

NANO-SAFETY

IEEE Nano 2011 Conference

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**Portland Marriott Downtown Waterfront
Portland, Oregon**

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SAFETY OVERVIEW

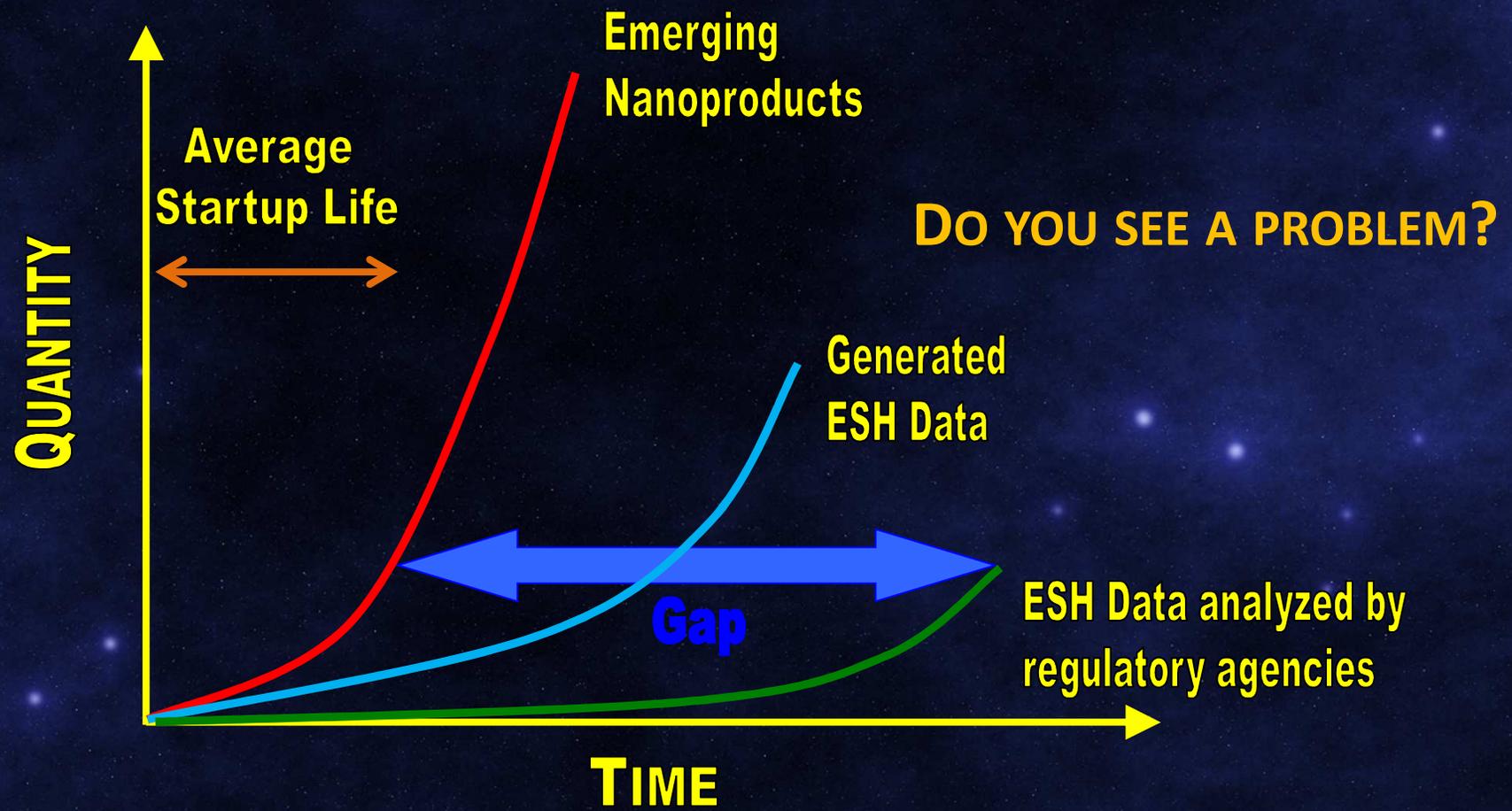
- **Current Status of Technology**
- **Key Elements of Nanotechnology**
- **What Next?**

CONCERNS¹

- Discussions of nanotechnology and safety opens up two traps:
 - Definitions
 - Generalities
 - Current understanding of nanomaterial risks has more holes than a Swiss cheese.
 - Engineered nanomaterials are accomplished shape-shifters.
 - People and the environment matter.
- Remember Nanotechnology is safety-neutral!

¹Adapted from "Ten things everyone should know about nanotechnology safety" by Andrew Maynard,
http://community.safenano.org/blogs/andrew_maynard/archive/2009/08/31/ten-things-everyone-should-know-about-nanotechnology-safety.aspx

EMERGENCE OF NANOPRODUCTS COMPARED TO ESH DATA GENERATED



CONCERNS OVER NANOTECHNOLOGY

One concern today is over Silver, which is accurate?

