

**Chemical Industry**  
**VISION2020**  
**Technology Partnership**

**“NNI-Chemical Industry Consultative Board  
for Advancing Nanotechnology (CBAN)”**

**Donald B. Anthony, Sc.D.  
President & Executive Director  
Council for Chemical Research  
Washington, DC**

**AIChE National Meeting  
November 3, 2005  
Cincinnati, OH**

# Outline

- **CCR/Vision2020**
- **Nanotechnology Market Opportunities**
- **Accomplishments**
  - **Nanomaterials R&D Roadmap**
  - **Vision2020 Steering Committee**
  - **Benefits Study**
  - **NNI-Chemical Industry CBAN**
  - **ESH Priorities**
  - **Research Priorities**
  - **Collaboration with other industries**
    - **Semiconductor**
    - **Forest Products**

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# Council for Chemical Research

**The Council for Chemical Research (CCR) was created in 1979 to improve trust and collaboration between the public and private research sectors.**

***“CCR's purpose is to benefit society by advancing research in chemistry, chemical engineering, and related disciplines through leadership collaboration across discipline, institution, and sector boundaries.”***

# CCR Membership

- **Represents research leadership in 3 sectors**
  - Industrial (27 corporations)
  - Academic (134 research universities)
  - Governmental (10 national labs and 1 international affiliate)
- **Organized as a “not-for-profit”**
  - Governing Board
  - President & Executive Director
  - Action Networks

# CCR Values and Goals

## Core Values

- Chemical research is essential to progress
- Research is central to education and key to discovery and innovation
- Chemical science and engineering impacts many disciplines
- Collaborative approaches deliver maximum leverage

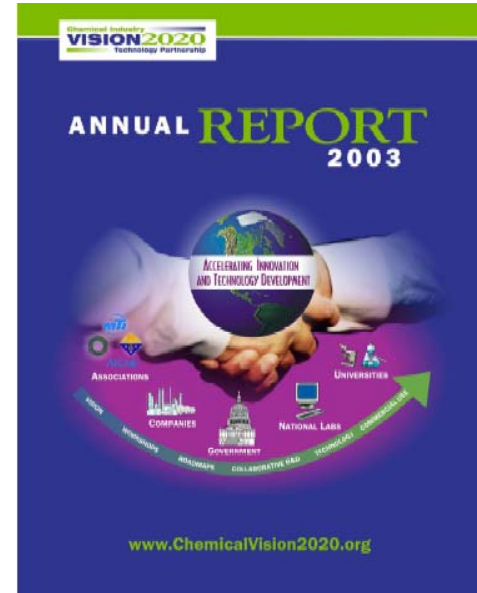
## Goals

- Advance Research Collaboration
- Advocate Research Investment
- Enrich Graduate Education
- Address Long-Range Issues

# Vision 2020

In 1997, the U.S. DoE in concert with the chemical industry represented by CMA (now ACC), SOCMA, ACS, AIChE, and the CCR created Vision 2020 *“to outline a path of research, development, and technology demonstration for the chemical industry to continue as the global leader into the next century.”*

In 2003, nearly 150 industry, academic and government organizations participated in Vision 2020 activities



# **Chemical Industry** **VISION2020** **Technology Partnership**

An industry-led program to accelerate technology development and innovation by leveraging technical and financial resources

- Air Products & Chemicals Inc.
- BP
- Cargill
- Ciba Specialty Chemicals
- The Dow Chemical Company
- E.I. du Pont de Nemours and Company
- Eastman Chemical Company
- General Electric Company
- Honeywell
- Praxair, Inc.
- Rohm and Haas Company
- American Chemical Society
- American Institute of Chemical Engineers
- Council for Chemical Research
- Materials Technology Institute

Visit us at

[www.ChemicalVision2020.org](http://www.ChemicalVision2020.org)

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# Nanomaterials Opportunity

**Nanomaterials offer the potential for unprecedented material performance that could**

- **Solve major societal problems**  
(e.g., energy, medicine, environment, manufacturing, communications, computing, and security)
- **Energize the economy for decades**
  - Revitalize existing businesses
  - Boost competitiveness globally
  - Create entirely new industries

*The race for global leadership  
in nanotechnology is underway.*

# Market Opportunities

- **NNI market estimates**

– Process	<b>\$100 billion</b>
– Power	<b>\$45 billion</b>
– Electronics	<b>\$300 billion</b>
– Medical	<b>\$180 billion</b>
– Materials	<b><u>\$340 billion</u></b>
<b>Total</b>	<b>\$965 billion</b>

