Securing Advanced Manufacturing in the United States – The Role of Manufacturing USA

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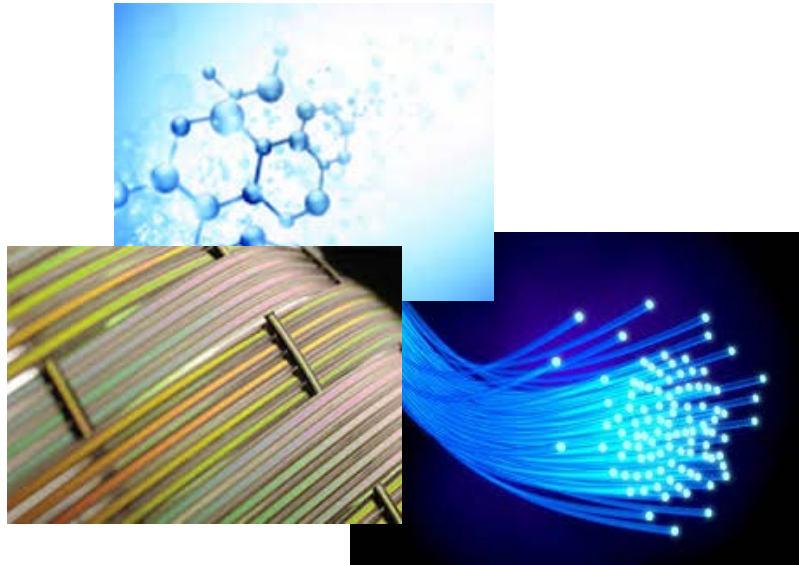
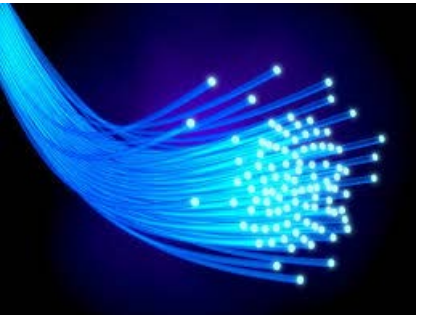


Part I – The Diagnosis:

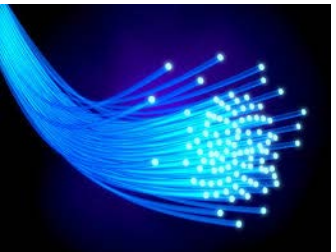
- Drawing from the report --
  -- What is the US manufacturing problem?



Snapshot One: Manufacturing is not Agriculture

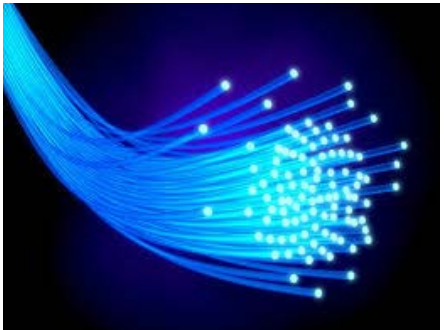
- For a long time US thought manufacturing *was* agriculture.
  - In 1900 half of population farming; now less than 2% farming
  - Producing more than ever, huge "productivity gains' in agriculture
- But the data tell us this manufacturing is *not* agriculture
- US lost 5.8 million manufacturing jobs from 2000 to 2010
  - US thought manufacturing ***output*** was holding firm, but it wasn't - on reexamination we're finding it was in decline (in 16 of 19 sectors)
  - So ***didn't get the productivity gains it thought***
    - ***US productivity: 1995-2005: 2.5%; 2005-2015: 1%***
  - ***Capital and plant investment level down in 2000s***
  - ***Major trade deficit: $800b manufactured goods***

– **Job loss data shows: US manufacturing *hollowing out, losing in int'l trade, jobs not lost through productivity gains***



Snapshot Two: Home Alone

- The data tell us for the past three decades we have been thinning out our manufacturing ecosystem
  - US used to have firms and supply chains that were very vertically integrated
  - US hit on a financial model of emphasizing quarterly returns, which led us to reduce risk by making our firms focus on "core competency" and go "asset light"
  - *And* complex technologies require more specialized firms
  - So the shared assets of training, bringing best practices to suppliers, thinned out
    - 60,000 factories closed in the 2000s
  - **The small & midsized companies in the US system are now much more *"home alone"***



Snapshot Three: The Scale Up Problem

•US has 3 manufacturing sectors:

•**1) Big multinationals** – they are global, they can get production efficiencies by producing in lower cost countries and they must be in all the global markets

•They're OK, although they are increasingly producing abroad

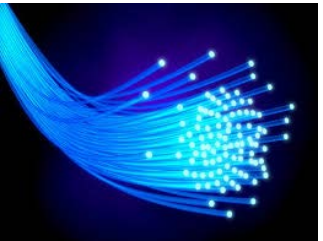
+ Two More Vulnerable Sectors:

•**2) Main Street firms** – they do 46% of U.S. manufacturing, there are 250,000 small and mid-size firms (under 500 ee's)

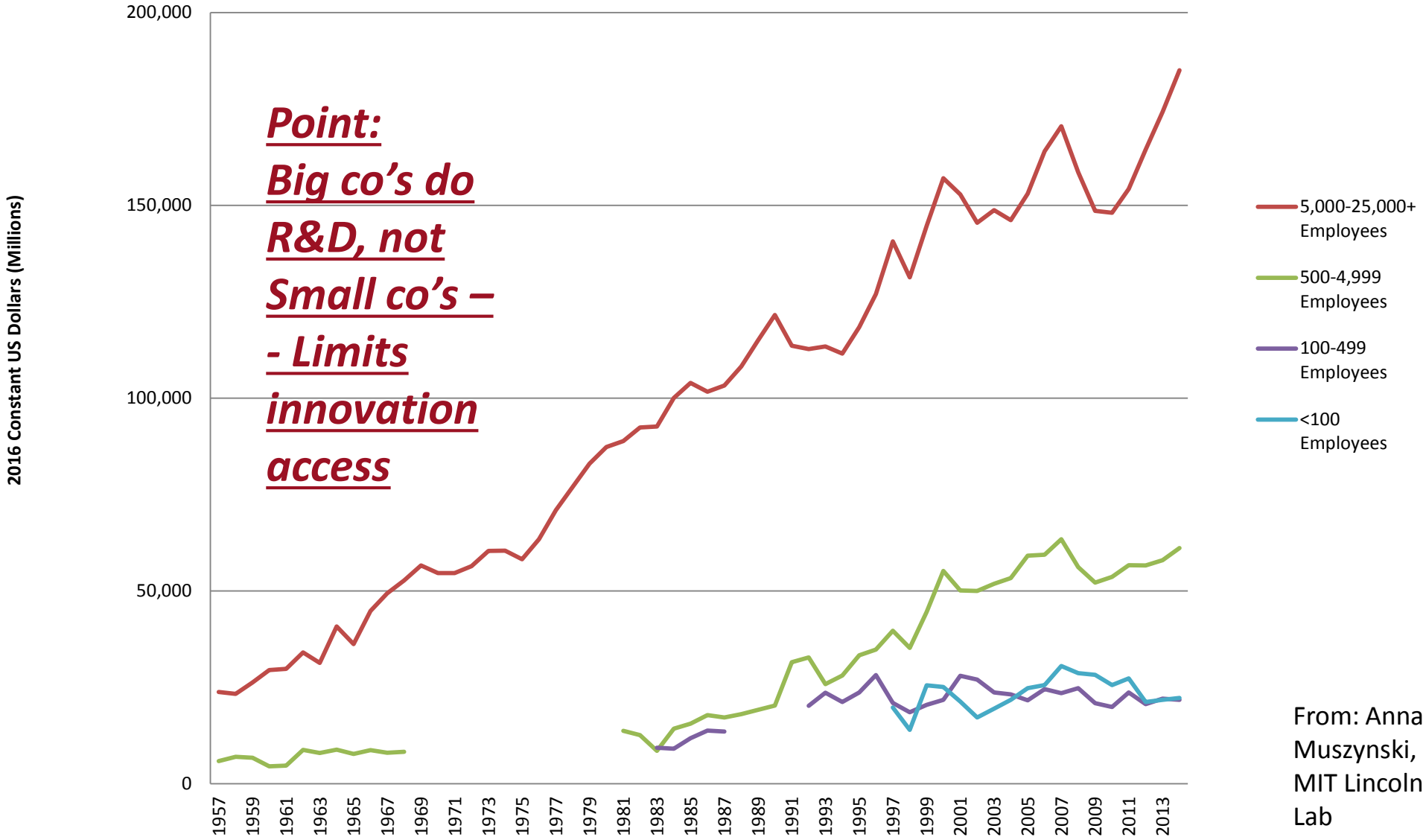
•They **have trouble getting production scale up funding**, they're *thinly capitalized, must be risk adverse to survive, and don't do R&D so limited access to innovation* (but can be innovative about process)

