Nanotechnology
The Current State of Affairs

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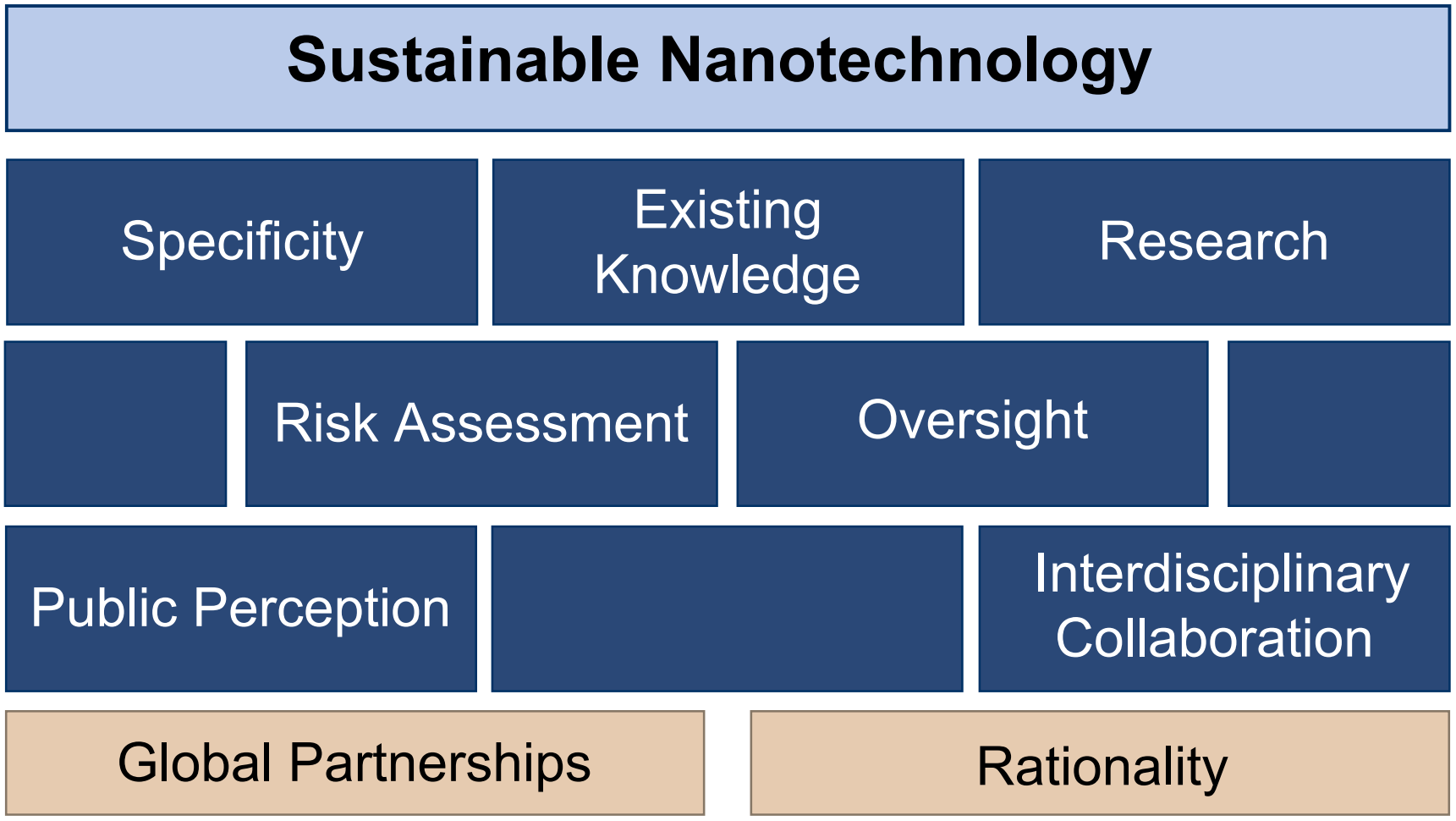
THE PEW CHARITABLE TRUSTS

Project on Emerging Nanotechnologies
at the Woodrow Wilson International Center for Scholars

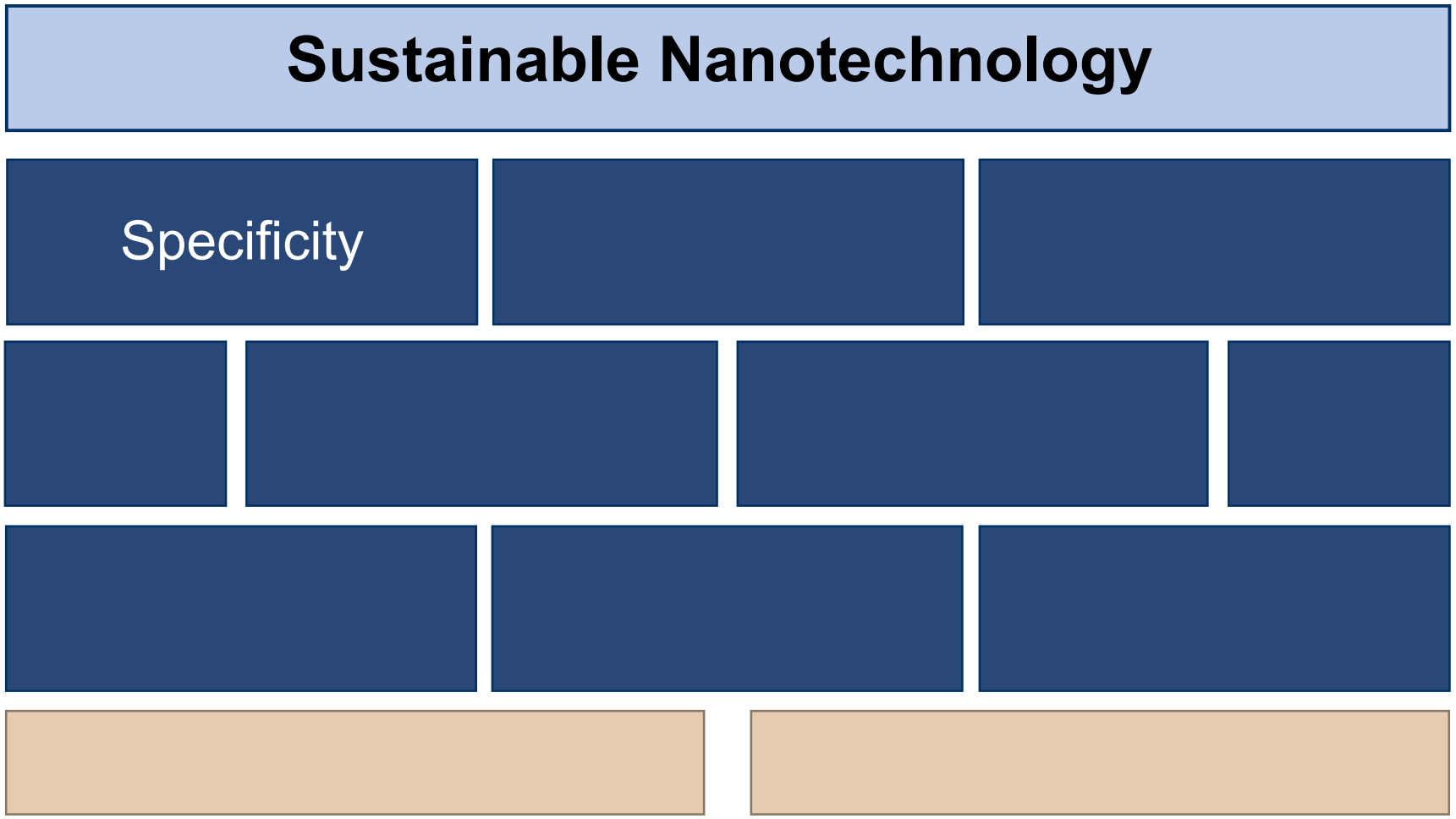
Challenge

- Nanotechnology has great potential
  - Revolutionary Technology
  - “Engine of Innovation”
  - Many societal and environmental benefits anticipated
- BUT..
  - There may be unanticipated roadblocks, including unexpected risk to human health and the environment
- Sustainable nanotechnology will depend on
  - Societal Acceptance
  - Minimizing risk
  - Maximizing benefits

Working towards Sustainable Nanotechnology



Working towards Sustainable Nanotechnology



Specificity

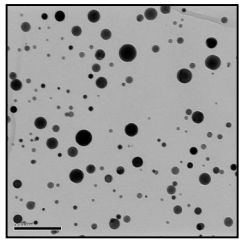
- Being sure of what we're talking about
  - ***Nanotechnology*** - a way of doing things
  - ***Nanotechnologies*** - Specific applications of *nanotechnology*

- The nanotechnology dialogue must be specific to:
  - Materials, devices and products
  - Processes
  - Categories and magnitudes of potential risk

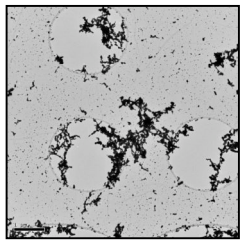
Setting Boundaries

Engineered nanomaterials which potentially present new challenges

- Criteria:
  - Nanomaterials capable of entering or interacting with the body
  - Nanomaterials which potentially exhibit nanostructure-dependent biological activity



Nanoparticles
Simple, complex, “smart”. Aerosols, powders, suspensions, slurries



Agglomerates
or aggregates of nanoparticles

Aerosolized suspensions
Including slurries and solutions of nanomaterials

Comminution
Aerosols from grinding, cutting, machining nanomaterials

Degredation/Failure
Aerosols and suspensions resulting from degradation and failure of nanomaterials