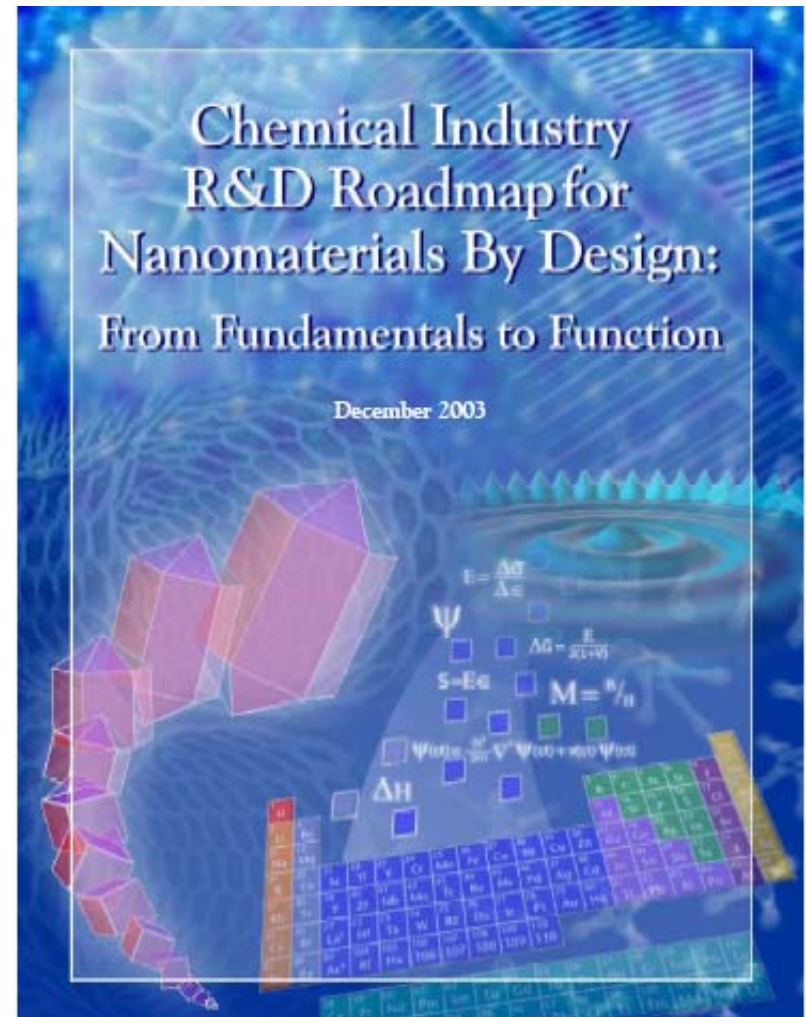
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# R&D Roadmap for Nanomaterials

[www.ChemicalVision2020.org](http://www.ChemicalVision2020.org)

- NNI and DoE partnered with Vision 2020 to develop an R&D roadmap
- Objective to provide industrial perspective on “Nanomaterials by Design”
- Over 100 participants in workshop (Oct. 2002)
- Roadmap published (Dec. 2003)



# Priority Research Requirements

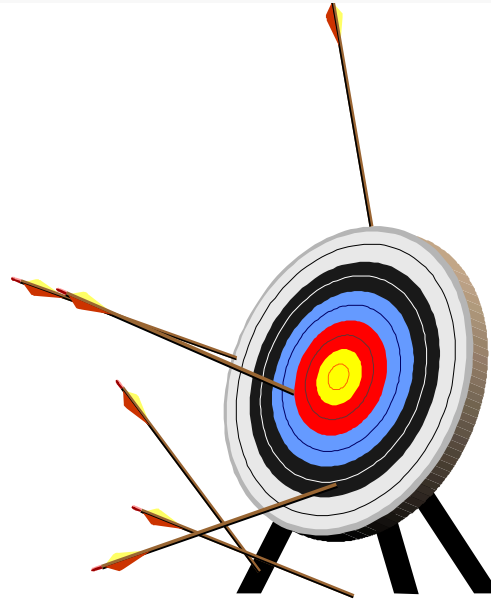
- Report identified over 30 priorities in 9 categories
- Specific recommendations were offered to bolster the effectiveness of the strategy
- Ultimate goal: *“accelerated commercialization of innovative technology based on nanomaterials”*