• **3) Our entrepreneurial startups that make something** –

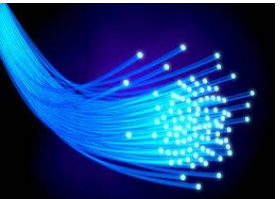
• they do well until they have to **scale up for production** of their product – they **lack financing for scale- up** here – Venture Capital doesn't fund this – So they turn to contract manufacturers abroad



Private Industrial R&D Funding in the U.S. by Company Size (1957 - 2014)



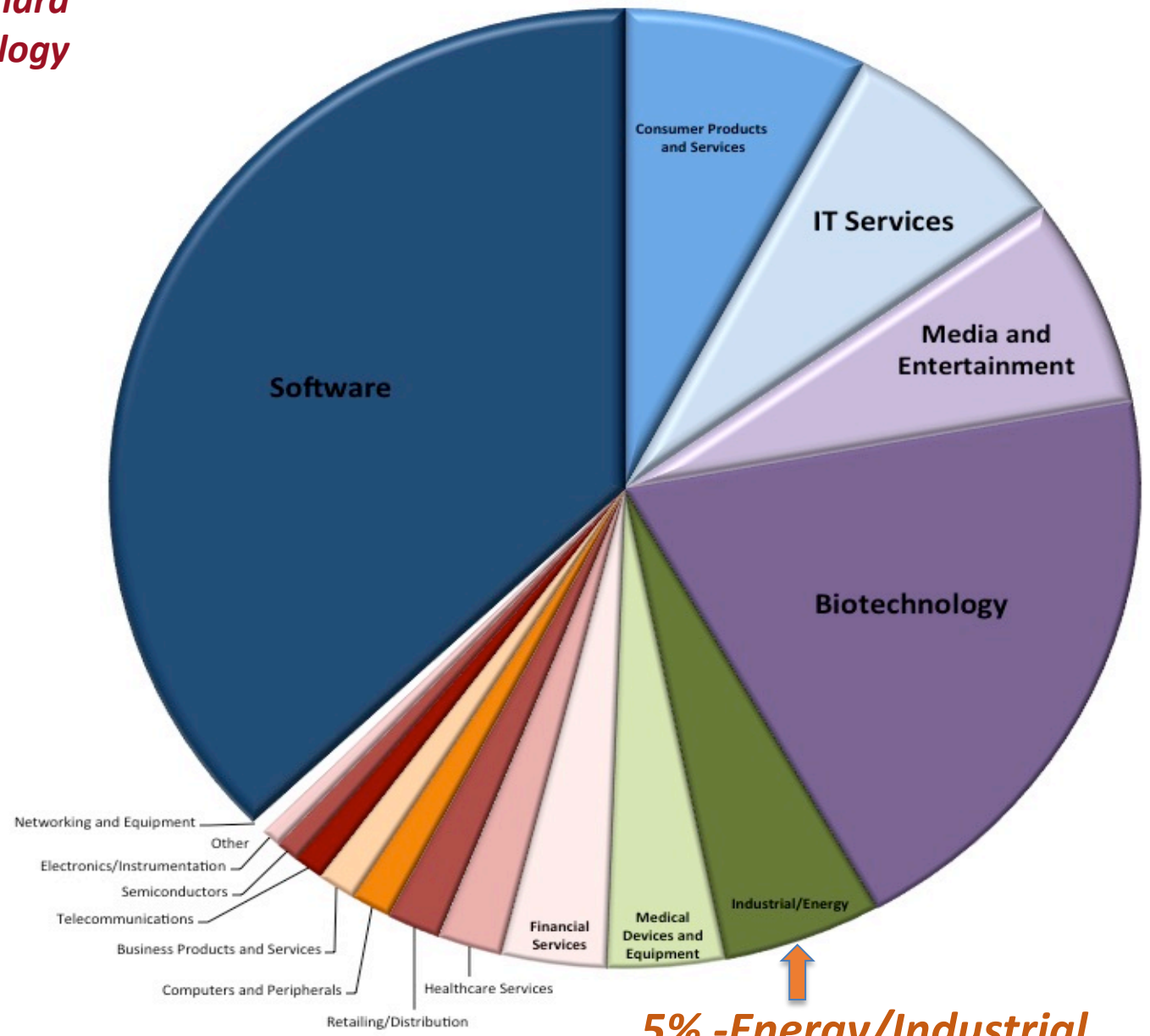
From: Anna Muszynski, MIT Lincoln Lab



Sources: "Domestic R&D Funded by Companies Doing Business in the US" 2014 - The NSF Business R&D and Innovation Survey (BRDIS), *in press*; 2008 to 2013 - The NSF Business R&D and Innovation Survey (BRDIS), https://www.nsf.gov/statistics/srvyindustry/; 1980 to 2007 - The NSF Survey of Industry R&D (SIRD), https://www.nsf.gov/statistics/iris/

