Some Key Elements for Nanomaterial Exposure Assessment and Management to Advance Sustainable Manufacturing

EH&S Panel II Discussion

Workshop on Enabling the Carbon Nanomaterials Revolution

Gaithersburg, Maryland

March 1, 2011

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National Institute for Occupational Safety and Health

Morgantown, West Virginia

Some background about NIOSH

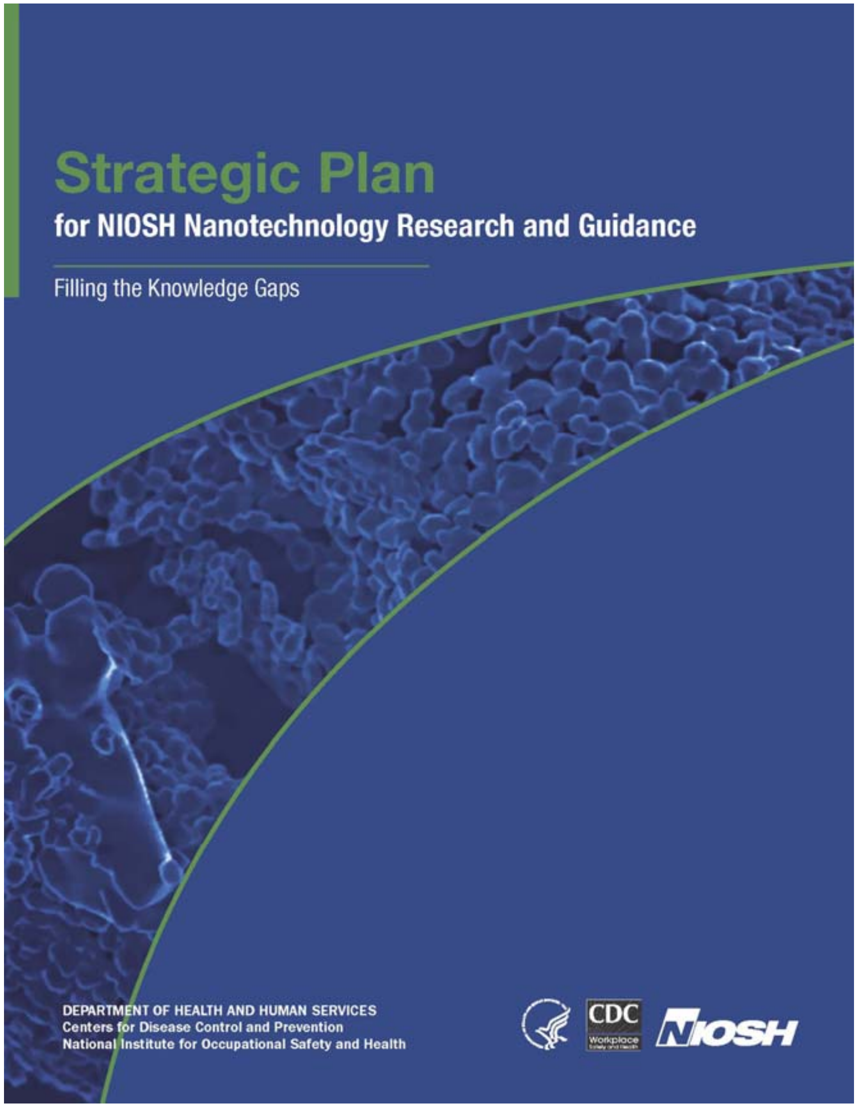
The National Institute for Occupational Safety and Health is:

the U.S. Federal agency *responsible* for *conducting research* and *making recommendations* for the **prevention of work-related illness, injury, disability, and death**.

We participate in the National Nanotechnology Initiative (NNI).

