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"Defense Industrial Base and U.S. Competitiveness: Implications for the Manufacturing Base and U.S. National Security"
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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
  - Andy Marshall – "The Revolution in Military Affairs"
  - 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 <u>potential</u> peer national competitors are arising
- One theory: Economic war will be the proving ground – it will be the decisive theatre

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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

Lynn: Global Economic Integration, Con't

SO:

3 Periods of US Economy:

- Hamilton to 1945: rational national self-dependence in mfg.
- 1945 – 1991 (end of Cold War) – US gov't entwines US-Europe-Japan in mutual dependence on Amer-centric mfg. system
- 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:

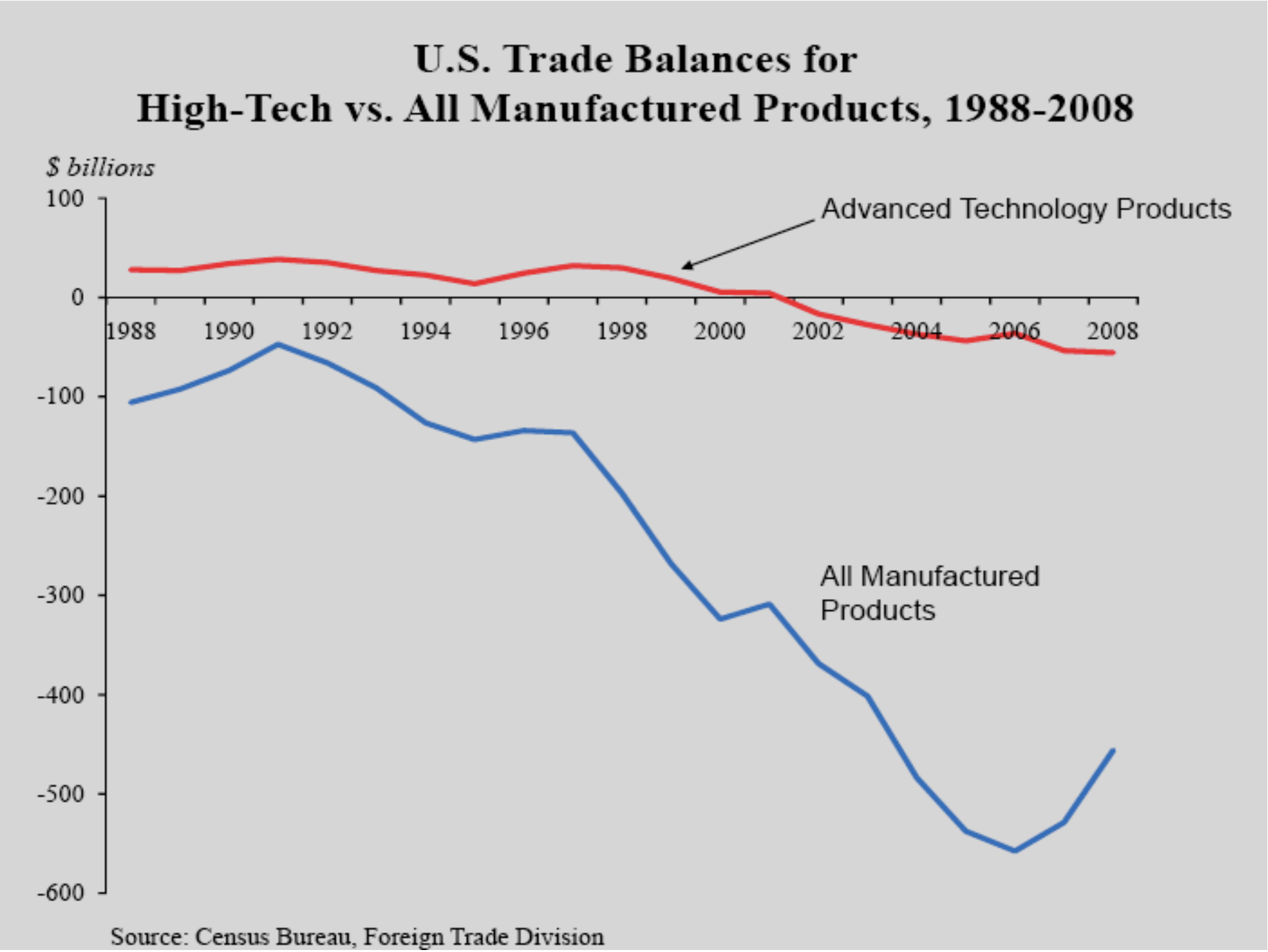
- Manufacturing contributes $1.6 trillion to GDP and employs ~12 million workers
- Manufacturing firms account for 70% of US industry R&D and employs 64% of scientists/engineers
- High-tech workers paid substantially more than service workers and major portion of the most technology intensive industries 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

BUT: Manufacturing Trends – Source: Greg Tassey (2009)

