

Nanotechnology and Advanced Manufacturing

“OS&H for 21st Century Manufacturing”

WestON
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Overview

- What is Nanotechnology? (Fast, I promise)
- Why is it important to NIOSH and to you?
- What has NIOSH done?
- Where have all the Nanomaterials gone?
- What is Advanced Manufacturing and why is it a big deal?

Nanotechnology: A Review

Nanotechnology: 30 Second Review

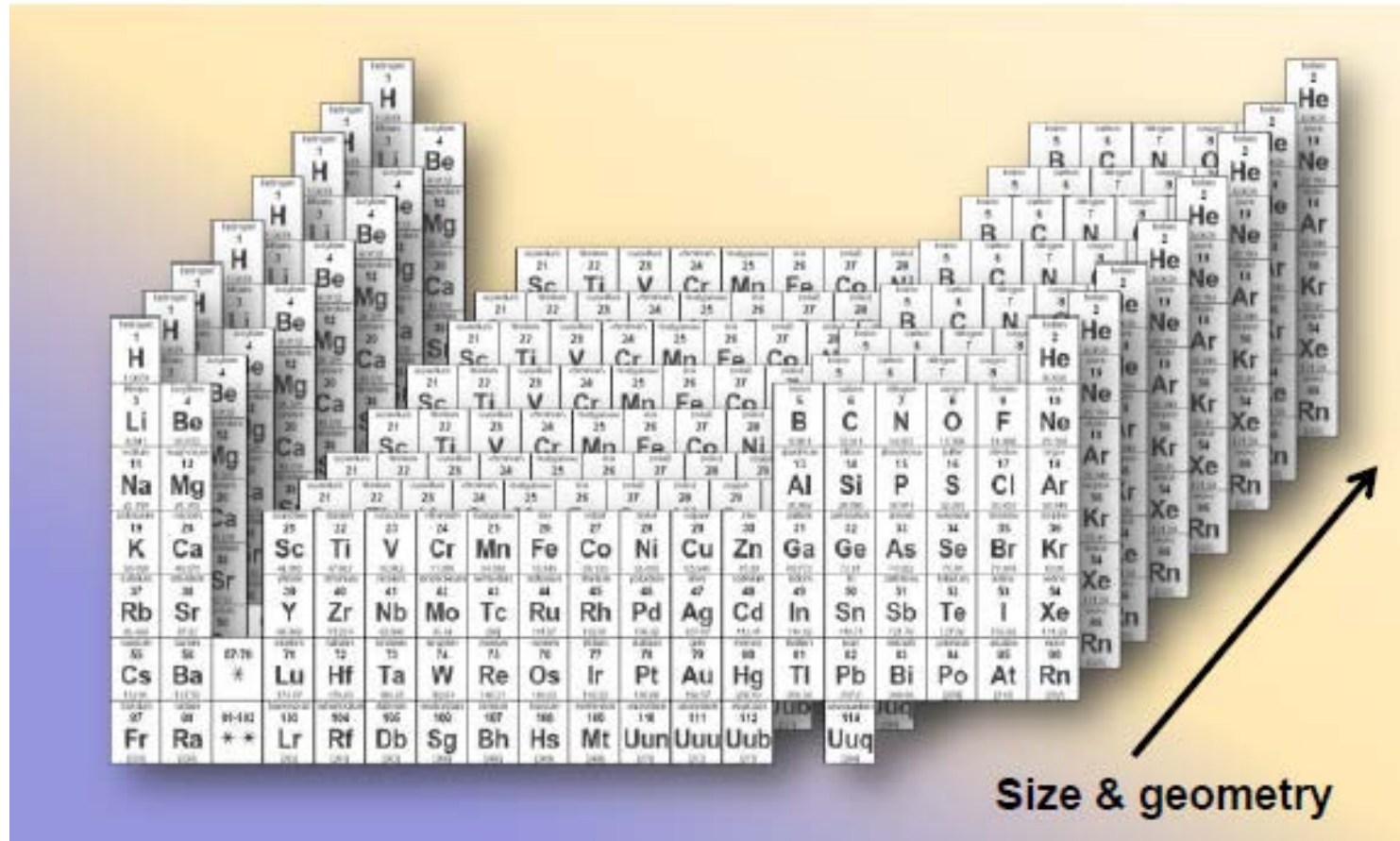
Old: Material behavior driven by chemistry and making things from big pieces

Nanoscale Science: making materials one molecule at a time at the nano scale

New: Material behavior driven by size, shape, surface chemistry. More active and efficient

Result: New material properties and behavior:
Higher or newer hazard?

Nanomaterial Science: Opening the 3rd Dimension of the Periodic Table



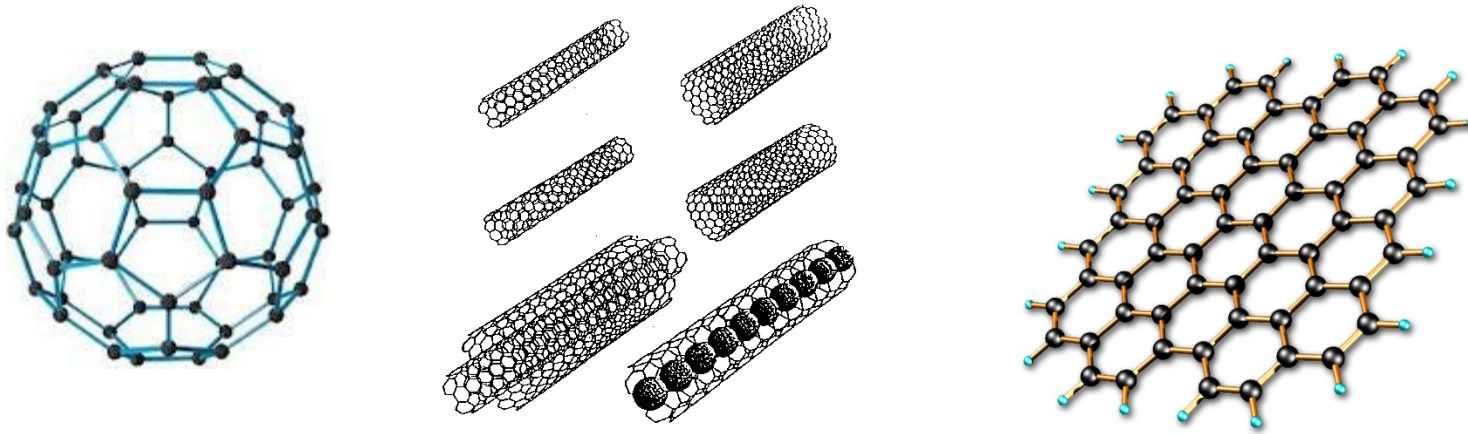
“Carbon just isn’t carbon anymore”



