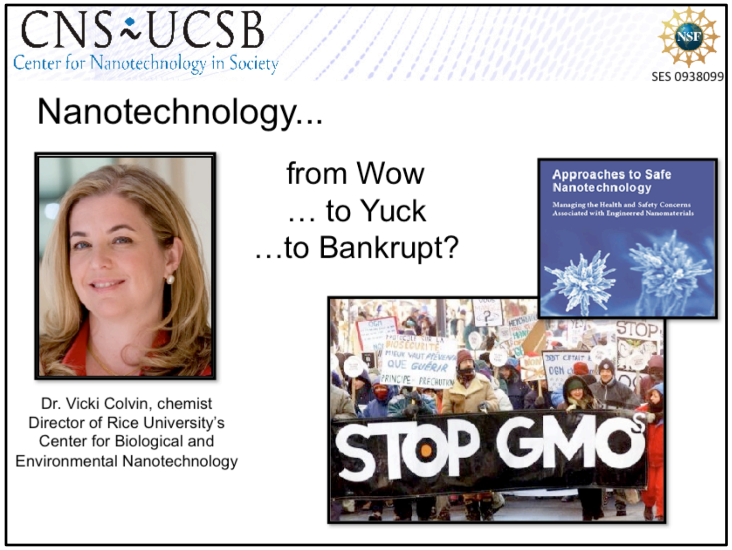

Outline:

•Example from my research (Applied Hist & How history helps us understand nano)




**<u>Historical Analogies & the Regulation of Nanotechnology</u>**

Abstract: Since the mid-1990s, researchers, policy makers, and business leaders have touted nanotechnology as a key emerging technology for the 21st century. At the same time, nanotechnology – a slippery term with definitions ranging from an ensemble of existing instrumental techniques to a specific class of new materials to a paradigm-shattering scientific frontier – arrived accompanied by uncertainty and risk. Previous technological controversies over nuclear power, DDT, recombinant DNA, asbestos, and genetically modified organisms provided nanotechnology's proponents and opponents with examples they could mobilize as they worked to shape public perception and policy. This paper explores how and why concerns about nanotechnology's environmental, health, and safety (EHS) issues moved so rapidly to the forefront of policy discussions. It also argues that the risk and regulation of previous technologies provided analogies for experts to debate the need to regulate this new emerging technology.




**<u>Nano: from WOW to YUCK to BANKRUPT?</u>**

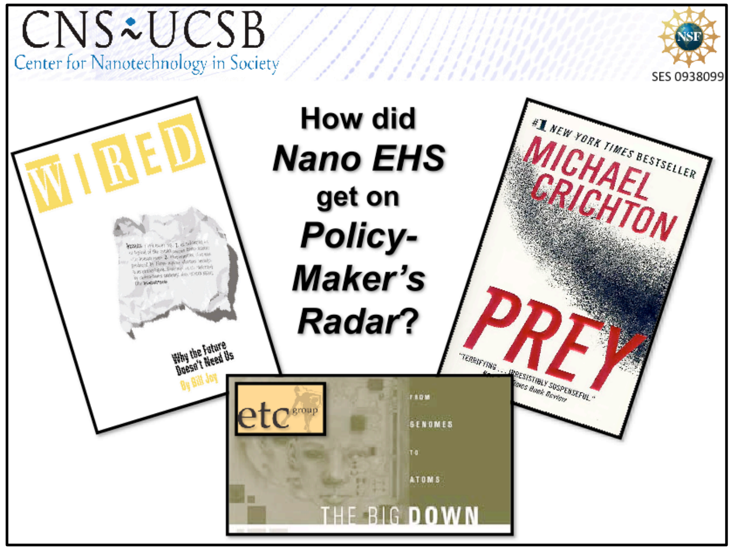
In April 2003, Vicki Colvin testified before Congress. Colvin, a chemist at Rice University, also directed that school's Center for Biological and Environmental Nanotechnology. She spoke about the societal implications of nanotechnology – the manufacture of materials and devices with dimensions 100 nanometers or less. This "emerging technology," Colvin said, had a considerable "wow index." Nanotech offered "potential benefits to the economy, human health, and quality of life." However, Colvin warned, every new such emerging technology came with its own particular set of concerns. Improperly handled, these concerns "can turn wow into yuck and ultimately into bankrupt." To drive her point home, Colvin shrewdly drew an analogy between this potentially bankrupt story of nano to a historical example that would resonate with policy makers – the "genetically modified foods industry." (GMOs) Colvin's analogy made for an effective sound bite. It suggested that policy makers needed to attend to the public perception and environmental consequences of new technologies, especially as they weighed possible future regulations. It was, however, a specious comparison that conflated two very different histories of specific emerging technologies.