Nano Silver is toxic – numerous blogs¹

Nano Silver is dangerous – quasi scientific²

Nano Silver safely used for years – IEEE³

Nano Silver treats AIDS – quasi scientific⁴

Tomorrow's concern will be over a different material

¹http://www.scienceagogo.com/news/20100202185834data_trunc_sys.shtml

²<http://www.sourcewatch.org/index.php?title=Nanosilver>

³<http://spectrum.ieee.org/nanoclast/semiconductors/nanotechnology/epa-may-have-been-regulating-nanosilver-since-the-1950s>

⁴http://www.ehow.com/facts_5009003_advantages-nano-silver-treatment-aids.html

INDUSTRY DEVELOPING NANOENGINEERED GOODS FRUSTRATED BY REGULATORS' LACK OF DEFINITIONS

Manufacturers of nanoengineered products are getting frustrated by the uncertainties about the regulatory definitions of chemicals, materials, and products made with nanotechnologies. The U.S. Environmental Protection Agency's Office of Pesticide Programs (OPP) has come out with its definition of a "nanoscale material": "an ingredient that contains particles that have been intentionally produced to have at least one dimension that measures between approximately 1 and 100 nanometers," along with a new policy stating that an active or inert ingredient will be considered new if it is nanoscale. But the size-based focus of that definition is different from the one used by the EPA's Office of Pollution Prevention and Toxics (OPPT), which says size alone does not determine whether or not a chemical is new, and therefore subject to review under the Toxic Substances Control Act (TSCA).

[From Meridian Institute Nanotechnology Portal on Tuesday, May 18, 2010 http://www.merid.org/NDN/](http://www.merid.org/NDN/)

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REGULATION

How do you regulate the unknown?

EPA OPP – nanoscale material is new¹

EPA OPPT – size alone does not define new¹

What if the information does not exist?

City of Berkeley ordinance on MSDS²

Piecemeal does not work!

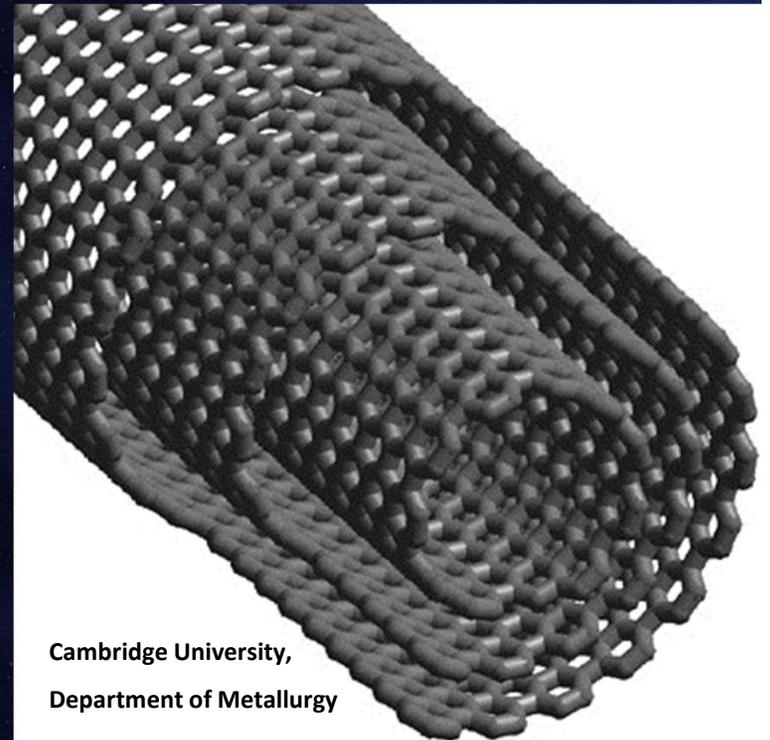
¹From Meridian Institute Nanotechnology Portal on Tuesday, May 18, 2010 <http://www.merid.org/NDN/>

²<http://www.seektress.com/berkeley.htm>

MSDS FOR MULTI-WALLED CARBON NANOTUBES, SECTION 11 TOXICOLOGY

“To the best of our knowledge the chemical, physical, and toxicological properties have not been thoroughly investigated.”

Is this language useful?



Cambridge University,
Department of Metallurgy

MSDS vs. *n*MSDS

Properties¹

Gold:

Melting point: 1064.18°C

Reactivity: LOW

Color: Yellow

Stability: GOOD

Toxicology: Very LOW

Transport: SAFE

Protection: NONE

OSHA Status: No Regs



Properties

Nano Gold:

Melting point: variable

Reactivity: unknown

Color: Red, but depends

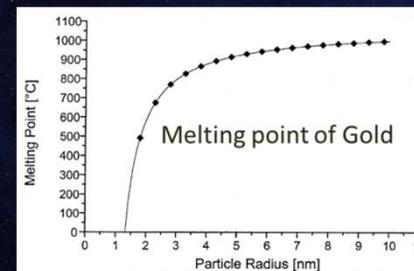
Stability: unknown

Toxicology: unknown

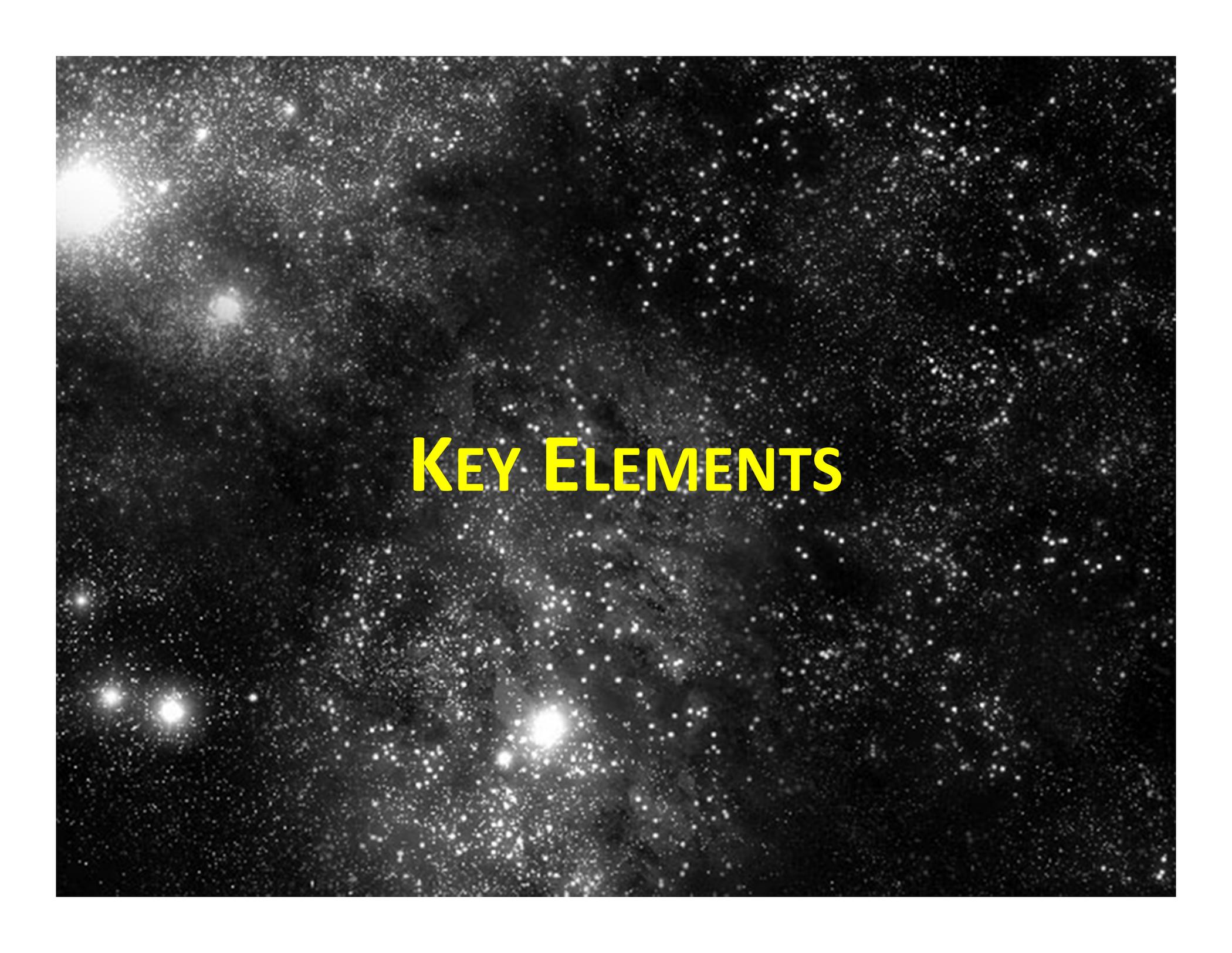
Transport: unknown

Protection: unspecified

OSHA Status: No Regs



¹Data - Oxford University

A photograph of a starry night sky, likely the Milky Way, with the text "KEY ELEMENTS" overlaid in yellow. The sky is filled with numerous stars of varying brightness, and the text is centered in the middle of the frame.

KEY ELEMENTS

NANO-SAFETY KEY CATEGORIES

- Regulations
 - Covered in the previous section
- Effect on People and the Environment
 - Nano-Health
- Education in Handling of Nanomaterials
 - Nanotechnology Safety
- Business Focus
 - Nanotechnology Safety
 - Nanotechnology Risk Management
- Nanomaterial Properties

NANO-SAFETY

Equals understanding, applying, and focusing efforts in



A systematic approach to the various aspects of concern.

FOUR PILLARS OF NANO-SAFETY

REGULATIONS

EMERGING TECHNOLOGY BUSINESSES

Material Properties

People & Environment

Education

Business

REGULATIONS

PEOPLE & ENVIRONMENT

- Toxicity investigations have been of significant interest [many call this Nano-Safety.]
- Promising medical advances being developed employ nanomaterials.
- Evaluation required on the impact of these materials on people and the environment.
- Beneficial materials, like silver below 30 nm aids in wound healing by attacking bacteria thus preventing infections, but the same silver particles will also attack good bacteria if the material is not controlled.
- KEY POINT: Control and handling of nanomaterials are important and must be followed.

NANO IS DIFFERENT

Traditional Toxicology

- **Substances do what they do because of their chemical properties**

Nanotechnology Toxicology

- **Substances behave in a certain way *because of their physical form, as well as their chemical makeup***
- ***Nanomaterials are shape shifters!***

Toxicology is only one aspect of safety.

CONCERNS REGARDING HUMAN IMPACT

Local Tissue Damage

Benign

Expelled

Biological
Fate

Dissolution

Re-Ingested

Systemic Toxicity

Cellular Interaction

Translocation

ISSUES AND DANGERS

- **Toxicity Issues**
- **Chemical Dangers**
- **Fire**
- **Explosion**
- **Dust**
- **Electrostatic**
- **Size**
 - **< 8nm, 8 to 20nm, >20nm**
- **Shape**
 - **Straight**
 - **Curved**
- **Volume**
- **Density**
- **Concentration**

EDUCATION

- How do you protect people from materials with properties that are unknown? The approach is similar to training firefighters to fight fires from unknown material?
- Numerous efforts around the country/world working as isolated communities.
- Collaborations exist:
 - OSHA Award to Rice University in collaboration with Texas State University-San Marcos, UT Tyler, UT Health Sciences Center – Houston.
 - Multiple NSF proposals involving both two-year and four-year programs from Texas to Minnesota – IH35 corridor.
- We are exploring additional collaborations and have reached out to institutes on both coasts.

