Revitalizing American Manufacturing
Putting "&" back in R&D

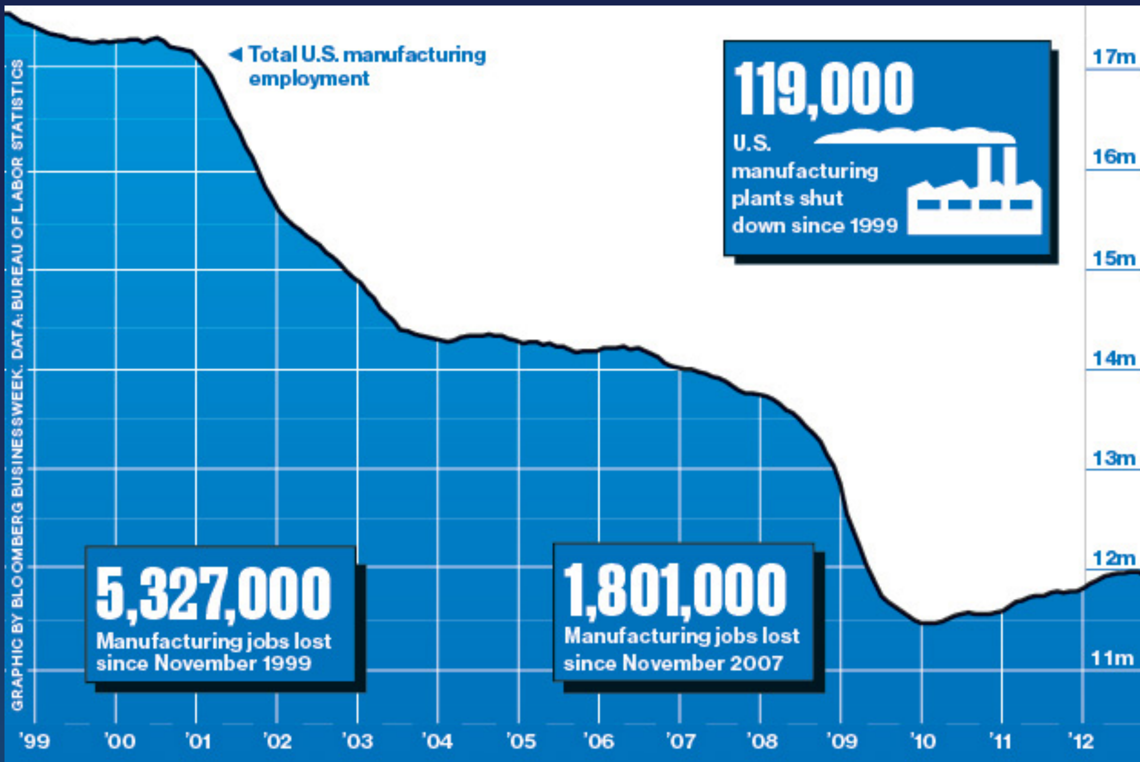
Sridhar Kota

Herrick Professor of Engineering
The University of Michigan, Ann Arbor

Former Assistant Director for Advanced Manufacturing (2009-2012),
White House Office of Science and Technology Policy

Nanocellulose Nanomaterials – A Path Towards Commercialization
Washington DC, May 20, 2014

- Over 63,000 U.S. manufacturing facilities were shut down during the recent economic downturn and nearly 6 million mfg. jobs lost in the last decade!



- U.S. Manufacturing still accounts for nearly
  - 12 percent of GDP (~ $ 2 trillion)
  - 9 percent of U.S. employment
  - 90 percent of all U.S. patents,
  - 50% of U.S. exports
  - $400 Billion R&D

Factors favoring offshore manufacturing

- High labor content; low-skill /semi-skilled labor at low wages
- Matured Manufacturing process
  - Design can be carried out independent of manufacturing (ex. foundry model; iPhone)
- Established supply chains located offshore (ex. consumer electronics)
- Lenient environmental and health regulations

It's not the labor costs…

Germany:

- Higher wages
- Same or higher structural costs
- Slightly lower taxes
- Spends one-sixth as much as the U.S. in total R&D
- Spends 6 times as much as the U.S. in "Industrial Production and Technology" category

Nearly trillion dollar advantage in trade balance on goods

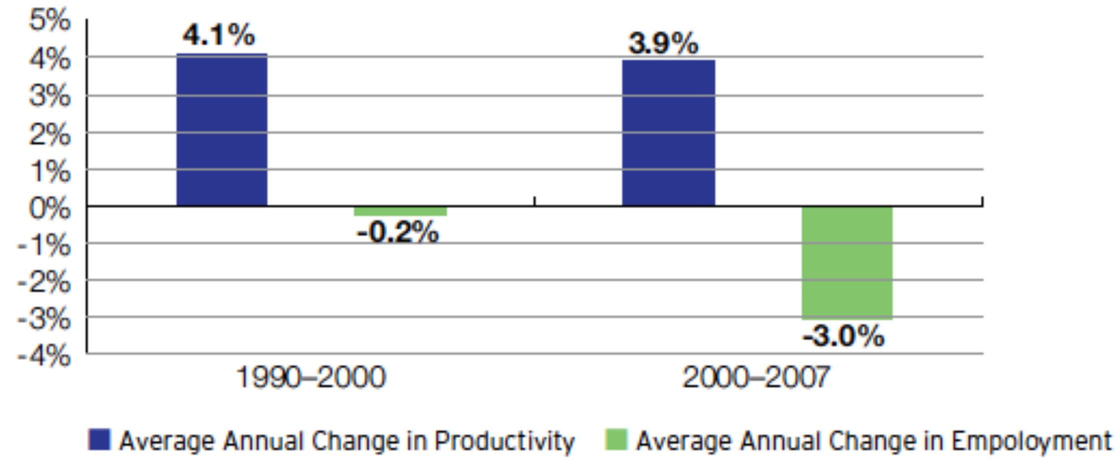
	U.S	Germany
Trade balance ($ B) (2011) • goods • services • net	 -738 +178 -560	 +214 -30 +184
Manufacturing as % GDP (2010)	**13**	**21**
Hourly Compensation of Manufacturing Workers (2011)	$35.53	$47.38
Govt. Research budget in billions of dollars (2011): Investment in Industrial Production & Technology (as percent of total R&D spending) As percent of nondefense R&D	164 0.963(0.6%) 1.2%)	26 3.3 (12.7%) 13.5%
Share (%) of Business R&D expenditures on Manufacturing	69.6	90.0
R&D as % GDP	2.68	2.53
Raw Cost Index of Manufacturers	**$0.47**	**$0.52**
Statutory Corporate Tax Rates(2012)	**39.1**	**30.2**
Social Insurance Expenditures & Other Labor Taxes (% of compensation)	33	42
Industrial Pollution Abatement and Control Expenditures (% of value added)	6.2	6.0
End-User Industry Energy Costs (Index U.S. = 100)	**100.0**	**124.7**