# A New Strategic Approach

**Discovery-based  
Product  
Development**

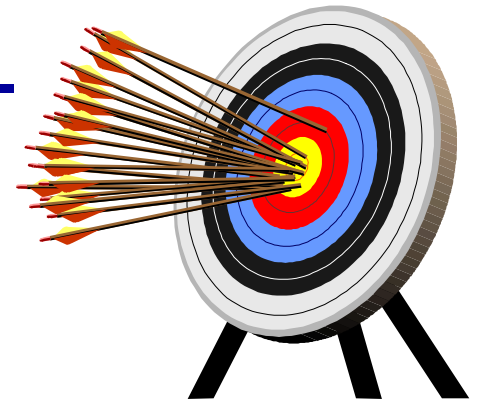
**Time**



**Nanomaterials  
By Design**

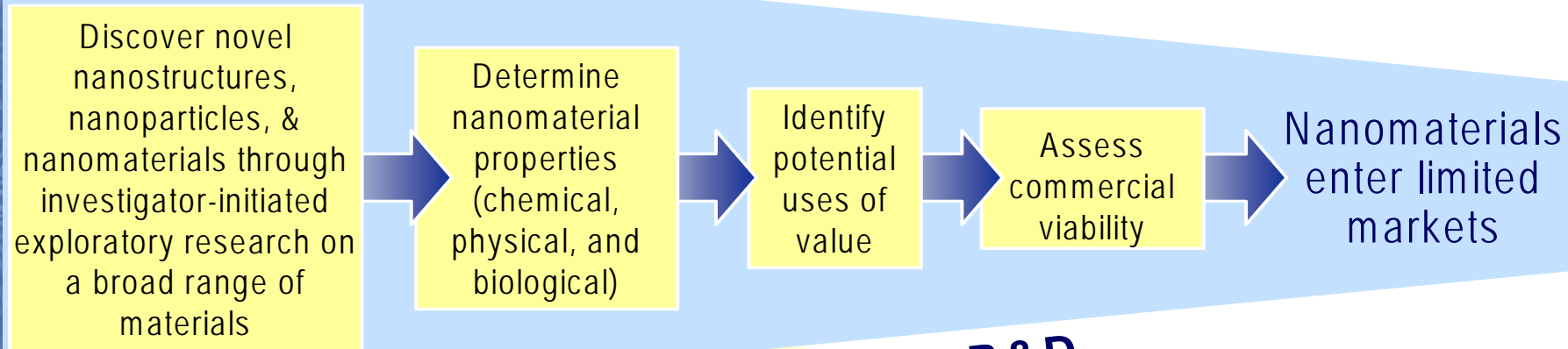
**Application-  
based  
Problem  
Solving**