EDUCATION

- The handling of Nanomaterials is a challenge due to the unknowns involved
- How do you protect people from materials with properties that are unknown?
- If there is a known impact, does it arise from only one part of the material distribution?
- Doing nothing is not acceptable
- Education guidance and handling procedures must be developed
- Key elements must be disseminated

PROGRESS ON EDUCATIONAL ISSUES

- A Texas based collaborative effort has been created among four institutions – TACNSE.
 - Rice University, Texas State University, University of Texas – Tyler, UT Health Science Center-Houston.
- OSHA grant was the first to fund development of educational materials specific to nano safety training.
- We are reaching out to schools across the country, but we can not find everyone.
- **We need institutions to contact us to increase the reach of the collaboration.**

ONE-STOP SHOP FOR NANOEHS INFO

The screenshot shows the homepage of the International Council on Nanotechnology (ICON). At the top left is the ICON logo with the tagline "A partnership for nanotechnology stewardship and sustainability". To the right are logos for "GoodNanoGuide" and "nanoEHS VIRTUAL JOURNAL". Below these are logos for "RICE UNIVERSITY" and "CEN". A navigation menu includes "Join Us", "About", "Newsroom", "Working Groups", "Projects", "Resources", "Virtual Journal", and "Events". A search bar is located on the right with a "SEARCH" button. A central banner features images of a globe, a scientist, a meeting, and a molecular model. The main content area is divided into three columns:

- News Digest** (RSS, Twitter):
 - [Archives](#)
 - Comparison of the Toxicity of Silver, Gold and Platinum Nanoparticles in Developing Zebrafish Embryos (Meridian Institute)
[Meridian News Release](#)
[EHS Database Entry](#)
18 June 2010
 - Taking the NanoPulse -- Toxic Substance Meets Poison Thinking (Industry Week)
- Items of Interest** (RSS, Twitter):
 - [Archives](#)
 - Webinar - July 9, 2010 - Inviting US national interested parties for input on Draft CEN/ISO TS Labeling of manufactured nano-objects
[Webinar Information and Registration](#)
17 June 2010
 - Just how risky can nanoparticles in sunscreens be? Friends of the Earth respond (2020 Science)
- GoodNanoGuide**
 - NanoEHS Database
 - EHS Database Analysis Tool
 - ICON Backgrounders
 - ICON Reports
 - Current Practices Survey
 - Research Needs Assessment
- ICON News** (RSS, Twitter):
 - [Archives - Event](#)
 - [Archives - News](#)
 - Nanotechnology and Public Health: A free webinar (ICON Blog)
[ICON Blog Post](#)

<http://icon.rice.edu>

BUSINESS

- With Unknowns, we must be proactive.
- Not looking for ISSUES is asking for litigation.
- Developing future products must consider any potential impact on people and environment.
- Organizations must have plans in place to address contingencies.
- KEY POINT: Medical testing can take over 5 years. The average lifespan of a start up is ~ 2 years.
- We must take action NOW!



BUSINESS

- Either businesses will take the initiative or there will be “decreed” Governmental regulation.
- Emerging companies need a means of accessing all the appropriate information. GoodNanoGuide addresses some of the needs.
 - <http://goodnanoguide.org/tiki-index.php?page=HomePage>
- There is a need for the creation of an organization that permits focusing research on generalized current issues, e.g., NDCC, CAM-I, or a consortia – a cross cutting organization.

NDCC is an Aerospace Consortium, CAM-I is a business process organization.

NANO-SAFETY ELEMENTS



All Elements are Needed



Without the Keystone

Understanding nanomaterial properties is the Keystone to applying nanotechnology.

