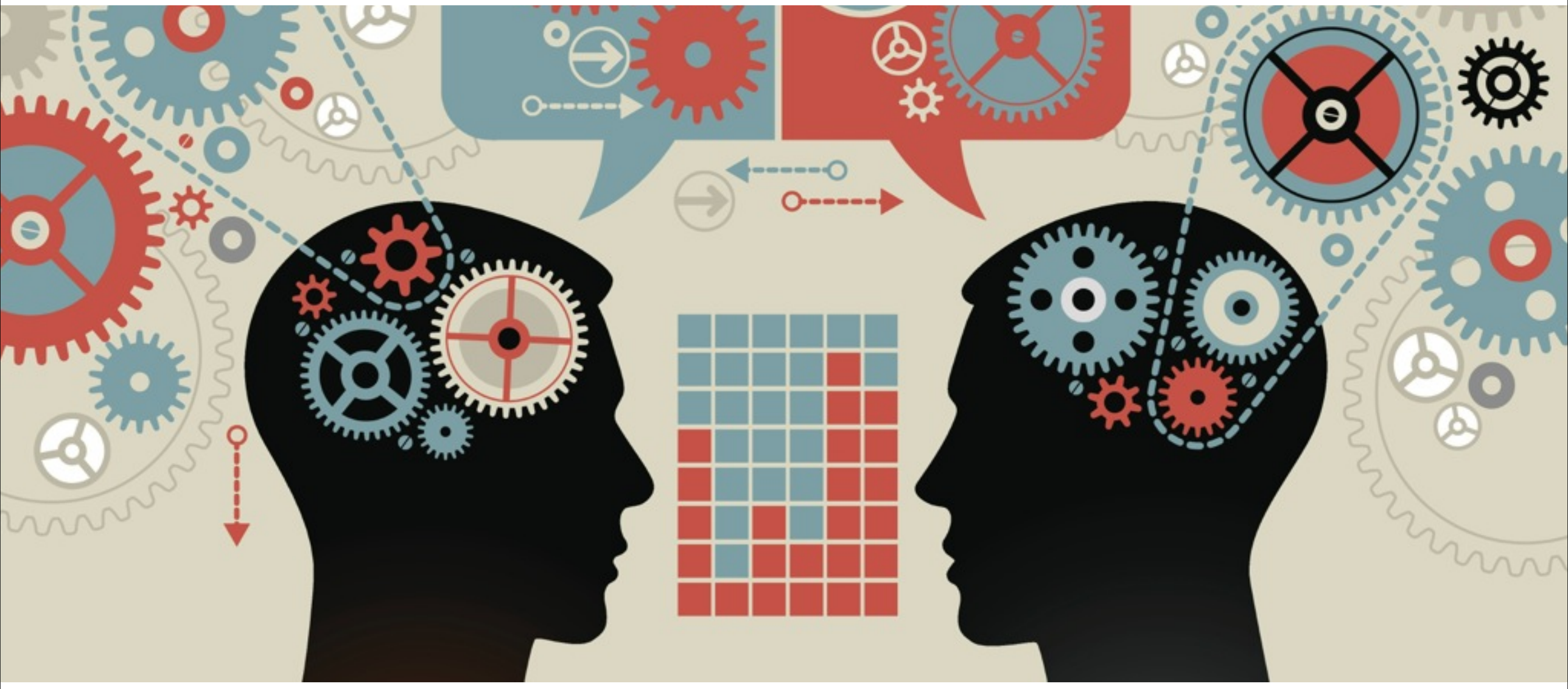
Innovative Approaches to **Emergent Risks**



Andrew D. Maynard

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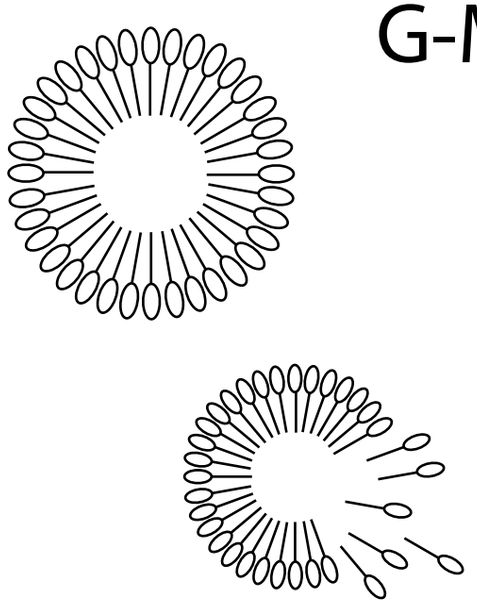
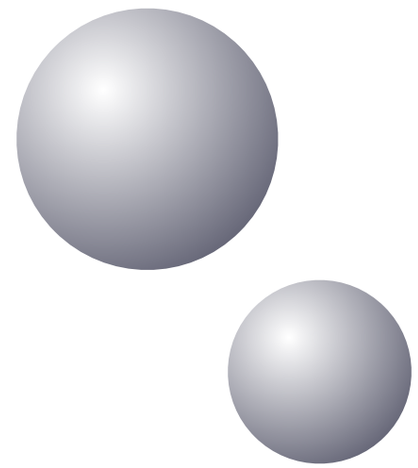
University of Michigan School of Public Health

Source: US Coast Guard
http://commons.wikimedia.org/wiki/File:Deepwater_Horizon_fire_2010-04-21.jpg