**Time**

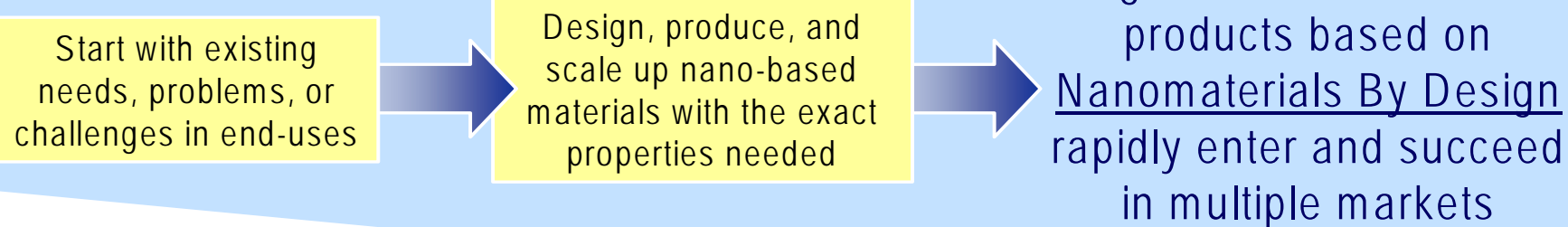


# The Roadmap Vision: Nanomaterials by Design

**TODAY:** Discovery-based Science & Product Development

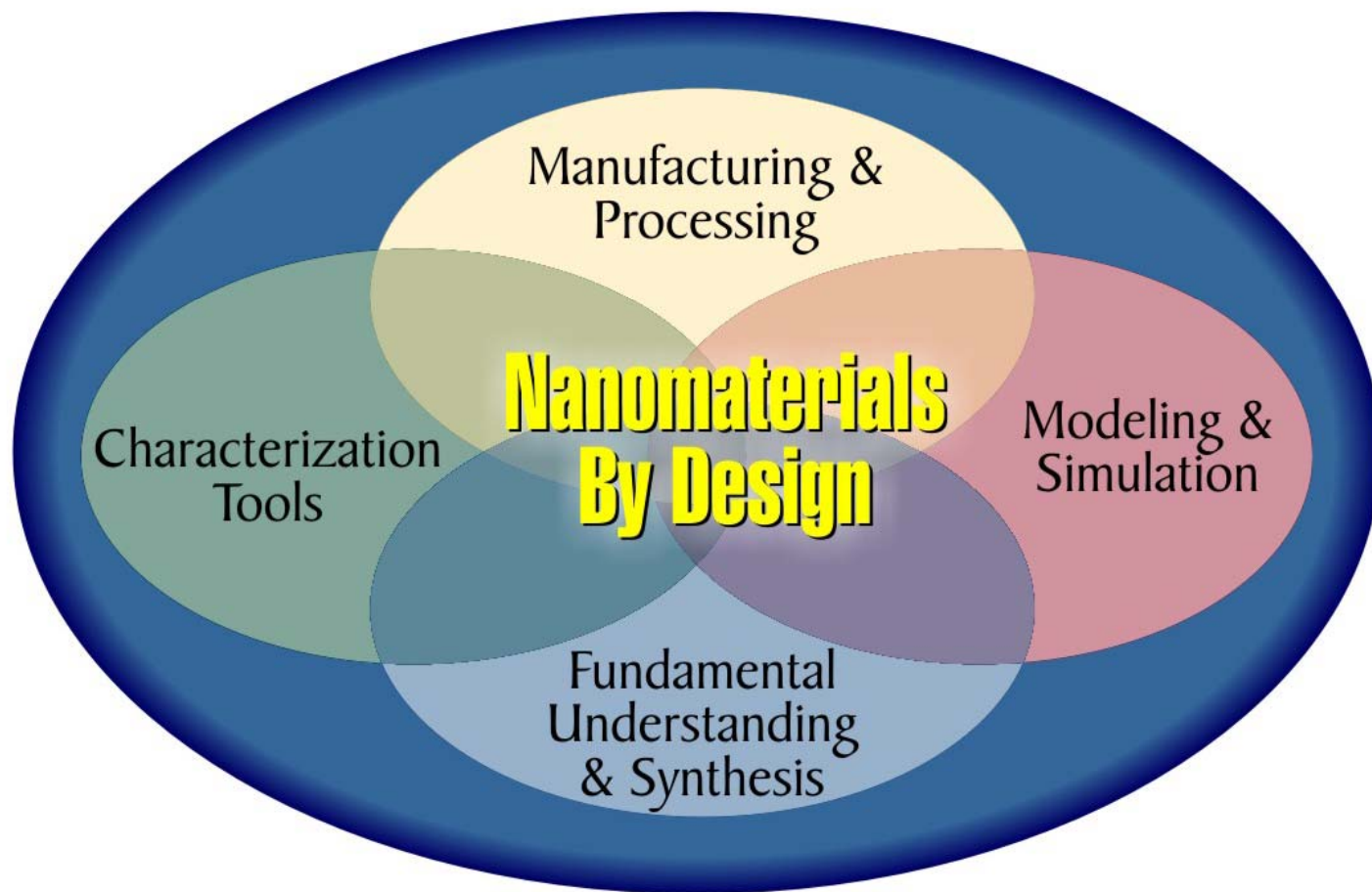


**Driving Change in R&D**



**FUTURE:** Application-based Problem Solving

# Implementation of Roadmap Strategy: Multidisciplinary, Interdependent, R&D Integrated From Fundamentals to Function



# R&D Strategy

Environment,  
Safety &  
Health

Standards &  
Informatics

Knowledge &  
Technology  
Transfer

Education  
& Training

Infrastructure  
& Enabling  
Resources

Manufacturing  
& Processing

Characterization  
Tools

Modeling &  
Simulation

Fundamental  
Understanding &  
Synthesis

*Cultural Change in the Way Science and Technology Are Pursued*

Accelerated Market Entry  
of Products Based on  
Nanomaterials By Design

# Recommendations

- ❑ Implement effective protocols to assure health and safety in nanomaterial R&D, production, transport, use, and disposal.**
- ❑ Invest significantly and concurrently in the priority R&D areas—fundamentals, synthesis, manufacturing, characterization, and modeling.**
- ❑ Facilitate intensive coordination and integration among these interdependent and multidisciplinary research areas.**
- ❑ Encourage universities and government laboratories to conduct R&D that will systematically build an understanding of nanoscale fundamentals to enable application-based problem solving.
- ❑ Provide both large and small companies increased access to U.S. government funding for fundamentals in addition to applications R&D.