Manufacturing Job Losses Are Not the Result of Rapid Productivity Growth

- Performance improvements in computers chips are included in the productivity calc.
- Cost of inputs imported are not accounted
- Temporary workers do not count as manufacturing workers

manufacturing productivity growth is 2.3 percent (not 5.4 percent)

Figure 3. Productivity and Employment Change in U.S. Manufacturing, 1990-2000 and 2000-2007



Source: Authors' analysis of Bureau of Labor Statistics Major Sector Productivity and Costs data (productivity) and Current Employment Statistics data (employment).

17 out of 19 manufacturing sectors showed decline in output between 2000-2007

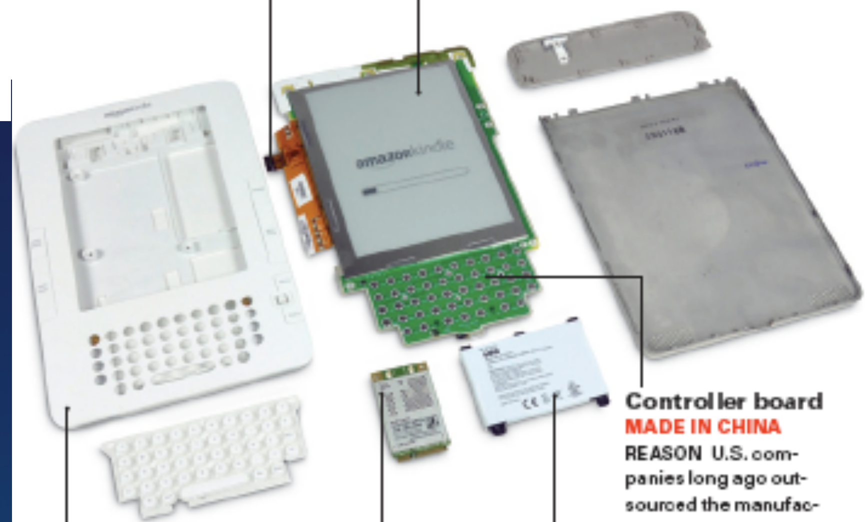
Why Amazon's Kindle 2 Can't Be Made in the U.S.

The Kindle 2 e-reader was designed by Amazon's Lab126 unit in California. The vast majority of its components are made in China, Taiwan, and South Korea, and it is assembled in China, a center for such work.

Taken from Gary Pisano and Willy Shih, "Restoring American Competitiveness", HBR, July 2009

Flex circuit connector
MADE IN CHINA
REASON U.S. supplier base eroded as the manufacture of consumer electronics and computers migrated to Asia.

Electrophoretic display
MADE IN TAIWAN
REASON Its manufacture requires expertise developed from producing flat-panel LCDs, which migrated to Asia with semiconductor manufacturing.



Controller board
MADE IN CHINA
REASON U.S. companies long ago outsourced the manufacture of printed circuit boards to Asia, where there is now a huge supplier base.

Highly polished injection-molded case
MADE IN CHINA
REASON U.S. supplier base eroded as the manufacture of toys, consumer electronics, and computers migrated to Asia.

Wireless card
MADE IN SOUTH KOREA
REASON South Korea used its infrastructure for designing and manufacturing consumer electronics to become a center for making mobile phone components and handsets, especially products using CDMA technology, which is widely used in South Korea.

Lithium polymer battery
MADE IN CHINA
REASON Battery development and manufacturing migrated from the U.S. to Asia along with the development and manufacture of consumer electronics and notebook computers.

Hollowing out high-tech supply chains

Prime View International acquires E Ink for $215 million

Summary: *E Ink, the company behind the e-paper displays on the Kindle and Sony e-book lineup, has been acquired by Prime View International, which makes e-paper displays. The deal was valued at $215 million.*

Flexible Displays?

And the Winner is – ITRI
Wall Street Journal Technology Award Sept. 2010.

Re-shoring?

Trend or Anecdotal?

- Chinese wages are rising 10-15% per year
- Currency rates
- Transportation costs
- IP protection

Strategizing around these can only provide a temporary bump

Only sustainable model is a renewed excellence in engineering and manufacturing of high technology products with high productivity and high-skilled workforce.

Unless we manufacture today's high-products, we lose our ability to innovate next generation products

Establishing a Robust Manufacturing Base

Creating new industries and strengthening existing industries

$100 billion trade deficit in Advanced Technology products

1800 suspected counterfeits in more than 1 million electronic parts in military equipment

Economic & National Security

Leadership in Advanced Technology Products

- Trade Surplus
- Trusted Sources

Innovation: Create New Industries

- Basic Research
- Translational R&D
- Early Adoption
- Capital
- Entrepreneurship
- Scaling
- Skilled Engineers

Competitiveness: Strengthen Existing Industries

- Digital Tools
- Shared Facilities
- Affordable Energy
- Access to Markets
- Free & Fair Trade
- Tax Incentives
- Smart Regulation
- Skilled Production Workers

S. Kota

Future of American Manufacturing

Factors favoring U.S.-based manufacturing

- Emerging technologies with nascent process technology - require investments in Translational R&D (NNMIIs); colocation of R&D & manf.
- Intellectual property protection
- Proximity to customers
- Skilled workforce at competitive wages
- Critical national security needs

Leverage U.S. inherent strengths

- Basic research and discoveries - universities and federal labs.
- Government procurement to accelerate innovation & scaling
- Affordable energy
- Availability of raw materials
- Entrepreneurship

Innovation

Scientific Discovery → Engineering Invention →Innovation → Manufacturing,..

A broader definition according to National Academies…

"Innovation commonly consists of being first to acquire new knowledge through leading edge research, being first to apply that knowledge to create sought-after products and services, often through world-class engineering; and being first to introduce those products and services into the marketplace through extraordinary entrepreneurship."