← **Old**

Your Grandfather's Carbon

New



The Nanomaterial designer's carbon

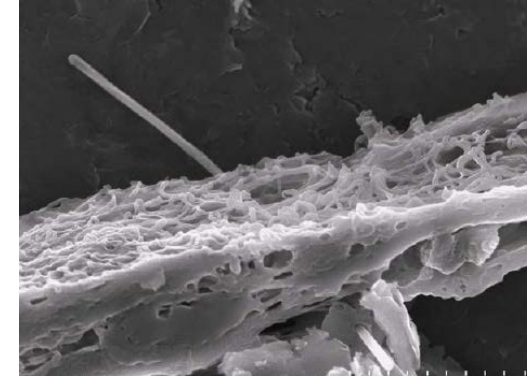
← **"Built" in the nm range**

Engineered Nanomaterials (ENMs)

- **Carbons**
 - e.g., nanotubes, nanofibers, fullerene, graphene
- **Oxides**
 - e.g., metal oxides, ceramics, TiO_2 , ZnO , SiO_2 , CeO_2 , Fe_3O_4
- **Metals**
 - e.g., Ag, Fe, Al, Si, Zn, Cu, Ni
- **Cellulose**
 - e.g., nano fibrils, nano crystals
- **Semiconductors**
 - e.g., CdSe, CdS, InAs, InP
- **Polymers/organics**
 - e.g., liposomes, dendrimers

NIOSH Response: A Research Program

- A blend of lab and fields projects -

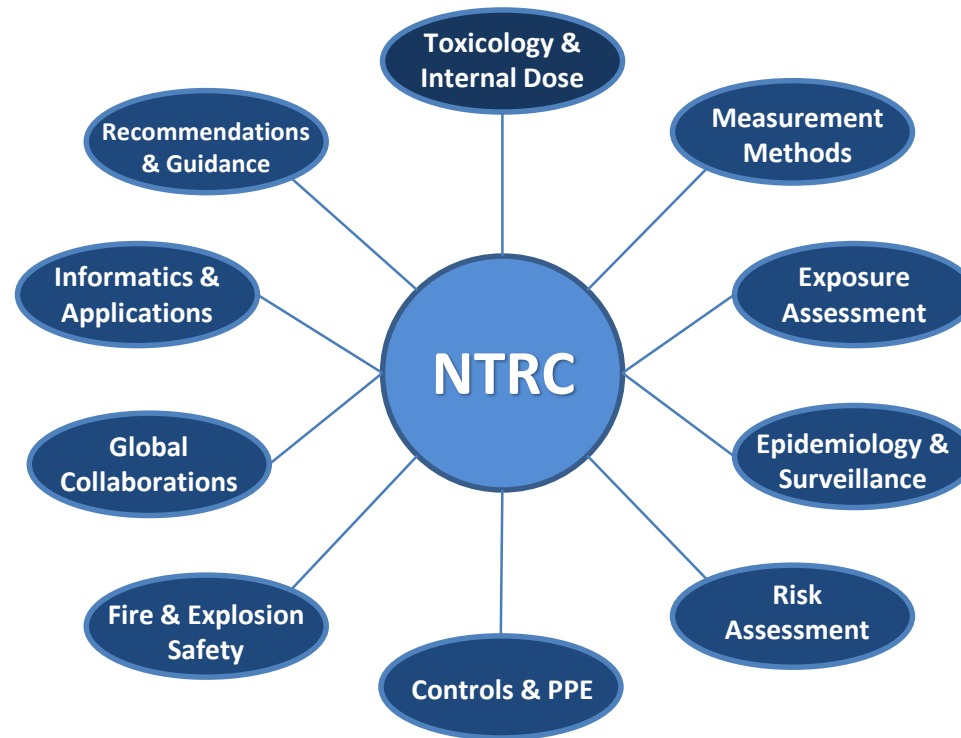


Nanotechnology Research Center (NTRC)



- **Established in 2004** to investigate new nanotechnology related hazards
- One of the **first** agencies to identify that exposures to engineered nanomaterials (**ENMs**) could cause disease
- Pioneered **techniques to generate aerosols** of engineered nanoparticles **for animal testing**
- First to show that certified **respirators and controls can protect workers**
- Published **practical guidance** on measuring exposures and summaries of field results

NIOSH Nanotechnology Research Center Active in Ten Critical Areas



Centrally managed and coordinated for maximum impact

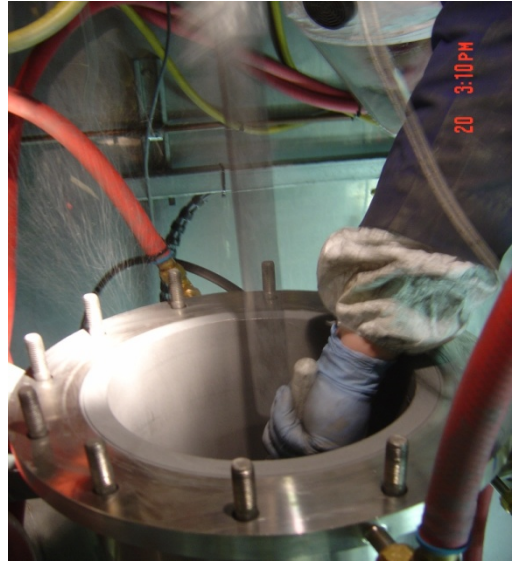
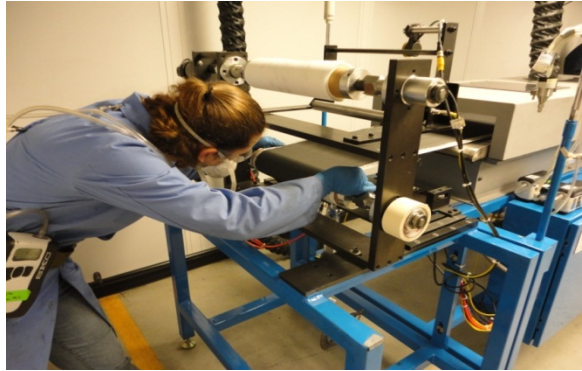
Priority Goals for 2015- 2016

1. Increase understanding of **new hazards** and related health **risks** to nanomaterial workers and expand initial findings
2. Expand **field investigations** and the creation of **guidance** on hazards, risks, and risk management approaches for workers, employers, agencies and policy makers.
3. Support **epidemiologic studies** for nanomaterial workers including medical and exposure studies
4. Assess and promote national and international **adherence** with risk management guidance.
5. Link to Advanced Manufacturing initiative