www.nano.gov

NIOSH Strategic Plan for Nanotechnology Research and Guidance

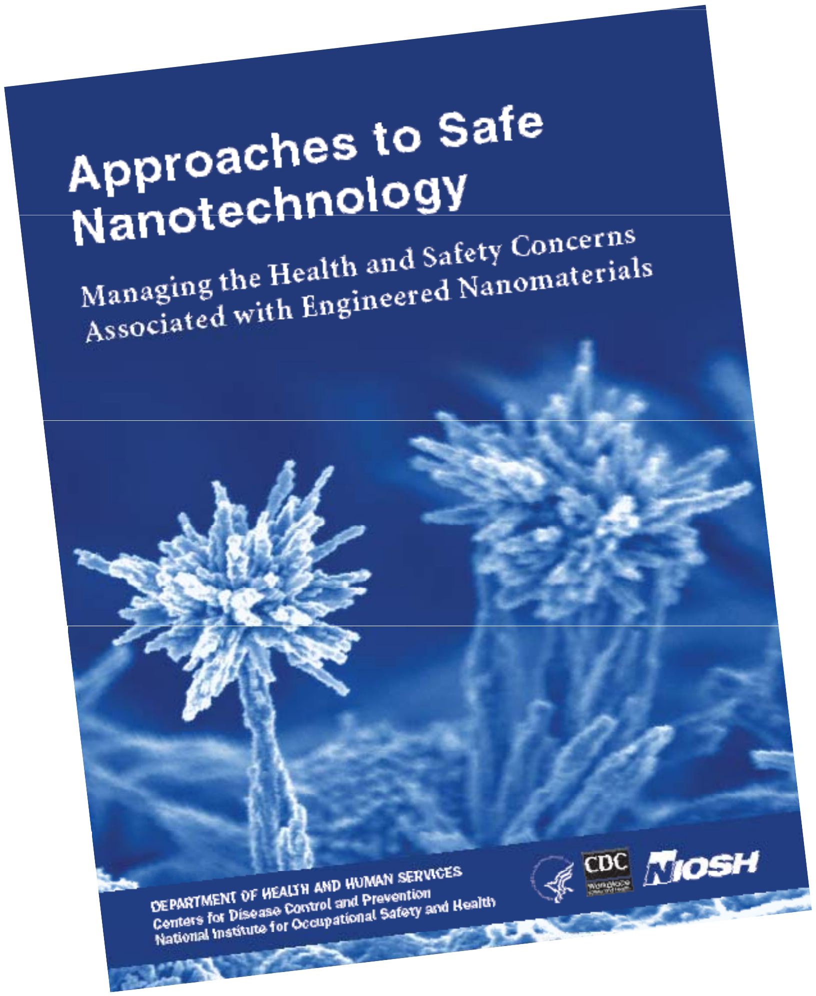


NIOSH Publication 2010-105

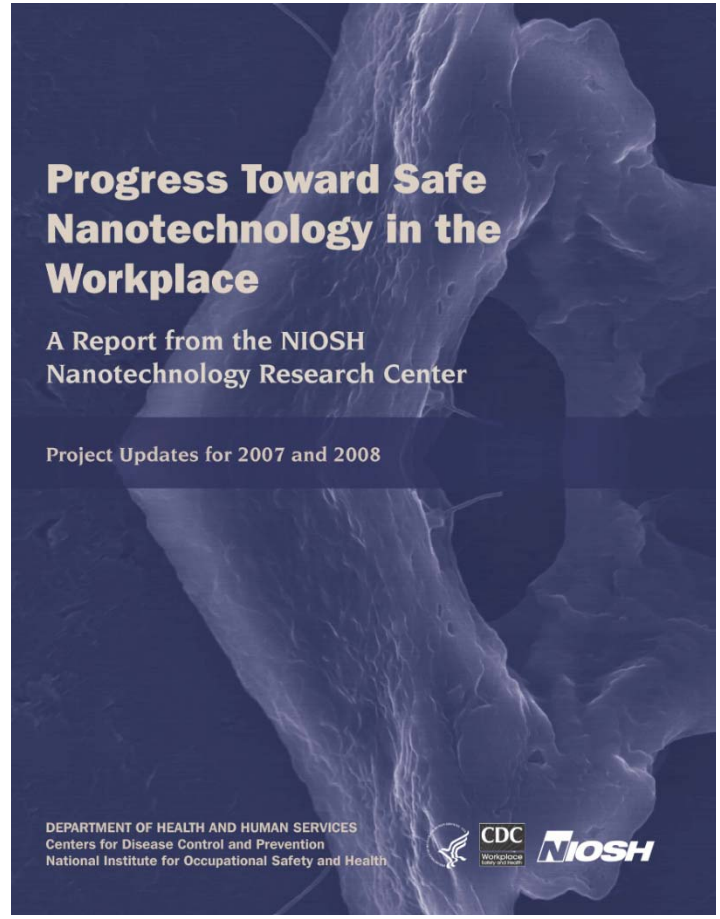
- NIOSH Intermediate and long-term objectives
- Performance measures
- Timeline for nanotechnology research
- Capabilities and gaps for nanotechnology measurements

www.cdc.gov/niosh/topics/nanotech/

NIOSH Approaches and Progress



NIOSH Publication 2009-125



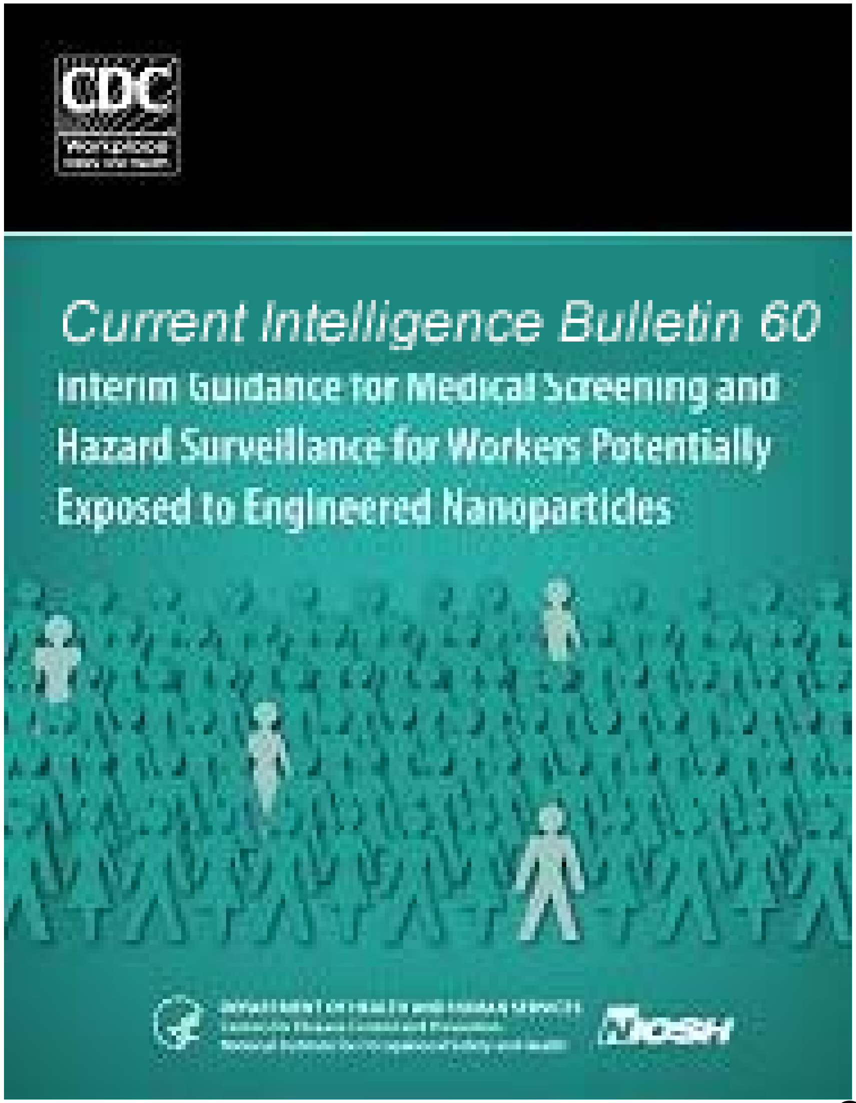
NIOSH Publication 2010-104

- Progress in 10 key areas
- Continuing project plans
- Opportunities for collaboration

www.cdc.gov/niosh/topics/nanotech

Interim Guidance for the Medical Screening of Workers Potentially Exposed to Engineered Nanoparticles

- ***Current Intelligence Bulletin 60:***
  Interim Guidance for Medical Screening and Hazard Surveillance for Workers Potentially Exposed to Engineered Nanoparticles



NIOSH Publication 2009-116

www.cdc.gov/niosh/docs/2009-116/

Key Elements of Risk Management

Are they hazardous?