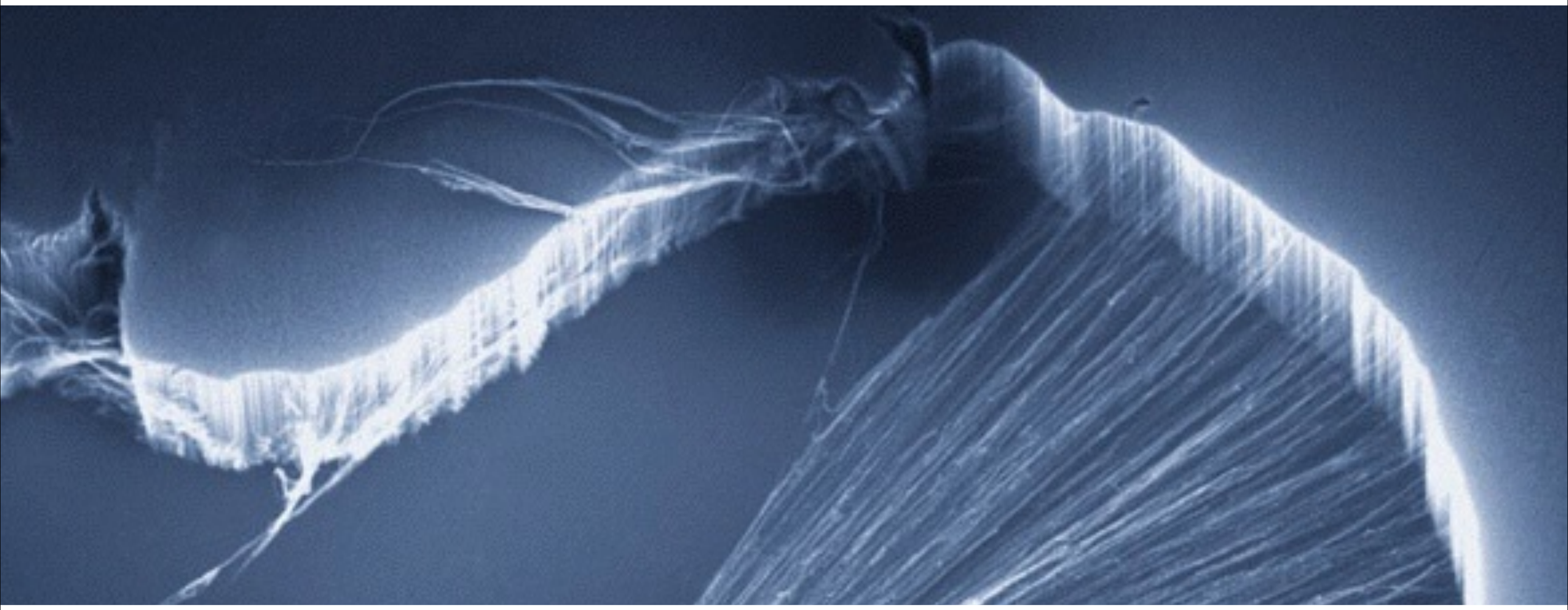
G-MARINE Fuel Spill Cleanup





Mesothelioma?!