Nothing useful is Left



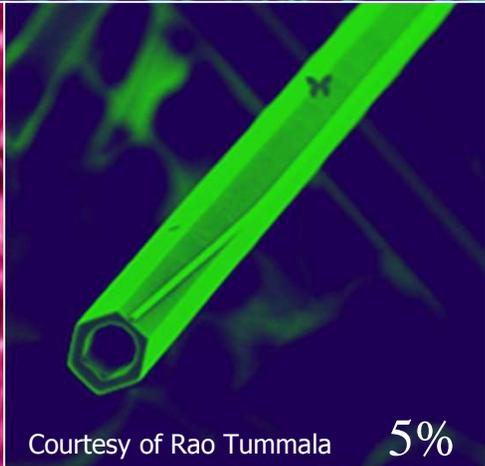
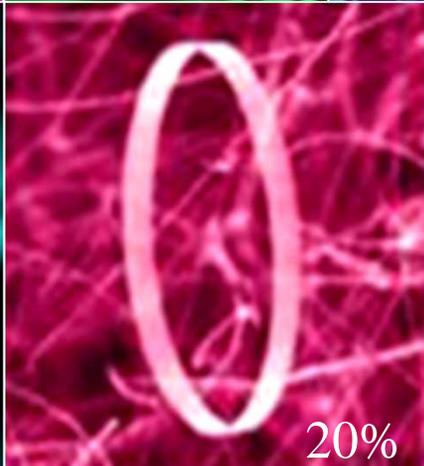
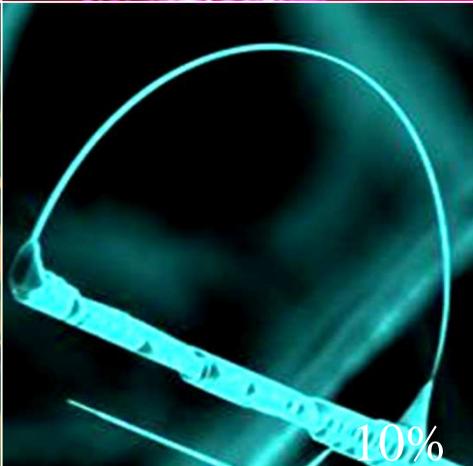
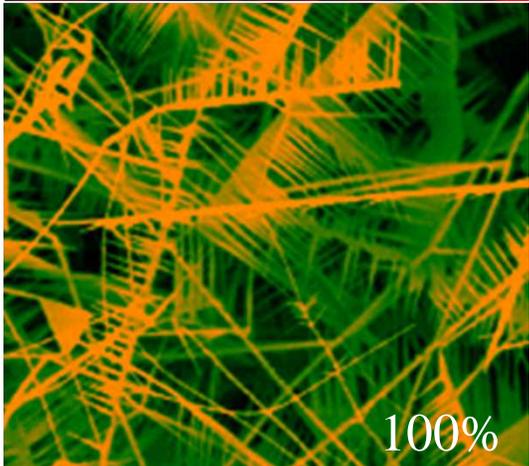
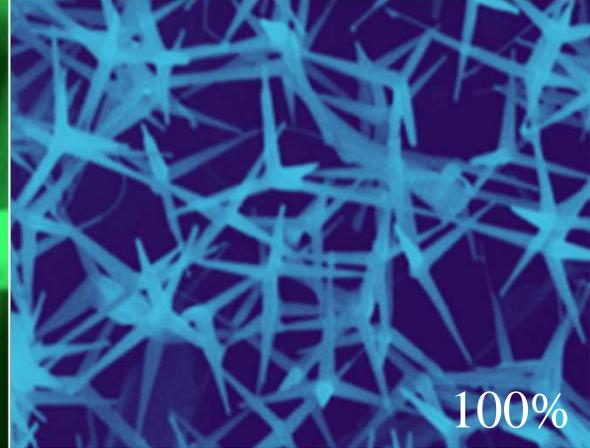
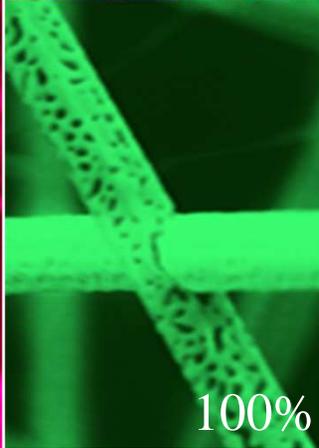
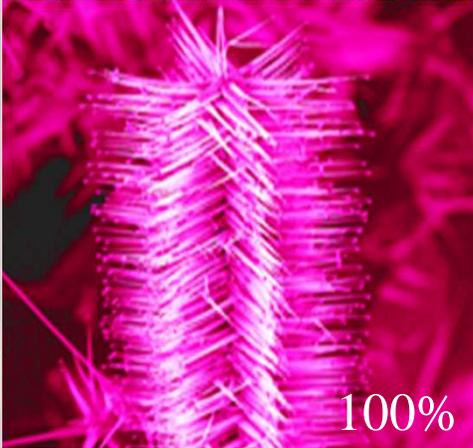
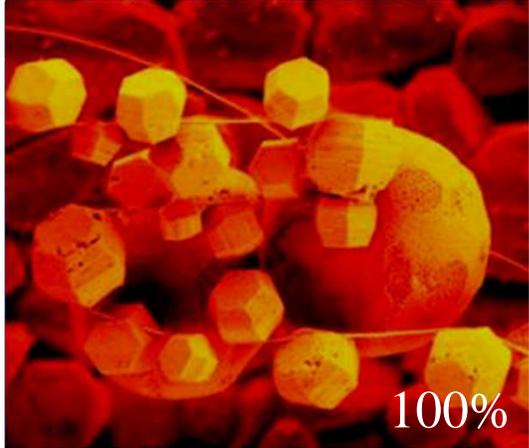
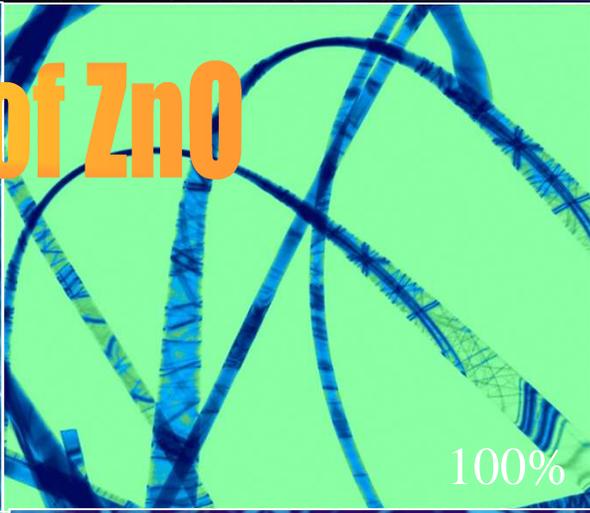
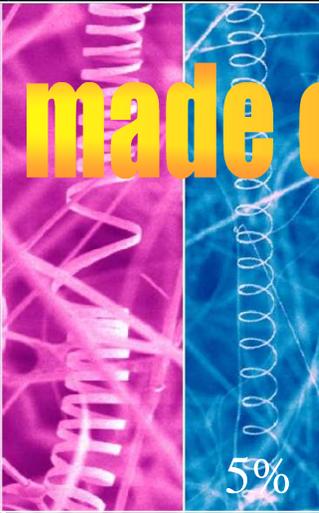
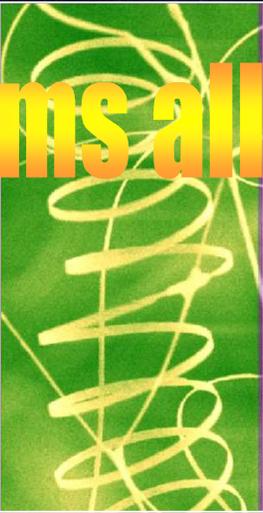
NANOMATERIAL PROPERTIES