Technological innovation is really about engineering – the "application of knowledge" to convert a promising idea into a practical product/process

Innovation and Manufacturing are Intricately Linked

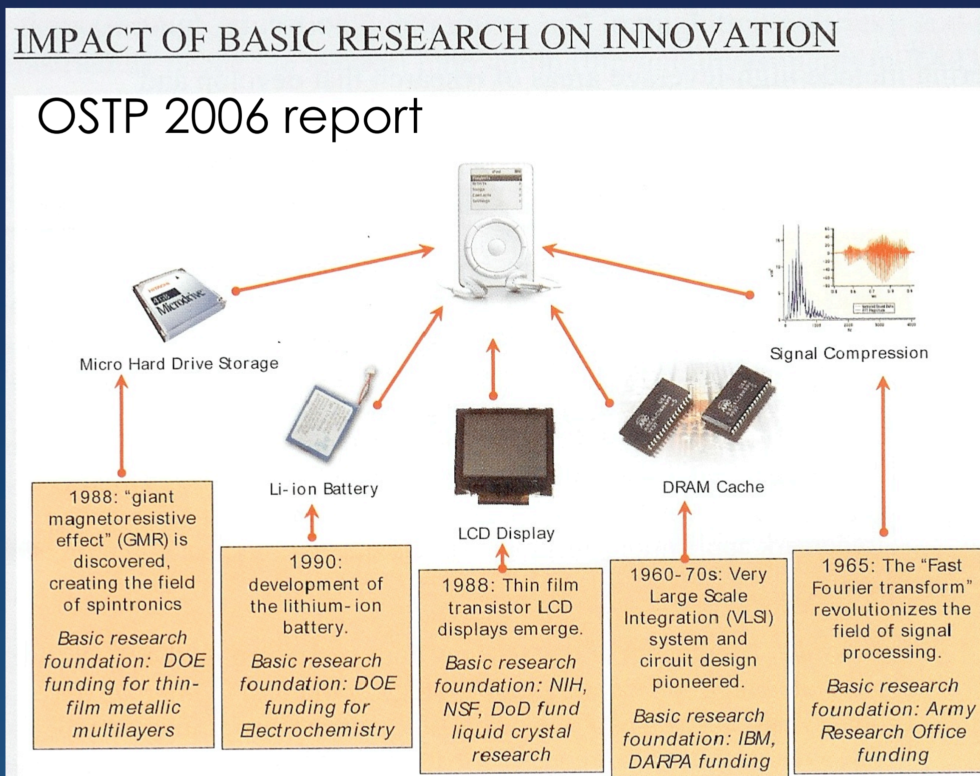
Scientific Discoveries → Inventions → Innovation → Manufacturing,...

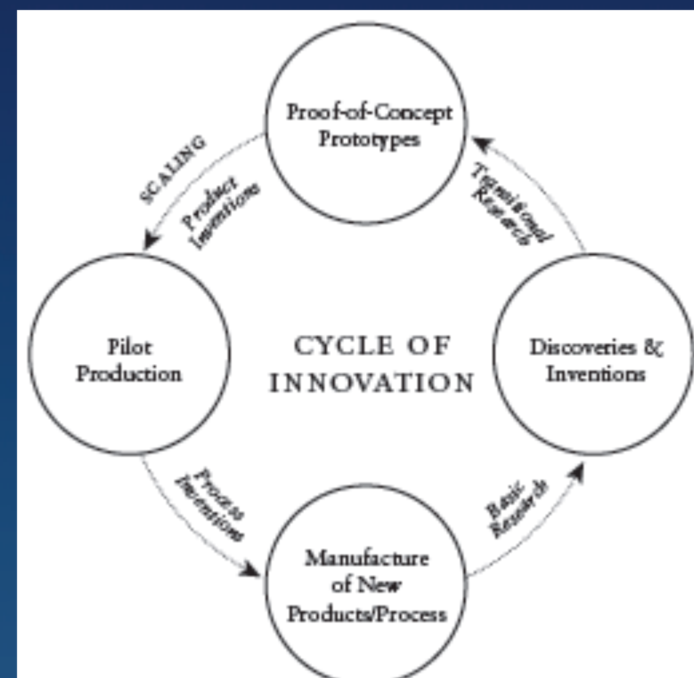
Federal R&D
$140 billion

Engineering

Mfg. deficit ~ $600+ billion
Adv. Tech. Products deficit ~ $100 billion

National Security Challenges





Creating Knowledge - not wealth

National Security Implications

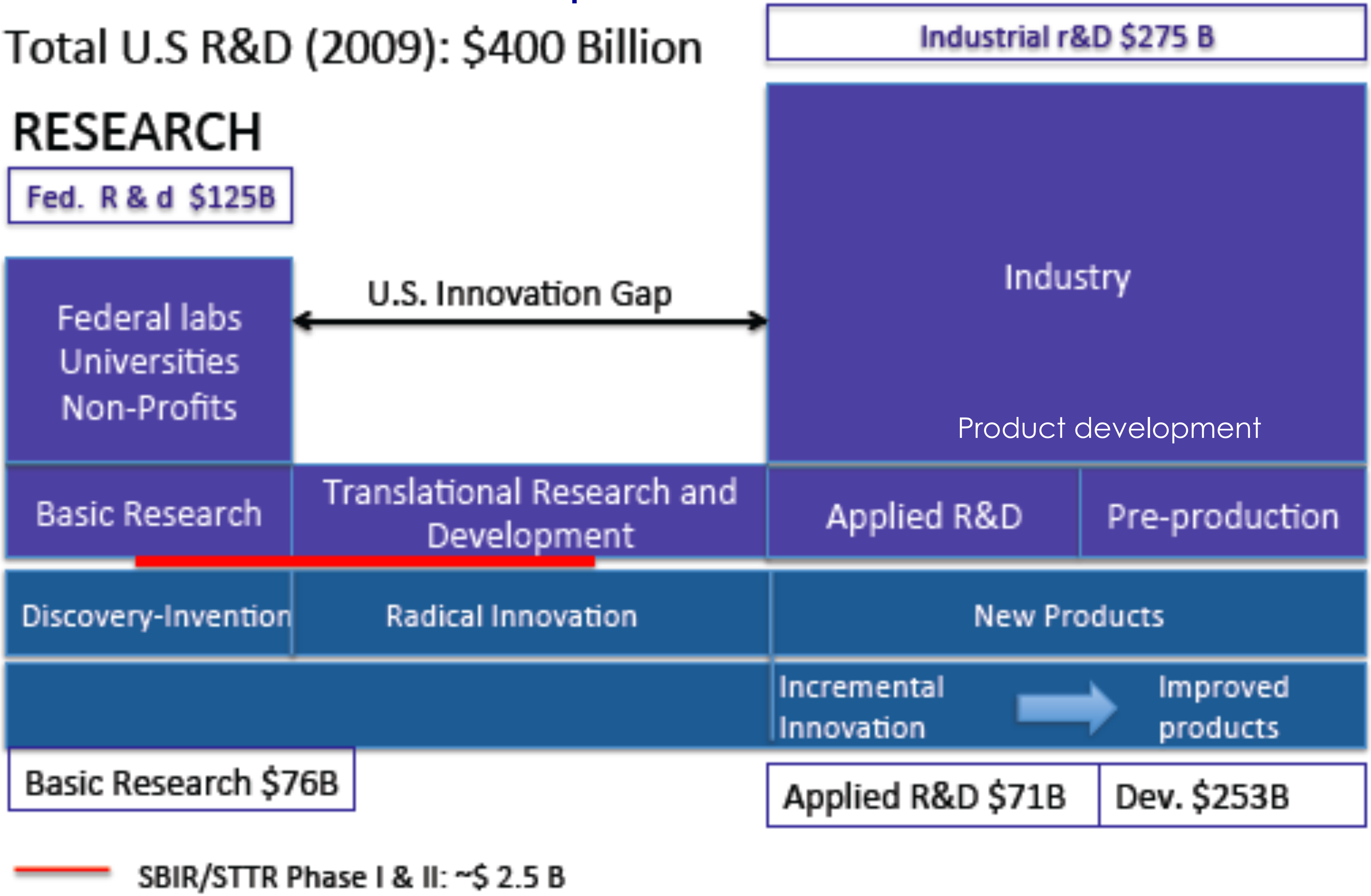
"if any particular manufacture was necessary, indeed, for the defense of the society it might not always be prudent to depend upon our neighbors for the supply."
- Adam Smith
Wealth of Nations 1804