Nanotechnology

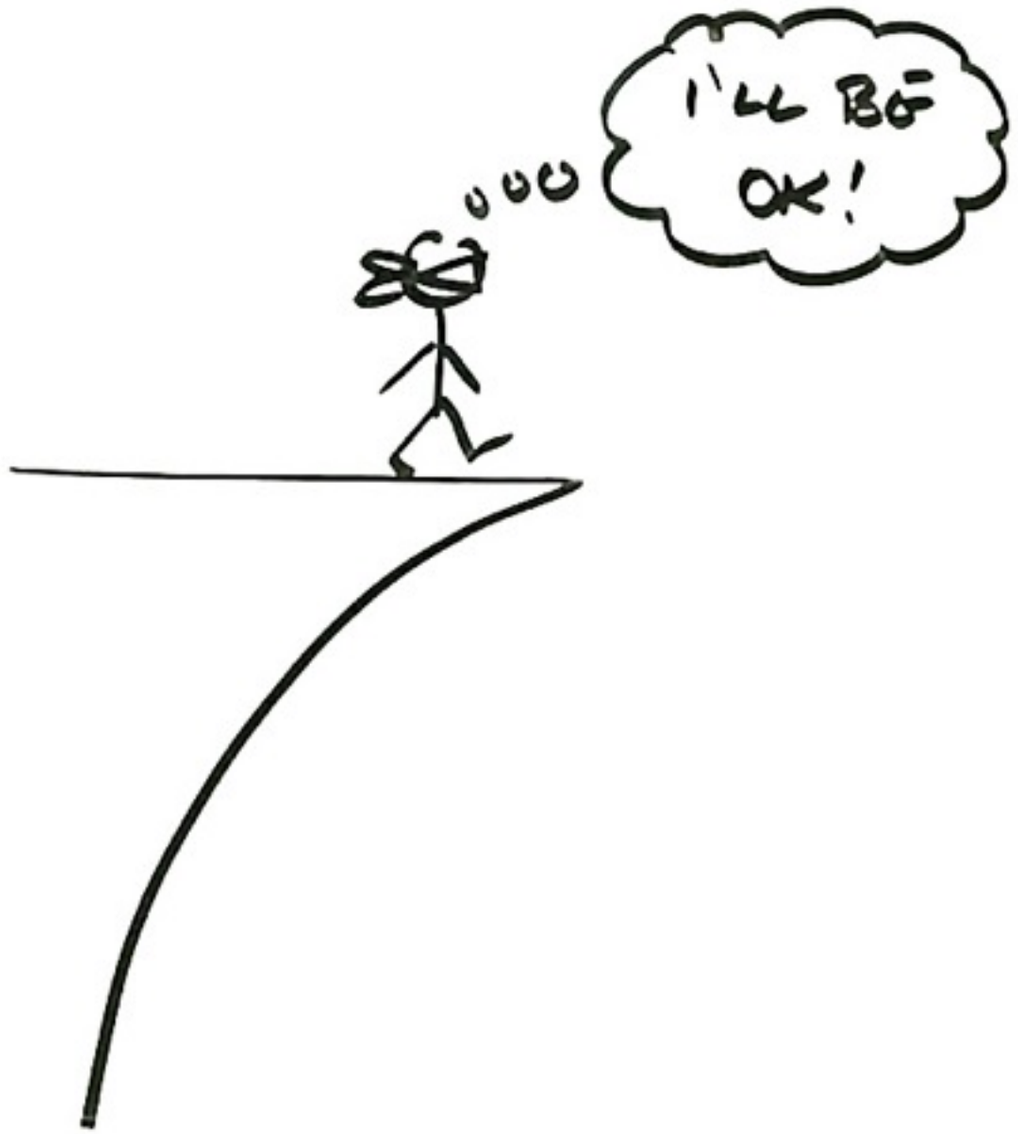


A valuable learning experience in how to do things better

Getting ahead of the
Technology Innovation Curve

- ☑ Intelligence
- ☑ Coordination
- ☑ Cooperation
- ☑ Research
- ☑ Regulation
- ☑ Collaboration
- ☑ Integration
- ☑ Innovation


The future...
...safe by design!


I'LL BE OK!

Smallest

Largest

Novel Behavior

CdSe Quantum Dots

Source: Wikipedia
http://de.wikipedia.org/wiki/Datei:Ewaste-delhi.jpg

So what went **Wrong?**

- [x] A focus on a technology "brand"
- [x] An over-emphasis of technology promotion
- [x] An assumption of emergent risk…
- [x] …that the academic community could identify and resolve