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Unintentional use
Potential exposure from unanticipated/unintentional use

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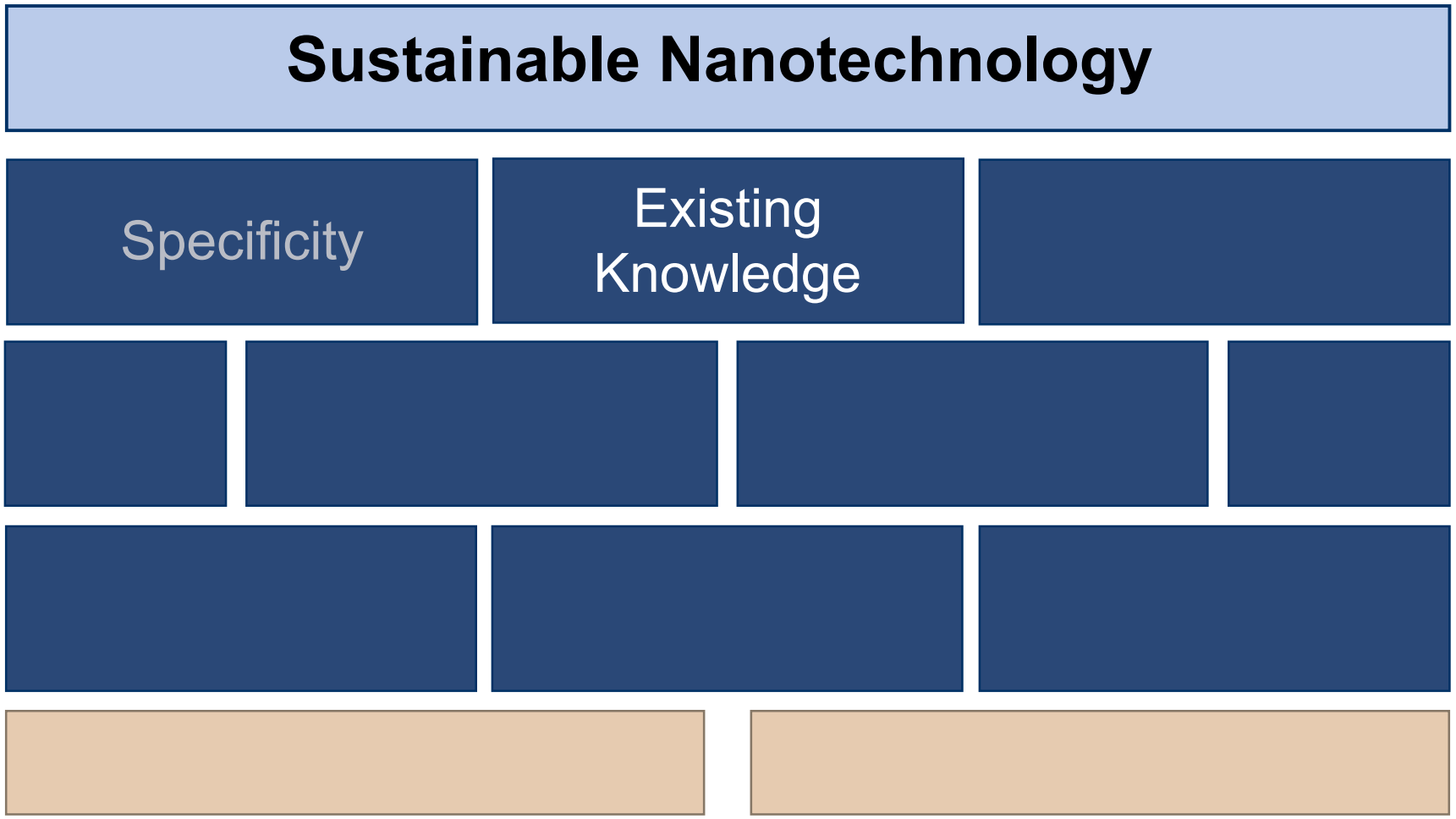


Existing Knowledge

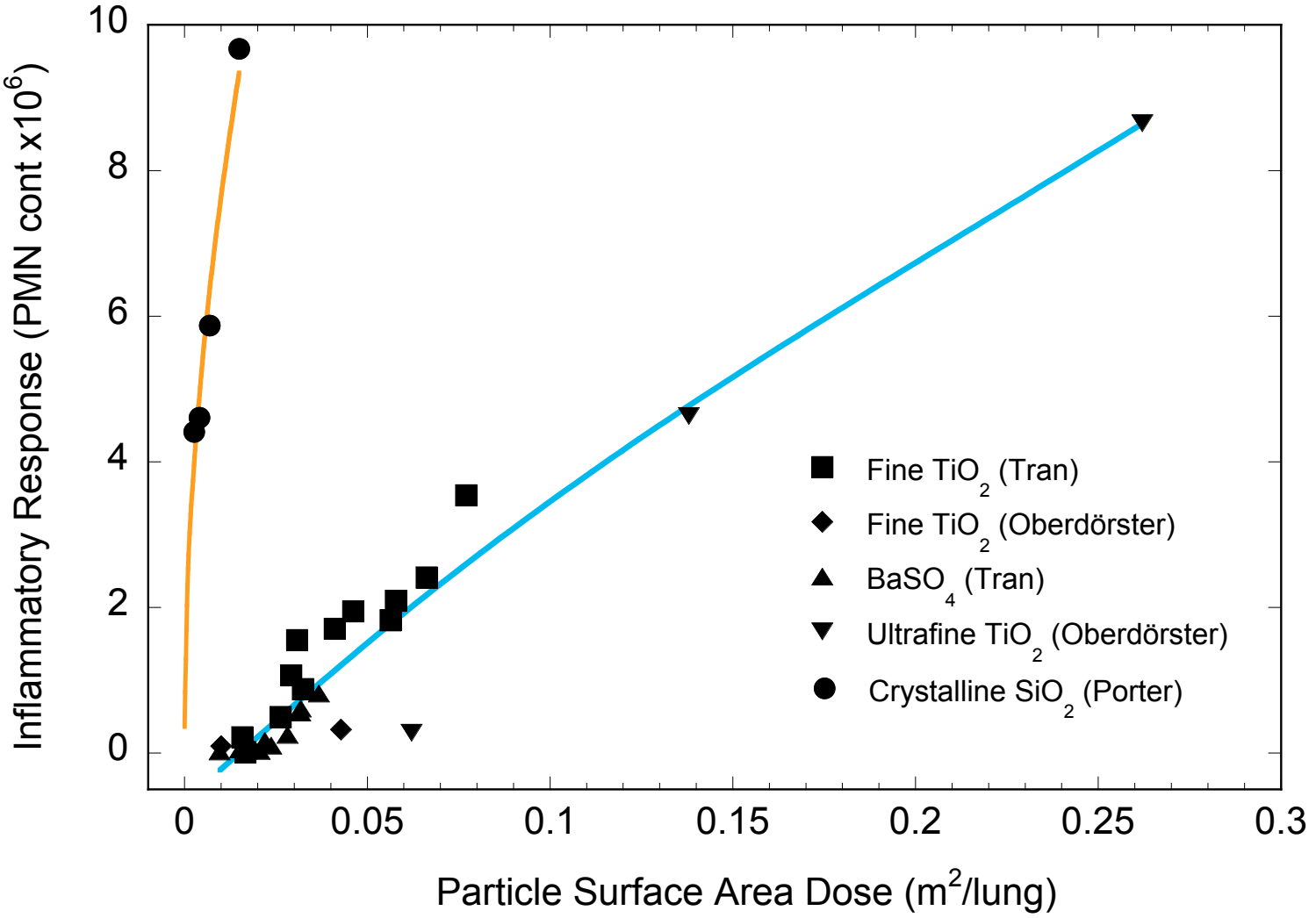
- Nanotechnology is new, unique and innovative, but…

…we have over 100 years of health-impact knowledge to draw on

- Similarity, analogy and first principles:
  - Aerosol behavior
  - Exposure control
  - Health effects - general
  - Hazard - ultrafines
  - Physicochemical significance - e.g. asbestos and crystalline silica
- Extrapolation can be dangerous, but used wisely it can provide strategic direction

Lessons from "conventional" materials

Comparison of insoluble materials with different biological activities



Maynard and Kuempel (2005)