Nanotoxicology Program: Current Directions

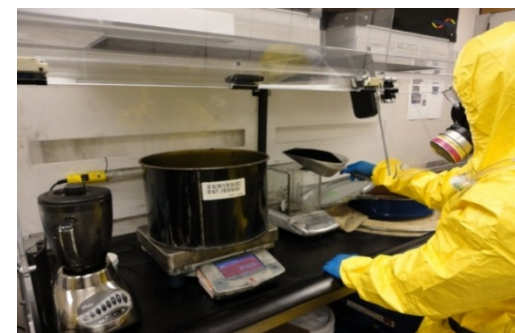
1. Toxicological Characterization of Emerging Nanomaterials
2. Mechanisms of Action of Established Biological Outcomes: Fibrosis and Cancer
3. High Throughput In Vitro Assays for Predicting Toxicity: Mode of Action of Nanomaterials
4. Occupationally Relevant Exposures/Doses: Partnering With Epidemiology and Industry
5. Extra-pulmonary Responses to Respiratory Exposure
6. Biomarkers for Exposure and Biological Outcome
7. Effect of phys/chem modification on biological response

Exposure Assessment in the Real World

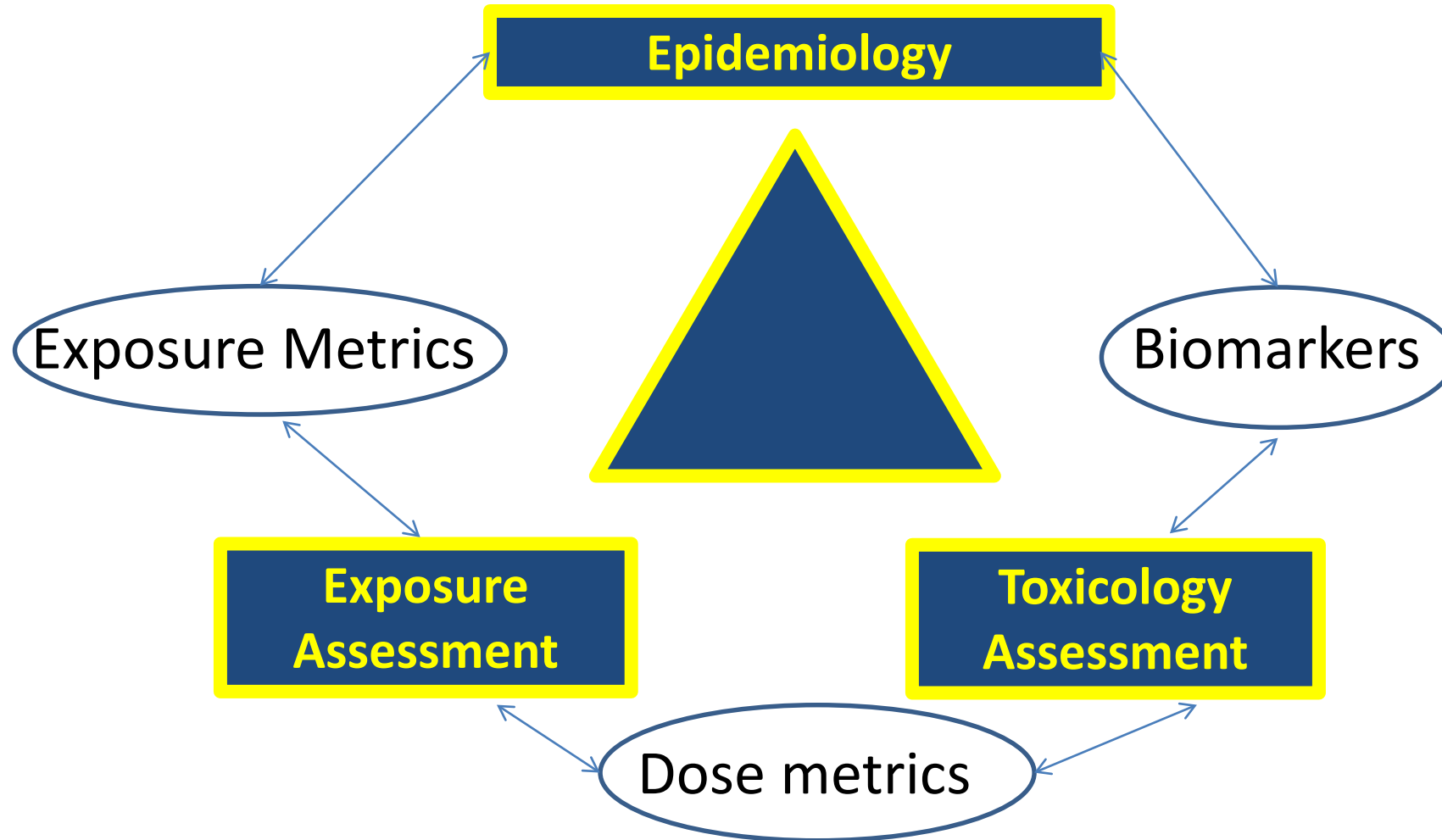


NIOSH Performs On-site Research

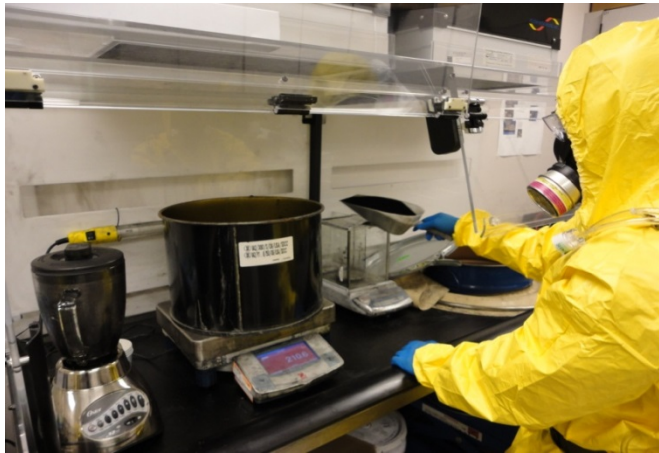
- To date, over 100 visits to 65 different sites
- Diversity in sites, materials, and applications
- Focused efforts: CNT/CNF, Controls
- Evaluate processes and personal exposures
- Use and extend existing methods
- **Partnerships with the private sector is a key to success**
- Guidance and recommendations given to employers
- Summary results published