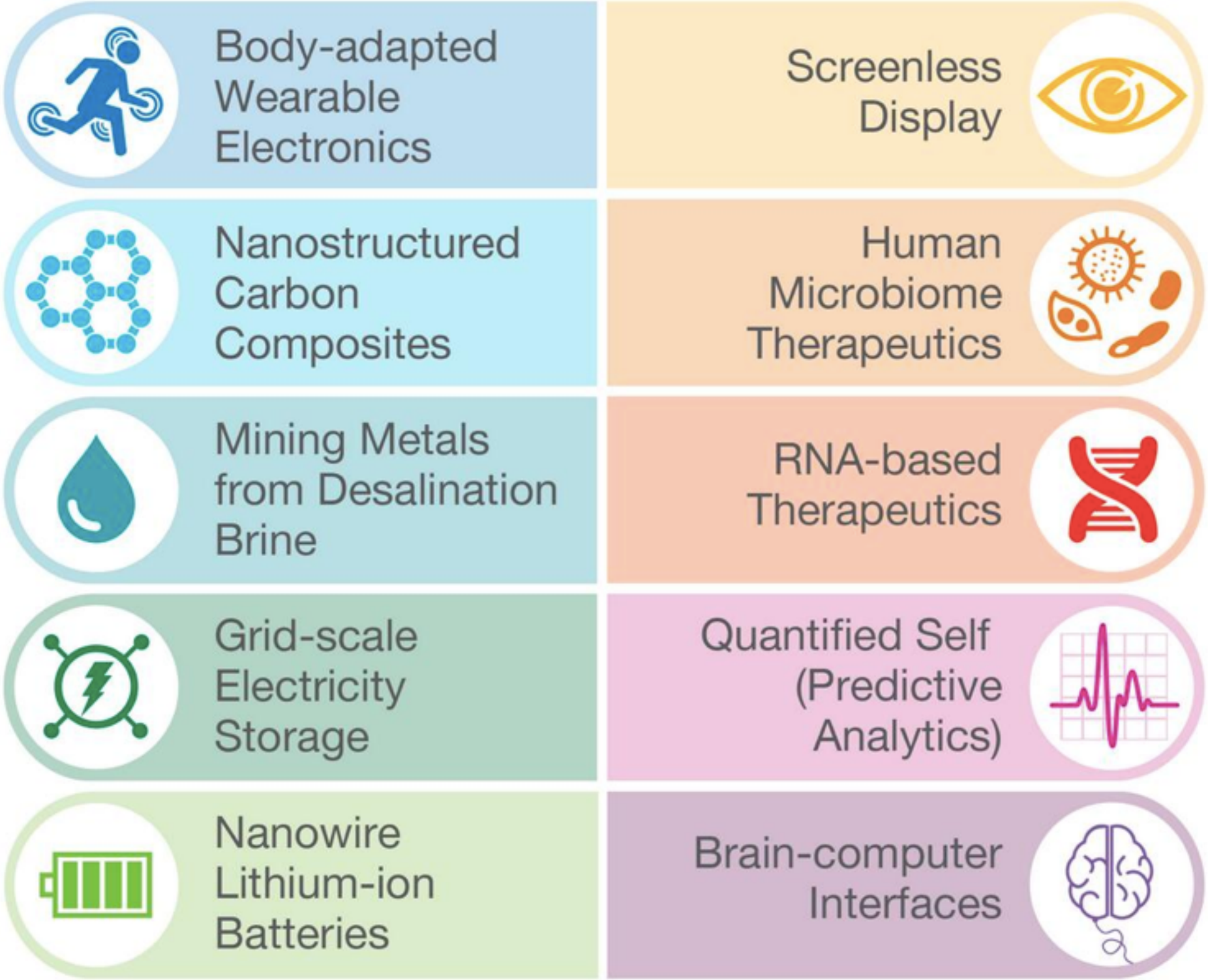
What could we do **Better?**

- [ ] Avoid getting tramlined

Top 10 Emerging Technologies 2014

WORLD ECONOMIC FORUM

http://wef.ch/etech14



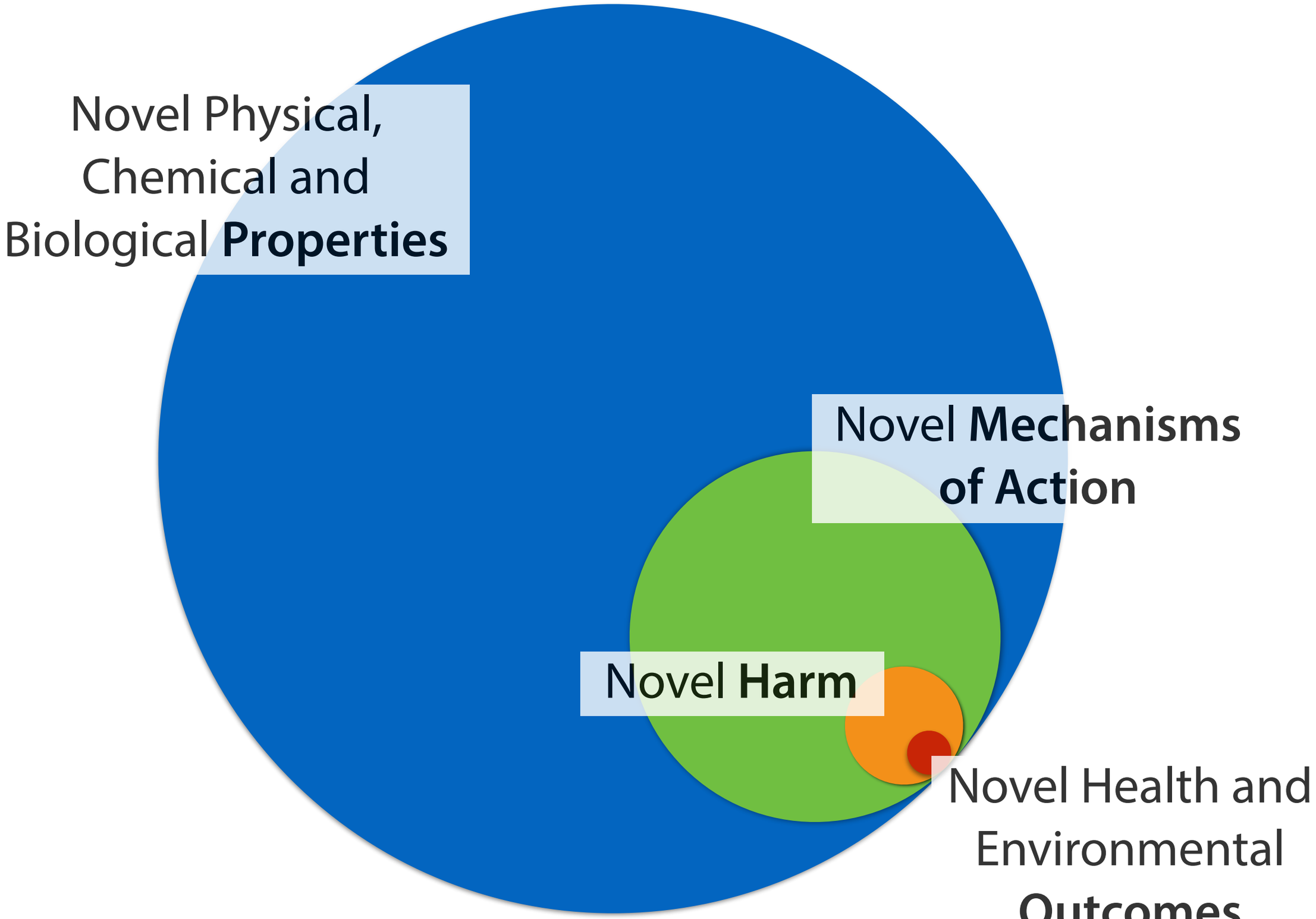
What could we do **Better?**

- ☐ Avoid getting tramlined
- ☐ Focus on key risk endpoints

What could we do **Better?**

- ☐ Avoid getting tramlined
- ☐ Focus on key risk endpoints
- ☐ Get the science right