Our paper's purpose is not to critique one scientist's use of history as a tool to speak to politicians and the public. Instead, our intent is to analyze how a range of actors – scientists, policy makers, and activists – drew on historical analogies to better understand nanotechnology, and how their analogies suggested different ways that nanotechnology might be regulated. In doing so, we consider the methodological use of historical analogy as well as the manner and context in which those analogies were deployed.


**Thinking About Analogies**

Analogies have been used before as tools to consider new technologies. In 1965, NASA requested comparisons between the 19th century American Railroad and the U.S. Space Program. In response, MIT historian Bruce Mazlish wrote a classic article analyzing the utility and limitations of historical analogies. Analogies, he explained, function as both model and myth. Mythically, they offer meaning and emotional security through an original archetype of familiar knowledge. Analogies also furnish models for understanding by construing either a structural or a functional relationship. As such, Mazlish described analogies as "a device of anticipation." Such tools can guide scientific understanding and foster what today is fashionably called "anticipatory governance."

Analogies tend to assume that the past both validates and predicts the future, thereby providing a model for action. But, ultimately, analogy merely suggests a possibility. "When used carelessly," Mazlish warned, "historical analogy can be a misleading guide. Worse, by establishing a facile resemblance, it may serve to prevent a more critical and analytical approach." Furthermore, an analogy that applies only to one instance clearly lacks the strength of an analogy to many instances. In order to truly understand something, Mazlish insisted that we study "the system, both dynamic and static, in which it rests." In other words, context matters, and differences of comparison could be as illuminating as similarities. We must therefore view critically the historical analogies applied to the complex phenomenon of nanotechnology, discard any fuzzy generalities, and look for a deeper understanding that might help us better control nanotech's social impacts and unintended consequences.




**<u>Getting on the Radar</u>**

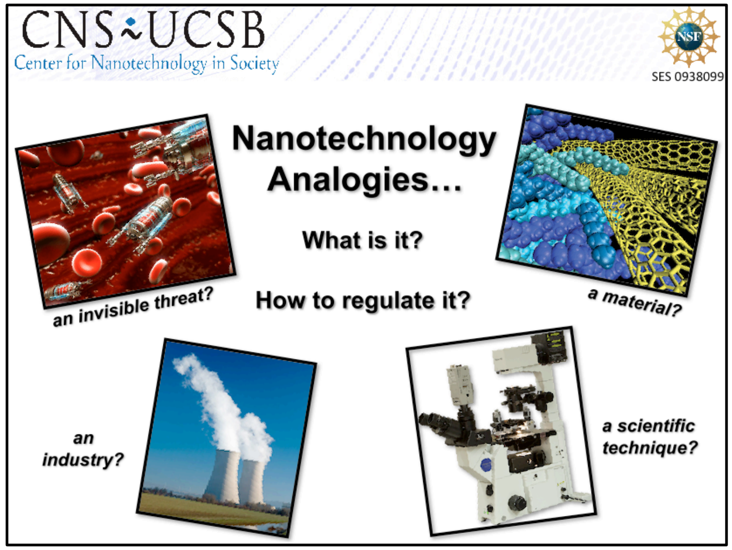
When the U.S. government first launched its National Nanotechnology Initiative in 2000, few if any policy makers expressed concerns about its environmental implications. But by 2003, it was impossible for the people charged with managing nano to have ignored its environmental, health, and safety (EHS) issues. So how did EHS issues get on the radar screen of policy makers and journalists? There are several causal factors; their common feature is that they all originated not in the laboratory but in the realms of popular culture, celebrity, and social activism.

An early shot across the bows of nano-advocates appeared even before Congress had approved Clinton's nano-initiative. It came from an unexpected source. Bill Joy was a Berkeley-trained computer researcher and dot-com millionaire. His incendiary article – published by Wired in April 2000 – was titled "Why the Future Doesn't Need Us." It highlighted perils he saw in several emerging technologies. Motivated partly by controversies over corporate development of genetically-modified crops, Joy identified self-replication of newly emerging nanotechnologies as a clear and future danger. The solution? Joy proposed "relinquishment" and limiting development of "technologies that are too dangerous." Accompanied by a flurry of international publicity, Joy's article came at an inconvenient time for nano-boosters as Congress was preparing to vote on Clinton's proposed new nano initiative.