Can they be measured?

Can they be controlled?

Hazard Identification
"Is there reason to believe this could be harmful?"

Exposure Assessment
"Will there be exposure in real-world conditions?"

Risk Characterization
"Is substance hazardous *and* will there be exposure?"

Risk Management
"Develop procedures to minimize exposures"

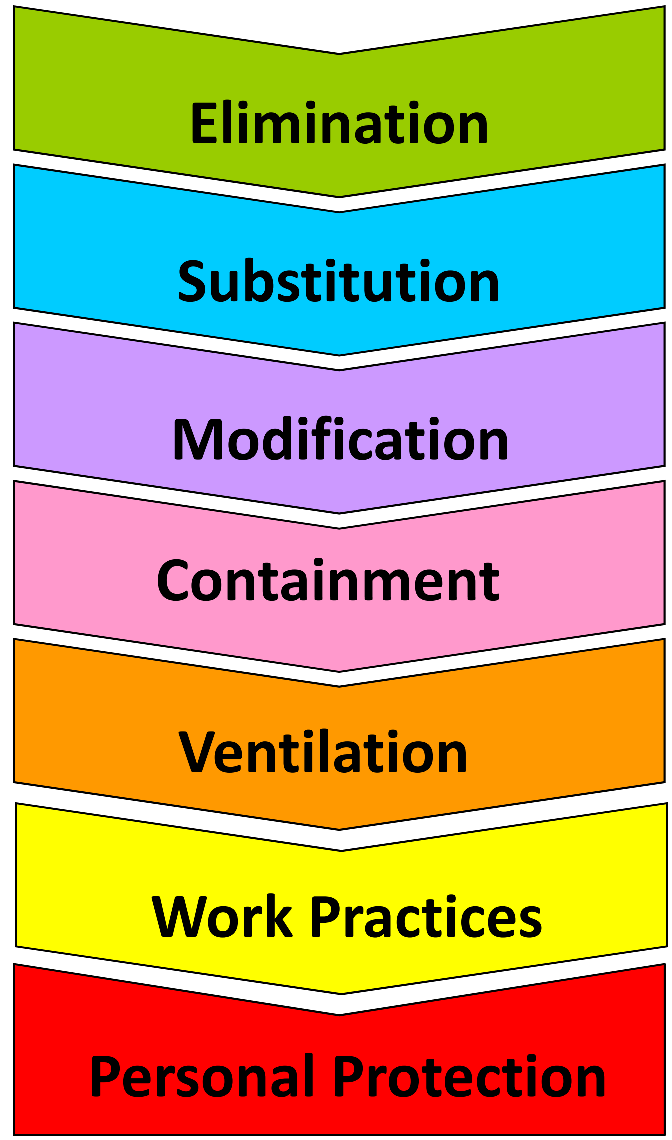
It makes sense to manage nanoparticles as a component of a traditional Radiation or Chemical Hygiene Program.

- Basic Rules and Procedures
- Chemical Procurement, Distribution, and Storage
- Environmental Monitoring
- Housekeeping, Maintenance, and Inspections
- Medical Program
- Personal Protective Apparel and Equipment
- Records
- Signs and Labels
- Spills and Accidents
- Training and Information
- Waste Disposal

Current Challenges

- **The traditional assessment and management strategy requires an occupational exposure limit (OEL).**
- **OELs for radioactive materials are based on a unified concept of dose.**
- **Such a unifying concept is not available for nanoparticles.**
- **How can an effective chemical hygiene program for nanotechnology be developed and implemented in the absence of comprehensive OELs?**
- **What control approaches are feasible and effective?**

Hierarchy of Exposure Control Practices



We are partnering to develop a *comprehensive* risk management scheme to:

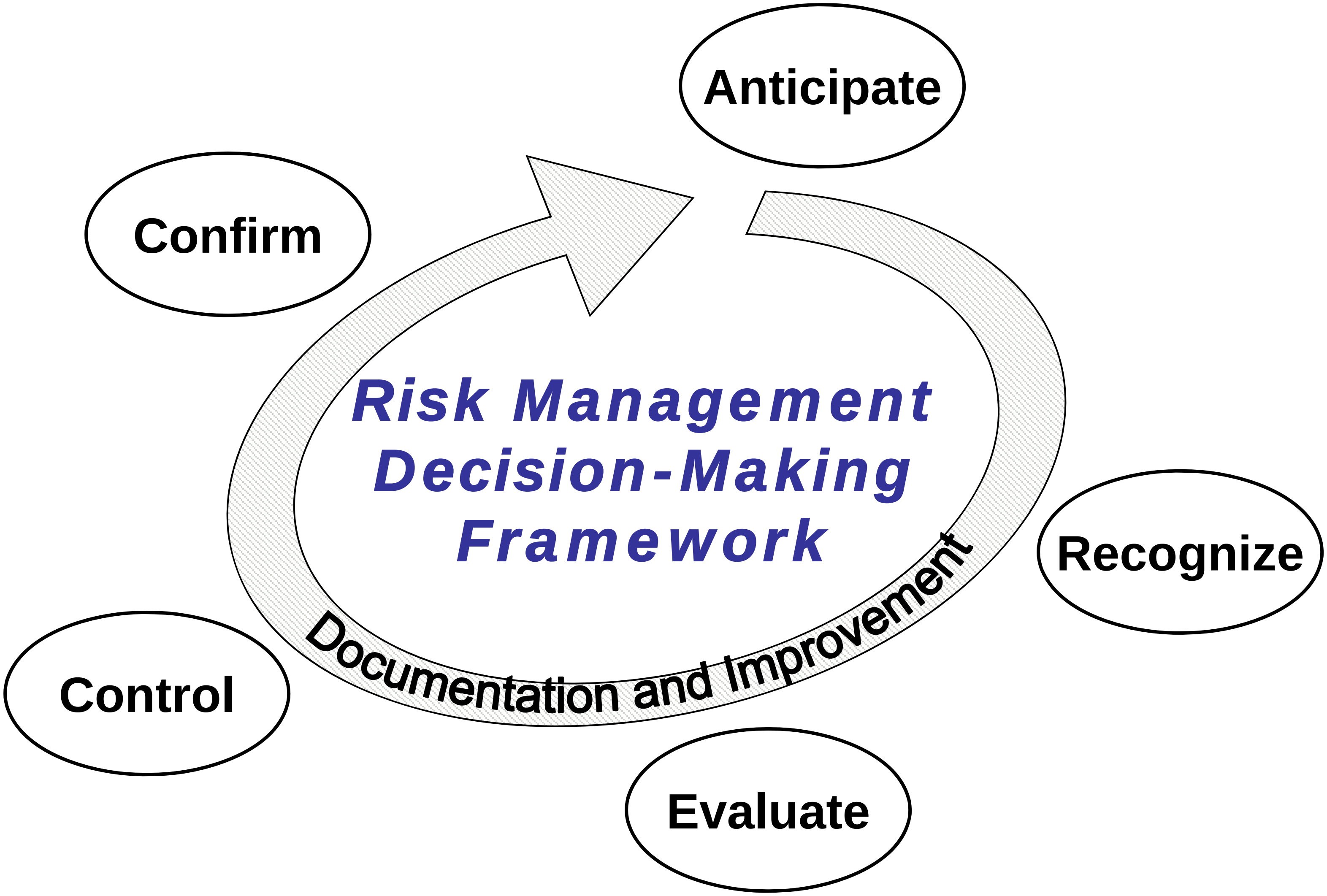
- **Anticipate,**
- **Recognize,**
- **Evaluate,**
- **Control, and**
- ***Confirm***

Hoover et al., Synergist, 22(1): 10, 2011

appropriate control of potential health risks for nanotechnology

by applying a science-based approach
to understanding and managing
the ***critical elements***
over which we have control.

A robust framework and approach



Hoover et al., Synergist, 22(1): 10, 2011

With a variety of delivery opportunities

Don’t cause *A RECC*

Nanoinformatics

November 3 - 5 2010
Arlington, VA

- Overview
- Themes
- Program
- Call for Papers
- Registration
- Accommodation
- Sponsor Opportunities
- Organizers
- Contact
- Nanoinformatics Wiki

media partners

nanoBUSINESSalliance

What's New in Nano? Nanotech-Now.com

InterNano

Nanopaprika.eu

National Nanotechnology Initiative at Ten NANOTECHNOLOGY INNOVATION SUMMIT

exhibitors

Expertool

Nanoinformatics 2010

A Collaborative Roadmapping Workshop

- Participants: Workshop Materials (login required)

Nanoinformatics 2010 is a collaborative roadmapping and workshop project at which informatics experts, nanotechnology researchers, and other stakeholders and potential contributors will jointly develop a roadmap for the area of nanoinformatics.

Nanoinformatics 2010 is designed to survey the landscape, generate a roadmap, and stimulate collaborative activities in the area of nanoinformatics. By doing so, it will accelerate the responsible development and use of nanotechnology. Workshop themes include:

- *Data Collection and Curation*
- *Tools for Innovation, Analysis, and Simulation*
- *Data Accessibility and Information Sharing*

Nanoinformatics involves the development of effective mechanisms for collecting, sharing, visualizing, modeling and analyzing information relevant to the nanoscale science and engineering community. It also involves the utilization of information and communication technologies that help to launch and support efficient communities of practice. Nanoinformatics is necessary for comparative characterization of nanomaterials, for design and use of nanodevices and nanosystems, for instrumentation development and manufacturing processes. Nanoinformatics also fosters efficient scientific discovery and learning through data mining and machine learning techniques.

Nanoinformatics 2010 is open to all members of the nanoinformatics community and will be organized and governed by that community. Contact the program committee to get involved.

The Nanoinformatics Roadmap is currently under development and is expected for release in early 2011. Stay tuned!

Thank you to all of our speakers!

- George Adams, Network for Computational Nanotechnology
- Andrei Nel, UCLA
- Mihail C. Roco, NSF
- Sylvia Spengler, NSF
- Vincent Caprio, Nanobusiness Alliance
- Sharon Gaheen, SAIC
- Stacey Harper, Oregon State University
- Gretchen Bruce, Intertox
- Aaron Small, Luna Innovations
- Yoram Cohen, UCLA
- Nathan Baker, Pacific Northwest National Laboratory
- Raul Cachau, SAIC-Frederick
- Rong Liu, UCLA
- Kate Keahey, Argonne National Laboratory
- Daniel Crawl, UCSD
- Paul Schulte, NIOSH
- Carol Hamilton, RTI
- Jean-Claude Bradley, Drexel University
- Sumit Gangwal, EPA
- Victor Maojo, ACTION Grid
- Mills Davis, Project10x
- Michael McLennan, Purdue University
- Krishna Rajan, Iowa State University
- Vicki Colvin, Rice University
- Mark Hoover, NIOSH
- Chuck Geraci, NIOSH
- Jeff Morse, National Nanomanufacturing Network
- Martin Fritts, Nanotechnology Characterization Laboratory
- Michele Ostraat, RTI
- Guillermo Lopez-Campos, Institute of Health "Carlos III"
- Derek Stewart, Cornell University