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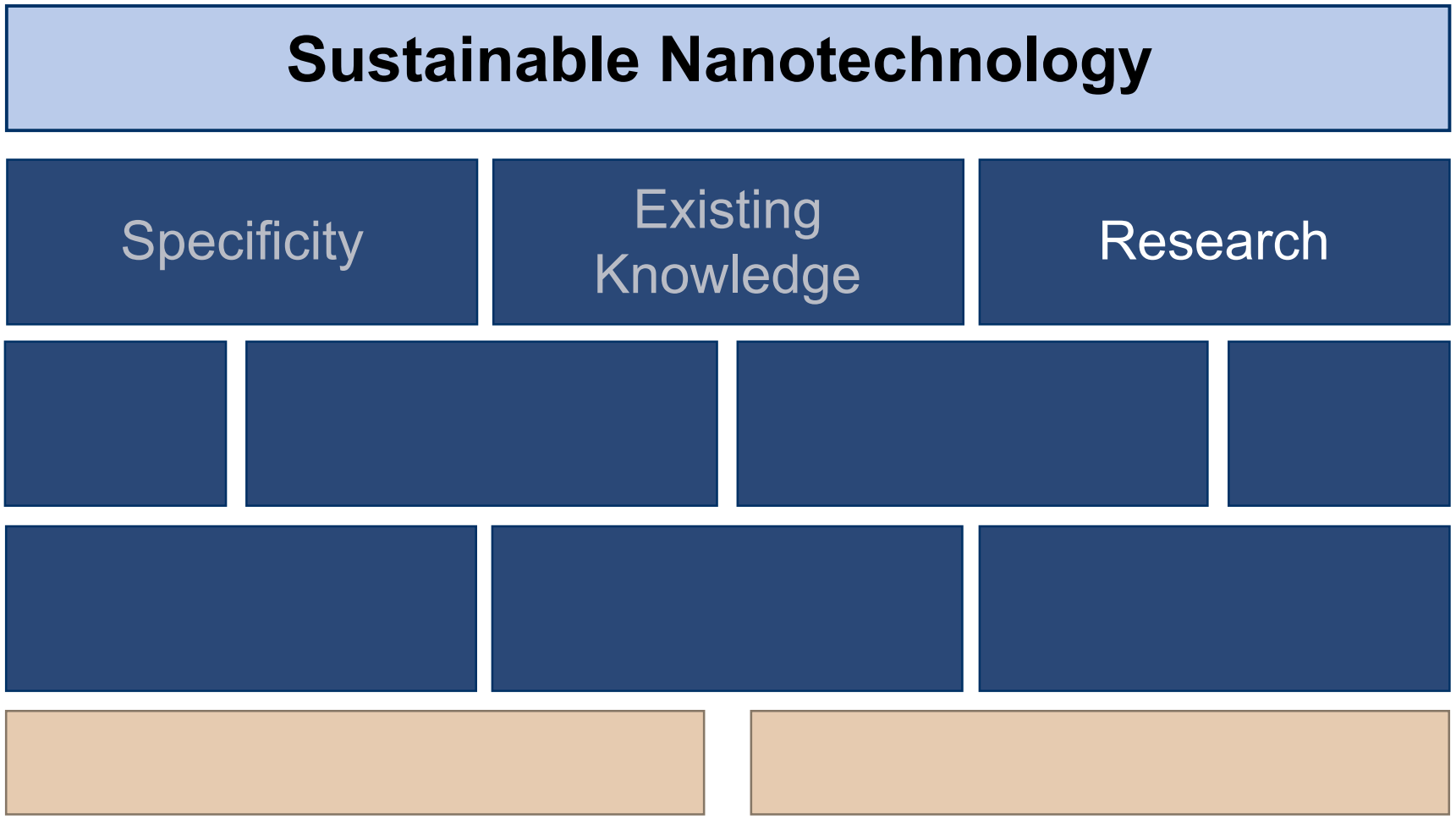
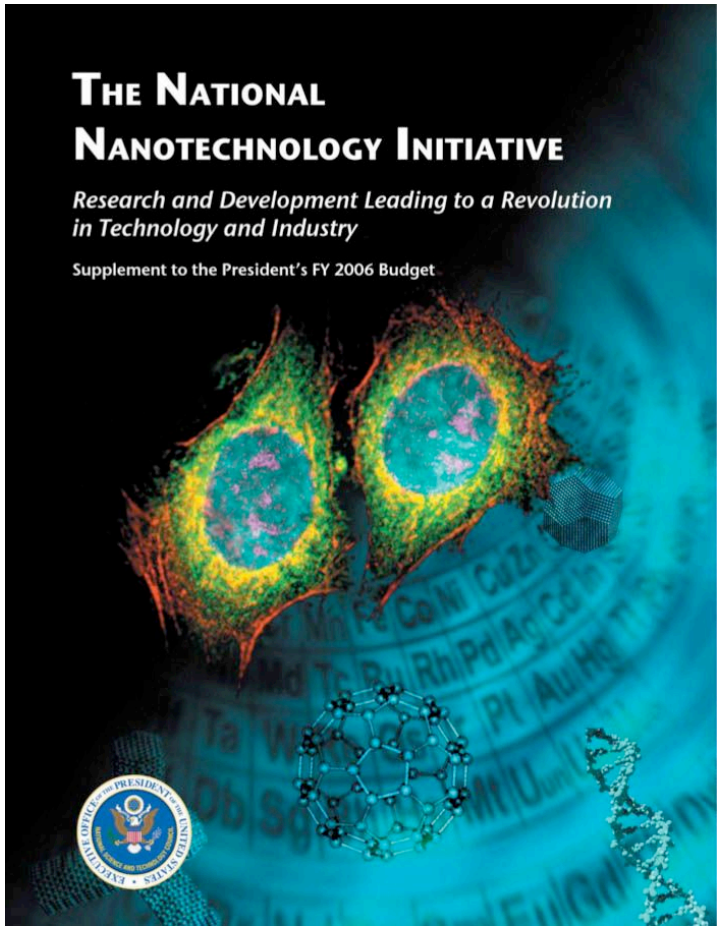


Estimated 2006 US Government EH&S R&D Investment

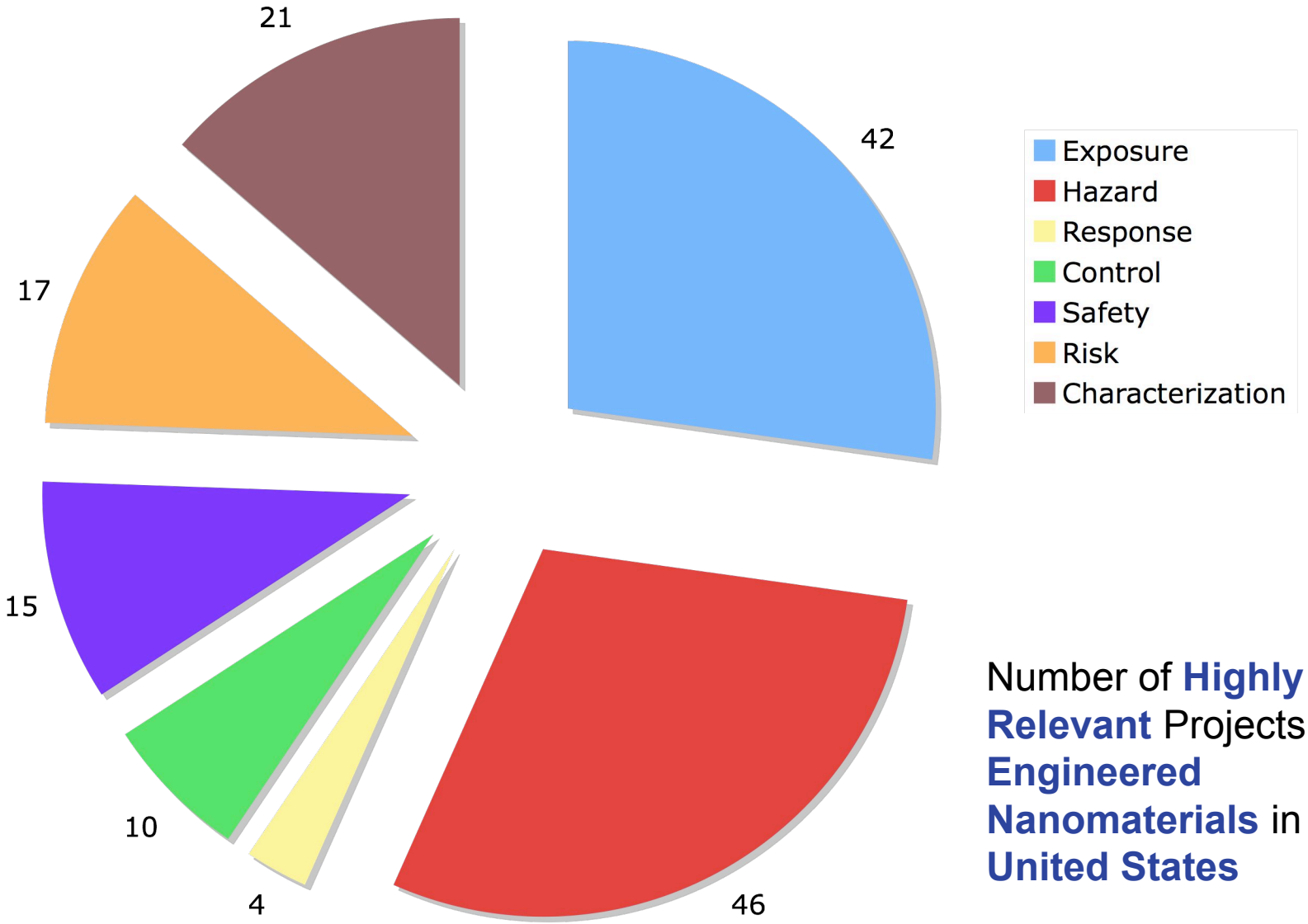
	Environmental, Health, and Safety R&D ($ million)
NSF	24.0
DOD	1.0
DOE	0.5
HHS(NIH)	3.0
DOC(NIST)	0.9
NASA	
USDA	0.5
EPA	4.0
HHS (NIOSH)	3.1
DOJ	1.5
DHS	
TOTAL*	38.5