Nano-anxieties were fanned anew in late 2002. On the Monday before Thanksgiving, HarperCollins published *Prey* by blockbuster novelist Michael Crichton. Central to its plot was the deliberate release of autonomous, self-replicating nanobots. Created by an amoral corporation working under contract to the Pentagon, the predatory swarm of millions of nanobots attacked people until it was destroyed. Crichton's book hit every button that might stoke public alarm about nanotechnology: a greedy, high-tech firm; lack of government regulation; new technologies turned into military applications.

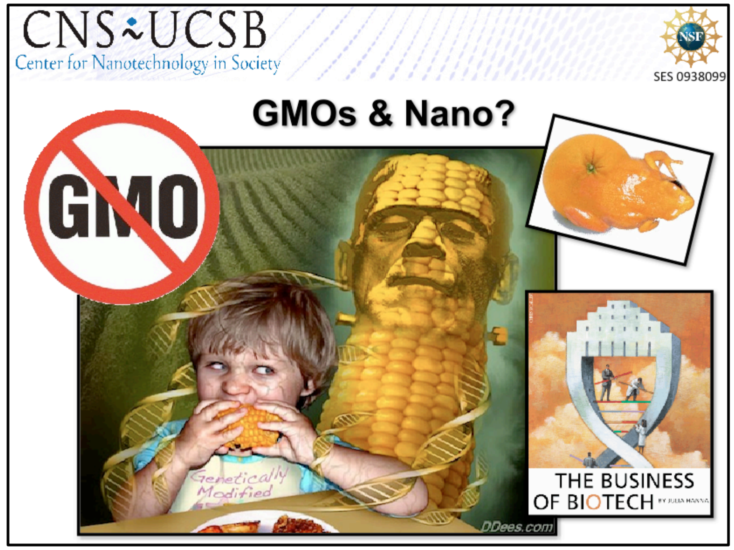
Non-governmental organizations helped keep controversies over nanotechnology in front of North American and European citizens. In January 2003, the Action Group on Erosion, Technology, and Concentration (ETC), a small Canadian NGO, released a report called *The Big Down*. ETC had previously led campaigns against genetically modified foods. Not surprisingly, their report savaged the idea of nanotechnology. ETC's report reflected their larger concerns, which were less about nanotechnology *per se* and more about restricting corporate power and maintaining cultural diversity and human rights.

These are just a few examples that suggest how the regulation of nanotechnology came to be seen as a necessity. What is striking about these examples is that none of them were about a specific *existing* technology. Instead, these spurs to regulation referred to *hypothetical* technologies and the creation of planet-threatening dangers. Soon, concerns about nano's regulation and EHS issues transcended vague existential threats to also light upon specific and potentially troubling techniques and materials. In the next section of our paper, we'll turn to these varying aspects of nanotech, the threats it imaginably posed, and the resultant regulations those threats suggested.




**Drawing Comparisons**

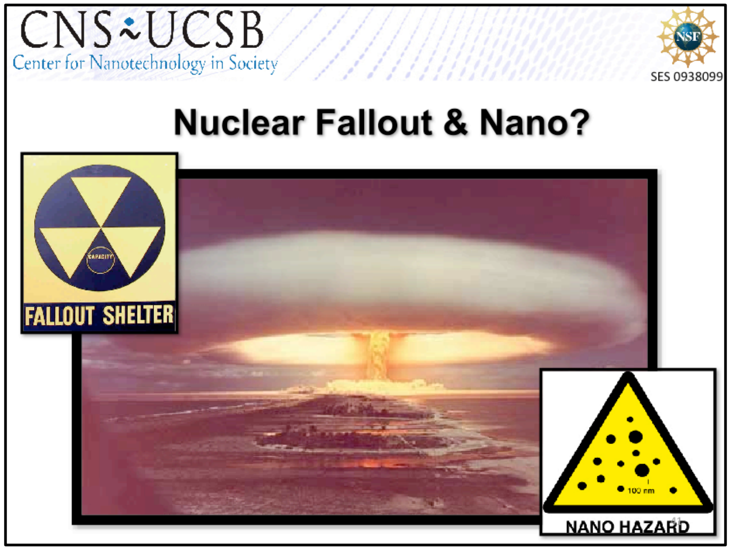
In order to draw fitting analogies that might indicate an ideal path toward the appropriate oversight or regulation of nanotechnology, stakeholders must first agree on its definition. Was it something with the capacity to spread across wide swaths of land, across borders, and reap tremendous environmental damage with the fear amplified in part because of its minute size and undetectability? Or perhaps nanotechnology was less an existential threat and instead a suite of scientific techniques and tools that require regulation? If not a particular technique, was nanotechnology a particular product, a specific category of material, a hazardous form of matter that should be controlled for the health and safety of workers and consumers? Or, does nanotechnology better represent an entire new industry in need of care and control in order to reap its economic benefits? As we show here, nanotechnology was all of these things. However, the analogies applicable to these opposing definitions of nanotechnology indicated very different actions for its actual regulation.