- Theoretical and experimental results indicate surprising findings
 - 13 atoms of Ag has a magnetic moment [Theory], and 13 atoms of Pt have shown a magnetic moment [Experiment]
- Materials in nano realm are unique and different
 - Transition metal in five different states: as hydrated atom; metal complexed in a small protein; metal adsorbed to surface on 1nm mineral particle; metal adsorbed to surface of 20nm particle; the same except to a 200nm particle.¹
- Crystal orientation preferences – size matters
 - $\text{CeO}_2 < 10\text{nm}$ habit of truncated octahedron with {100} and {111} faces. $\text{CeO}_2 > 10\text{nm}$ shifts toward {111} octahedron.²
 - The conductivity of copper below 50 nm is a function of crystalline orientation and grain boundaries.
- Distributions of nanoparticles are challenging to determine.
 - Complicating the issue is that portion of the distribution that causes observed effects is not known.
- AND, we really don't know all the possibilities

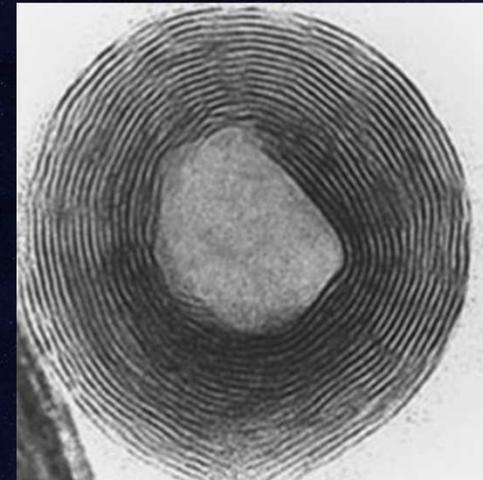
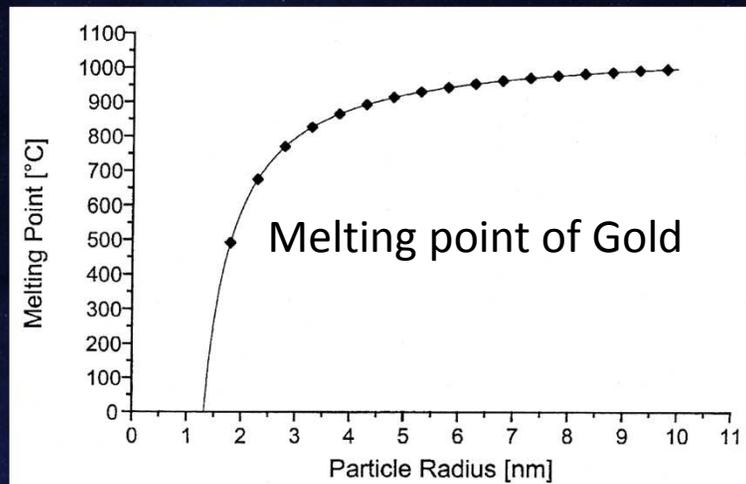
1 - Hochella, Michael F. Jr.. Nanogeoscience: From Origins to Cutting Edge Applications. December 2008 issue. Vol. 4, pp. 373-379.

2 - Waychunas, Glenn A., Hengzhong Zhang. Structure, Chemistry, and Properties of Mineral Nanoparticles. December 2008 issue. Elements. Vol. 4, pp381-387.

Various Forms all made of ZnO



KNOWN MATERIAL PROPERTIES?