NIOSH is part of a community-based nanoinformatics ***Roadmapping initiative***

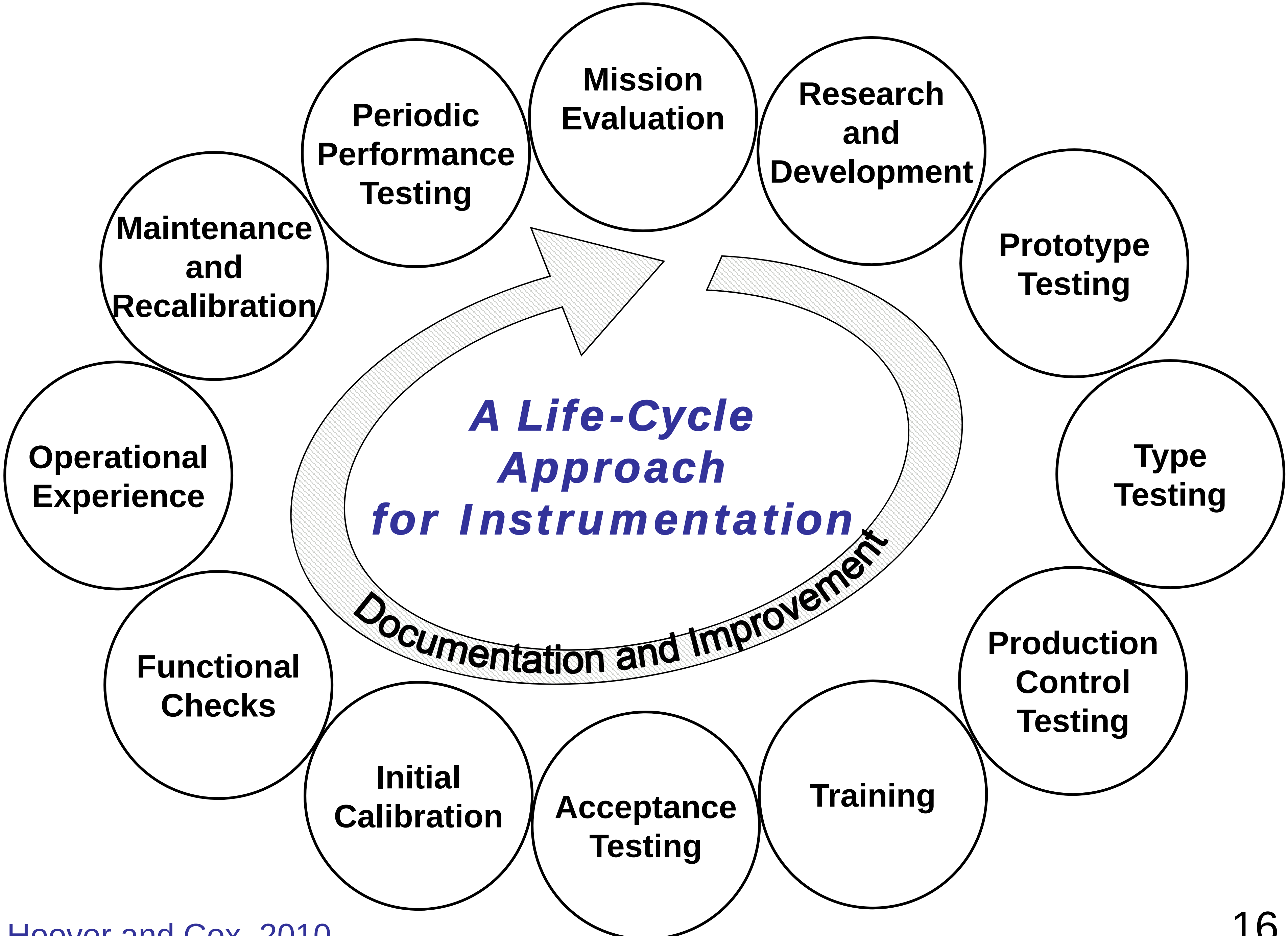
www.nanotechinformatics.org

Nanoinformatics

(a working definition)

- The **science and practice** of determining which information is relevant to the nanoscale science and engineering community,
- and then developing and implementing effective mechanisms
- for *collecting, validating, storing, sharing, analyzing, modeling, and applying* that information.

What are some useful frameworks and paths forward for advancing sustainable manufacturing for nanomaterials?



Hoover and Cox, 2010

Four Steps for Community Action

- Engage the community
- Inform the interested
- Reward the responsive
- Understand and incentivize the reluctant

Suggested Informatics Guidelines for Preventing Injury and Disease*

1. Emphasize literacy and develop critical thinking;
2. Develop and use real-life data examples;
3. Stress conceptual understanding rather than mere application of procedures;
4. Foster continuous improvement and active discussions;
5. Use technology for developing conceptual understanding and for analyzing and sharing information (e.g., modeling and simulation, databases, wikis, etc.);
6. Use assessments to improve and evaluate the efficacy and impact of these activities.

*as adapted by Mark Hoover from the American Statistical Association (ASA) *"Guidelines for Assessment and Instruction in Statistics Education (GAISE)"* which are available at http://www.amstat.org/education/gaise/ .

Communication and Education Message and Audience Planning Tool for (insert project name)

	Workers	Health and safety practitioners	Management	Policy makers and regulators	Equipment and system vendors	Consumers	Legal community	Researchers	Educators	Media	Society
Literacy and Critical Thinking											
Real Life Examples											
Understanding (not rote application)											
Continuous Improvement											
Modeling and Sharing											
Assessment											

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The matrix can be used to clarify what elements the stakeholders need and what elements they can provide.