**GMOs**

The most common analogy drawn between nanotechnology and an existing technology was the comparison to GMOs and agricultural biotechnology. As mentioned earlier, Bill Joy, the ETC group, and chemist Vicki Colvin all invoked GMO's as analogous to nanotechnology, which captured the attention of policy-makers, investors, and the media. But Colvin, ETC, and Joy were hardly the only ones making this analogy. Historian of technology, Langdon Winner, warned Congress about the "crisis" surrounding biotechnology and GM foods as his primary example of "technological backfire…relevant to the rise of nanotechnology." Winner also noted that in Zambia and amid severe famine, public fears over the unknown risks of GMOs led to its refusal of genetically altered corn, even as a charitable gift. Congressman Rick Smith, the chairman of the House Subcommittee on Research, considered such testimonies as lessons for avoiding a repeat of biotech's supposed "slowdown" of research, and by implication, its limitations on profit. By these accounts, the lessons from GMOs indicated that nano policy-maker and other stakeholders must include the public early and often in their technological decision-making; they must make transparent the possible risks of nanotechnology before they arise; they must elevate consumer or social benefits as a priority; and they must create international standards for nano-embedded products to avoid their premature prohibition from valuable European markets and other emerging markets.

While many of these lessons from GMOs are quite appropriate for controlling the development nanotechnology, the analogy between GMOs and nanotech contains several holes. Unlike GMOs, nanotechnology does not always involve biological material. And despite the suggested threat that, like GMOs, nano might move from "'wow' to 'yuck' to 'bankrupt,'" genetic engineering in general, never enjoyed an unalloyed "wow" period. Criticism accompanied GMOs from the very start. Furthermore, giant agribusiness firms like Monsanto never faced bankruptcy. They prospered handsomely even after the public's widespread negative reactions to their products. Lastly, living organisms – especially those associated with food – *designed* for broad release into the environment were almost guaranteed to generate concerns. Rhetorically, the GMO analogy was powerful, but a deeper analysis clearly suggests more differences than similarities.




**Fallout**

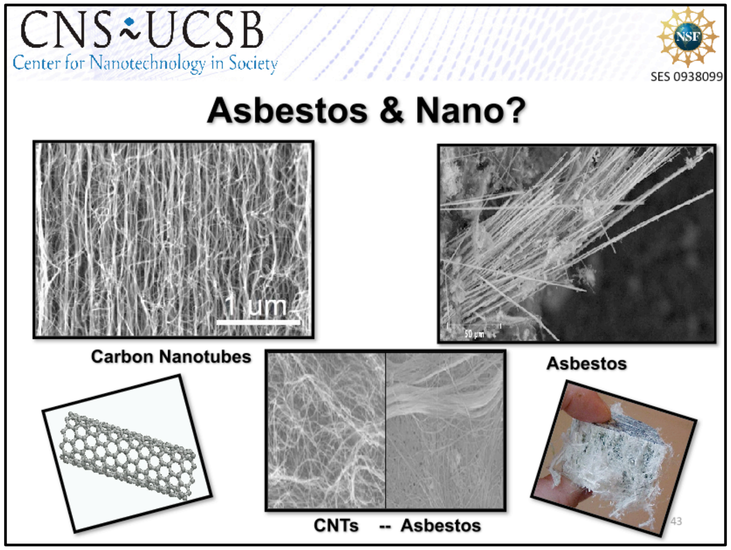
With their visions of grey goo and self-replicating nanobots, actors like the ETC Group, Michael Crichton and Bill Joy defined nanotechnology as an invisible unknown that posed a potential existential threat. This line of thinking hints at analogies to other invisible, yet life-threatening technologies. Take Cold War era concerns about radioactive fallout as an example.