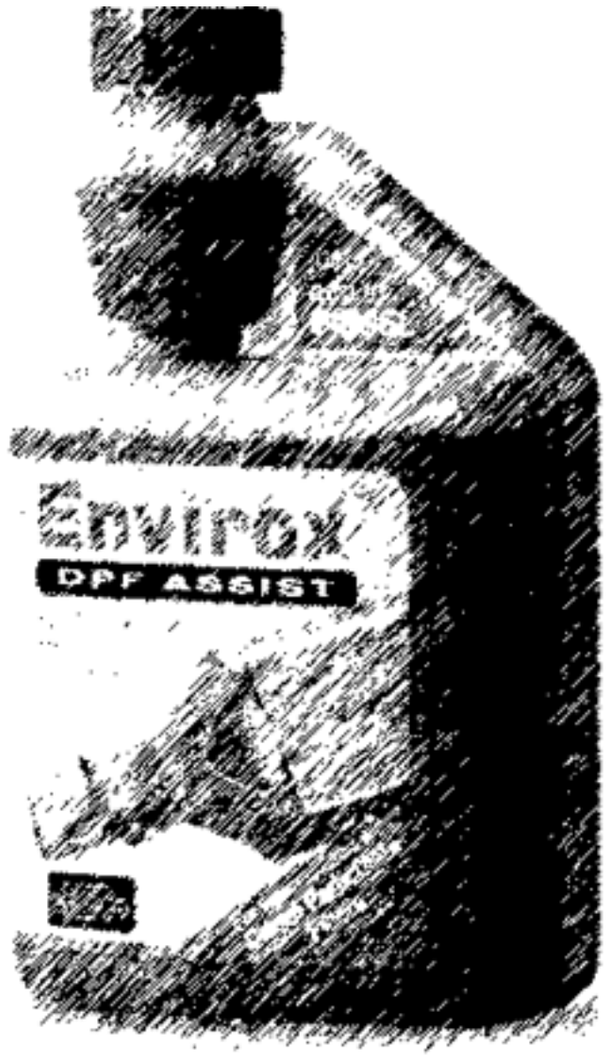
Domains of **Novelty**



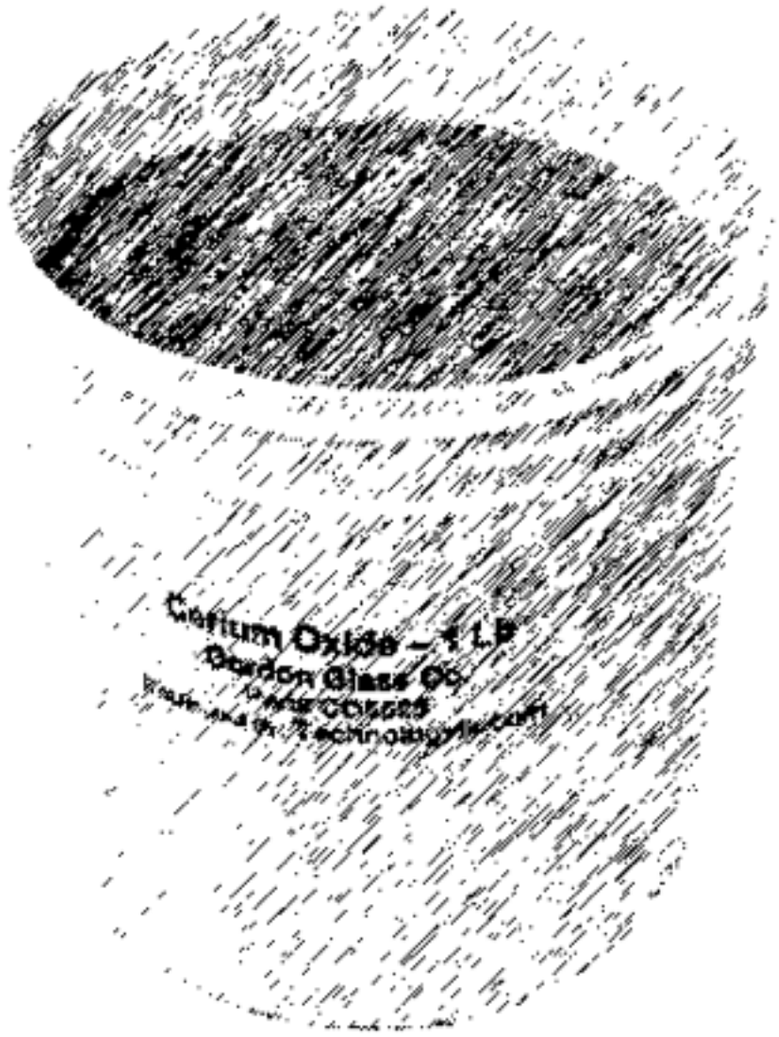
What could we do **Better?**

- ☐ Avoid getting tramlined
- ☐ Focus on key risk endpoints
- ☐ Get the science right
- ☐ Ask the right questions

Cerium Oxide particles



Diesel additive



Glass/silica polishing agent

What could we do **Better?**

- ☐ Avoid getting tramlined
- ☐ Focus on key risk endpoints
- ☐ Get the science right
- ☐ Ask the right questions
- ☐ Be proactive

journal of
RESPONSIBLE INNOVATION

http://www.tandfonline.com/loi/tjri20

What could we do **Better?**

- ☐ Avoid getting tramlined
- ☐ Focus on key risk endpoints
- ☐ Get the science right
- ☐ Ask the right questions
- ☐ Be proactive
- ☐ Be inclusive

Source: Wikipedia
http://commons.wikimedia.org/wiki/File:No_Nano_Grenoble_P1150729.jpg

And **Synthetic Biology?**

- ☐ Frame and parameterize the challenges based on the science, plausible outcomes, desired and undesired endpoints and alternative paths forward

- ☐ Explore new ways of integrating risk assessment and risk management

- ☐ Encourage creativity

Source: US Coast Guard
http://commons.wikimedia.org/wiki/File:Deepwater_Horizon_fire_2010-04-21.jpg

Discussion

Integrated product-centric approaches to Technology Innovation

Multiple sensors

Latest generation ICs

Advanced touch screen

Durable glass

High performance battery

Metals: Pt, Al, Ag, Au, Cu

Rare Earth Minerals: Y, La, Pr, Nd, Eu, Gd, Tb, Dy

Jobs

Economic growth

Improved health

Improved well-being

More Innovation

Solutions to complex problems

Life enrichment

Benefits

Materials production?

Materials transport?

Secondary production?

Product transport?

Use?

Disposal?

Recycling?