A recent investigation revealed a "flood of counterfeit electronic parts coming into the Defense Department's supply system." Senate Armed Services Committee May 21, 2012

America is almost completely dependent on foreign sources for 19 key specialty metals, many of which are mined in volatile regions of the world.

The security of U.S. military communications systems is threatened by the rapid growth of foreign-manufactured network equipment in global telecommunications systems.

The Innovation Gap



The Innovation Gap

- *The "Bell labs" of yesteryear have disappeared; they used to do discovery, invention and innovation*

- *Today's corporate R&D is short term;*

  The average time Wall Street investors held a stock has dropped from 8 years in the 1960s to 4 months in 2010

- *Private sector is less inclined to invest in nascent technologies*

  - *Technical and market risks*
  - *Market failures, spill-over effects – no one company or industry can capture the full benefits of its investment in emerging technologies*

"Bell Labs" Models for Technology Development

U.S. Innovation Gap

Universities, Federal Labs Scientific Discoveries & Engineering Inventions	German Fraunhofer Institutes Taiwan's Industrial Tech Research Inst.		Industrial R&D
Basic Research	Translational Research	Development/Testing	Pre-production

Fraunhofer

- 59 Institutes, 17 000 employees
- Non-profit organisation
  - ≈ 33 % basic funding by goverment
  - ≈ 33 % public funded projects
  - ≈ 33 % direct contracts by industry

ITRI
Industrial Technology Research Institute

- Information and Communications
- Material, Chemical and Nanotechnologies
- Biomedical Technologies
- Advanced Manufacturing and Systems
- Energy and Environment

- Total Patents: 10,132
- Start-Ups: 158

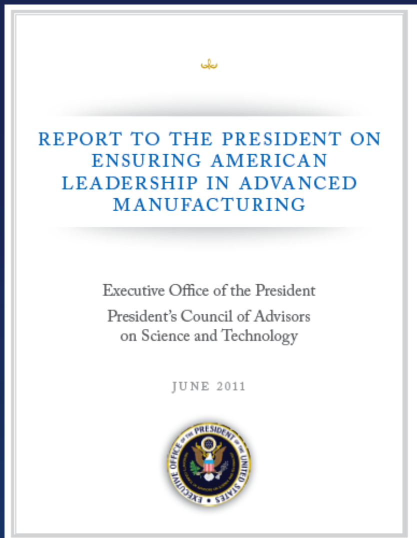
Korea's Industrial Core Research Projects Program

We need an innovation policy (not industrial policy) to establish our own Edison Institutes to bridge the innovation gap (2010)

Translational R&D

- Involves mostly Engineering; some engineering-science
- Helps identify practical technologies among "promising" technologies
    - *Any technology need to compete on performance, cost, reliability, safety , compatibility with existing infrastructure*
- Establishes "industrial commons" – i.e., knowledge, tools, equipment, and systems integration skills needed to manufacture high tech products and to innovate next generation products.
- Helps establish supply chains for new and next generation products/processes

Closing the Innovation Gap



REPORT TO THE PRESIDENT ON ENSURING AMERICAN LEADERSHIP IN ADVANCED MANUFACTURING

Executive Office of the President

President's Council of Advisors on Science and Technology

JUNE 2011

Launched an Advanced Manufacturing Initiative to support precompetitive translational research on broadly applicable emerging technologies through public-private partnerships

- *$1 billion (DOE, DOD, NIST and NSF) to establish a National Network of Manufacturing Innovation Institutes*

June 2011

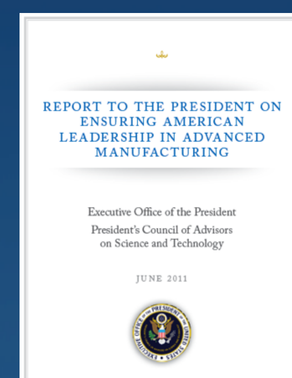
Four Manufacturing Innovation Institutes were established since

- Additive Manufacturing - Youngstown, OH
- Next Gen Power Electronics (NC)
- Lightweight and Modern Metals Mfg. (Detroit)
- Digital Manufacturing & Design Innovation (Chicago)

PCAST 2011 Report-Advanced Manufacturing

Criteria for establishing Public Private Partnerships:

- Coordinated and Strategic Investment (DOD, DOE, NIST, NSF)
- Technology has high potential payoff in employment and output
- Identifiable market failures impede adequate private investment
- Industry co-investment
- First mover advantage to capture large markets
- Teams of small and large companies, universities and federal labs; driven by non-profit organization
- Mature from TRL 4 to TRL-7 and MRL 7
- Anchor US-based manufacturing via early procurement & loan guarantees