Known Properties



Color as a function of size

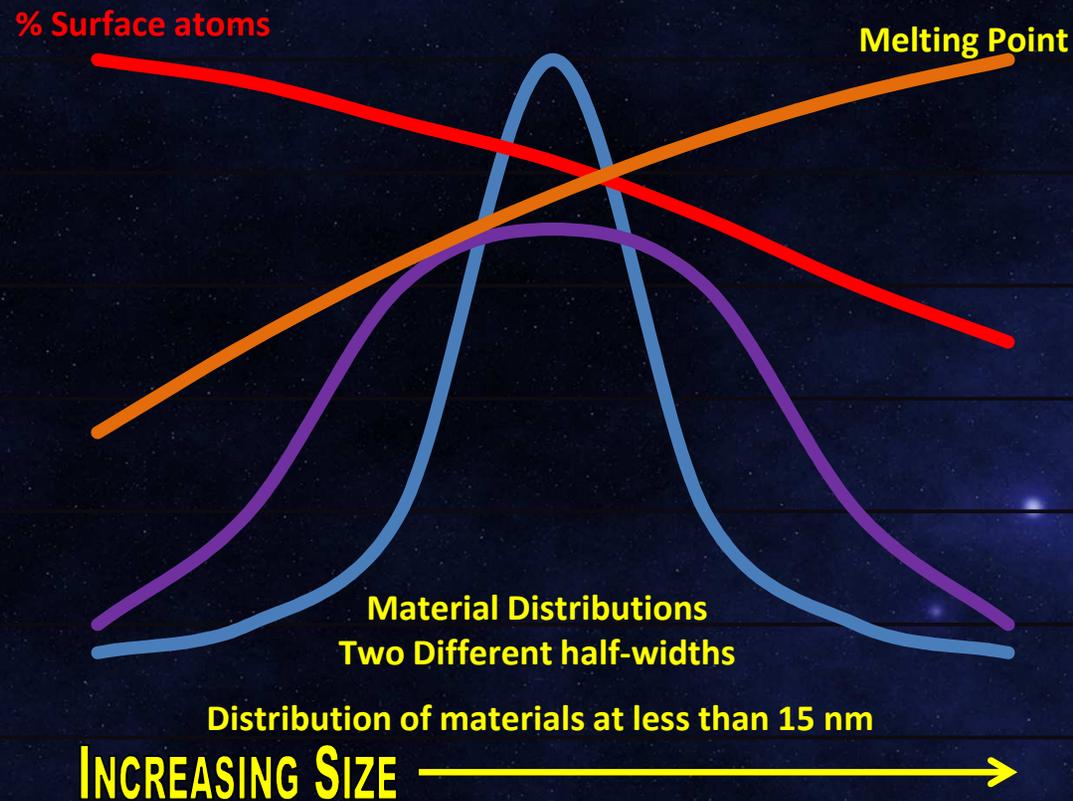
Inorganic fullerene-like nanostructures
Withstand 250 tons per square centimeter



Magnetic Materials – 13 atoms

Silver properties reported May 30, 2006 in NanoTechWeb.
Platinum experiments reported by University of Stuttgart.

NANOMATERIALS' REALITY



According to current regulations, the two distributions will react identically. Obviously, there is a lot of work needed to find out the actual situation.

THE CHALLENGE

Our current efforts



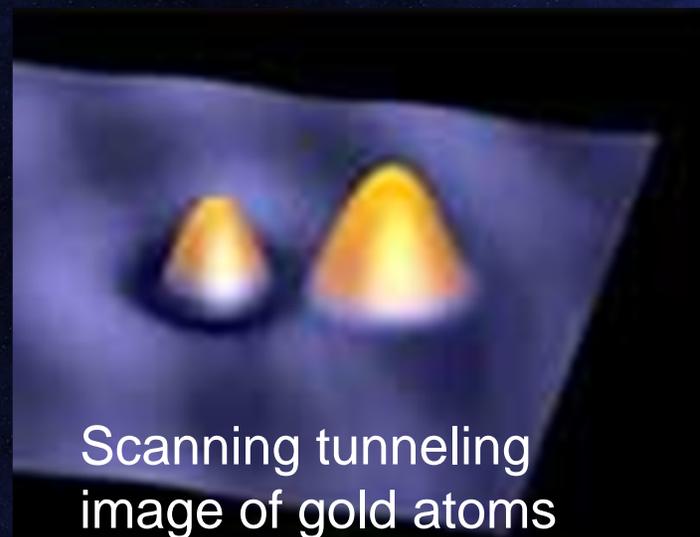
In understanding safety

This is the immediate need!

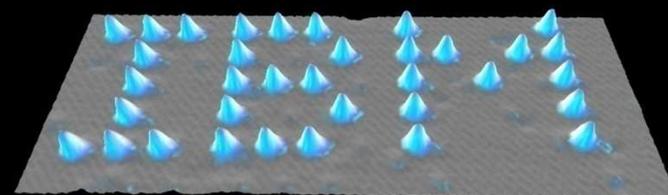


SHEER NUMBER OF CHEMICALS WILL BECOME TRULY DAUNTING

- OSHA has 40 year-old standards for 600 chemicals
- **62,526,489** chemical sequences, Chemical Abstract Service on 02/23/11
- 112 known elements
- 10^{200} to 10^{900} distinct nanoscale particle possibilities



Scanning tunneling image of gold atoms



Writing with atoms (Eigler, 1990)