# Recommendations (continued)

- ❑ Implement new strategies to build a shared-knowledge infrastructure.
- ❑ Provide industry access to national user facilities with equitable fees and ownership of intellectual property.
- ❑ Establish intellectual property policies at universities and government laboratories that create a more favorable climate for partnering with companies and for accelerating commercialization.
- ❑ Develop standards needed for research and commerce.
- ❑ Increase government funding in all physical sciences underlying nanotechnology.
- ❑ **Work with NSET to develop effective means of collaboration between NSET and the U.S. chemical industry to foster effective roadmap implementation.**
- ❑ **Encourage NSET to adopt this roadmap as a core strategy for its Grand Challenge in Nanomaterials By Design.**

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# Implementing the Roadmap

## **Chemical Industry Vision2020 Implementation Team**

- Alastair Hill, Cheryl Sabourin, David DePaoli, Don Anthony, Emory Ford, Guy Steinmetz, Hank Whalen, Jack Solomon, Douglas Rundell, Sharon Robinson, Steve Andrews, Timothy Donnelly

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# Vision2020/LANL Benefits Study

- **Report titled “Some Examples of the Economic Effect of Nanomaterials Produced by the Chemical Industry”**
- **Study conducted by Los Alamos National Laboratory**
- **Methodology**
  - **Identify nanomaterials impact (e.g., cost savings, yield improvements, etc.) for applications in 7 different industries**
  - **Use REMI model to estimate economic effects**
- **Results**
  - **Energy Savings = 0.5 to 1.1 quads/yr**
  - **Value Creation = \$10-20 B/yr**

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# **NNI-Chemical Industry CBAN**

- **Consultative Board for Advancing Nanotechnology (CBAN) in the chemical industry**
- **Agreement on March 12, 2004**
- **Purpose:**
  - **Joint planning and support of collaborative R&D**
  - **Identification and promotion of new R&D**
  - **Expansion of nanotechnology R&D in industry and academia**
  - **Enhanced communication**
- **Organization**
  - **Consultative board or steering group**
  - **2 working groups (research focus areas & ESH issues)**

# Board and Working Groups

<b>Mike Roco, NSF</b>	<b>Jim Murday, DoD</b>	<b>Brian Valentine, DoE</b>	<b>Bob Shull, NIST</b>
<b>Don Anthony, CCR</b>	<b>Jack Solomon, Praxair</b>	<b>John Carberry, DuPont</b>	<b>Katie Hunt, R&amp;H</b>
<b>Don Anthony, CCR Lead</b>	<b>Jim Murday, DoD Lead</b>	<b>Emory Ford, MTI Lead</b>	<b>Barbara Karn, EPA Lead</b>
<b>Steve Andrews, Ciba</b>	<b>Bob Shull, NIST</b>	<b>Bronek Drozdowicz, Air Products</b>	<b>Don Marlow, FDA</b>
<b>Rajeev Gorowara, DuPont</b>	<b>John Miller, DoE</b>	<b>Tom Landry, Dow</b>	<b>Jan Miller, DoE</b>
<b>Douglas Rundell, BP</b>	<b>Brian Valentine, DoE</b>	<b>David Warheit, DuPont</b>	<b>Nora Savage, EPA</b>
<b>Cheryl Sabourin, GE</b>	<b>John Sargent, DoC</b>	<b>Al Wiedow, Ciba</b>	<b>Mike Roco, NSF</b>
<b>Hank Whalen, ACS</b>	<b>Mike Roco, NSF</b>	<b>Jack Solomon, Praxair</b>	<b>John DiLoreto, ACC</b>
<b>Bill Grieco, R&amp;H</b>	<b>Art, Ellis, NSF</b>	<b>Clayton Teague, NNCO</b>	<b>Steven Kinsler, Intel</b>

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# Accomplishments: ESH Working Group

- **Developed recommendations on R&D directions in three areas:**
  - **Toxicity of Nanomaterials**
  - **Measurement and Detection of Nanomaterials**
  - **Worker Protection and Industrial Hygiene**
- **Coordinated effort with Semiconductor Research Corporation CWG5 to define common priority items**
- **Will present at NEHI (Nanotechnology Environmental and Health Implications Working Group of the NSET subcommittee) meeting, November 7.**
- **Supported development of a nanotechnology ESH literature database**