Source: NNI 2006 supplement to the President's FY2006 budget

Inventory of Current Research

ES&H Implications of Nanotechnology - Relevance of research



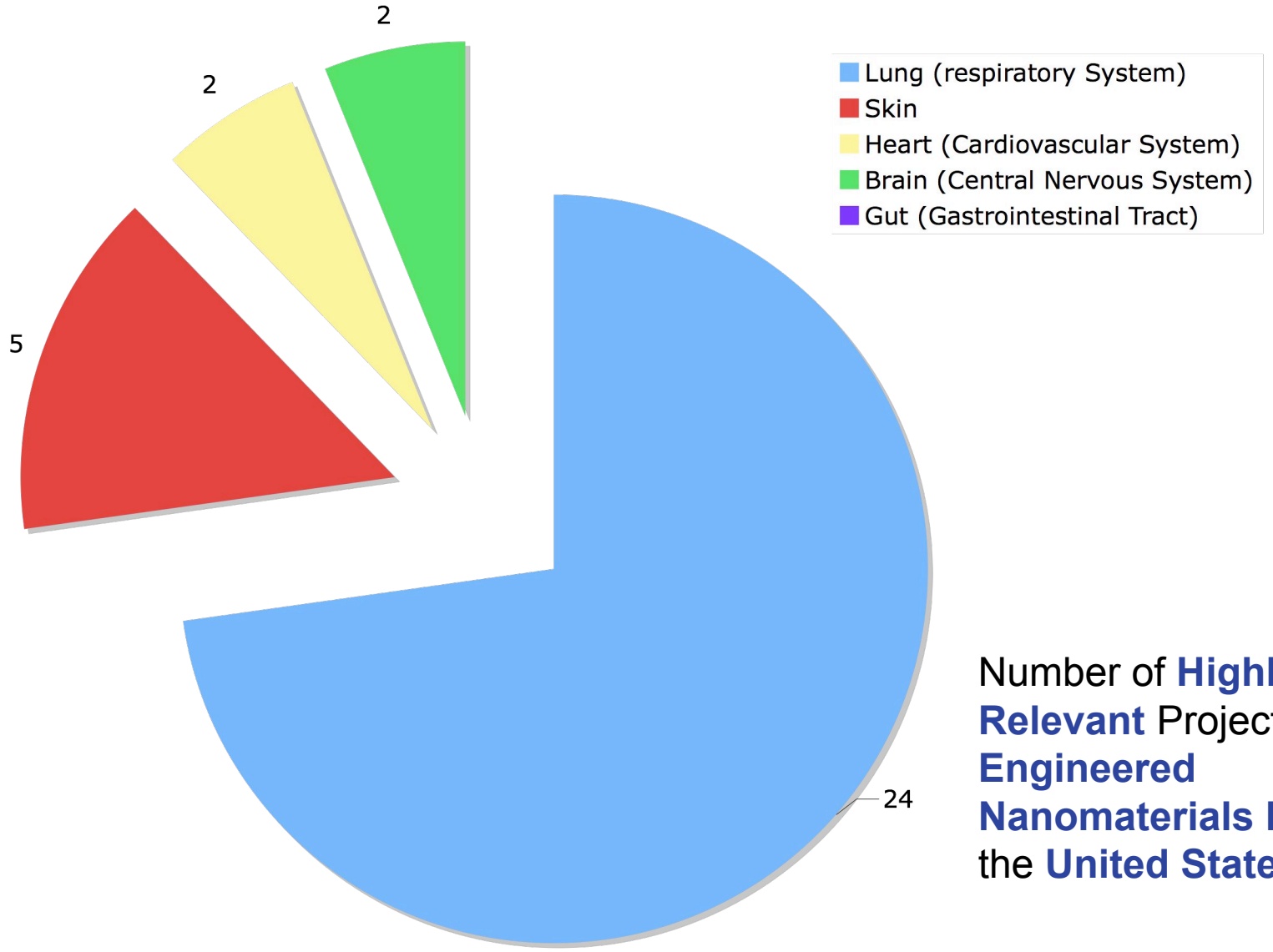
Number of **Highly Relevant** Projects on **Engineered Nanomaterials** in the **United States**

Analysis: November 23rd 2005

www.nanotechproject.org

Inventory of Current Research

ES&H Implications of Nanotechnology - Human health impact



Number of **Highly Relevant** Projects on **Engineered Nanomaterials Hazard** in the **United States**

Analysis: November 23rd 2005

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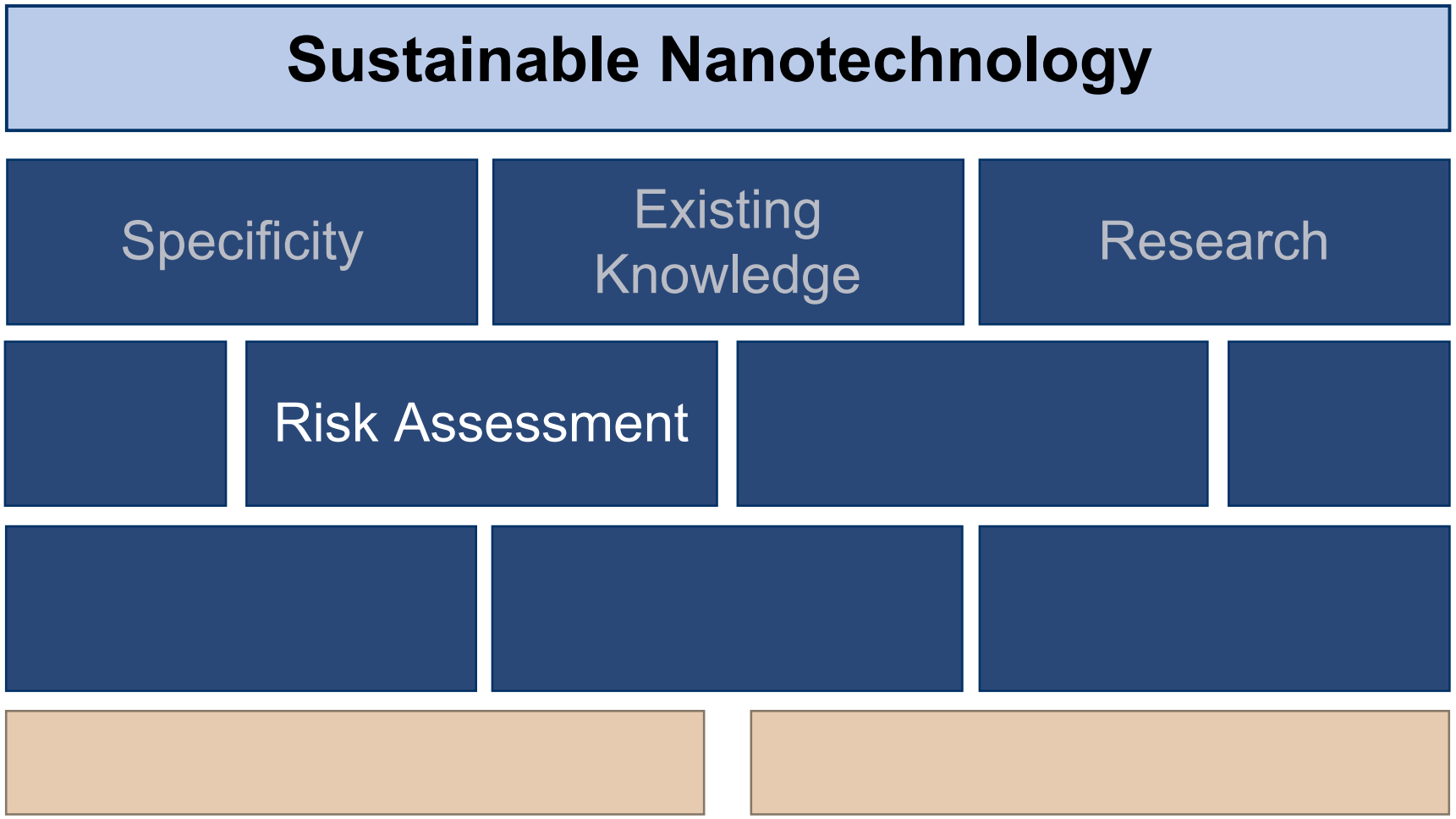
Current Research