Purpose of the Assessment

BASIC AEROSOL CHARACTERIZATION

Understanding relevant physicochemical and biological properties of the aerosols of interest

WORKER HEALTH PROTECTION

Ensuring that worker exposures are within allowed limits and As Low As Reasonably Achievable (ALARA)

ENVIRONMENTAL MONITORING

Ensuring that environmental releases of aerosols are within allowed limits and ALARA for environmental and public health concerns

PROCESS QUALITY ASSURANCE AND CONTROL

Ensuring that processes and process controls are operating properly

EMERGENCY PREPAREDNESS AND RESPONSE

Providing a basis for appropriate actions when things go wrong

DEMONSTRATION OF COMPLIANCE

Documenting that administrative and regulatory requirements are met

RESEARCH

Advancing a comprehensive understanding of aerosol behavior, measurement, and control

Hoover, 2011 (Adapted from Hoover and Newton, 1993)

Can foster synergisms and multiuse opportunities.

Graded Approach to Exposure Assessment

<table>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td>Initial Screening and Detection</td><td>Comprehensive Characterization and Assessment</td><td>Routine Monitoring and Control</td></tr>
<tr><td>• Process knowledge
• Gross mass or activity counting
• Optical particle counting
• Condensation particle counting
• Microscopy</td><td>• Composition
- Elemental and chemical
• Particle size
- Physical
- Aerodynamic
- Thermodynamic
- Electrical mobility
• Exposure Concentrations
- Peaks, averages, variability
• Biophysical properties
- Shape, surface area, solubility
• Other factors relevant to the assessment</td><td>• A necessary and sufficient subset of Level 1 and 2 methods for the material and situation of interest</td></tr>
</table>

Adapted from Hoover, 2011

Essential for cost and feasibility

Beta sponsors

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Beta Version - GoodNanoGuide Advanced

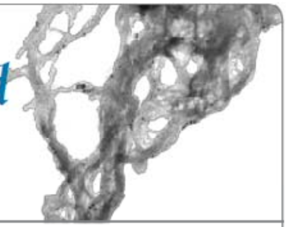
Welcome to the GoodNanoGuide-OHS Expert Matrix

The GoodNanoGuide is structured along a conceptual framework for occupational risk management designed to control and minimize exposures to engineered nanomaterials in the presence of uncertainty. Each organization should have a management structure to assess and minimize risk. In this section, the GoodNanoGuide has established a matrix in which the potential handling hazards of nanomaterials are rows labeled by the leftmost column, and the various physical forms of the nanoparticles are in four vertical columns.

Nanoparticles in: →	Dry Powder	Liquid Dispersion	Solid Polymer Matrix	Nonpolymer Matrix
First Step: Identify	Potential Hazard	Potential Hazard	Potential Hazard	Potential Hazard
Second and Third Steps: Risk Assessment and Management				
Material Unpacking	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Synthesis	Exposure Potential	Exposure Potential		
	Controls	Controls		
Weighing and Measuring	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Dispersing	Exposure Potential	Exposure Potential		
	Controls	Controls		

www.goodnanoguide.org

The Nanotechnology Field Research Team Update



In 2006, NIOSH established a Nanotechnology Field Research Team to expand its knowledge and understanding of the potential health and safety risks that workers may encounter during the research, production, and use of engineered nanomaterials. This effort has complimented NIOSH's extensive laboratory-based research program, as well as helped NIOSH identify and more fully understand the variety of work processes used to generate and manufacture engineered nanomaterials. It has also provided NIOSH with the opportunity to observe and evaluate work practices and engineering controls used to ensure worker health and safety in the nanotechnology industry.

NIOSH has conducted site visits to several facilities around the country that are involved in the research, manufacture, or use of various types of nanomaterials including, metal and metal oxide nanoparticles, carbon nanofibers, electrospun nanofibers, quantum dots, fullerenes, and nanocomposites. As a result, NIOSH obtained valuable information that is being used to assist in developing workplace guidance documents to protect nanotechnology workers from occupational injury and illness, and has learned that:

- basic particle counting and sizing instruments can be used to identify emissions from nanomaterial processes,
- careful interpretation of the particle data is needed to differentiate between incidental (background) and process-related nanoparticles, and
- engineering controls do minimize workplace exposure to engineered nanoparticles.

Companies interested in receiving a visit by the Field Research Team are encouraged to contact NIOSH. All site visits are initiated by the respective companies and are completely voluntary. This program is fully funded by NIOSH; therefore, there is no monetary cost to the participant. Three companies who have voluntarily received site evaluations from the NIOSH Field Research Team were recently interviewed by Nanowerk, LLC for its August/September 2007 issue of Nanorisk (www.nanorisk.org/). Overall, they described the collaboration as beneficial, and encouraged other companies to take advantage of NIOSH's expertise, services, instrumentation, and unbiased assessments.

For more information about occupational safety and health topics pertaining to engineered nanomaterials, including fact sheets about the Field Research effort and other nanotechnology research programs, please visit the NIOSH nanotechnology topic page at www.cdc.gov/niosh/topics/nanotech. To discuss the possibility of receiving a site evaluation by the NIOSH Field Research Team, contact Charles Geraci, Ph.D., CIH at (513) 533–8339, CGeraci@cdc.gov or Mark Methner, Ph.D., CIH at (513) 841–4325, MMethner@cdc.gov.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Collaboration with NIOSH

- Share knowledge
- Use expertise
- Build experience
- Partner

www.cdc.gov/niosh/docs/2008-120/

Questions ?

