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“Defense Leadership and the Role of Technology and Manufacturing”

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The Cold War and Economic War

• Japan, 70’s and 80’s: “the economy is war”
• Didn’t win the Cold War simply because of Ronald Reagan’s Star Wars and confrontation with the “evil empire”
• Didn’t win the Cold War simply because of Harold Brown’s and Bill Perry’s “offsets theory” and worked on technological superiority and precision strike
• The underlying issue: the Soviets could not keep up with US technological leadership under a robust innovation model
The American Way of War is Technological Leadership…

- Success in the Cold War coincided with US leadership of the IT innovation wave – that’s when the gap between the economies opened up:
  - Military applied the IT model --
  - Precision strike
  - Art Cebrowski, Bill Owens and others - “network centric” warfare theory behind it
  - But: During IT revolution, US economy grew by $10T
- It’s been the American way of war since the Civil War:
- It’s US industrial superiority and technological leadership – the Rad Lab and Manhattan Project –winning edge in WW II
The Cold War is Economic War

- The Cold War is a lesson in symmetric warfare – the economic war is decisive; the last four decades say there is no massive hot war
- And technological leadership is the key
- That *is* the war
And Now?

- A new generation of potential peer national competitors are arising
- One theory: Economic war will be the proving ground – it will be the decisive theatre

All US economic theory starts with:
Source: Barry Lynn (2007) – Re: Global Eco Integration

• Hamilton: **mfg. independence** is key to American independence and security – it made US independent from Europe

• Cold War- US pursued **mfg. interdependence** – integrated industrial complex from Europe to Japan - this promoted US independence

• New Era - **Outsourcing**: vertically integrate elements in mfg. process but divest control to spread risk – formerly domestic control, now: international

• Now: **participating nations: integrate** their technology, capital and labor – control decentralized among participants – belongs to all participants and to none – no national or int’l controls
  – Example: 2008 world financial crisis
SO:

3 Periods of US Economy:

- **Hamilton to 1945**: rational national self-dependence in mfg.
- **1993** – Clinton- complete laissez-faire in mfg. – bind world into interdependent economic system tied by joint mfg., no national controls
Lynn: Global Economic Integration, Con’t

• China – West’s production system is merging with China’s

• Security Perspectives:
  – **Integrationists**: extending the West’s mfg. production system will bring emerging nations into the global economic system, benefiting US needs long term
  – **Realists**: profound differences in nations’ geopolitical goals and political systems remain – only question which nation gains the advantage from economic interdependence

• DOD lesson – can’t sever civilian economy from military economy – former is a fish in latter water
Case for Domestic Manufacturing Technology Strategy – the Pluses:

- Manufacturing contributes $1.6 trillion to GDP and employs ~12 million workers.
- Manufacturing firms account for 70% of US industry R&D and employs 64% of scientists/engineers.
- High-tech workers paid substantially more than service workers and major portion of the most technology intensive industries are in manufacturing.
- Significant majority of world trade is in manufactured products – increasingly in complex, high-value manufactured goods – this is the currency of int’l trade.
- High-tech service jobs are growing but are not a panacea.
  - These jobs are increasingly “tradable” – they are in a global market.
  - 30 nations have policies to promote service exports.

- Over 50 years (1957-2007), manufacturing’s share of GDP has shrunk from 27% to 12%
- For most of this period (1965-2000), manufacturing employment remained constant at 17 million
- Last decade, mfg. employment fell to around 12 million
  - Note: mfg. employment measurement issue: that is the no. of jobs in actual production phase, not industrial employment
- Value of manufacturing output (shipments) in constant dollars grew due to productivity growth but, constant-dollar shipments remained flat (2000-2007), although still world leading with 22% of world output
  - But: Atkinson (2009): US mfg. output value data significantly overstated since it includes a productivity factor for IT goods
    - not real estimate of real output
Production is to employment - like an hourglass:

- Input employment – resources, suppliers, etc.
- The production moment – limited employment, but key to other stages
- Output employment – distribution, services, sales, repair, etc.
U.S. Trade Balances for High-Tech vs. All Manufactured Products, 1988-2008

$ billions

Source: Census Bureau, Foreign Trade Division
National R&D Intensities, 2005
Gross R&D Expenditures as a Percentage of GDP

Source: OECD, Main Science and Technology Indicators, May 2007
Tassey: Trends in Manufacturing, Con’t

• U.S. national R&D intensity same as in 1960, while other competitive economies have steadily increased their intensity
  – Input/Output theory: Freeze a major input, limit growth
  – (Intensity: defined as R&D spending relative to GDP)