General Trends

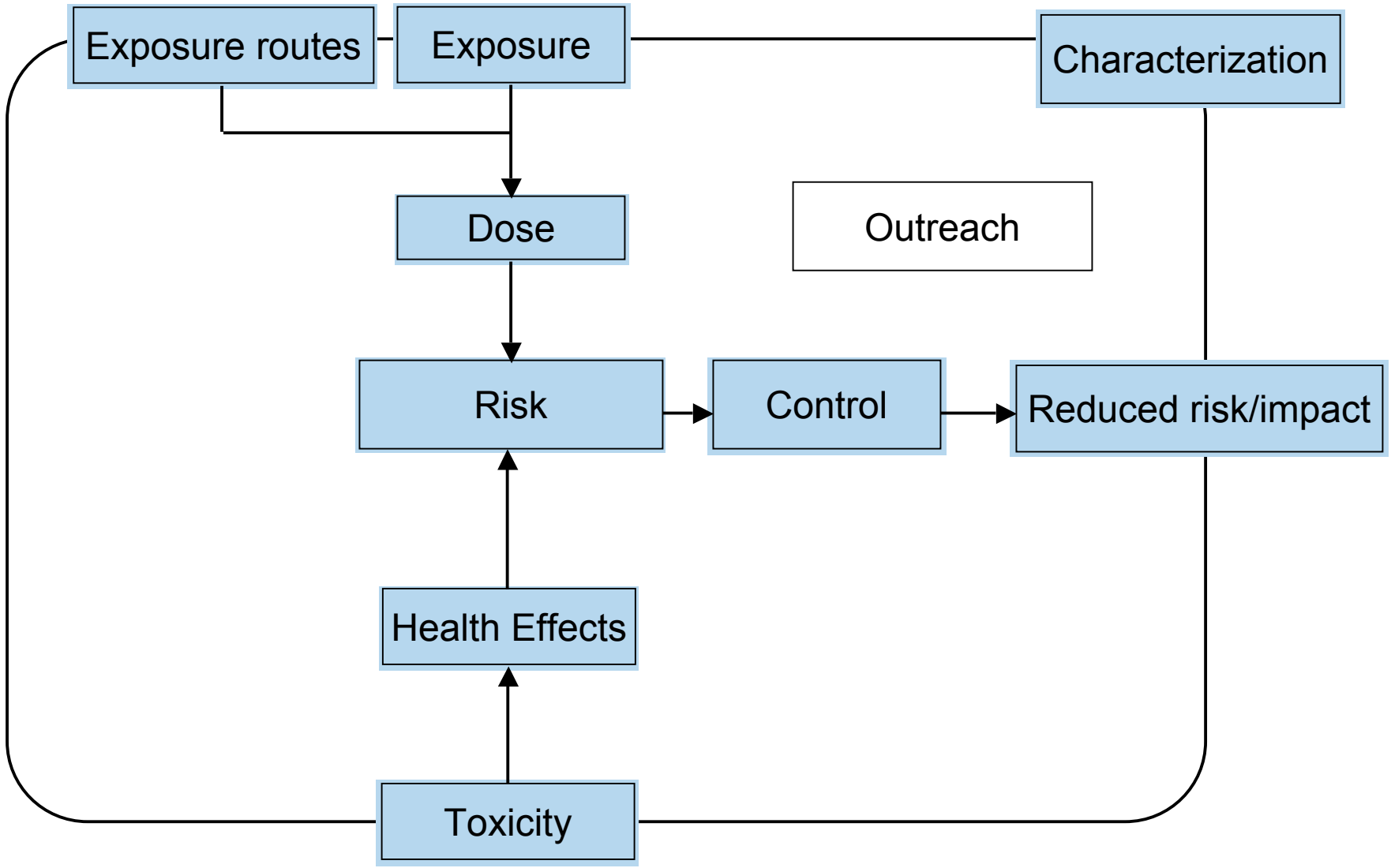
- Relatively strong pre-emptive response to potential impact of nanotechnology
- A lack of an overall strategy is apparent
  - Significant research gaps exist
  - Research within specific fields is largely driven by investigator interest and expertise, and not by critical information needs
- Funding levels are low
  - US Government funding for research highly relevant to engineered nanomaterials: $6 million per year listed, between $10 - $15 million estimated (1% of the annual NNI R&D budget)
- It is questionable whether current research initiatives will provide answers to critical questions within a reasonable timeframe

Working towards Sustainable Nanotechnology



Risk Assessment

(Simplified schematic)



Characterization

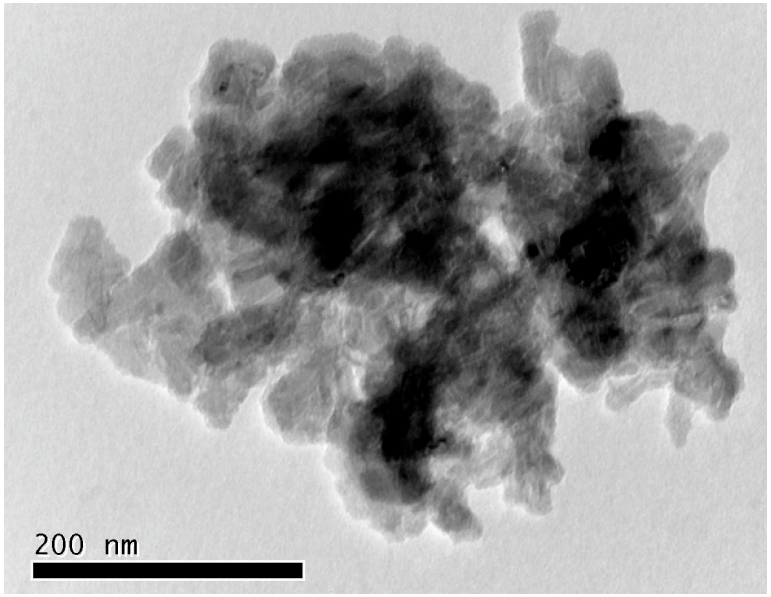
- The properties of engineered nanomaterials depend on structure, as well as chemistry
- Risk can not be quantified and quantitatively reduced without an accurate description of the materials and products being used.
- The complexity of many nanomaterials demands sophisticated characterization - frequently beyond what is considered 'normal'

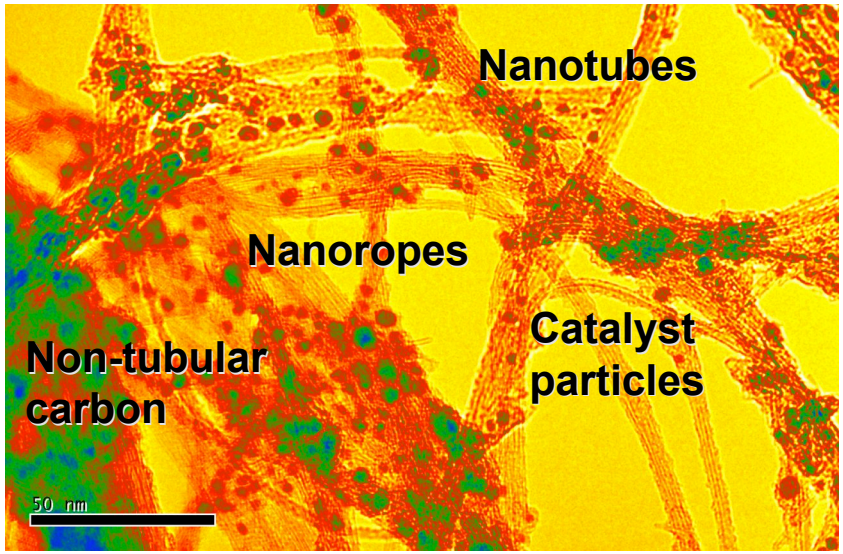
"The dependence of nanomaterial behavior on physical and chemical properties places stringent requirements on physicochemical characterization, and includes assessing a range of properties…"

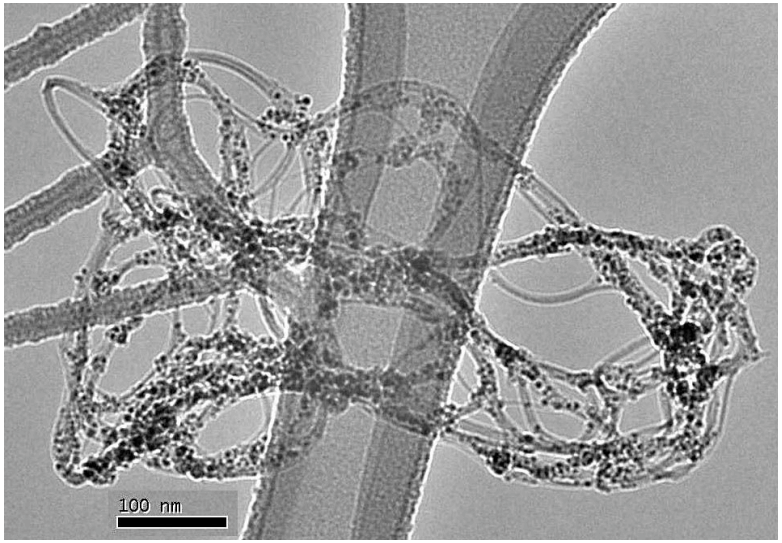
Oberdörster et al. Particle and Fibre Toxicology 2005 2:8