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- George Newton
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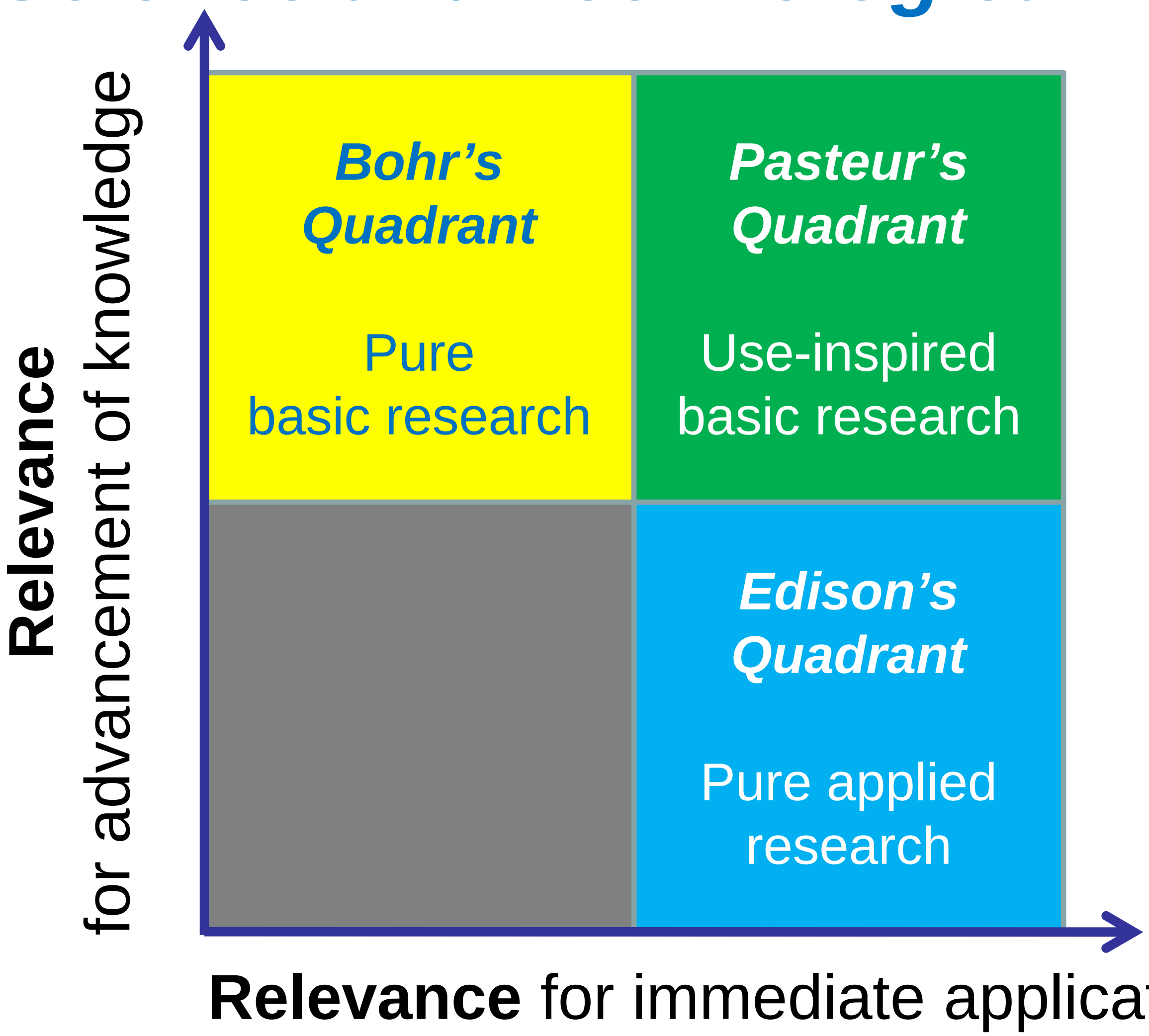
- James Slawski
- Aleks Stefaniak
- Cindy Striley
- Abbas Virji
- Martha Waters
- Robert Watters
- Ainsley Weston
- David Weissman
- Ralph Zumwalde

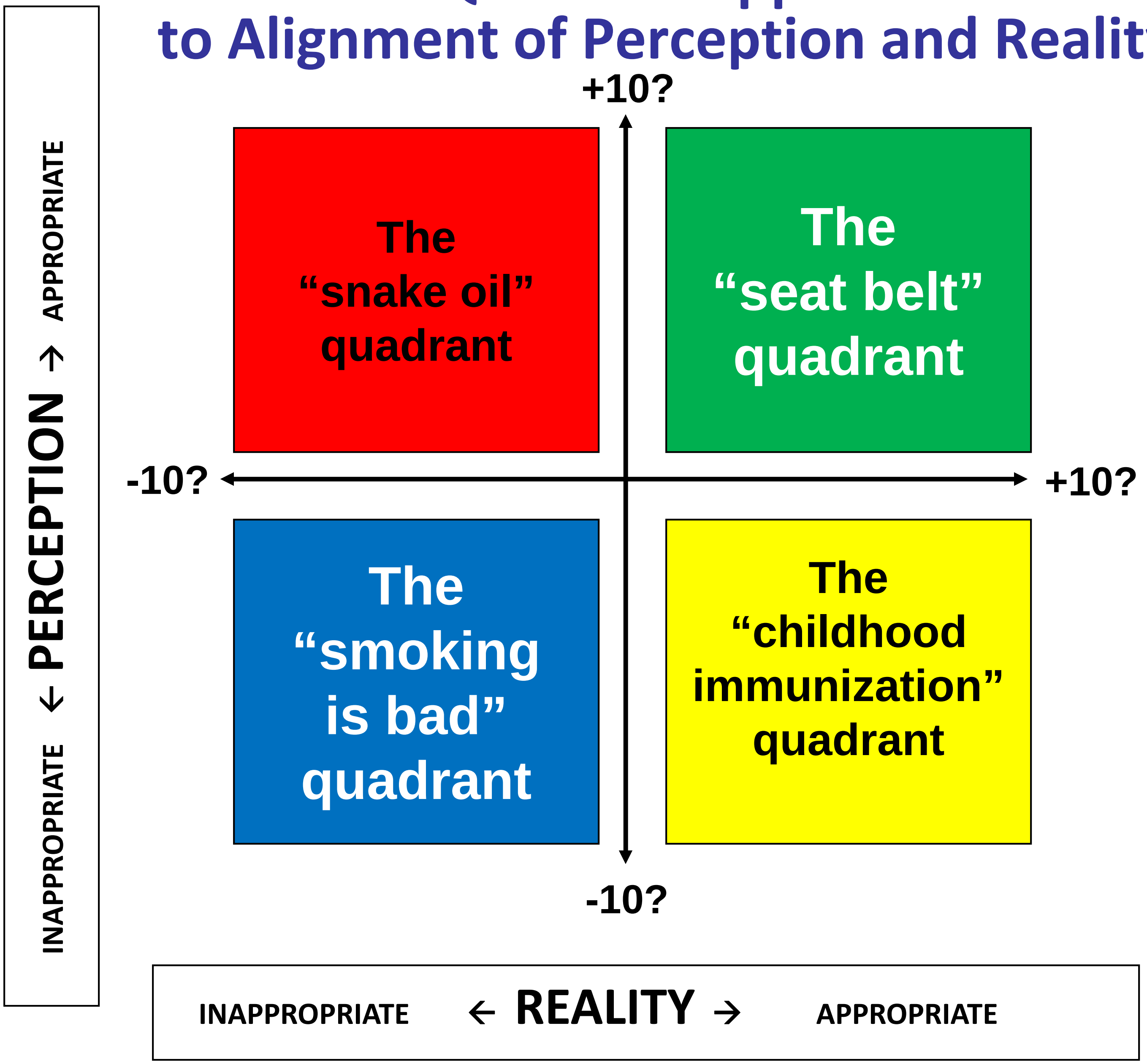
Additional slides related to the group discussion of “quadrant approaches” to understanding and advancing basic and applied research