• Although domestic corporate R&D spending increased relative to GDP for most of this period, ratio now in decline

• Major reason: U.S. manufacturing firms have dramatically shifted their R&D investments strategies during the last twenty years toward an increasingly global scope.
  – U.S. manufacturing firms increased offshore R&D at three times the rate of domestic R&D spending

• U.S. manufacturing firms have shifted composition of their R&D portfolios toward shorter-term development objectives.
  – The “valley-of-death” (barriers between investment in radical or breakthrough research for new technologies, with strong long-term potential, and development) is widening.
Don’t Worry, Services will Make up for It…

• Our economy is already 80% service, just continue the trend

• One indicator – trade deficit

• Pre recession – end of 2007, trade deficit in mfg. goods ~$420B/yr, trade surplus in services ~$160B/yr

• Growth in services surplus dwarfed by the size of the deficit in goods – it will not offset it anywhere in foreseeable future
Should DOD Care?

• Pisano and Shih (2009): The “Kindle 2” could not be made in the US:
  – Flex circuit connector – China
  – Electrophoretic display – Taiwan
  – Controller – China
  – Lithium polymer battery – China
  – Wireless card – China
  – Injected molded case – China

• Eroding US ability to create:
  – every brand of US notebook computer (except Apple) and mobile/handheld designed in Asia

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Should DOD Care?, Con’t

• Advanced Technology at risk of shifting abroad (from: Pisano/Shih):
  – Advanced materials:
    • Gone: advanced consumer composites, advanced ceramics, IC packaging
    • At Risk: carbon composite components for aerospace/wind
  – Computing and Communications:
    • Gone: desktop, notebook, netbook PC’s, low end servers, hard disk drives, routers, home network tech
    • At Risk: midrange servers, blade servers, mobile handsets, optical comm. equipment, core network equipment
Should DOD Care?, Con’t

• **Green technology/Storage:**
  – Gone: Lithium ion, lithium polymer batteries for consumer electronics, chrystalline and polycrystalline silicon solar cells, bulk of wind turbines
  – At Risk: thin film solar

• **Semiconductors:**
  – Gone: fabless chips, bulk of SC mfg.
  – At Risk: flash memory chips

• **Displays:**
  – Gone: LCDs, electrophoretics
  – At Risk: next gen “electronic paper”
And DOD Production Cost Problem

- Based on the cost per unit inflation rate of the JSF, the entire defense budget in 2054 will be spent to purchase one aircraft.

- Product development time – aircraft: 220 months, and climbing – radically limits DOD flexible response – weapons don’t fit needs at arrival.

- Point: DOD increasingly unable to manage complex product development and production cycle.
Suppose we decided we wanted to go back to Production Leadership…

• We will need a strategy
• We will need to understand key factors we do not understand now

• What do we need to understand?
New Manufacturing Paradigms

• Historically, shifts in manufacturing advantage have stemmed from introduction of:

  1. technology advances
  2. with accompanying process advances
  3. and new business and organizational models
Historical Examples of Shifts with Tech-Process-Business Model Sequence:

1. US takes leadership of Industrial Revolution through development of the “American system” of interchangeable machine-made parts
   - Result of 20-year DOD technology development of precise machine tools at Harper’s Ferry Arsenal

2. Japan 1970’s-80’s – new quality price tradeoff, just in time inventory, making labor fixed price for labor flexibility

3. US recaptures Semiconductor manufacturing lead in 80’s – focus on mfg process – advances in SC equip suppliers, roadmap
What technology advances = new manufacturing paradigms?

- “Network centric”
  - mix of advanced IT, RFID, sensors in every stage and element, datamining and recall, advanced robotics
- Advanced materials
  - “materials genome” – ability with supercomputing to design all possible materials with designer features
  - Biomaterials, and bio assembly
  - Lightweighting everything
- Nanomanufacturing
  - fabrication at the nano-scale
- Mass Customization
  - Production of one at cost of mass production
- Distribution efficiency
  - IT advances that yield distribution efficiencies (incl. in supply chain)
- Energy Efficiency – energy is “waste”
Next - Sectoral Evaluation

• Manufacturing is sectoral, but with increasing sectoral overlap for complex, high value goods
  – An airplane is aero design, electronics, IT, materials, etc.