# Nanomaterials ESH Literature Database

AUTHOR	TITLE	JOURNAL	PMID
	Nano's Troubled Waters: Latest toxic warning shows nanoparticles cause cancer	Genotype, Thursday, 1 April 2004	
Alberti G, Casciola M, Pica P	Preparation of nano-structured polymeric proton conducting membranes for fuel cells	Ann N Y Acad Sci. 2003 Mar;984:208-25. Review.	PMID: 12711111
Allemand E, Guillet J			PMID: 12711111
Allemand E, Guillet J			PMID: 12711111
Allen TM, Cullis			PMID: 12711111
Alonso MJ, Sanjaume M			PMID: 12711111
Alyaudtin RN, R			PMID: 12711111
Anderson SA, R			PMID: 12711111
Arango MA, Ca			PMID: 12711111
Arango MA, Ca			PMID: 12711111
Araujo I, Loben			PMID: 12711111
Araujo I, Loben			PMID: 12711111
Arbab AS, Bash			PMID: 12711111
Arbab AS, Yocu			PMID: 12711111
Arbos P, Campa			PMID: 12711111
Arnold T, Zorn T			PMID: 12711111
Arslan-Alaton I,			PMID: 12711111
Atanasiu R., Ra			PMID: 12711111
Atanasiu R., Ra			PMID: 12711111
Aylott JW.,			PMID: 12711111
Bae E, Choi W.			PMID: 12711111
Balint I, Miyazak			PMID: 12711111
Barichello JM, M			PMID: 12711111
Barratt G.,			PMID: 12711111
Barratt GM.,			PMID: 12711111
Barroug A, Kuhr			PMID: 12711111
Barroug A, Kuhr			PMID: 12711111
Beck P, Kreuter			PMID: 12711111
Bennett WD.,			PMID: 12711111
Bhadra D, Bhadra S, Jain F	Pegology: a review of PEG-ylated systems.	Pharmazie. 2002 Jan;57(1):5-29. Review.	PMID: 12711111
Blagoeva PM, Balansky RN	Diminished genotoxicity of mitomycin C and farnorubicin included in polybutyl methacrylate	Mutat Res. 1992 Jul;268(1):77-82.	PMID: 12711111
Boehm AL, Martinon I, Zern	Nanoprecipitation technique for the encapsulation of agrochemical active ingredients	J Microencapsul 2003 Jul-Aug;20(4):433-41	PMID: 12711111

- **Generated by Borges et al., ORNL**
- **Most comprehensive public database**
  - **1,342 records for pertinent articles on ES&H issues related to nanomaterials**
- **Transferred to Rice Univ. CBEN**
  - **Web-accessible through ICON** (International Council on Nanotechnology) **site**
    - <http://icon.rice.edu/research.cfm>
  - **Living database**
    - **On-line comment/input capability**
- **Current focus of ICON efforts**
  - **Generated roadmap for improving and expanding**
  - **Currently summarizing existing information**

# Database Impact – Prominently Featured on NNI Homepage

Address  <http://www.nano.gov/>

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## NATIONAL NANOTECHNOLOGY INITIATIVE



The National Nanotechnology Initiative (NNI) provides a multi-agency framework to ensure U.S. leadership in nanotechnology that will be essential to improved human health, economic well being and national security. The NNI invests in fundamental research to further understanding of nanoscale phenomena and facilitates technology transfer.

Leading to a Revolution in Technology and Industry

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[Government Dept./Agencies](#)  
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### Nano Coalition Unveils Environmental, Health and Safety Database

The International Council on Nanotechnology (ICON) and Rice University's Center for Biological and Environmental Nanotechnology (CBEN) today launched the world's first online database of scientific findings related to the benefits and risks of nanotechnology. The database can be accessed by [clicking here](#). This environmental health and safety database marks the first effort to integrate the vast and diverse scientific literature on the impacts of nanoparticles, which are tiny pieces of matter with dimensions measuring between 1-100 nanometers and containing between tens and thousands of atoms. The database is the result of the collected efforts of Rice researchers, the chemical industry and the U.S. Department of Energy. [Read more.](#)

### Nano Currents

- [NCI Alliance for Nanotechnology in Cancer](#)
- [Nanotubes Inspire New Technique For Healing Broken Bones](#)