Connecting the Key Exposure Assessment Elements



Evaluating Physical Hazards Airborne Dust Generation

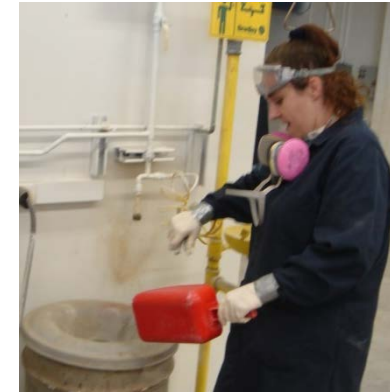


Dry Powder Operations

Dustiness
Powder Quantity
Type of Operation
Engineering Controls
Ventilation

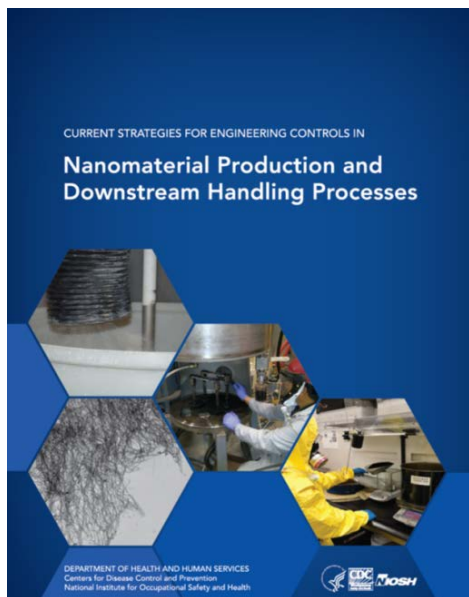
Factors Influencing
Airborne Dust
Generation

Health Concern

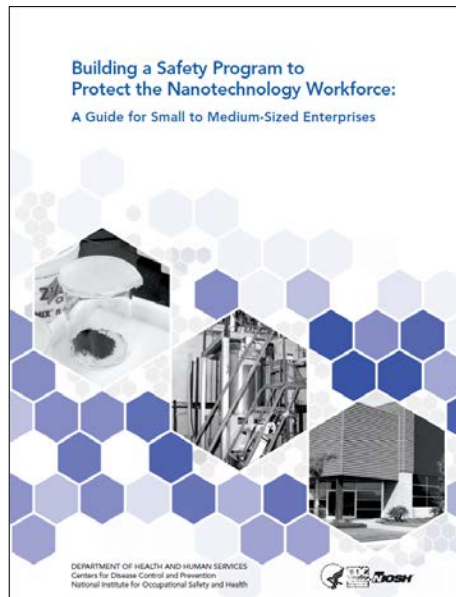


Safety Concern

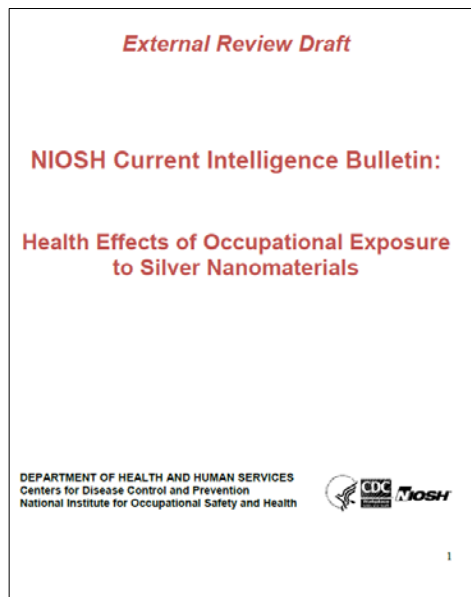
Recent Activities and Outputs



Guidance for Engineering Controls



Assistance for Small to Medium Enterprises

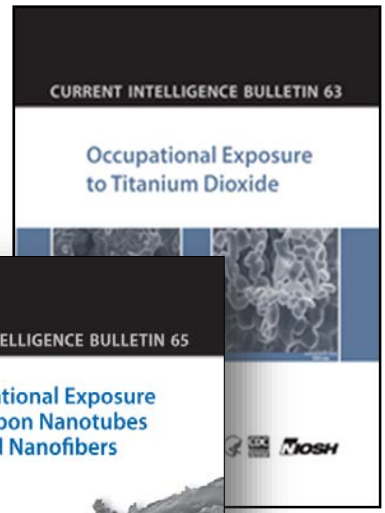
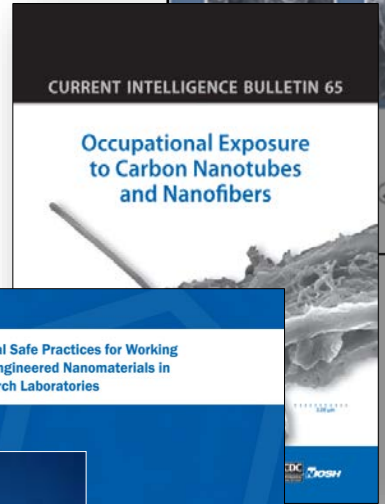
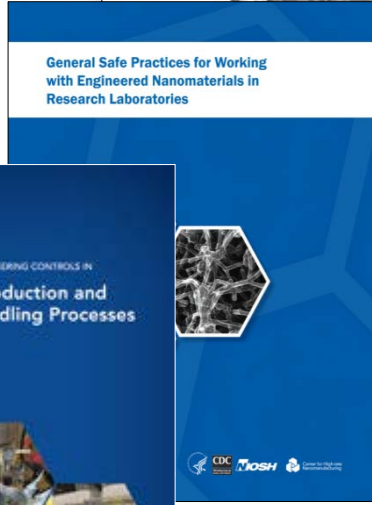
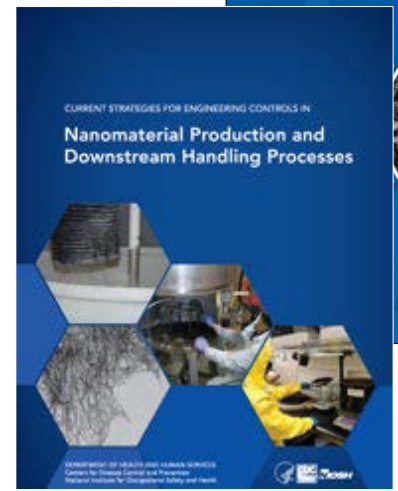
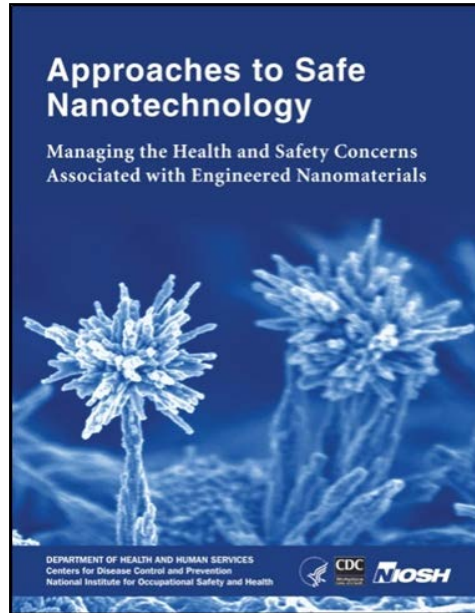
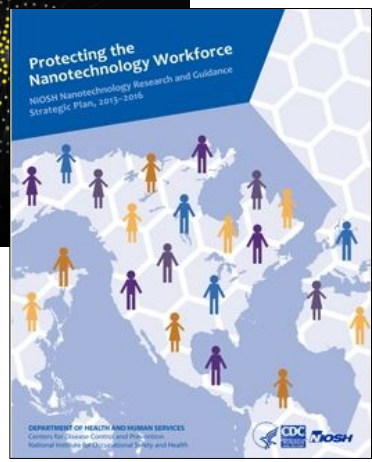
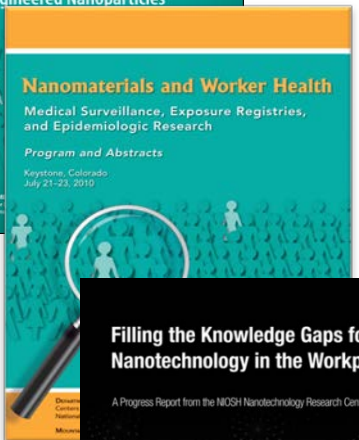
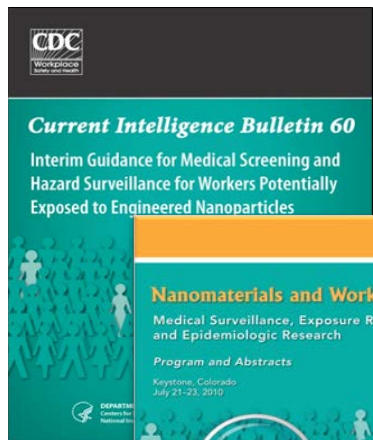