CONTROL BANDING IS A POSSIBILITY

A. D. Maynard

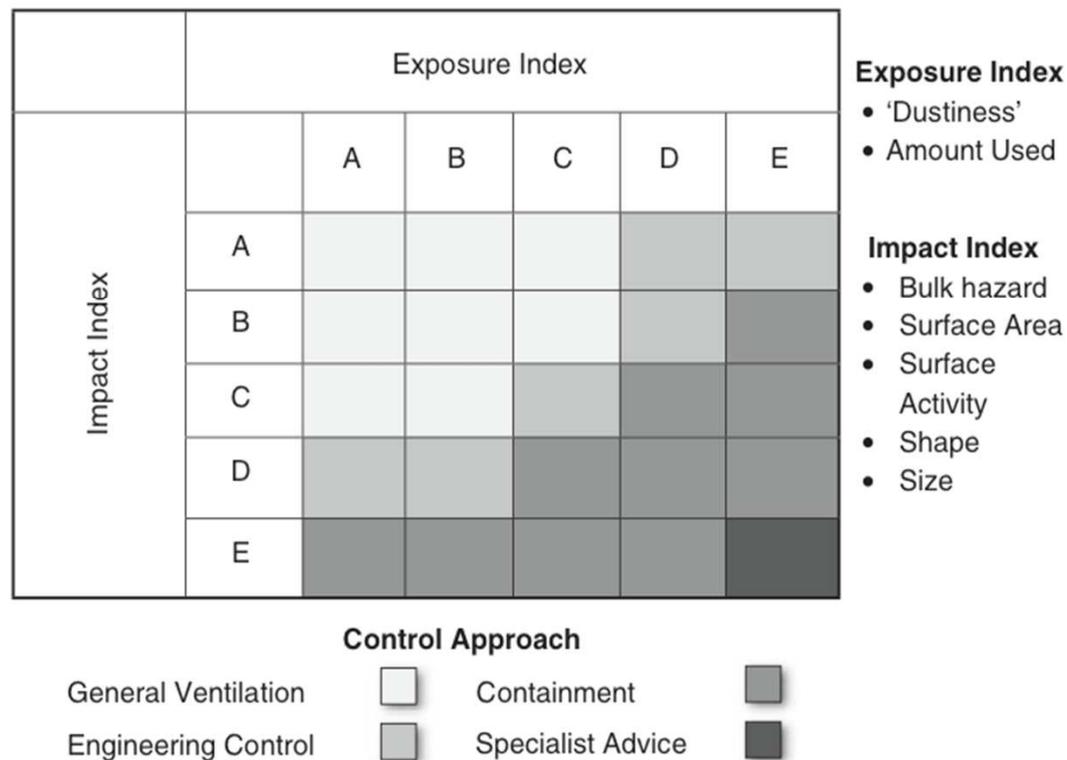


Fig. 7. Conceptual interpretation of how a control-banding type of approach might be applied to airborne engineered nanomaterials.

Control Banding was proposed for nanomaterials in 2007 (Maynard)

APPLYING BANDING TO NANO?

- Furthermore, given the current state of knowledge on manufactured nanomaterials, it is highly likely that many years will be needed before we know precisely which types of nanomaterials and associated doses represent a real danger to humans and their environment. Indeed, the assessment of potential health effects following exposure to a chemical must take into account the extent and duration of exposure, the biopersistence, and inter-individual variability, all subjects on which we have practically no knowledge for the field of nanomaterials.
- It is therefore extremely difficult to conduct a quantitative risk assessment in most work situations involving nanomaterials with the currently available methods and techniques.

IT WILL BE CHALLENGING – AT BEST

RESOLVING MATERIALS' ISSUES

- Our current understanding of nanomaterial properties is piecemeal, at best.
- A nano equivalent of the Materials Handbook is needed, but we do not know what properties should be investigated and categorized.
- **I propose to hold a meeting(s) of top researchers to prioritize which investigations should be done first.**
- **I am looking for organizations to collaborate in developing this effort.**

A deep blue-toned image of a starry night sky. The background is filled with numerous small, bright blue and white stars of varying sizes. In the center, there is a larger, more diffuse and glowing blue nebula or galaxy core. The overall effect is a vast, cosmic scene.

WHAT NEXT?

OBSERVATIONS

- The entire field is a work-in-progress.
- Current understanding of nanomaterial risks has more holes than a Swiss cheese¹.
- Engineered nanomaterials are accomplished shape-shifters¹.
- Our current knowledge base provides directions but not absolutes.
- **It is necessary to address the issues in a scientific manner.**

¹Adapted from "Ten things everyone should know about nanotechnology safety" by Andrew Maynard, http://community.safenano.org/blogs/andrew_maynard/archive/2009/08/31/ten-things-everyone-should-know-about-nanotechnology-safety.aspx

WHERE TO FROM HERE?

- With unknowns, we must be proactive
- In many cases, we don't know what we are looking for!
 - Then the question is: "How do we proceed?"
 - While we don't have all the answers, we can take a number of precautions
- The focus of our actions must be to:
 - Keep yourself safe
 - Keep your colleagues safe
 - Keep the general populace safe
 - Keep the facilities safe
 - Keep the environment safe

WHAT DO WE NEED?

- Increased Educational efforts at two- and four-year schools
 - Has begun to spread
- Partnership focusing on investigating critical areas and developing procedures
- Sources for information dissemination to the general public
 - Some, like ICON, are available
- Links to reputable suppliers in areas related to NANO-SAFETY

CONCLUSIONS

- Current Status of Technology
 - Many concerns, piecemeal approach to solutions
- Key Elements of Nanotechnology
 - Material Properties, People and the Environment, Education, Business
- What Next?
 - Systematic approach to investigations
 - Collaboration among all interested organizations

RECOMMENDATIONS

- This presentation is a Call to Action
- A systematic approach to the identification of materials is required.
- The Educational Community needs to focus additional resources to address the issues.
- The Business Community needs to ensure the safety of workers and products.
- Business, Academia, and Government need to coordinate addressing the solution of the issues.

INTERESTED IN BEING PART OF THE SOLUTION?

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PRESENTATION AVAILABLE:

<http://www.nano-safety.info/IEEENano2011.pdf>