- [Debut of Nanooze - The Science Web Magazine for Kids](#)
- [Nanoscale "Cell Within A Cell" Delivers Multiple Therapies that Kill Tumors](#)
- [NNI Environment and Health Safety Research](#)

### NNI Workshop Report on Nanobiotechnology Now Available



# Database impact – Acknowledged Broadly Since Aug. 18 Press Release

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## Nanotechnology Database Focuses on Safety Questions

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▶ Consulates  
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## Nano coalition unveils environmental, health and safety database

August 19, 2005 [Latest News By E-mail](#) [Print this news](#)

The International Council on Nanotechnology (ICON) and Rice University's Biological and Environmental Nanotechnology (CBEN) today launched a database of scientific findings related to the benefits and risks of nanotechnology. The database can be accessed at <http://icon.rice.edu/research.cfm>

**Explore Nanotechnology** **Dust Monitors and more**

Stanford Nanotechnology courses. Latest portable real time Monitors for indoor and outdoor use. Leading experts.

[Ads by Goooooogle](#)

This environmental health and safety (EHS) database marks the first effort to integrate the vast and diverse scientific literature on the impacts of nanoparticles, which are tiny pieces of matter with dimensions measuring between 1 and 100 nanometers and containing between tens and thousands of atoms. (One nanometer is one-billionth of a meter or approximately 60,000 times smaller than the width of a human hair.) The database is the result of the collected efforts of Rice researchers, the chemical industry and the U.S. Department of Energy. This database will be updated and enhanced over the next year.

Dennis Kucinich

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## The International Council on Nanotechnology (ICON)

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Author	Message
<b>Claudia Slate</b> Site Admin Joined: 14 Oct 2004 Posts: 3668 Location: South Dakota	<p><b>The International Council on Nanotechnology (ICON)</b>  <a href="http://icon.rice.edu/research.cfm">http://icon.rice.edu/research.cfm</a> - effort to integrate the vast and diverse scientific literature on the impacts of nanoparticles. The database can be accessed at <a href="http://icon.rice.edu/research.cfm">http://icon.rice.edu/research.cfm</a></p> <p>Posted: +0000, Fri Aug 19, 2005 10:42 PM</p> <p>The International Council on Nanotechnology (ICON) and Rice University's Center for Biological and Environmental Nanotechnology (CBEN) today launched a database of scientific findings related to the benefits and risks of nanotechnology on August 19, 2005.</p> <p>This environmental health and safety (EHS) database marks the first effort to integrate the vast and diverse scientific literature on the impacts of nanoparticles, which are tiny pieces of matter with dimensions measuring between 1 and 100 nanometers and containing between tens and thousands of atoms. (One nanometer is one-billionth of a meter or approximately 60,000 times smaller than the width of a human hair.) The database is the result of the collected efforts of Rice researchers, the chemical industry and the U.S. Department of Energy. This database will be updated and enhanced over the next year.</p> <p>The database can be accessed at <a href="http://icon.rice.edu/research.cfm">http://icon.rice.edu/research.cfm</a></p>

• Coming soon – C&EN article?

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# Accomplishments:

## Research Focus Area Working Group

- **Defined priority areas**
  - Coatings, catalysts, high-strength materials, sensors
- **Participated in Office of Naval Research solicitation on nanomanufacturing** (FY05 MURI Topic #13)
  - Explicitly addresses issues identified in the *Nanomaterials by Design* Roadmap
- **Developed weighting criteria that reflect industries needs for review of proposals to ONR solicitation and future solicitations**
- **Communicated research priorities at NNI Research Directions II meeting, Sept 8-10**
  - Workshop purpose – define top research areas for NNI five-year plan
  - Presentations by Katie Hunt & Jack Solomon
  - Handouts of roadmap & weighting criteria