Each of the 500 or so open-air, nuclear tests exploded between 1945 and 1980 released minute, invisible, radioactive debris called “fallout,” which circulated around the planet’s stratosphere before falling back to earth, exposing humans and the environment to its harmful radioactivity. The global spread of these materials throughout ecosystems and into human bodies occurred without full public or private consideration of risks by policy-makers, by scientists, or by unknowingly exposed citizens.

Partial Nuclear Test Ban Treaty, 1963
Initialing ceremony, Moscow, USSR
(U.S. Nat'l Archives & Records Admin.)

**Limited Test Ban Treaty (1963)**

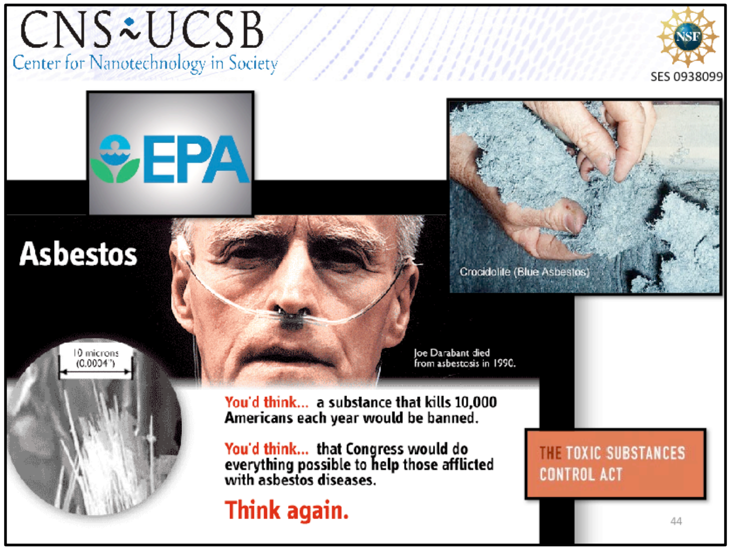
The nanotechnology enterprise has also produced novel engineered particles that exist at near-invisible scales. The impact of nanotechnology on the environment and the human world may require the leading nano-nations to institute a standardized form of international regulation, similar to the leading nuclear nations' eventual control of atomic fallout. In 2003, Oregon Congressman David Wu hinted at the analogy between nanotechnology and nuclear fallout by citing the success of regulating fallout via the 1963 Limited Nuclear Test Ban Treaty. Though Representative Wu celebrated the Test Ban Treaty for its international cooperation and control of hazardous fallout, he noted that "in many respects, the Nuclear Test Ban Treaty is nothing but a ban on experimentation." At the time, organizations like ETC, Greenpeace, and Friends of the Earth-Australia had called for a ban on nanotechnology production until researchers clearly understood all of nanotechnology's EHS risks. As with other examples, one's definition of nanotechnology – here as an invisible, existential, and global threat – determined the appropriate analogy to prior technologies. That definition, in turn, indicated to various nano-stakeholders particular forms of precaution, regulation, and control. If nanotechnology was analogous to fallout, the analogous regulation appeared to be an outright ban until all future risks could be contained.




**Asbestos**

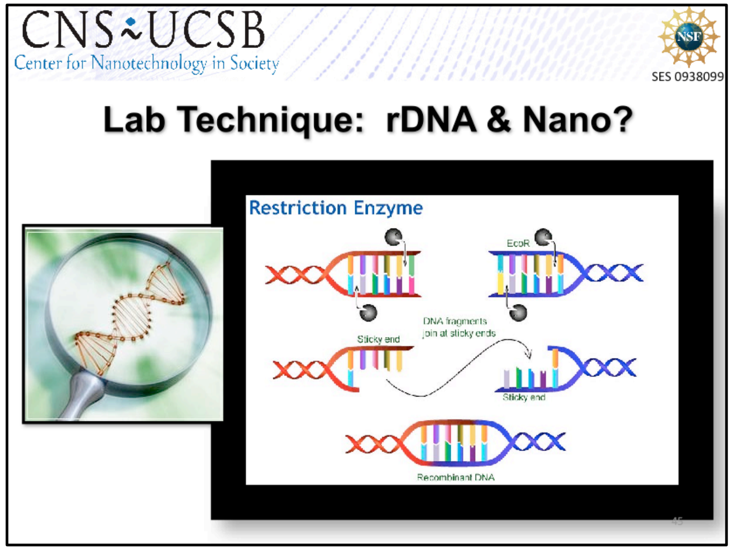
Another definition of nanotechnology treats it less an invisible existential threat and more like a new form of matter requiring special oversight, particularly in workplace and occupational safety arenas. Such a material definition of nanotechnology inspires an analogy to asbestos.

