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
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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

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

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

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

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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

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

National Security Challenges

Creating Knowledge - not wealth
National Security Implications

“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.

“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
The Innovation Gap

Total U.S R&D (2009): $400 Billion

**RESEARCH**

- Federal labs
- Universities
- Non-Profits

**U.S. Innovation Gap**

- Basic Research
- Translational Research and Development

**APPLIED R&D**

- Applied R&D $71B
- Dev. $253B

**DEVELOPMENT**

- Industrial R&D $275B

- Industry

- Product development

**SBIR/STTR Phase I & II**: ~$ 2.5 B
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
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

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**

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)

June 2011
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

Examples: Flexible Electronics, Lightweight structures, Intelligent Design and Manufacturing, Next generation Optoelectronics etc.
Addressing the Problem: Building on our Strengths

Multiagency Collaboration

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

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.

- 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

National Nanotechnology Initiative

Collaborative, Multi-agency, Cross-cut Program Among 27 Federal Departments/Agencies/Entities.

R&D to Advance Understanding and Control of Matter at Nanoscale toward:

- National economic benefit
- National and homeland security
- Improved quality of life

S. Kota
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

Government funding (US$ million by Fy)

- United States
- Japan
- Germany
- Russian Federation
- France
- China
- South Korea
- United Kingdom
- Netherlands
- Canada
- Taiwan
- Sweden
- Australia
- Italy
- Switzerland
- Israel
- India
- Brazil
- Singapore

Colors represent:
- 2007
- 2008
- 2009
Reports typically highlight publications, citations, patents, papers to patent ratio, citations to paper ratios, etc.

RESEARCH OUTPUTS: PUBLICATIONS AND PATENTS

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

Federal funding of broad fields of research, FY 2001-2011 (not including ARRA)

- All fields: +8.1%
- Life Science: +7.0%
- Math/Computer Science: +4.3%
- Physical Science: +0%
- Engineering: -4.3%

2005 constant $ million

- Minus 4.3%

STEM Field of Focus ($3,440 M)

- Science, $1,393.83, 41%
- Math, $15.07, <1%
- Agency Specific, $883.29, 26%
- Engineering, $14.13, <1%
- Science & Math, Engineering, or Technology, $110.63, 3%

# of Investments = 252
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
“... 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

• 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

- Fundamental R&D
  - U.S. Forest Service (Lead Agency)
  - Supporting Agencies
  - Academia

- Translational

- Commercialization

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<th>Technology Readiness Level</th>
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- Forest Products Industry Companies
- Additional Industries

Direct Funding - U.S. Government
Direct Funding - Industry
In-Kind Funding - Industry

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

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

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