- 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

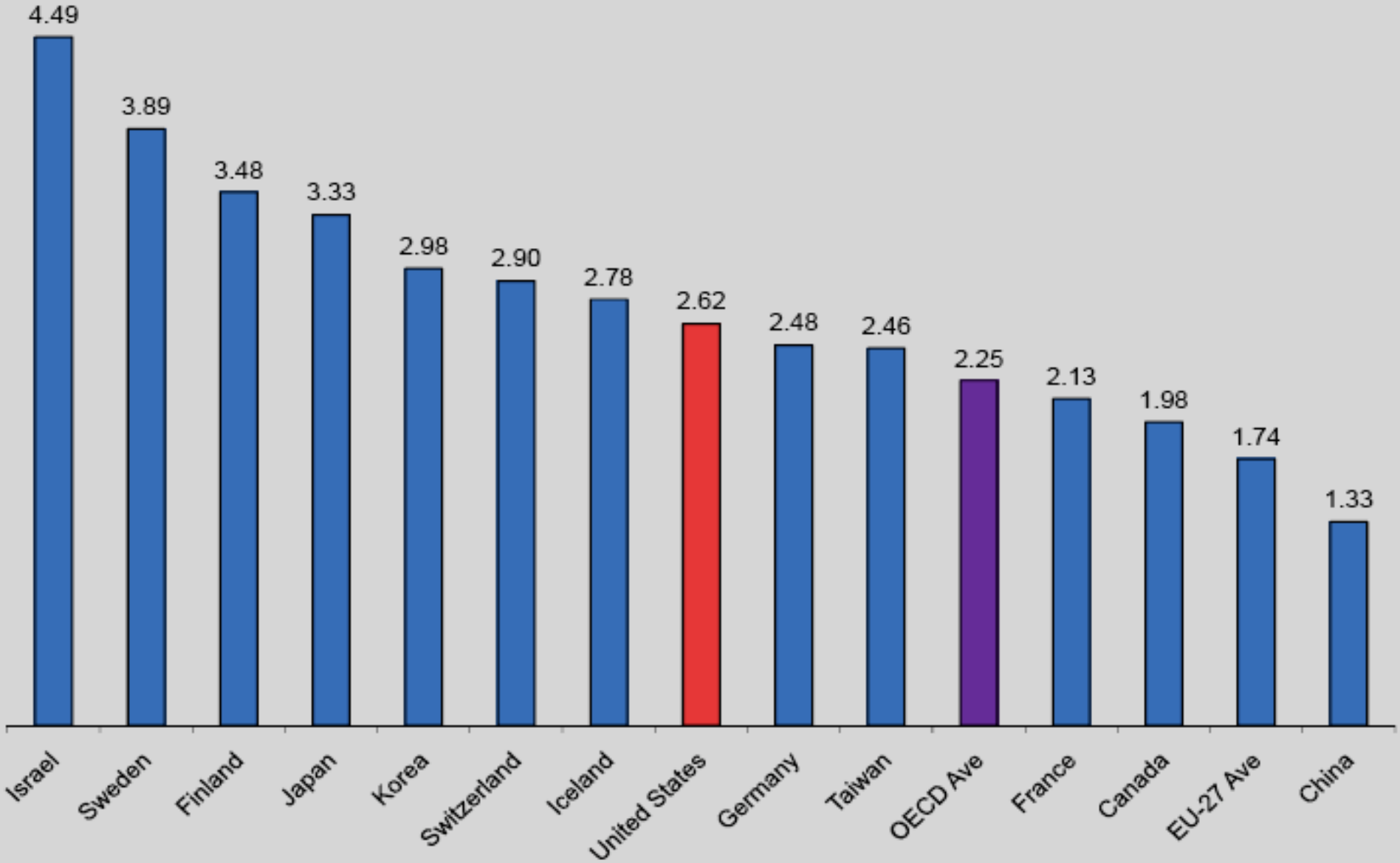
Production is to employment - like an hourglass:

- ←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
100
0
-100
-200
-300
-400
-500
-600
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Advanced Technology Products
All Manufactured Products
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