Risks

Materials production

Jobs

Materials transport

Economic growth

Secondary production

Improved health

Product transport

Improved well-being

Use

More Innovation

Disposal

Solutions to complex problems

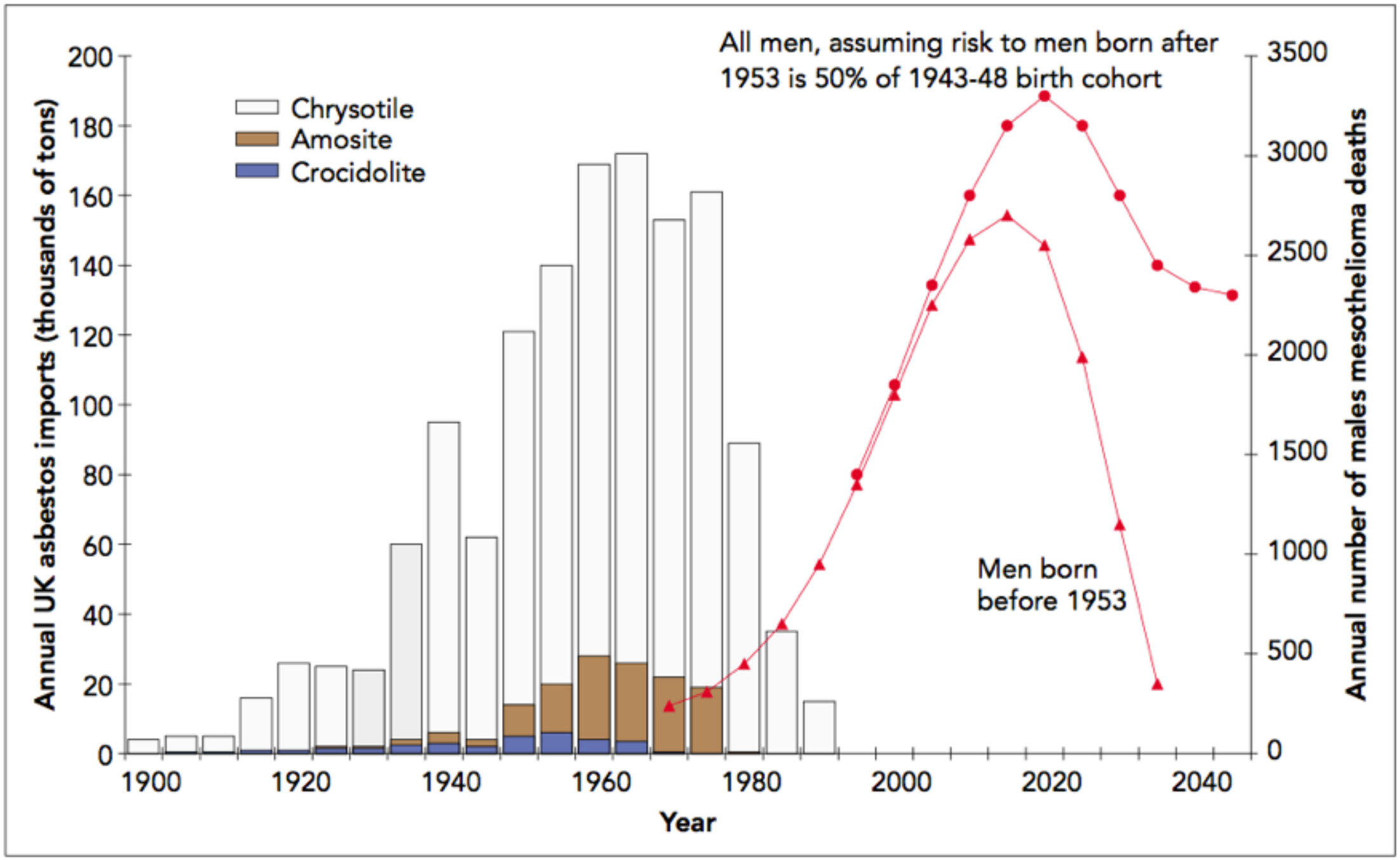
Recycling

Life enrichment

Benefits & Risks

Addressing the most appropriate questions

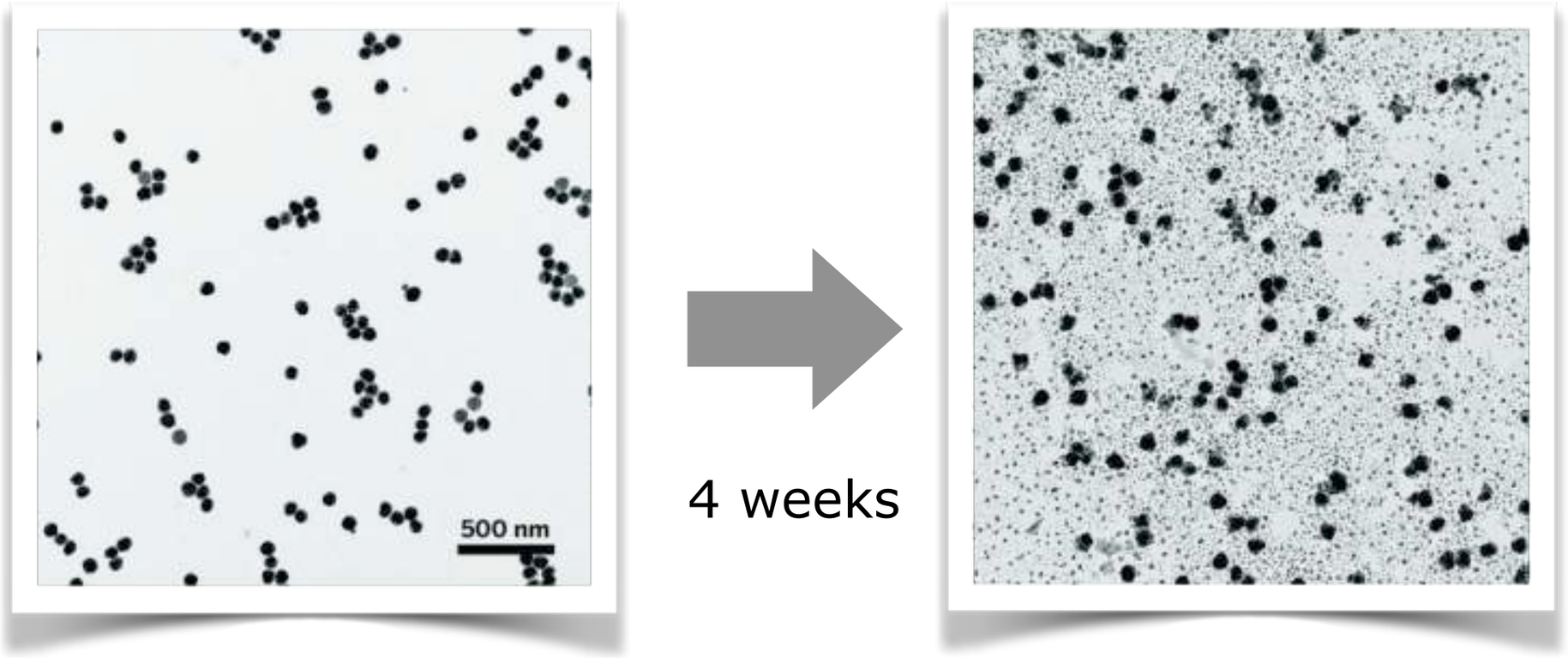
UK asbestos imports and predicted mesothelioma deaths



Late lessons from early warnings: the precautionary principle 1896–2000
http://www.eea.europa.eu/publications/environmental_issue_report_2001_22

Source: Flickr
http://www.flickr.com/photos/jimstr/2977755032/

Ubiquitous **Ag Nanoparticles...**



Glover RD, Miller JM, Hutchison JE. 2011. Generation of Metal Nanoparticles from Silver and Copper Objects: Nanoparticle Dynamics on Surfaces and Potential Sources of Nanoparticles in the Environment. ACS Nano 10.1021/nn2031319.

Product-based Plausible Prospective Scenarios

Exploring boundaries around the safe use of advanced materials: A Prospective Product-Based Case Studies approach (2014). A Maynard, in Nanotechnology Environmental Health and Safety, Second Edition: Risks, Regulation, and Management (Micro and Nano Technologies) 2nd edition (Eds. M Hull and D Bowman). In Press

PRODUCT

Final Production

How is the intermediary product containing the advanced material most likely incorporated into the final product?

Product Transportation

How is the product likely to be stored and transported from the point of manufacture to the point of sale and use?

Intermediary Production

What intermediary products is the advanced material potentially incorporated into, and what else is included in these products?

Product Use

Who is expected to use the product, and how are they likely to use it?

Material Generation

How is the advanced material likely to be produced, handled and stored?

Product Disposal

How is the product most likely disposed of? Is it likely to be recycled, and if so, how?

Exposure Potential

Is the material potentially released, and in what form, in what media, in what quantities, and with what else. How might it get into the body, and how might exposure be reduced?

Risk Red-Flags

Are there aspects of the material and its exposure potential that suggest it might present a plausible health risk? Can these potential risks be reduced using established approaches?