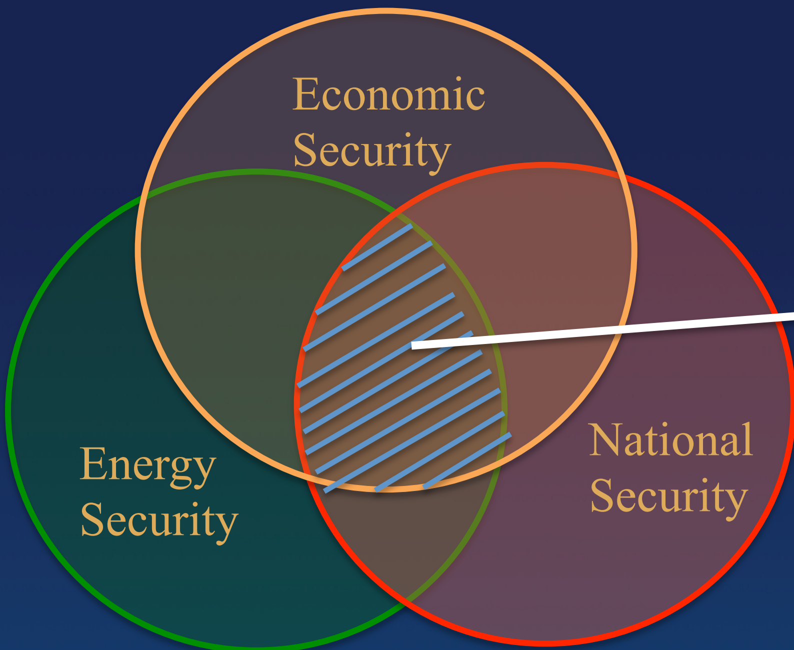

REPORT TO THE PRESIDENT ON ENSURING AMERICAN LEADERSHIP IN ADVANCED MANUFACTURING

Executive Office of the President
President's Council of Advisors on Science and Technology

JUNE 2011

Examples: Flexible Electronics, Lightweight structures, Intelligent Design and Manufacturing, Next generation Optoelectronics etc.

Addressing the Problem : Building on our Strengths



Example: Advanced Vehicles – fuel efficient, connected vehicles: According to Army Energy Security Office, a 1% fuel savings will result in 6,444 fewer soldiers trips.

Multiagency Collaboration

- Reduce overall costs to government
- Leverage strengths and resources
- Govt. Procurement
- Federal loan guarantees
- Scaling through industry cost sharing

- Lightweight structures – cost-effective manufacturing of composites including nanocomposites such as low-cost carbon and nanocellulosic composites.
- Intelligent transportation systems

U.S. Federal government has invested over $17 Billion since 2000
Approximately 25% of world nanotechnology R&D

S. Kota

Nanotechnology

Observations

1. The 2010 PCAST report and 2012 NNI assessment placed emphasis on projects that bring research to market.

New signature initiative on nanomanufacturing

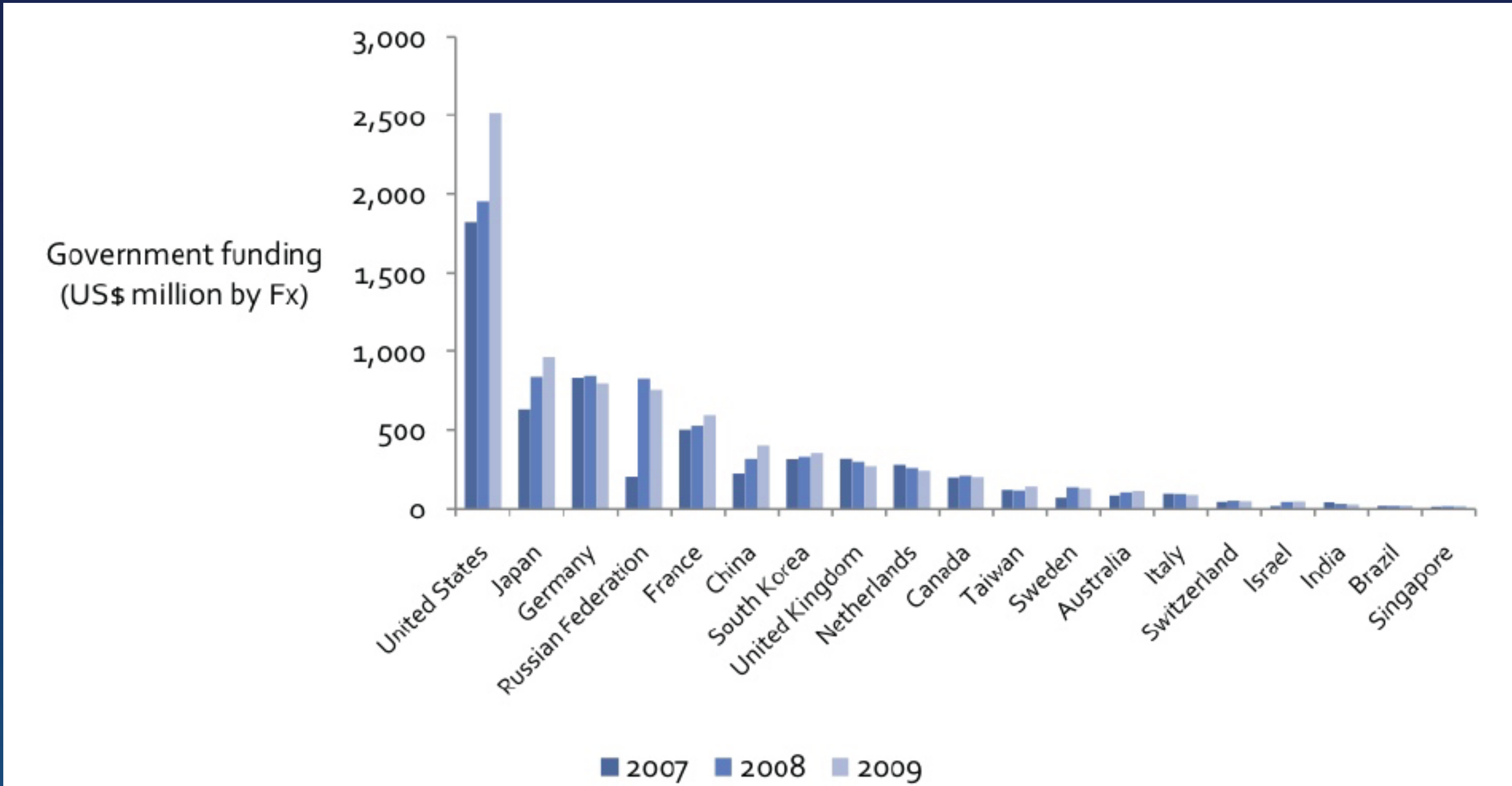
Developing appropriate manufacturing process technologies