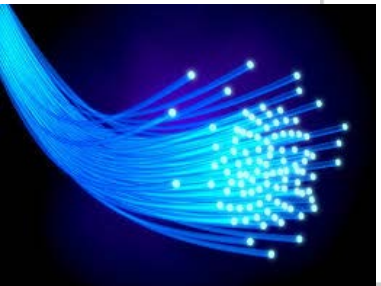
Point: Venture Capital withdraws from "hard" technology

Total VC Investment in 2015



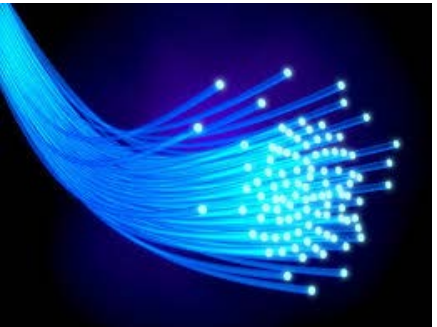
5% -Energy/Industrial

Source: P. Singer, MIT, 7/16 from NVCA & PWC data



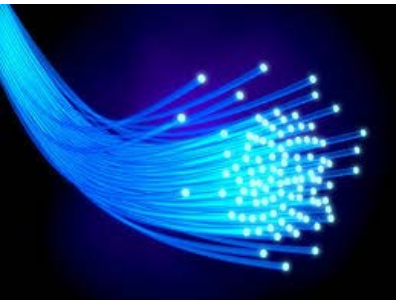
Snapshot Four: The tie between Innovation and Production

- US had: *innovate here/produce here* – got full spectrum of gains
- Then US did*: innovate here/produce there*
- But - for most products need to tie innovation closely to initial production
  - Need dense feedback loops as you do product design-initial production requires very creative engineering and design – it's part of innovation
  - So if you shift production capability, in many cases innovation capability has to follow it
  - Result: *Produce there = Innovate there*
- Innovation is U.S. strong suit –what it does best
- But if many important innovations have to follow production, endangers US core innovation strength
- And Tech Innovation is the key factor in growth



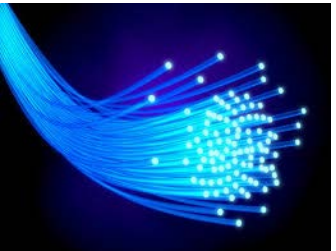
Snapshot Five: Production must be seen as part of the Innovation System

- Manufacturing not pictured in the US as part of the innovation process
  - US past focus on only R&D: fragmented view
  - Innovation is a system, from early-stage research through production
- Production is the major enabler of “increasing returns” in an economy – it is a scale-able factor
  - a foundational societal wealth creator.
- treat production as critical element that must be connected to innovation system
  - or risk innovation erosion



Snapshot Six: Lessons from Germany

- US thought that it had to lose manufacturing jobs to low cost producers in Asia because it was high wage.
- But Germany is high wage and high cost – German wages and benefits are 60% higher than the U.S.
- Germany runs a major manufacturing surplus, including a manufacturing surplus with Asian nations
- Germany has a deep ecosystem for their manufacturers, small and large – they aren't "home alone"
- Extensive collaborative R&D shared by industry- gov't-universities around manufacturing technologies and processes – *Fraunhofer Institutes*
- Shared training system for their workforce
- Ways to link their supply chains for rapid scale up
- Some German practices don't apply, some do



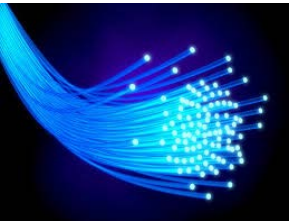
Snapshot Seven - Behind it all
-- Understanding the Hourglass --

<---- Resources, Suppliers, Components, Innovation

<--- Production (12m jobs)