PLAUSIBILITY

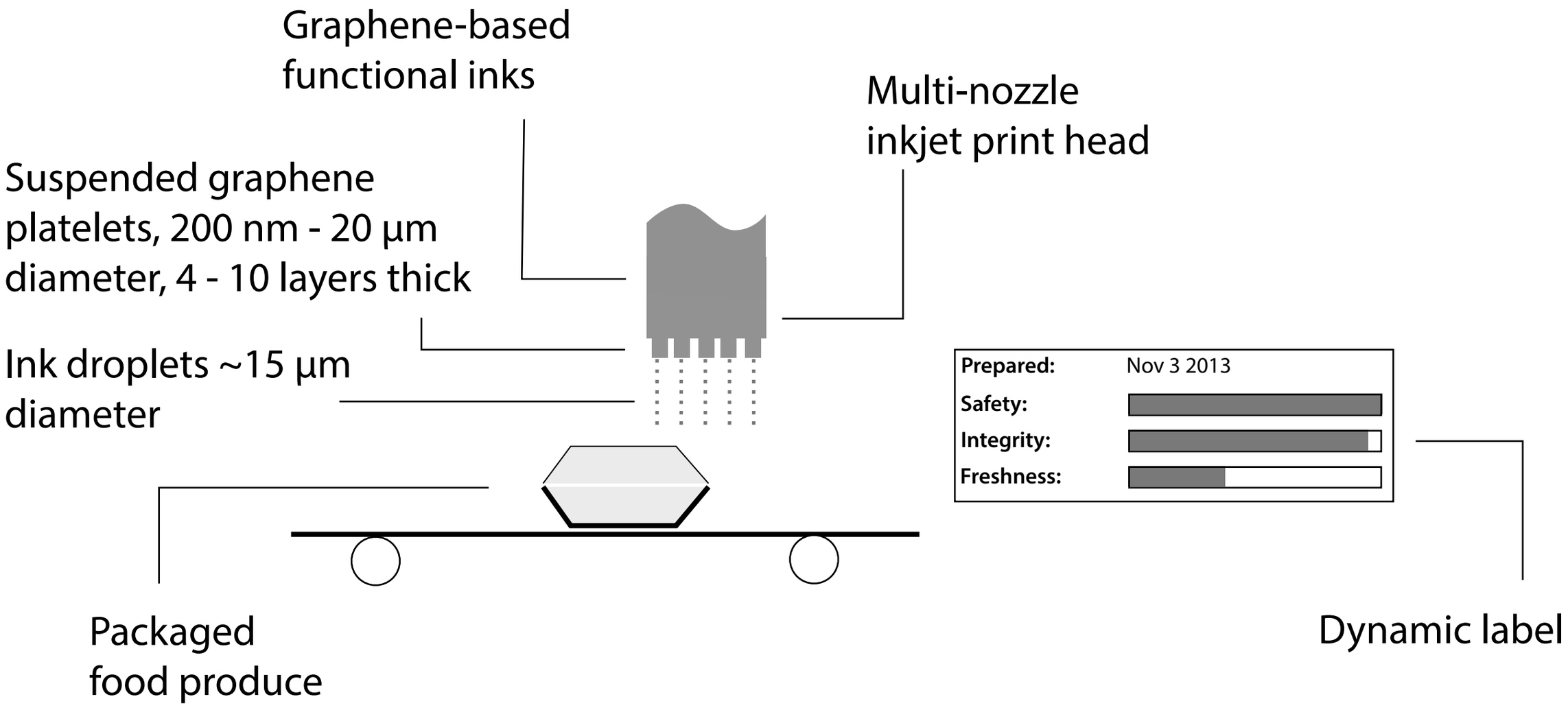
Technological

Economic

Social

Example

A graphene-based dynamic labels for food products



Material Generation

- Starting material: high purity graphite
- Added to 1-pyrenesulfonic acid salt solution, and ultrasonicated
- Excess graphite removed via centrifugation
- Suspension stored in 55 gallon drum

Exposure Potential

- Aerosolization, spray and splash dominate
- Formation of inhalable and respirable droplets
- Exposure to discrete graphene particles highly unlikely
- Dermal exposure without adequate protection
- Similar exposure profile to many industrial processes
- Established exposure control methodologies likely to reduce exposures substantially

Intermediary Production

- Formulation into conductive ink
- Py-SO(3) slurry centrifuged
- Graphene platelets repeatedly washed & centrifuged
- Graphene added to deionized water at 1 part per 100 concentration
- Surfactant added at 1 part per 100 (e.g. polyvinylpyrrolidone)
- Stabilizing agents added
- Resulting ink stored in 1 gallon containers

Exposure Potential

- Aerosolization, spray and splash dominate
- Formation of inhalable and respirable droplets
- Exposure to discrete graphene particles highly unlikely
- Dermal exposure without adequate protection
- Maintenance and cleanup
- Similar exposure profile to many industrial processes
- Established exposure control methodologies likely to reduce exposures substantially

Final production

- Multi component inkjet print head
- Ink supplied from large capacity reservoir - replenished manually
- Printing head enclosed.
- Multiple printing heads operating in parallel
- Print area under negative pressure, with LEV leading to HEPA filters
- Printed labels air dried
- Cleanup and maintenance following standard practices

Exposure Potential

- Resuspension during cleanup and maintenance
- Resuspension likely to consist of large aggregates - exposure to discrete graphene particles highly unlikely
- Established exposure control methodologies likely to reduce exposures substantially

Product Transportation

- Product transportation at temperatures down to -20 °C likely
- Transportation via road, rail and air
- Abrasion of labels possible - on outside of packaging

Exposure Potential

- Direct contact transferral - low probability
- Migration to food product - extremely low probability
- Abrasion and resuspension - possible, at low levels. Large particles anticipated, possibly too large to be inhaled
- Unlikely to be substantial release
- Physicochemical nature of material released dependent on mechanisms leading to release

Product Use

- Retailers will use labels for product quality and security feedback
- Consumers will use labels for product quality and security feedback
- Labels will be one use, and will be disposed of with packaging

Exposure Potential

- Direct contact transferral during handling - low probability
- Release through abrasion/mechanical stress possible
- Abrasion and resuspension - possible, at low levels. Large particles anticipated, possibly too large to be inhaled
- Possible dissolution and subsequent dermal contact
- Unlikely to be substantial release
- Physicochemical nature of material released dependent on mechanisms leading to release

Product Disposal

- Collection
- Landfill
- Incineration
- Recycling

Exposure Potential

- Shedding through abrasion/mechanical stress
- Complete incineration (graphene oxidizes efficiently at ~800 °C)
- Partial incineration a low probability
- Re-incorporation into recycled materials a significant possibility
- Physicochemical nature of material released dependent on mechanisms leading to release

Risk Red Flags

- Clarity of exposure pathways and effectiveness of conventional exposure control approaches mean that plausible products are unlikely to lead to significant exposure
- **Inhalation**
  - Discrete graphene platelets potentially harmful. However, few exposure points where such exposure is likely to be significant.
  - Inhalation of droplets during manufacture could lead to graphene particle delivery to deep lungs - of concern if exposure not controlled
  - Resuspension during manufacture likely to lead to large aggregates - some inhalable, but toxicity of aggregates uncertain
  - Abrasion/mechanical release during use unlikely to lead to significant exposure/risk
- **Dermal**
  - Dermal exposure likely to particles during production and aggregates at later stages of life cycle. No clear evidence that this is a significant exposure route.
  - Some concern if ink is water soluble after application to food packaging
- **Ingestion**
  - Limited possibility of ingestion during product use
  - More information needed on behavior in GI tract
- **Summary:** very few risk red flags with a well-designed, plausible product

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YouTube: http://youtube.com/riskbites