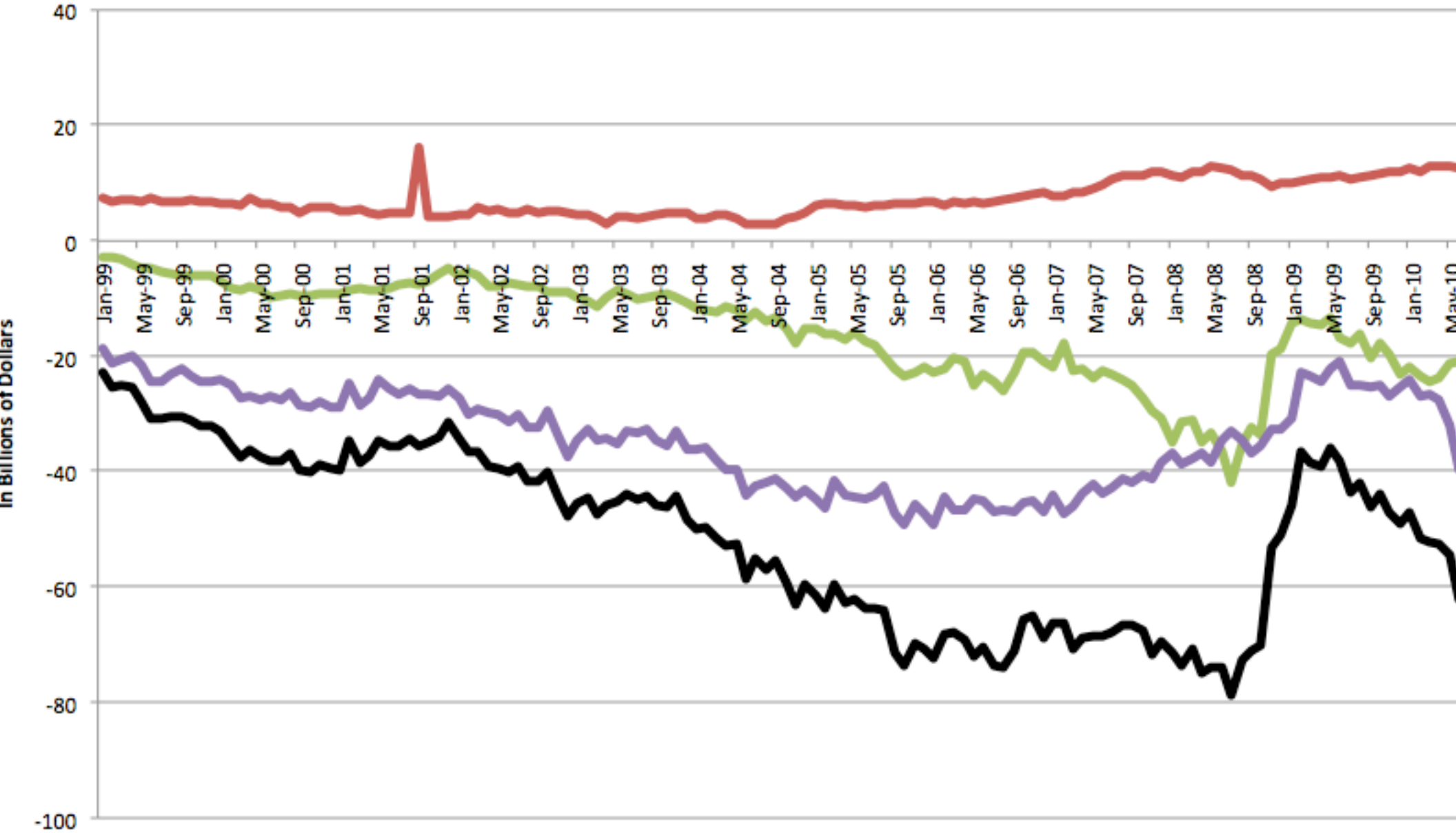
Tassey: Trends in Manufacturing, Con't

- 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
- <u>Growth in services surplus dwarfed by the size of the deficit in goods – it will not offset it anywhere in foreseeable future</u>

U.S. Monthly Goods and Services Balances, all months between 1999-2010, seasonally adjusted



ta Source: U.S. Census Bureau.
art prepared by Christopher
yder, MIT Washington Office.

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

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 poly-crystalline 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

- Ken Gabriel, DARPA Dep. Dir. (3/2910):
  - 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, <u>shifts in manufacturing advantage</u> have stemmed from introduction of:**
  1. **<u>technology</u> advances**
  2. **with accompanying <u>process</u> advances**
  3. **and new <u>business</u> and organizational <u>models</u>**

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

Sector and Mfg. Pardigm	Bio/ pharma	Aero-space	IT/ electro nics	Heavy Equip ment	Digital search, network	New energy	Trans port
Network - centric	x	x	x	x	x	x	x
Advanced materials	x	x		x		x	x
Nano Mfg.	x	x	x	x	x	x	x
Mass Customi-zation	x	x	x	x	x	x	x
Distribution Efficiency	x	x	x	x		x	x
Energy Efficiency	x	x	x	x	x	x	x

It's no longer Manufacturing *OR* Services

- **Emerging:**
  - **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 <u>and hand"</u>
  - 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, <u>still</u>, 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 <u>little investment in manufacturing R&D (including tech, process, business model)</u>
- 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 – <u>big disconnects between actors</u>
  - 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”)

AGENCY:	APPROXIMATE FUNDING:
Dept. of DEFENSE (DARPA & Mantech), total	~$264.4 million
Dept. of ENERGY, total	~$ 96 million
NIST (R&D and MEP), total	~$158.9 million
NSF, total	~$188 million
TOTAL, all above agencies:	**~$707.3 million**

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