Bridging the gap between inventions and practical applications

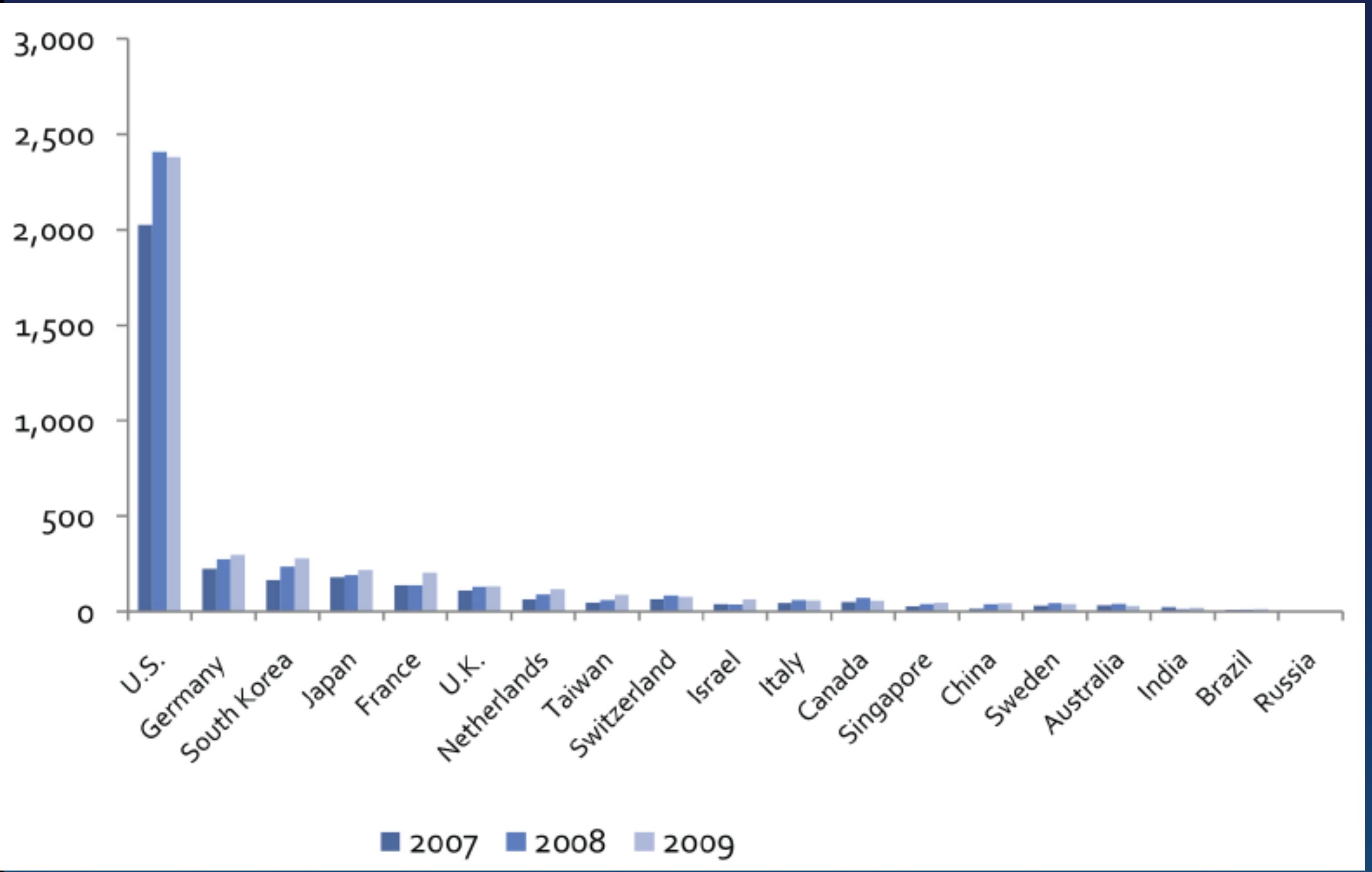
2. Opportunities to incorporate nanotechnology into existing products; making current products better.

- Nanotex - Stain-repellent moisture management fabrics and in paints
- High performance tennis rackets and golf clubs
- Nanoparticle enhanced sunscreens (2001)
- Nanocomposites in autos (“step assist” GM vans, Toyota bumpers 2001)
- Nanofilms (3M window treatment)
- Nanocoatings (Kennametal cutting inserts)
- And more

U.S. Government's Investments (2007-09)-Nanotechnology



Metrics



Reports typically highlight publications, citations, patents, papers to patent ratio, citations to paper ratios, etc.

RESEARCH OUTPUTS: PUBLICATIONS AND PATENTS

NSF Science and Engineering Index

WHY IS THIS IMPORTANT?

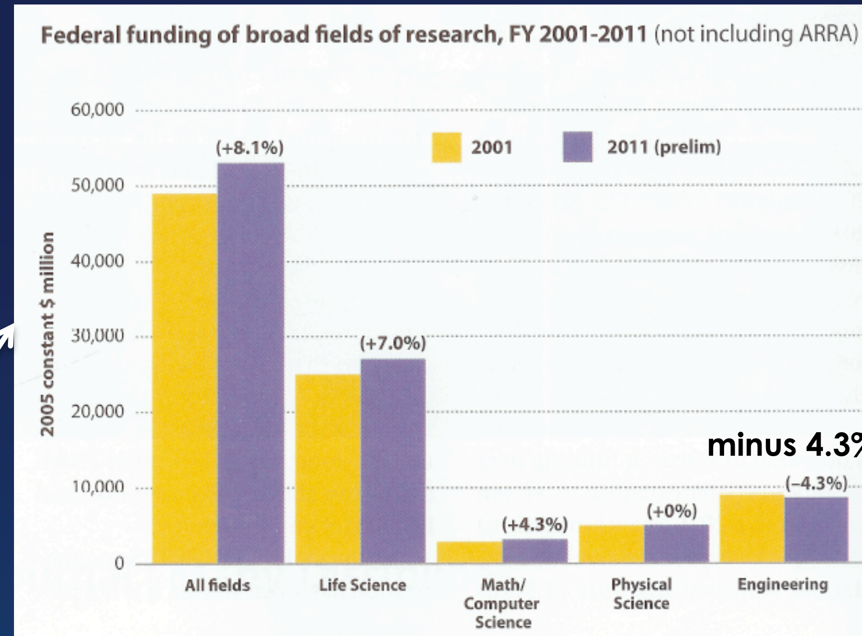
Research produces new knowledge, products, or processes. Research publications reflect contributions to knowledge, patents indicate useful inventions, and citations on patents to the scientific and technical literature indicate the linkage between research and practical application.