Example

Airborne Single Walled Carbon Nanotubes







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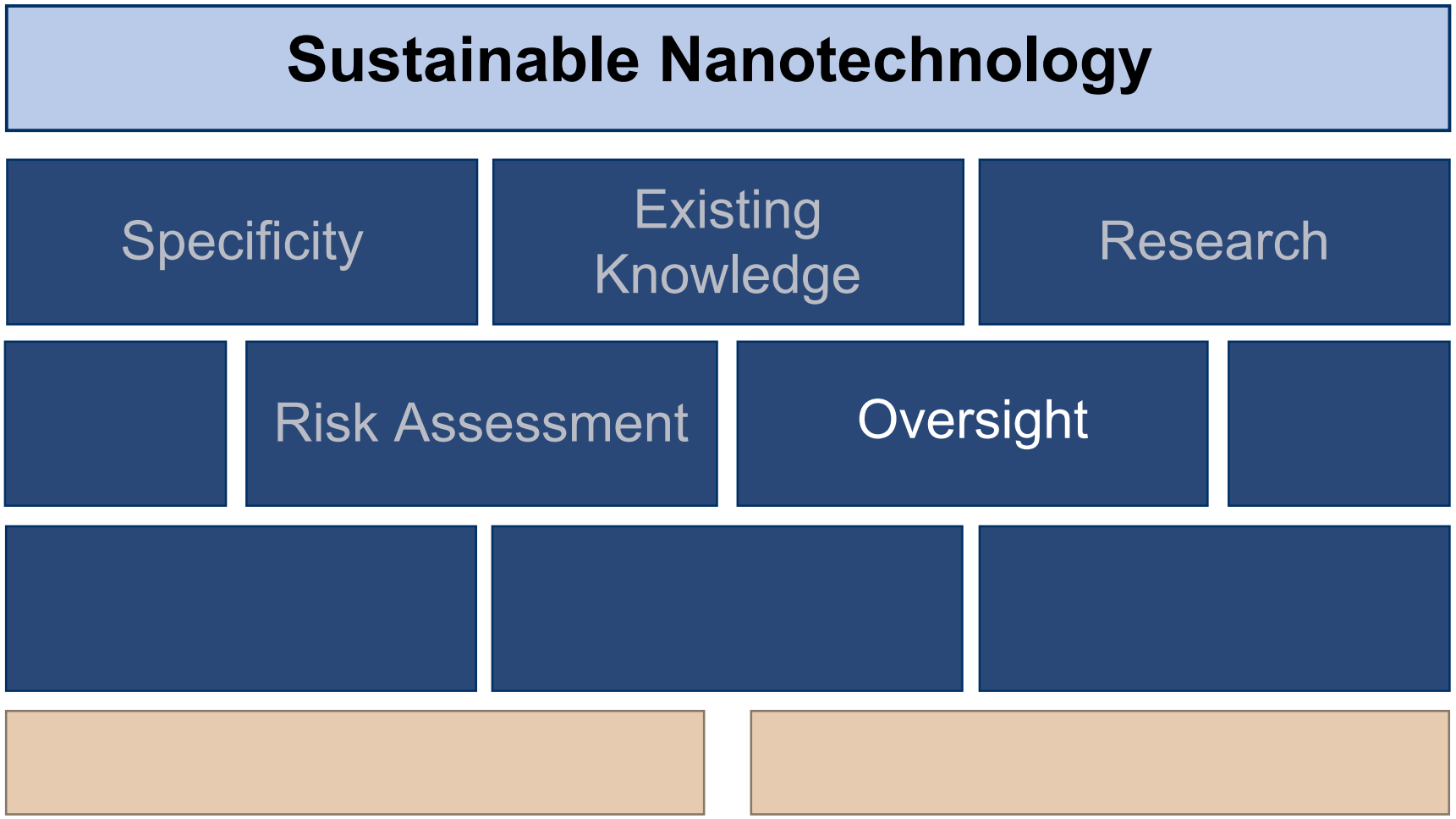


Oversight

- Context
  - New challenges - are existing oversight frameworks robust enough?
  - “Nano” is in the marketplace now
  - Sustainable nanotechnology needs a viable oversight framework to:
    - Minimize risk
    - Clarify rules and responsibilities
    - Maintain public confidence

- Responses include:
  - New risk governance models
  - New risk assessment and management models
  - Best Practices
  - Voluntary Programs and Regulation

Exposure Management

Control banding - concept

Parameters

- Hazard Group
- Dustiness
- Amount Used

Control Approach

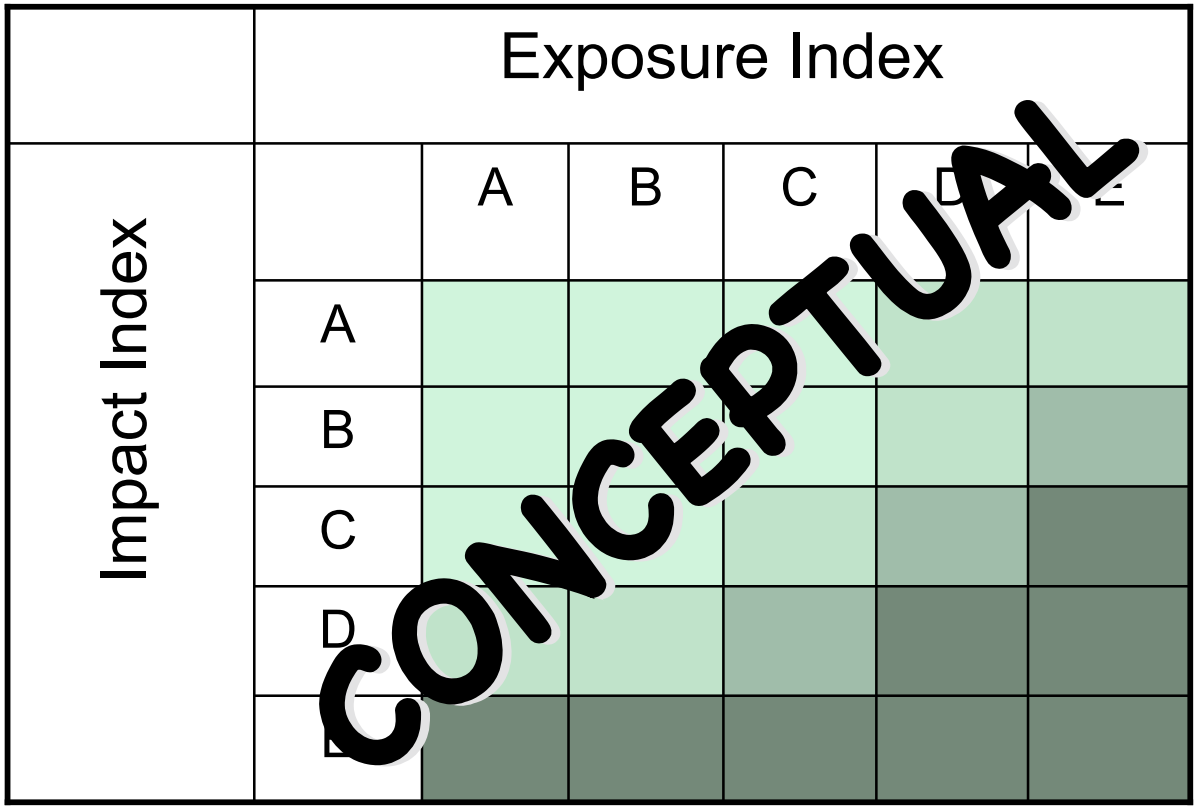
1. General Ventilation
2. Engineering Control
3. Containment
4. Specialist Advice

Amount Used	Low Dustiness	Medium Dustiness	High Dustiness
Hazard Group A			
Small	1	1	1
Medium	1	1	2
Large	1	2	2
Hazard Group B			
Small	1	1	1
Medium	1	2	2
Large	1	3	3
Hazard Group C			
Small	1	1	2
Medium	2	3	3
Large	2	4	4
Hazard Group D			
Small	2	2	3
Medium	3	4	4
Large	3	4	4
Hazard Group E			
For all hazard group E substances, choose control approach 4			

www.ilo.org

Exposure Management

Can Expert Control Banding be used?



Exposure Index

- 'Dustiness'
- Amount Used

Impact Index

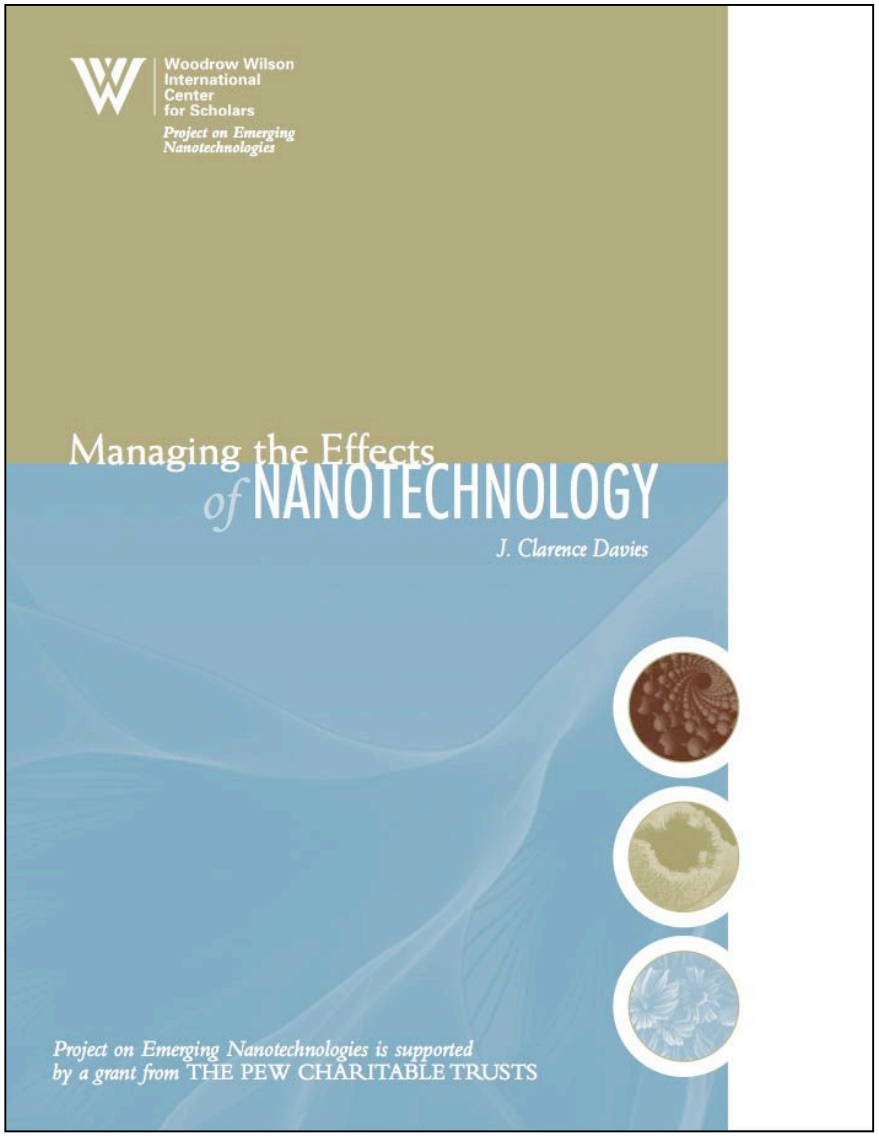
- Bulk hazard
- Surface Area
- Surface Activity
- Shape
- Size