Draft CIB on Silver Nanomaterials



Outreach

Nanotechnology Guidance Documents



Nanotechnology is 'Alive and Well'

The cumulative public in nanotechnology since 2001 is over \$24 Billion – matched by private funding.

Is EHS important?

It is one of the national strategic goals with nearly \$900 Million invested.

What is still needed?

Translation of EHS research into practice!

Complicating the Task

- Applications research is moving faster than EHS research. **Keeping pace with a moving target.**
- No overt cases of injury or illness reported. **Have we been good or lucky?**
- “Nano has gone stealth”. **Its all now Advanced Materials**
- Reporting and tracking requirements are minimal. **Likely to stay that way.**
- A precautionary approach, though warranted, is difficult to sell. **See No. 2.**

Interface of Two Key National Initiatives

Nanotechnology
and
Advanced Manufacturing

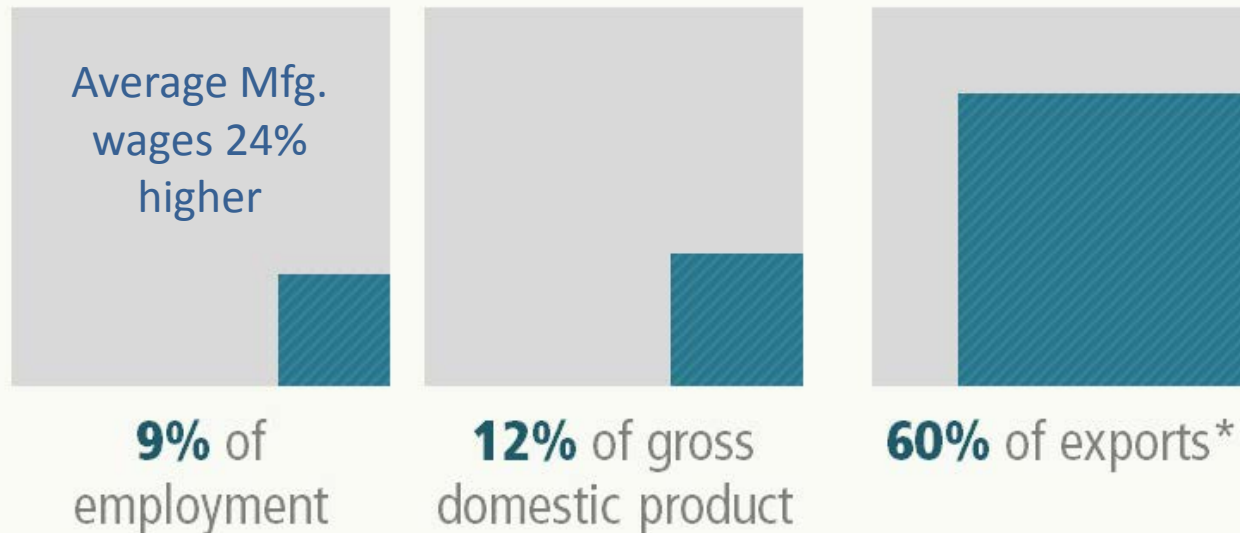
Why is this so important to learn about Advanced Manufacturing?

Manufacturing: Still a Huge Economic Impact



Manufacturers contributed \$2.17 trillion to the U.S. (NAM News)