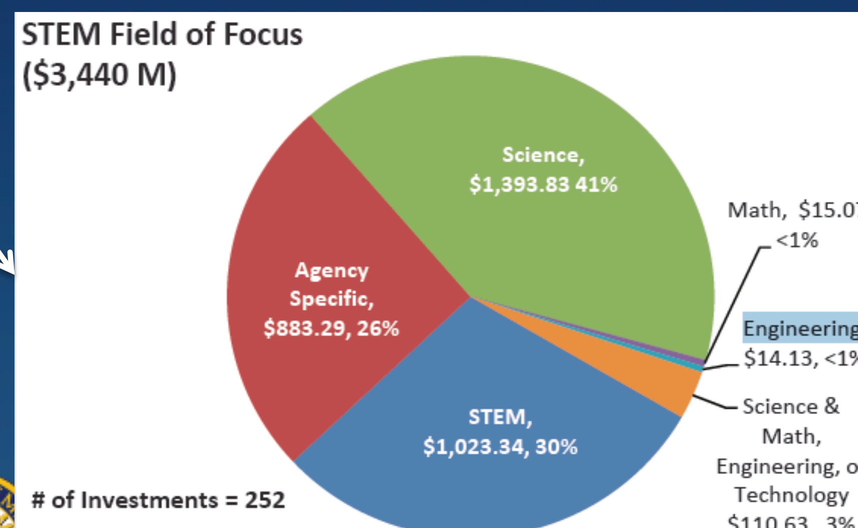
Generalization of science to include engineering has had real consequences in investments and outcomes

This is NOT Rocket Science

It is Rocket Engineering

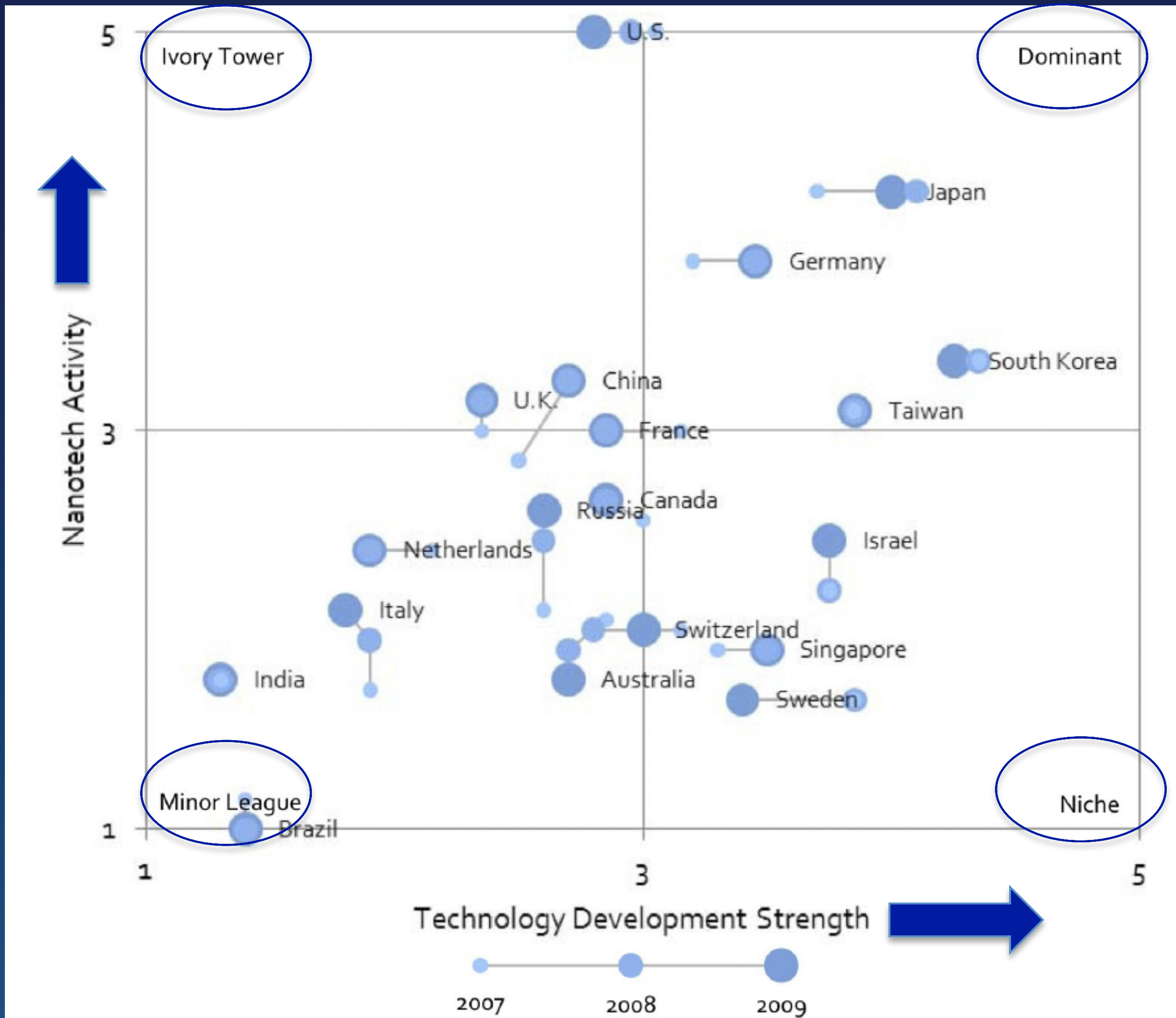
Investments





Outcomes

Example: International Benchmarking of Nanotechnology



We need to move from "Ivory Tower" category to "Dominant" Category to get a real return on investment of taxpayers dollars

Source: "Ranking the Nations on Nanotech"- Lux Research Report, August 2010

Different Viewpoints

Congressional Testimony by a senior government official (2010)

"… recent analyses of the number of nanotechnology citations, patents, and publications show that we are very quickly being surpassed by other nations in an area where, until recently, we had a strong lead. This has the potential of putting our national security at risk, since technological superiority has been a foundation of our national security strategy since World War II."