Control Approach

1. General Ventilation
2. Engineering Control
3. Containment
4. Specialist Advice

Regulation and Nanotechnology

Managing the Effects of Nanotechnology



- Context
  - A review of options currently available to provide government oversight of nanotechnology in the US

- Main findings:
  - Nanotechnology is difficult to address using existing regulations
  - Anew law may be required to manage potential risks of nanotechnology
  - New mechanisms and institutional capabilities are needed

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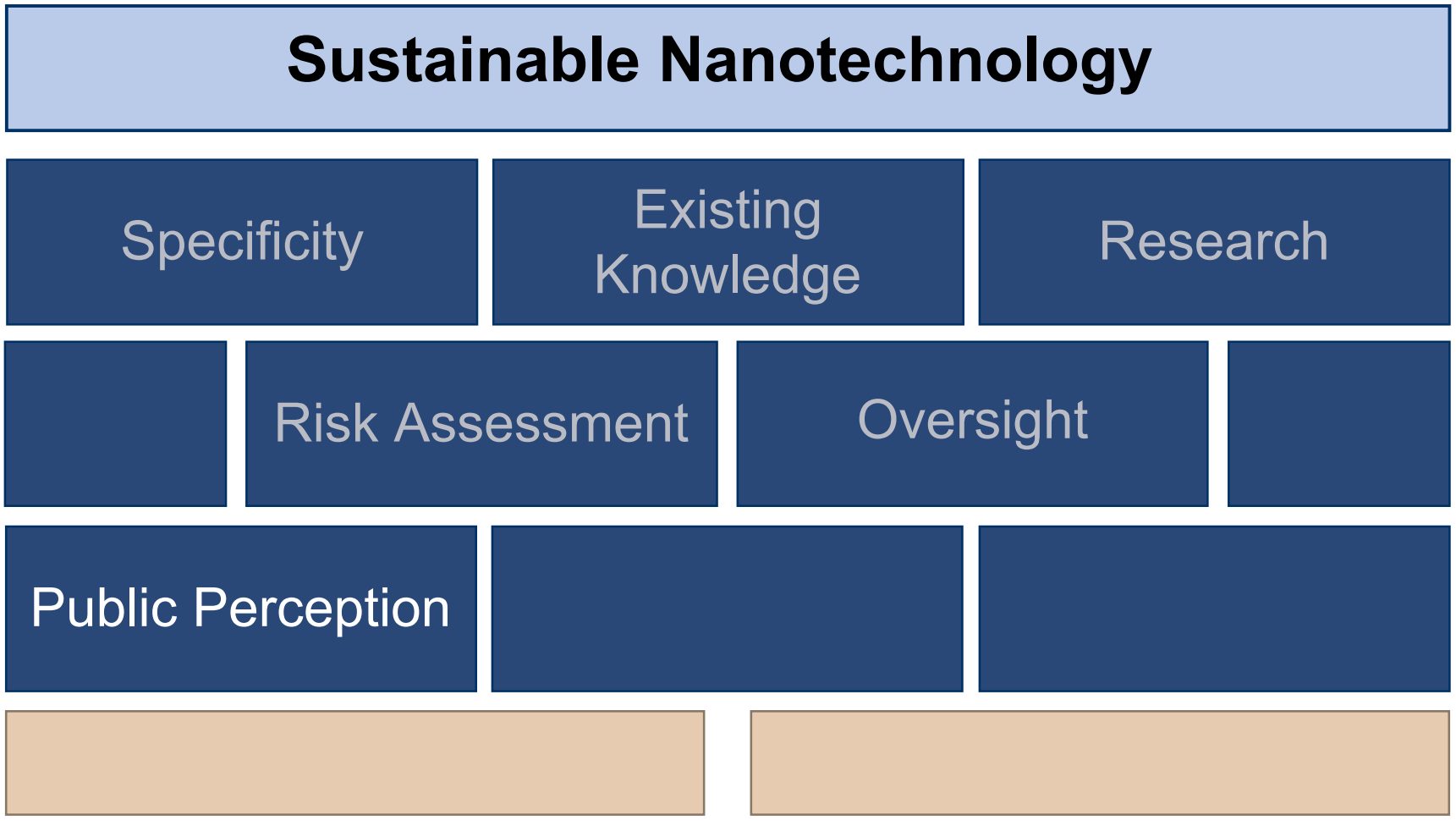
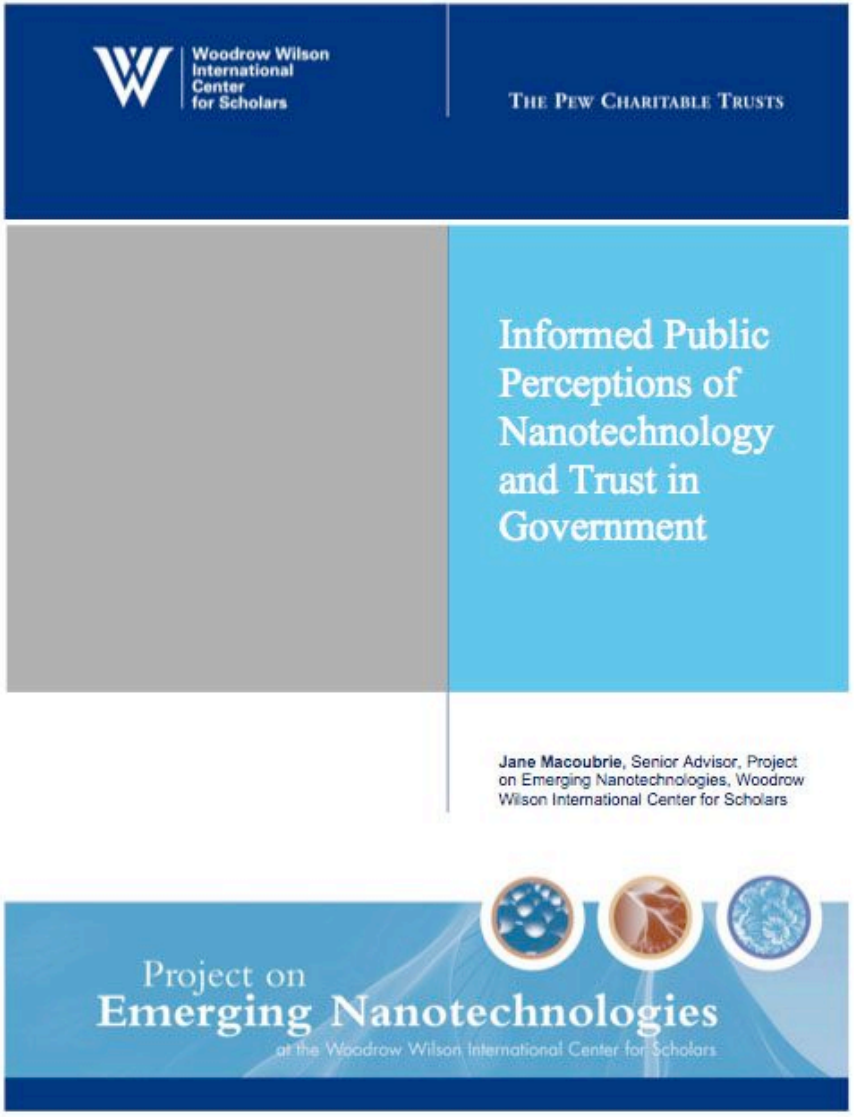


Public Perceptions

Macoubrie, September 2005



- 80 - 85% of public has heard "little" or "nothing" about nanotechnology
- Perceived benefits outweigh risks
- Top perceived potential benefits include:
  - Disease detection and treatment
  - Environmental remediation
  - National Security
  - Improved human abilities
  - Cheaper, longer lasting consumer products
- Top concerns include:
  - Military uses
  - Long term health effects
  - Environmental impacts
  - Loss of freedom and privacy
- Low trust in both government and industry to manage risk

From: Macoubrie, J. "Nanotechnology: Public Concerns, Reasoning, and Trust in Government"

Nano-consumer products

Over 200 products are commercially available worldwide
(based on manufacturer-identification as “nano”)