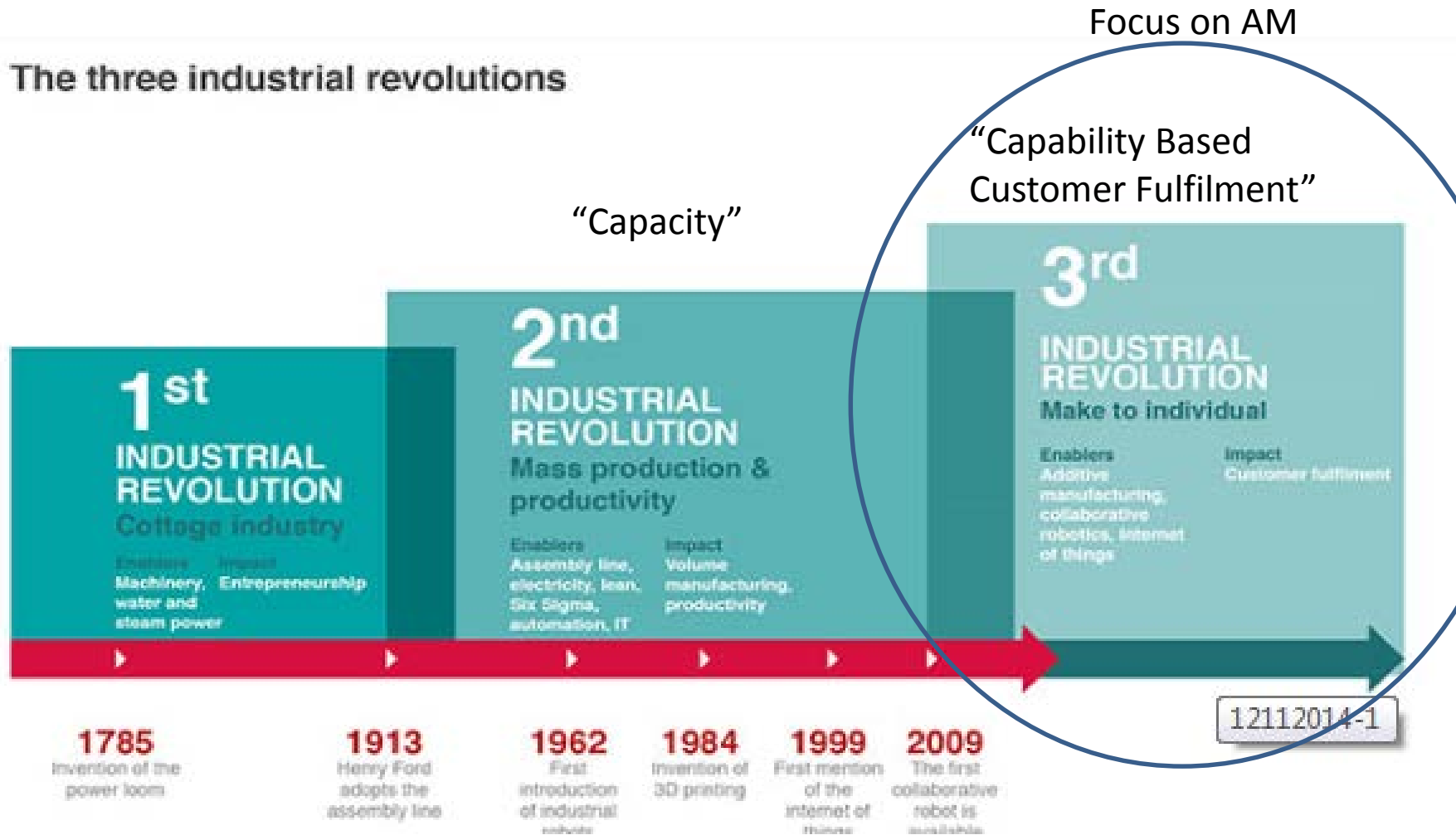
If U.S. Manufacturing were a separate country, 9th largest economy worldwide



U.S. manufacturing fundamentals strong again: 900,000 direct jobs added since recession

* EXPORTS DATA FROM 2010. R&D DATA FROM 2009, THE LATEST YEAR AVAILABLE. ALL OTHER DATA FROM 2011.

“Industry and Manufacturing in the Future” is not too far off.



Merging Initiatives

Nanotechnology: AKA Nanomaterial Science

---Has Given Rise to-----

Advanced Material Science

Nanomaterials, Nano-bio materials, Synthetic
Biology products, Functional materials, and more

---All Moving into---

Advanced Manufacturing Technology

Defining 'Advanced Manufacturing'

We are moving from the Industrial Age to the Information Age, but we still need to **make things**.

How we make things is evolving from mechanical processes to technology based processes.

Many of these new processes will use **advanced materials created by Nanotechnology**

Attributes of Advanced Manufacturing

- Heavy and increasing use of information technology
- Modeling and simulations in manufacturing processes
- Closing the innovation to commercialization gap
- Flexibility to meet customer need
- Sustainable manufacturing (*CLG says this must include worker safety*)

Trends, Examples?

- Semiconductors
 - Foundation of information technology applications
 - Rapid research to improve performance
 - New materials and structural technology
- Advanced (Nano) Materials
 - Superior performance properties tuned needs
 - Enhanced performance; reduced quantities
 - Computational engineering

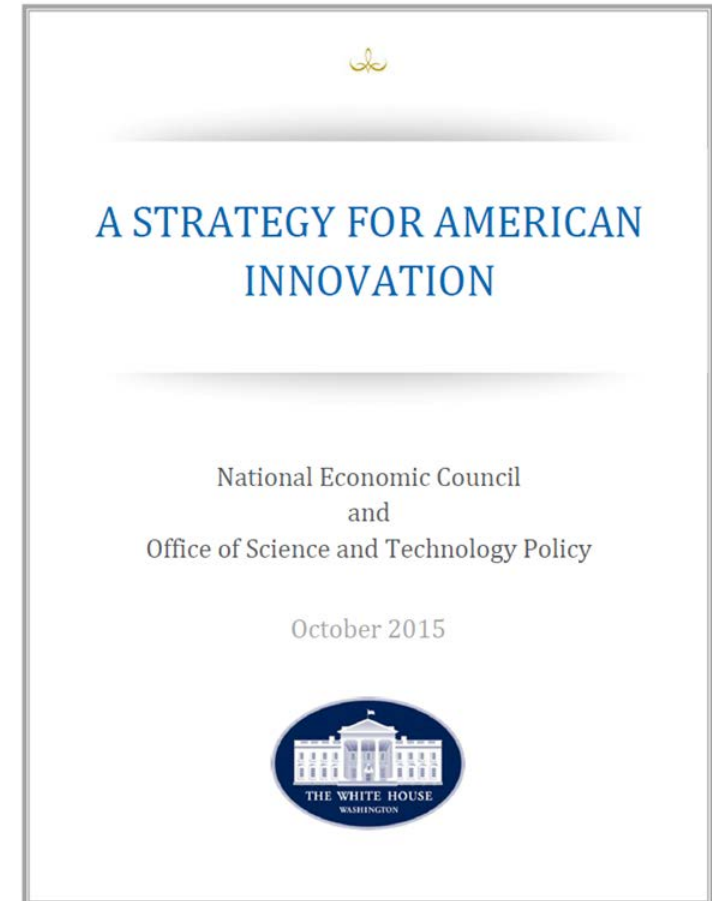
More Trends, Examples?

- Additive manufacturing: Not new but evolving
 - 3D Printing, Rapid Prototyping, Layering and Deposition, Selective Laser Sintering , and more,
- Synthetic Biology
 - Manufacture biological substances from engineered biological systems
 - Biomanufacturing: using biological templates or processes for manufacture of materials systems

The US Landscape

National Network of Manufacturing Innovation (NNMI) – rebranded as **Manufacturing USA**