Given decades of enormous and expensive asbestos litigation, the analogies between asbestos and nanotechnology have prompted substantial toxicological analysis on new materials. Carbon nanotubes are best known of these materials. With a long and thin structure that resembles that of asbestos, numerous toxicological studies indicate that CNTs share a similar toxicity as well. These similarities and the historical circumstances of attempts to regulate asbestos in the United States, all offer suggestions for how to proceed toward the regulation of certain nanotechnologies.



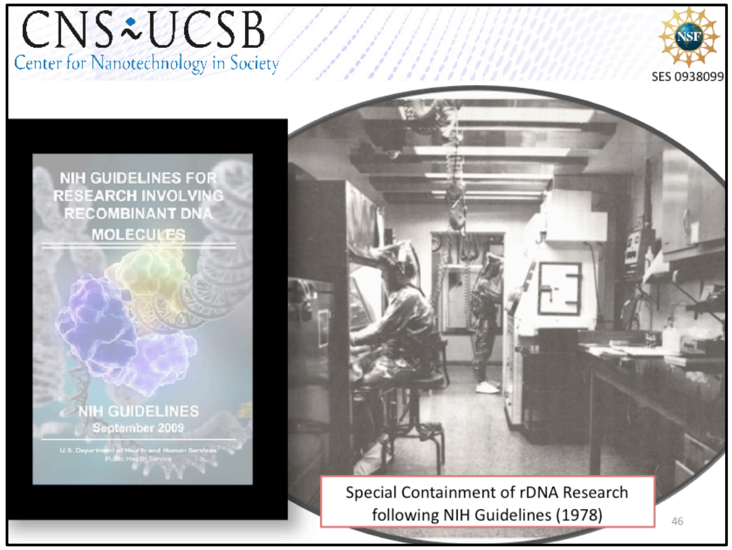

**Asbestos weak regulation**

Worldwide, upward of sixty nations have partially or completely banned asbestos. Given the known threats of asbestos, the U.S. EPA attempted an all-out ban on its manufacture and use; however, in 1991, the U.S. Fifth Court of Appeals claimed EPA did not meet the requirements to impose the "least burdensome" controls. In overturning the ban, the court promptly lifted the ban for all but the most dangerous existing asbestos products. The inability of EPA to ban asbestos, despite decades of evidence confirming its hazards, indicates the need for serious reform of TSCA, the existent United States' law for chemical regulation. While this need for reform applies for existing substances like asbestos, it applies even more so for novel and analogous nanotechnologies like CNTs.




**Ensembles of Lab Techniques (rDNA)**

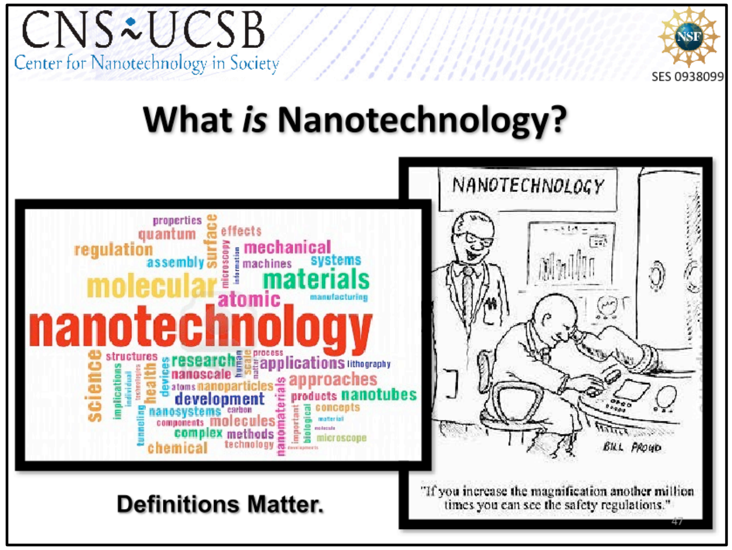
A final definition for nanotechnology moves beyond consideration of novel forms of matter and instead identifies nanotechnology as a suite of technological practices for manipulating nature – techniques that render the natural world as unnatural. This identification of nanotechnology with particular lab practices yields an analogy to the debate about recombinant DNA (rDNA) techniques of the 1970s. Recombinant DNA involves isolating and removing a section of DNA molecules from one species, and then splicing that section into the DNA of a completely different species. The result is an entirely new, human-made, and hybridized biological entity. When the technique was first developed, concerns were rife that the research might create novel carcinogenic bacteria or viruses that could escape the lab into the environment.