• Technology paradigms have to make sense in the sectors

• Run a matrix – technology options against sectors they apply to – pick technologies with payoff across sectors

• Include emerging sectors
## MATRIX: Tech Sectors/Mfg. Paradigms

<table>
<thead>
<tr>
<th>Sector and Mfg. Paradigm</th>
<th>Bio/pharma</th>
<th>Aerospace</th>
<th>IT/electronics</th>
<th>Heavy Equipment</th>
<th>Digital search, network</th>
<th>New energy</th>
<th>Transport</th>
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<tbody>
<tr>
<td>Network - centric</td>
<td>x</td>
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<td>x</td>
<td>x</td>
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<td>Advanced materials</td>
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<td>Nano Mfg.</td>
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<tr>
<td>Mass Customization</td>
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<td>x</td>
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<tr>
<td>Distribution Efficiency</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Energy Efficiency</td>
<td>x</td>
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<td>x</td>
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It’s no longer Manufacturing OR Services

• Emergent:
  – new kind of firm that mixes services, production, supply chain management and innovation (the “21st century” firm)

• Need to look at this emerging firm model:
  – is it vertical or horizontal?
  – is it integrated or the result of flexible leveraging other firms’ specialty capabilities?
  – Strengths and weaknesses of distributed mfg. model
  – are there examples of both forms? – look at firms attempting this model and their issues they face in pursuing it

– Business model stage will need to look at optimal combined model
Better look over our shoulder…

• Need to look a competitor nation strategies
  – Hard to understanding the future of U.S. manufacturing without evaluating the context of global manufacturer competitors and their strategies
  – Look at:
    • China/India/Brazil – large emerging
    • Germany/Japan – large established
    • Korea/Taiwan – smaller scale, key niches
  – We will learn from them
Workforce Issues-

• STEM Ed leadership req’d
• But innovation also requires “mind and hand”
  – Skilled artisans key to past innovation; it’s a mix of skills, experimentalists and theorists
  – It’s not just design as a stand-alone stage, design is over time also the ability to make, as well
  – Very hard, still, despite distributed manufacturing, to sever design from production – mutually informative
• Lessons from Germany?
The Pipeline and the Seams

- **US pipeline innovation** model organized with heavy federal basic research investment,
  - some applied (from DOD),
  - very little investment in manufacturing R&D (including tech, process, business model)
- We institutionalize the “Valley of Death” in our R&D model
- Other countries don’t do it that way
- And profound **problems at the seams** of the innovation pipeline – big disconnects between actors
  - Research – basic research agencies, univ’s
  - Applied – industry, some DOD support
  - Predominantly small firm supplier/production but limited dissemination
- Need new networked organizational models
Could the US assemble a program?

– Need to look at the assets on the table in the federal, private and university sides that could be brought to bear around a strategy that emerges from a thesis

  • Review existing programs at DOD, NIST, DOE, and NSF, and programmatic elements that could be part of a new strategy

  • Review potential institutional assets in private and academic sectors that could be relevant in a manufacturing strategy
Summary of Manufacturing R&D at Four Leading Agencies

(mfg. tech and process R&D and dissemination not mfg. “related”)

<table>
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<tr>
<th>AGENCY:</th>
<th>APPROXIMATE FUNDING:</th>
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<tr>
<td>Dept. of DEFENSE (DARPA &amp; Mantech), total</td>
<td>~$264.4 million</td>
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<td>Dept. of ENERGY, total</td>
<td>~$ 96 million</td>
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<tr>
<td>NIST (R&amp;D and MEP), total</td>
<td>~$158.9 million</td>
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<tr>
<td>NSF, total</td>
<td>~$188 million</td>
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<tr>
<td>TOTAL, all above agencies:</td>
<td>~$707.3 million</td>
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Source: E.Eddison, MIT study (2010)
You could start to see a collaborative effort…

• Embedded system, if interagency collaboration:
  – R&D efforts in key potential technology paradigms at DOD (mass customization, advanced materials, etc.), DOE (energy efficiency), NSF (nano mfg.), NIST, etc.
  – Develop a cross agency strategy – like Nat’l Nano Initiative, only more deeply connected
  – Bring in key private sectors
  – DOD’s Mantech: testbeds to prove out process and business model
  – Existing dissemination programs: Mantech and NIST’s Manufacturing Extension Program
DOD: Central Player: testbeds, initial markets - in sectors that concern it

DOD’s 20th Century Innovation Waves:

- Aviation
- Electronics
- Nuclear Power
- Space
- Computing
- The Internet
Need the DOD Systems Model:

- DOD did the IT revolution by playing at every stage of the innovation system
  - From research to development to demonstration, on the innovation Front End,
  - To test beds to financing to procurement to creating the initial market on the innovation Back End
- A mfg. transformation is at least as hard as IT
- We’re going to need to operate at all the stages of the system
- DOD could play role in an mfg. innovation system through R&D, and use its procurement – can be testbed and initial market
- DOD actually seems worried: strategic and tactical concerns and efficiency/cost needs