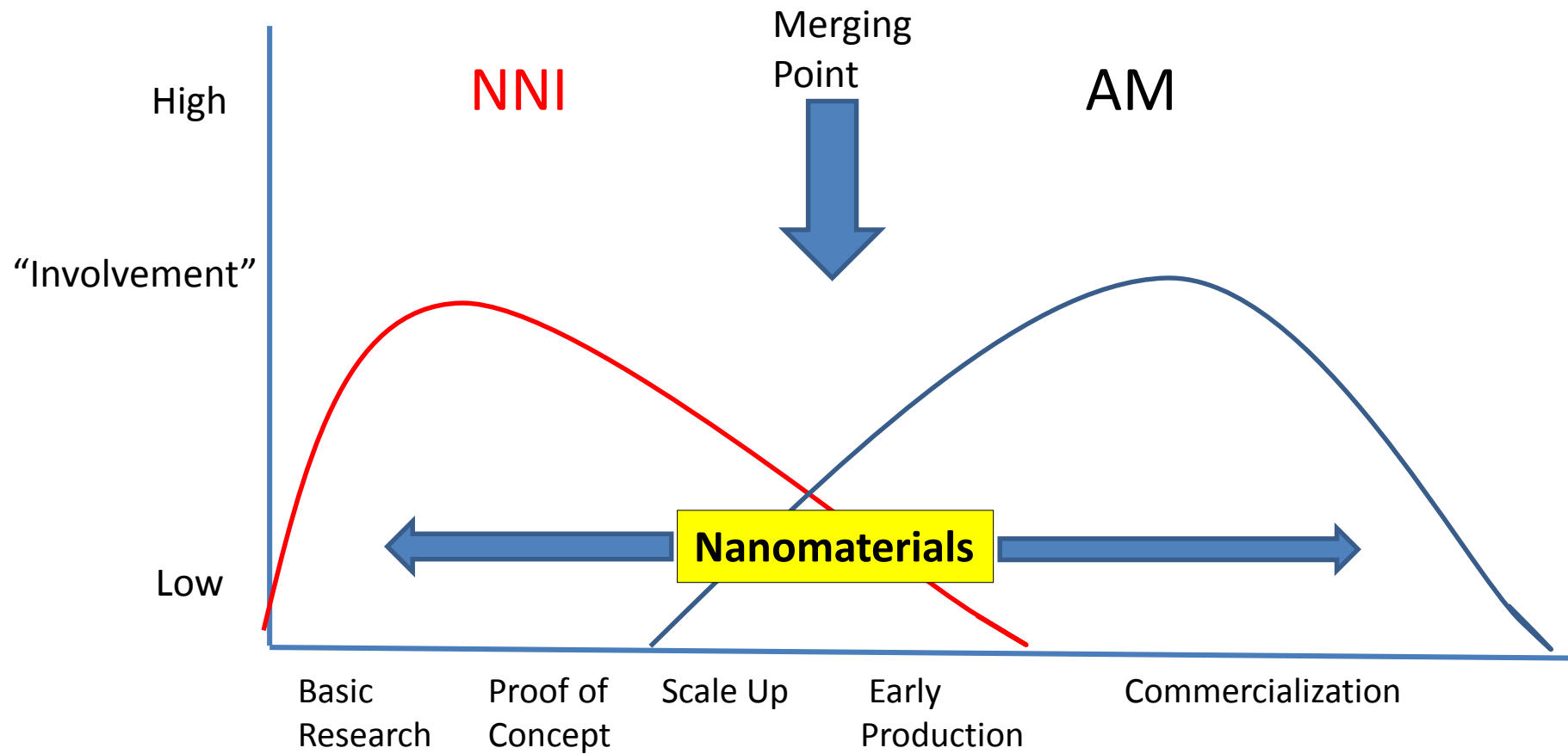
- FY 2016 Budget: \$1 Billion investment matched by private sector
- Create **15 Manufacturing Innovation ‘Centers’** over the next 5 years, as many as 45 in 10 years



Where does Advanced Manufacturing Fit?



Life Cycle of Two Initiatives. A common Thread?



Manufacturing Innovation Institutes so far...



America Makes
Additive
Manufacturing
DOD–Youngstown OH



DMDII
Digital Mfg & Design
Innovation
DOD – Chicago IL



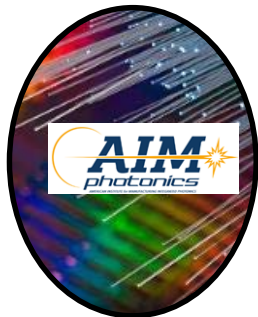
LIFT
Lightweight &
Modern Metals
DOD – Detroit MI



PowerAmerica
Power Electronics
Manufacturing
DOE – Raleigh NC



IACMI
Adv. Composites
Manufacturing
DOE – Knoxville TN



**Integrated
Photonics**
DOD
Rochester NY



**Flexible Hybrid
Electronics**
DOD
San Jose, CA



**Smart
Manufacturing**
DOE
Los Angeles, CA



**Advanced
Functional Fabrics**
DOD
MIT



**Advanced Tissue
Fabrication**
DOD Solicitation



**Robots in Manufacturing
Environments**
DOD Solicitation

Additive Manufacturing: a simple view

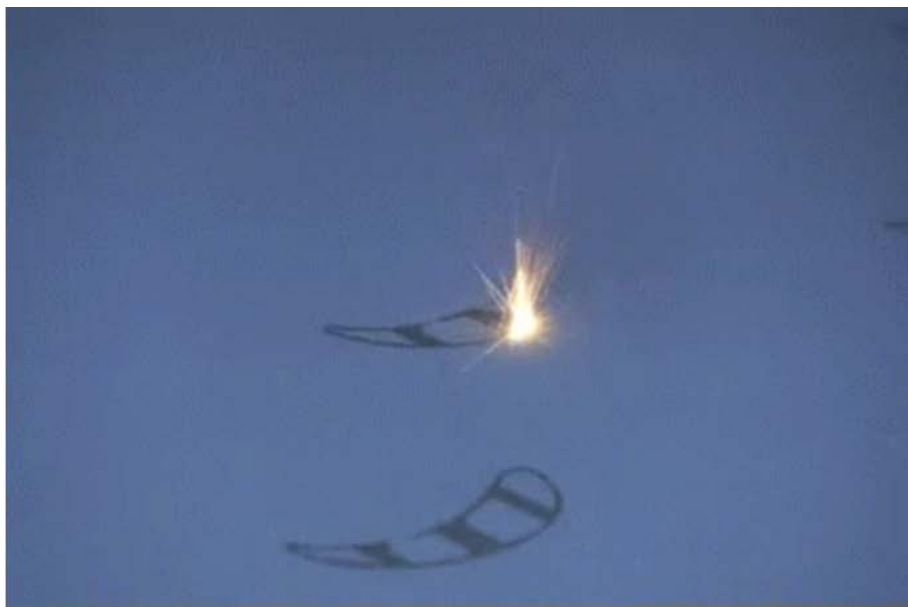
Traditional (Subtractive)