**<u>rDNA moratorium & soft regulation</u>**

In the mid-1970s, scientists agreed to a moratorium on rDNA practices until they better understood the technology and until the U.S. National Institutes of Health (NIH) could establish proper guidelines. After the famous Asilomar Conferences, the NIH's Recombinant DNA Advisory Committee (or, RAC) produced its research guidelines. These guidelines clearly defined rDNA techniques and instituted multiple layers for its control, including requirement of biological containments. After the research moratorium ended, this ensemble of lab practices helped stimulate the rapid commercialization of modern biotech research.

Nanotechnology-stakeholders have identified a similar goal of early anticipation and mutually agreeable control through their framework of anticipatory governance. However, definitive action toward actual oversight of nano-scale engineering remains mostly discursive, even after 10+ years of nanotechnology's federal funding and development. For some nanotech stakeholders – particularly entrepreneurs affiliated with commercialized industry – the NIH's decision to institute *guidelines* for rDNA technology, rather than push for legally binding *regulations*, offers possible paths for the eventual oversight of nanotechnology. Government guidelines consist of procedures that people are expected to follow when receiving federal dollars, whereas regulations are substantive rules for all actors that carry the authority of law. However, drawing lessons from rDNA and applying them to nano comes with drawbacks –for example, guidelines similar to those from the RAC might only apply to federally funded research. This would leave privately funded research in a different regulatory regime, subject not merely to guidelines, only to the hard law of regulation.




**Conclusions: What *IS* nano? Definitions Matter.**

If this paper has one main point, it is that one's definition of nanotechnology helps determine the analogy one draws to prior technologies. This, in turn, can shape one's understanding for how to best regulate nanotechnology. In its current usage, "nanotechnology" functions as a short-hand label for several different phenomena, a socially constructed collection of techno-scientific ideas, practices, and materials. But with such a broad and sometimes vague set of definitions for nanotechnology used by scientists, policy-makers, activists, and businesses, how can nano-stakeholders know *what* to regulate?

Perhaps a rigid definition isn't needed. Some scholars, including Andrew Maynard, a leading expert on risk science, believes that a precise definition for nanotechnology would actually *impede* proper regulation. Instead of a categorical definition, Maynard now argues that objective science must dictate proper regulation of engineered nanomaterials; that regulation must focus on its various "trigger points," or empirical points that transition a material from conventional to risky.

But policy makers have recently moved in the opposite direction. In late 2011, Health Canada as well as the European Commission announced specific, "cross-cutting," and politically designed definitions for nanomaterials to use explicitly "for all regulatory purposes." Similarly, the United States' most recent research strategy for environmental, health, and safety emphasized the need for federal agencies to establish an agreed-upon standardization – e.g., a definition – for nanomaterials.

Definitions matter. A half century ago, when space exploration was poised to be a hugely disruptive technology with unknown societal implications, historian Mazlish indicated that we must view the technological object as a "complex *social invention*" – something shaped by its historically constructed contexts. As such, that object requires complex, politically invented, and socially agreed-upon definitions for its social control and regulation. Smartly chosen and appropriate historical analogies can help inform this process.

In 2003, participants at an NSF-sponsored workshop on nanotechnology's societal implications warned that "policy makers and leaders of social movements may respond to nanotechnology not as it actually is, but in terms of false analogies." To avoid this fate, policy-makers and other stakeholders in the nano-enterprise face the daunting challenge of inventing an agreed-upon definition for what nanotechnology is and what it means. If the historical analogies analyzed in this paper teach us anything about the potential regulation of nanotechnology, it's our need of socially and politically constructed definitions – not based on science alone – to mirror the complex realm of research, policy, and application. Acting upon uncertainty and forming a definition of nano so that it can be politically and scientifically regulated wisely requires that we take a little risk.


Thank you:

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