Pasteur's Quadrant: Basic Science and Technological Innovation

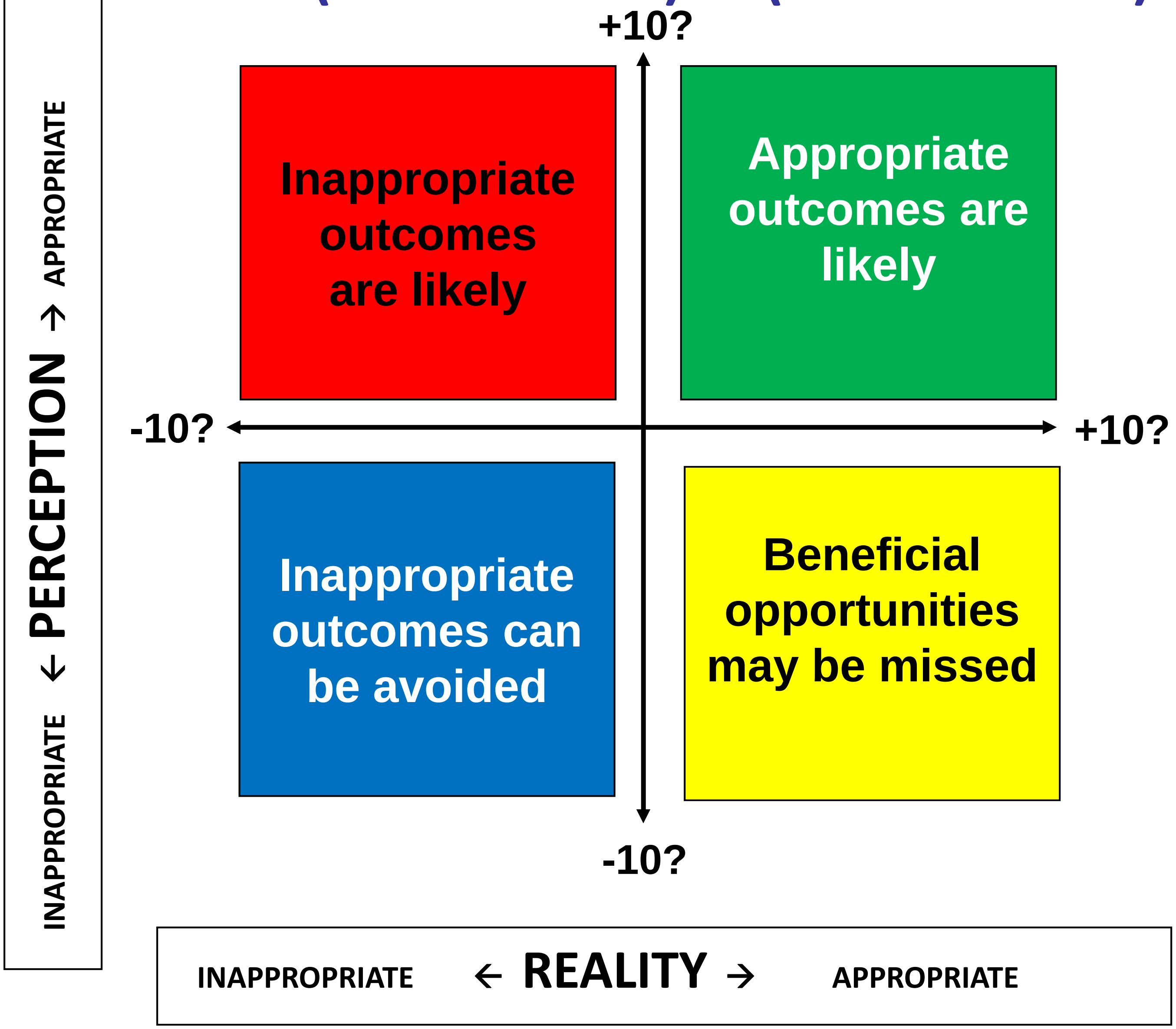


Adapted from *Pasteurs Quadrant: Basic Science and Technological Innovation,* by Donald E. Stokes, Brookings Institution Press, 1997.

A Quadrant Approach
to Alignment of Perception and Reality



Draft Issue Evaluation Matrix
for (*insert variable*) in (*insert situation*)



Draft for discussion (Hoover, Mathews, and other contributors, 2010)