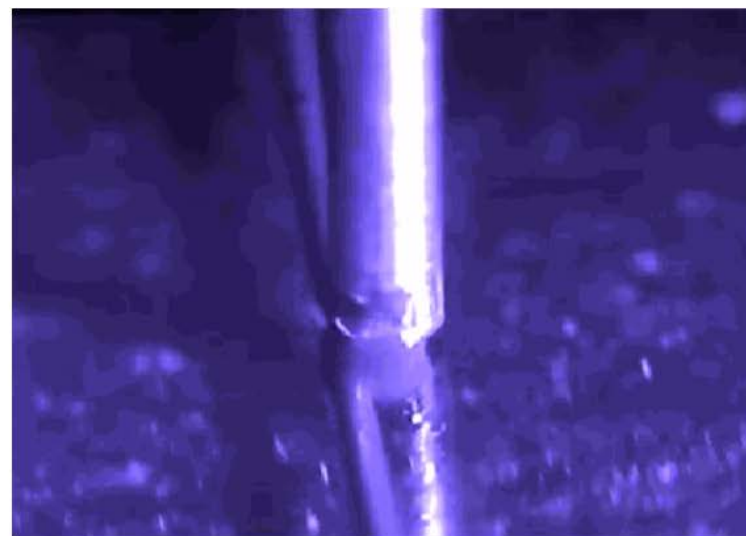
Additive Manufacturing



Additive Manufacturing: Now



GE scientists are devising new ways to put sensors in hard-to-reach places through Direct Write technology.



GE Aviation was looking for alloys to 3-D print jet engine parts. They found them in alloys that are used for joint replacements and dental implants.

Market Impact

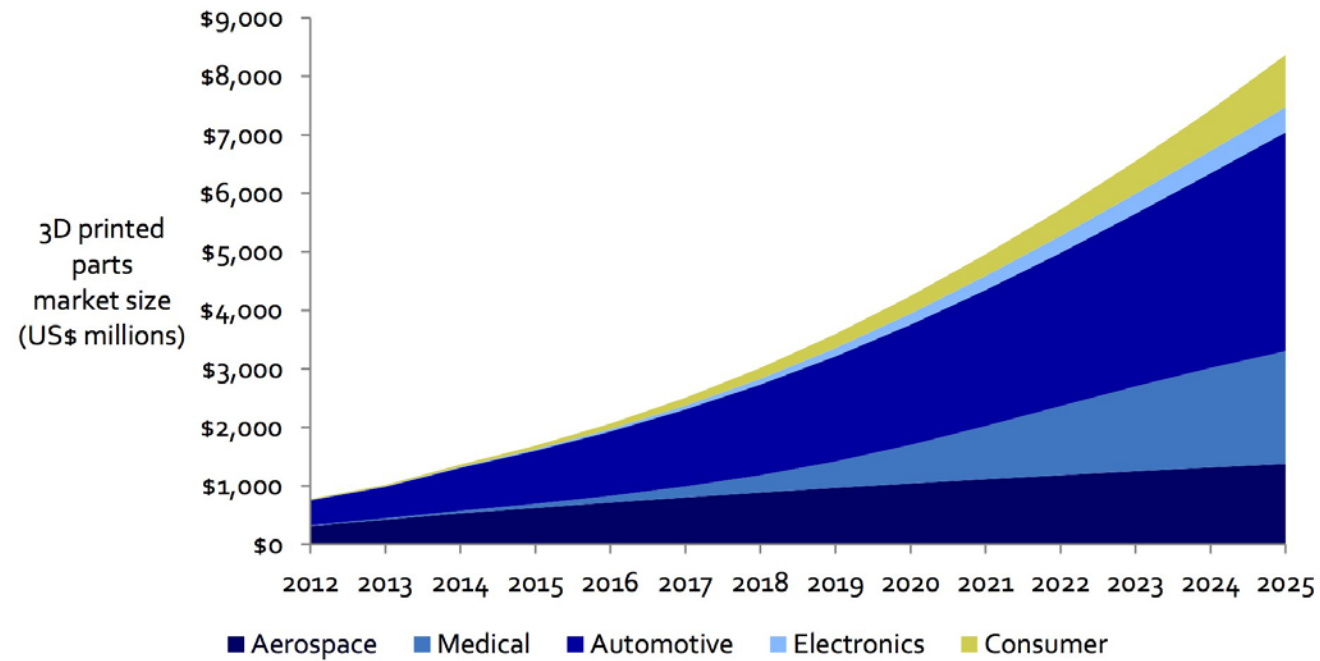
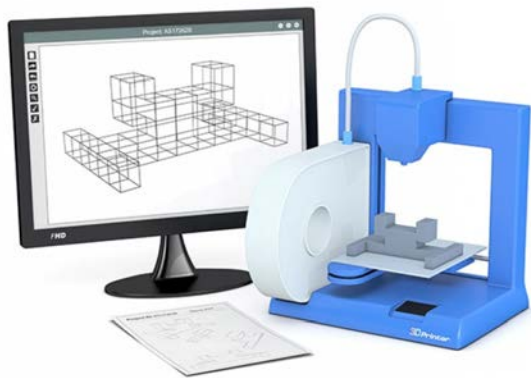


Image source: Lux Research Inc., 2013

Additive Manufacturing Institute: Key Objectives

INCORPORATING 3D PRODUCTS



- Advanced/nano materials
- Growing numbers
- Exposures not well known
- Entry barriers are low for small devices

Skilled workers should be skilled in OS&H.

ADVANCING 3D TECHNOLOGY



The technology is being taught, but does it include health and safety?

GROWING THE 3D WORKFORCE



3D Printing is not just for desk tops.



Advanced Composites Institute Profile

IACMI, The Composites Institute
Knoxville, TN
Launched June 16, 2015

Agency sponsor: DOE
Startup funding: \$70M public,
\$159M co-investment



+344,000 square feet in five core regions
regions – composite manufacturing,
laboratory, instructional and collaboration
space



Lightweight & Modern Metals in Manufacturing



6 Pillars of Technology Development

-  Melt processing
-  Powder Processing
-  Thermo-mechanical processing
-  Novel/Agile Processing
-  Coatings
-  Joining and Assembly

Many of the metals and processes were under the NNI as a private-public partnerships.

- Full EHS characterization?
- Exposure and risk potential?
- Safe practices?

Digital Manufacturing

A new interface between the worker and the intelligent supply chain and the intelligent workplace



How will the worker deal with:

- Distributed manufacturing
- Direct interface with supply chain
- Advanced interface with manufacturing processes

The OS&H challenges are not new and are likely a blend of material and process safety, work organization, and stress.

Occupational Safety and Health Opportunities

- Nanomaterials
 - Nanometals (powders, additives)
 - Additives and enablers (CNT, metals)
- Complex Environment
 - Multiple chemicals
 - Biologicals
 - Energy
- Exposures and Controls
 - Material Handling
 - Emissions
 - Waste management
 - Machine maintenance
- Risk Management
 - Distributed workplace
 - Dominated by small businesses
 - Communication

Thank you!



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www.cdc.gov/niosh/topics/nanotech