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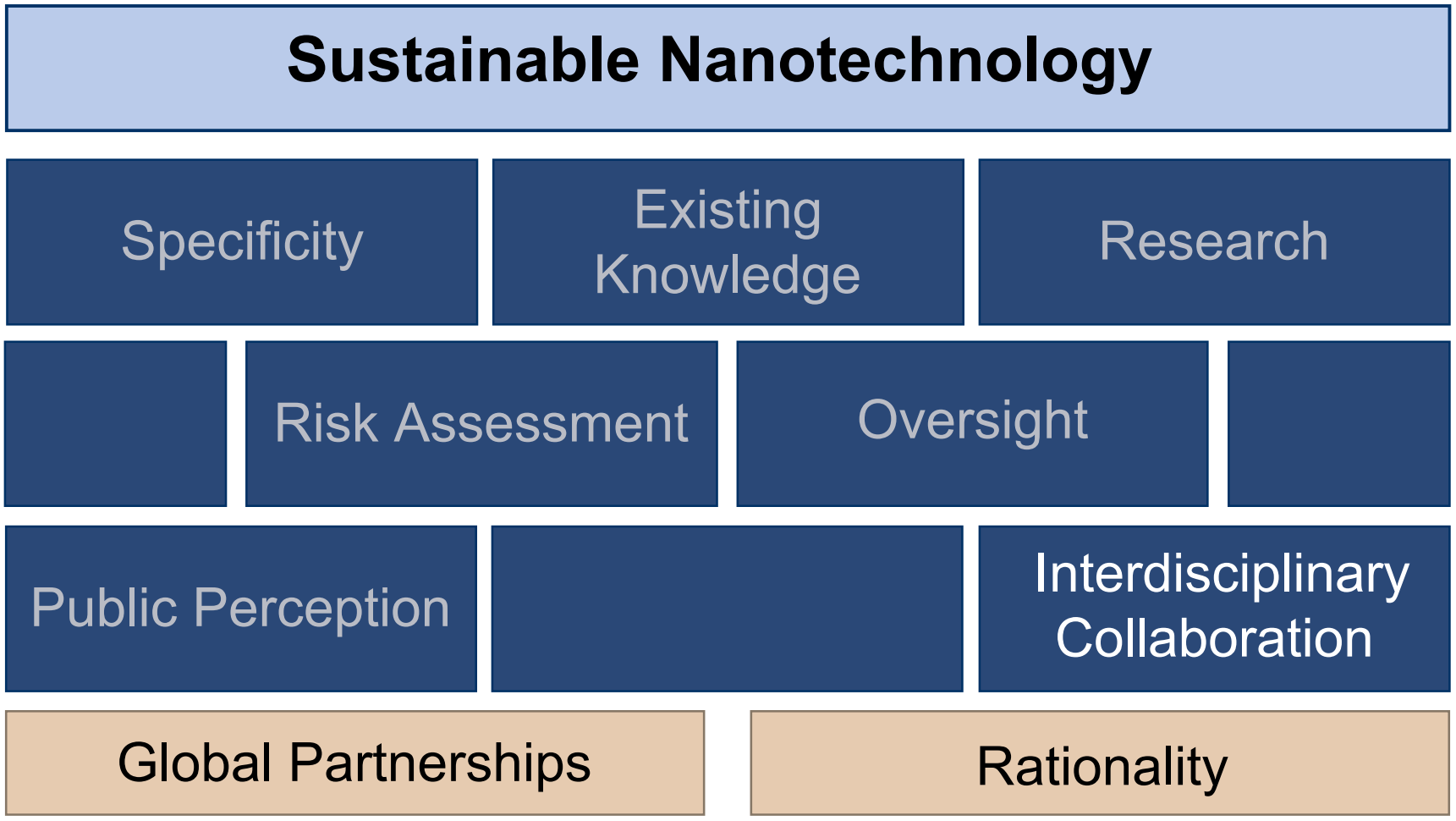

Interdisciplinary Collaboration

- Major scientific breakthroughs occur in the grey regions between established disciplines and fields of research
- Nanotechnology is no exception
- Understanding implications to human health will also require working together in [sometimes] uncharted waters between disciplines

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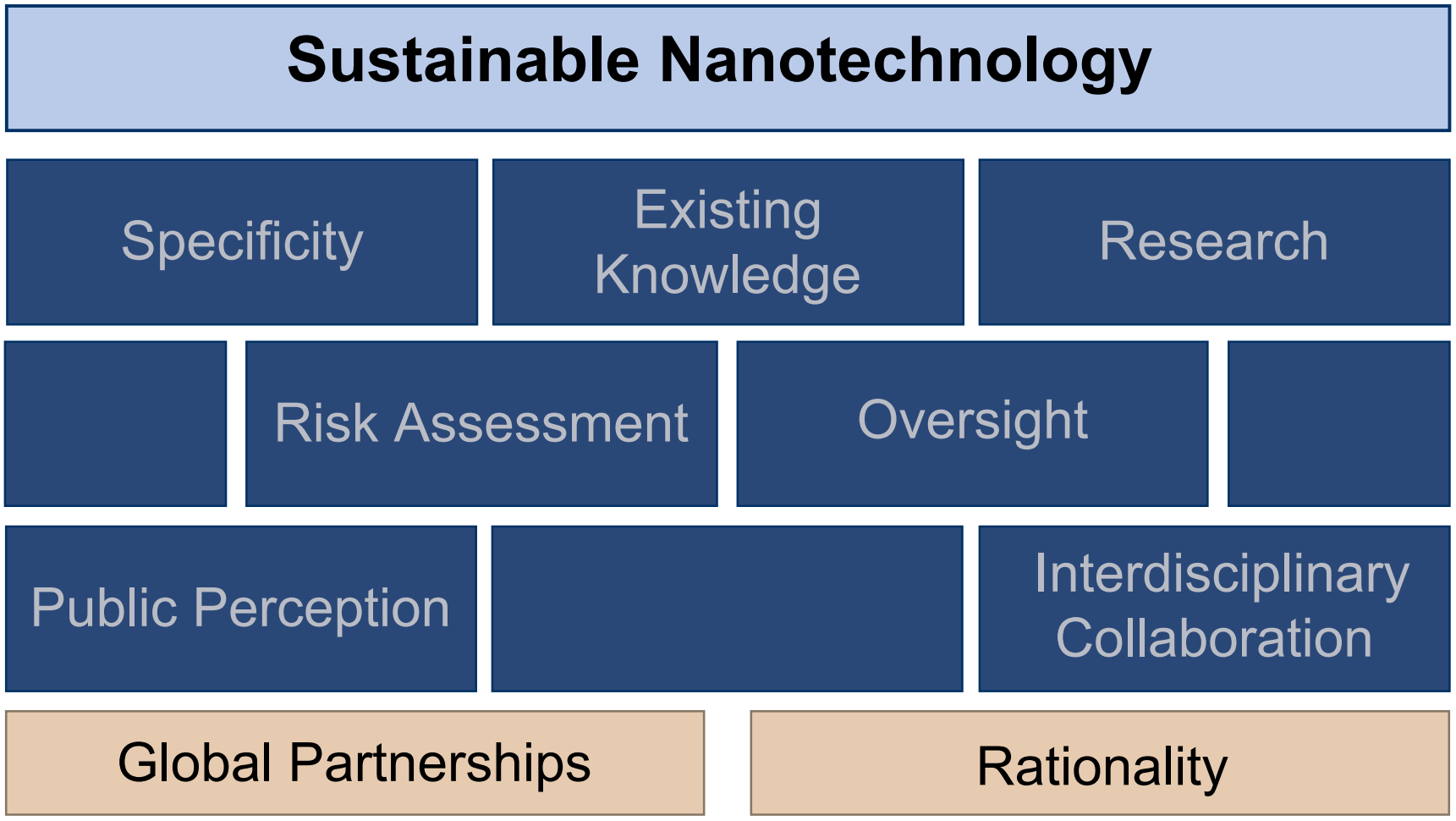


Global Collaboration

- Global implications require global cooperation and collaboration
- Complex problems require coordinated approaches to finding solutions
- Resources are limited
- Synergism

Rationality

Cutting through the hype

- Nanotechnology is revolutionary…

  …but we've been through technology revolutions before

- Nanomaterials have unique properties…

  …but the body responds to foreign materials in limited ways

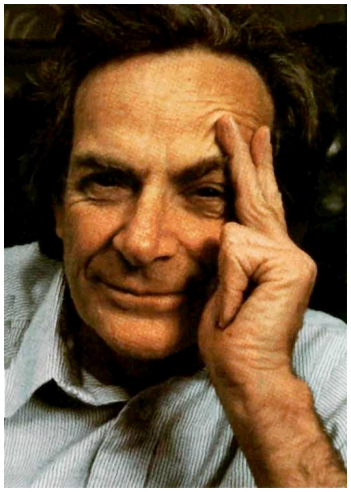
- Little is known about the health impact of engineered nanomaterials…

  …but we're not starting out from a point of total ignorance

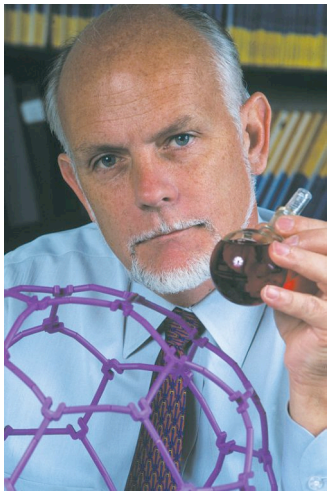
Beyond the hype and confusion, sustainable nanotechnology will ultimately depend on scientifically valid questions being asked, and scientifically robust answers being found.

A final thought…

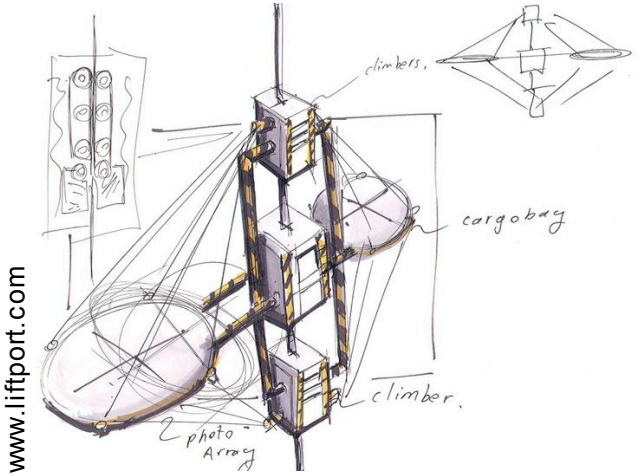
The Promise of Nanotechnology



Richard Feynman
1919 - 1988



Richard Smalley
1943 - 1985



The First Space Elevator
20??

- Nanotechnology has huge potential
- Let's make sure we get things right now, so that potential is realized