# Weighting Criteria Reflect Industrial R&D Needs

Roadmap Priority		General (100 total)	MURI (80 total)
Fundamental Understanding and Synthesis	Develop a fundamental understanding of structure-property-processing relationships at the nanoscale.	5	5
	Develop models, theories, and experimental validation of physics and chemistry at the nanoscale, including the kinetic and thermodynamic principles guiding synthesis and assembly.		
	Develop new paradigms for creating nanoscale building blocks based on understanding the physics and chemistry at the nanoscale.	12	12
	Develop new design strategies and paradigms for the controlled assembly of nanocomposites and spatially resolved nanostructures with long-range order.		
	Develop new high-throughput screening methods to determine structure-property relationships.	3	3
	Determine nanomaterial performance at the laboratory scale.	0	0
	Develop a compendium of methods to synthesize and assemble nanomaterials that will perform per-determined functions in specific applications.	0	0
Manufacturing and Processing	Develop unit operations and robust scale-up and scale-down methodologies for manufacturing.	12	12
	Develop novel manufacturing techniques for hierarchical assembly.	6	6
	Develop dispersion and surface modification processes that retain functionality.	5	5
	Develop process monitoring and controls to achieve nanomaterial and product consistency.	5	5
	Develop processes to integrate engineered materials into devices while retaining nanoscale properties.	2	2
	Develop the ability to remove impurities from raw material precursors to meet application specifications.	0	0
Characterization Tools	Develop real-time characterization methods and tools needed for research and manufacturing.	10	10
	Develop the infrastructure essential to tool development and manufacturing.	5	0
Modeling and Simulation	Develop fundamental models to accurately predict nanostructure formation.	10	10
	Develop methods for bridging models between scales, from atoms to self-assembly to devices.	10	10
	Improve research infrastructure to support model advancement.	5	0
Environmental, Safety, and Health	Assess human health and environmental impact hazards.	0	0
	Determine exposure potentials for nano-sized materials.	0	0
	Establish handling guidelines for operations involving nanomaterials.	0	0
Standards and Informatics	Develop standard procedures for nanomaterials synthesis.	0	0
	Develop a set of reference materials for property measurement standardization.	2	0
	Develop standard methods for physical and chemical property evaluation.	2	0
	Develop computational standards to information processing and transfer for modeling and simulation.	0	0
	Develop standards for material evaluation in applications.	2	0
	Establish internationally recognized nomenclature standards.	4	0
	Establish the organizational infrastructure and other requirements to foster standardization and development of standards.	0	0
	Establish technology transfer policies that foster nanomaterial commercialization.	0	0
Knowledge and Technology Transfer	Build an infrastructure to encourage knowledge sharing in order to facilitate nanoscience understanding and foster near-term commercialization.	0	0
	Implement strategies to attract and prepare a workforce for nanomaterial research and manufacturing.	0	0
Education and Training	Promote public awareness of nanoscience and technology.	0	0
	Priorities to support R&D are addressed in other areas.	0	0
Infrastructure and Enabling Resources			

# **“Next Steps” Project**

**Goal: To provide a detailed implementation plan for the R&D Roadmap**

- Workshop held Feb 15 in Baltimore**
- Identified key industry needs over next five years and provided next level of detail to the roadmap**
- Special project team commissioned to identify appropriate agencies for each aspect and develop draft solicitations**

# Workshop Identified Priority R&D Needs for Nanotechnology Commercialization

## Nanoscience

### Synthesis and Assembly

Develop new paradigms to create nanoscale building blocks

Develop approaches for controlled assembly of nano-composites and nanostructures

### Characterization tools

Develop analytical tools for measuring and characterizing nanomaterials

### Modeling and Simulation

Develop models of nanomaterials processing and predict bulk properties of materials that contain nanomaterials

Bridge models between scales, from atoms to self-assembly to devices

## Nanotechnology

### Manufacturing & Processing

Develop unit operations and robust scale-up and scale-down methodologies for manufacturing

- Synthesis
- Separation
- Purification
- Stabilization
- Assembly

### Characterization tools

Develop real-time tools for measuring and characterizing nanomaterials, particularly online and in-process

**Chemical Industry Application Areas**  
Catalysts, coatings, ceramics, sorbents, membranes

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# **Semiconductor/Chemical Industry Cooperation on Research Needs**

- **Teams identified in July to develop specific needs in common research areas:**
  - **Fundamentals & Synthesis**
    - New design strategies
    - Scalable self assembly
  - **Characterization Tools**
    - Real-time characterization methods & tools
  - **Modeling & Simulation**
    - Multiscale modeling methods & tools
- **Workshop scheduled for Nov 29-30 to finalize recommendations**

# Forest Products R&D Strategy

CCR/Vision2020 participated in a recent Forest Products Industry workshop on a nanotechnology R&D roadmap which identified six areas of research focus:

1. Polymer composites and nano-reinforced materials
2. Self-assembly and biomimetics
3. Cell wall nanotechnology
4. Nanotechnology in sensors, processing, and process control
5. Analytical methods for nanostructure characterization
6. Collaboration in advancing programs and conducting research