According to Lux Research report (2010),

Japan, South Korea, and Germany will be much more successful growing their economies with nanotech

Opportunities for Cellulose Nanomaterials

- Light Weight Nano Composites
- Batteries and Super-Capacitors
- High Efficiency Filters
- Reinforced Polymers
- Bio Plastics
- Nano Coatings
- Sensors
- Flexible Displays
- Photonic Devices
- Nano Membranes
- Multifunctional Packaging

Cellulose Nanomaterials can be produced in tens of millions of ton quantities

Nanocellulose
Opportunities and Challenges

- Replace petroleum-based polymers with natural polymer that is abundantly available in the U.S.
- An opportunity to revitalize (existing) paper industry and create new industries
- Existing national coordination office to create a multi-agency initiative
- First-mover advantage I(?)
- Public-private partnerships to overcome market failures
- Private sector job growth across multiple industry sectors (Paper & Pulp, packaging films, coatings, cosmetics, concrete, energy storage, displays, etc.)

Nanocellulose Structures and Devices

Translational R&D Topics with industry buy-in

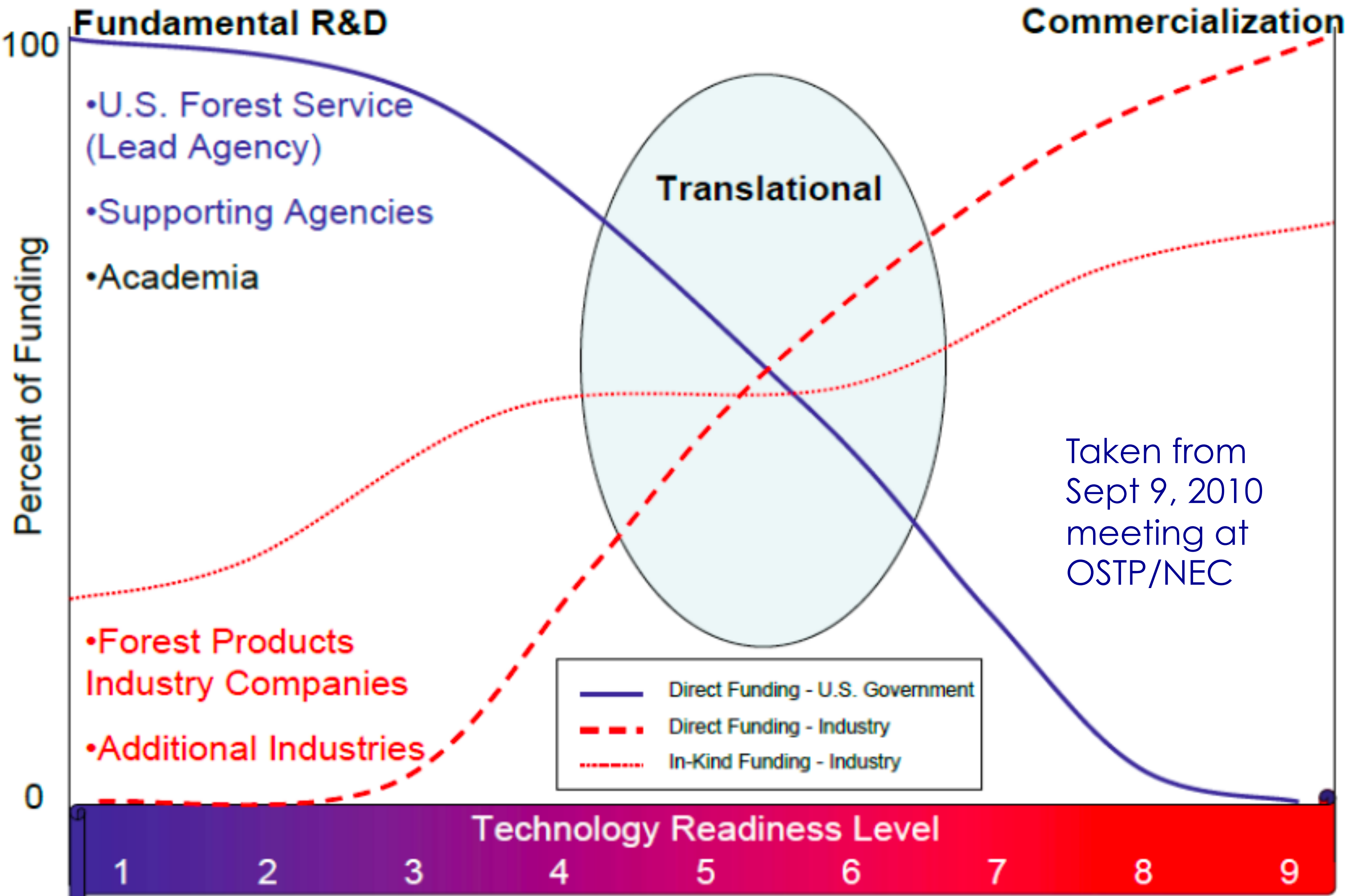
The research community in close collaboration with various industry sectors must identify translational R&D topics that advance TRL from 4 to 7 and MRL 7.

Application-driven R&D
(ex: Nylon toothbrush… nylon parachutes)

Examples (need greater clarity)

- Process scale up and process monitoring reliably produce uniform, high quality, stable, and consistent nano-materials in high volume and at high throughput.
- Chemical modifications to impart new functionalities
- Interfacial engineering of nano-composites
- Manufacture of high quality long-fibers

Public Private Partnership Engagement Model



Taken from Sept 9, 2010 meeting at OSTP/NEC

Summary

Being the world's best in science is still vital to our success but is no longer sufficient to compete in the global economy

- Appropriate metrics for ROI
- Coordination + strategy
- Nanocellulose Engineering
- Public-private partnerships
- Policy + legislation that provides incentives for domestic manufacturing

Identify topics for translational R&D plus early adoption opportunities to establish a public-private partnership institute

"And when we make things here, we perfect that next idea." - President Obama on "Launching Advanced Manufacturing Initiative on June 24 2011