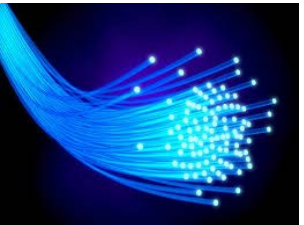
<--- Distribution, Sales, Life Cycle

AND: Value Chains run throughout



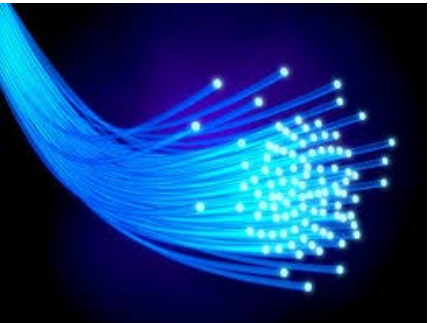
Snapshot Eight: Manufacturing Decline = Social Disruption

- Between 2000 and 2010, U.S. manufacturing employment fell by 5.8 million jobs:
  - from 17.3 million to 11.5 million;
  - 2015 only recovered to 12.3 million
- Manufacturing - important middle class pathway for high school educated males –
- Importantly, *median income of men without High Sch. diploma fell by 20% between 1990 and 2013;*
- *-- men w/High Sch. diploma or some college fell 13%*
- Not just white working class – 10% of mfg. jobs, African Americans; 16% Hispanics – even harder hit, blocked a pathway
- This was clear a signal of:
  - a loss to middle income ranks and growing income inequality
- *Can Advanced Manufacturing speak to this?*



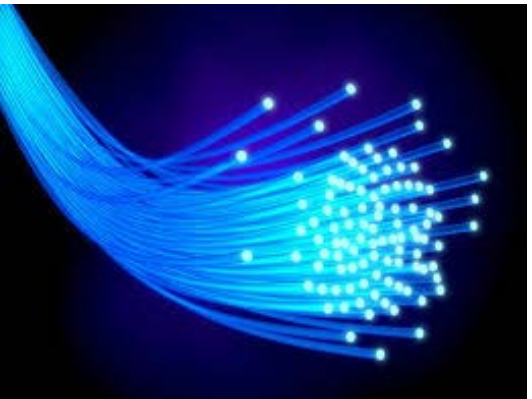
Problem Summary:

- Manufacturing is not Agriculture
- U.S. Manufacturing Firms are Increasingly "Home Alone"
- Big Scale-Up problem for small, mid-sized, and start-up firms – financing gap for scale-up
- U.S. Delinked innovation/production
- But: Manufacturing is part of Innovation System
- Germany: strong mfg. ecosystem tied to innovation
- Lost 1/3 Mfg. Jobs – manufacturing is the largest job multiplier, far higher than services
- Social disruption
- ***Way out? Apply innovation* model?**



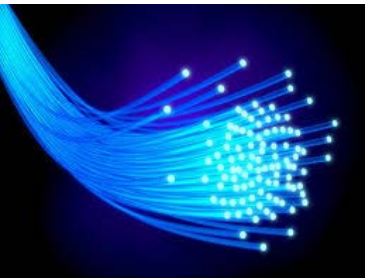
Part II – the Remedy

- Applying the Innovation System to the Problem
- “Advanced Manufacturing”

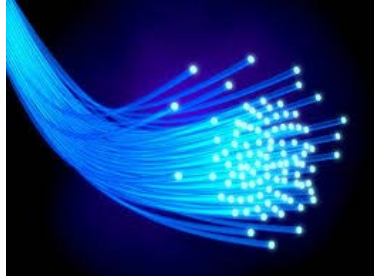


Policy Background: *Is Advanced Manufacturing ---> A New Innovation Model?*

- *The Four Innovation Models:*
  1. "Pipeline Model"
     - US focus since postwar: "Front end" of Innovation System
     - Fundamental research is role of US R&D agencies
     - Performs potential breakthrough research, can lead to radical technology advance
     - "Technology Push"/Technology Supply
  2. "Induced Innovation"
     - Industry led – does incremental advance
     - Responds to "Technology Demand" in Market – "Demand Pull"
  3. "Extended Pipeline"
     - Role of Department of Defense
     - Connected model – all stages of innovation



Issue: The innovation Pipeline:



THE INNOVATION PIPELINE:

Research-> Dev-> Prototype-> Demo-> Testbed-> Production-> Market

NSF, DOE OS, NIH, Etc.: *Pipeline Model – Basic Research*

DOD:

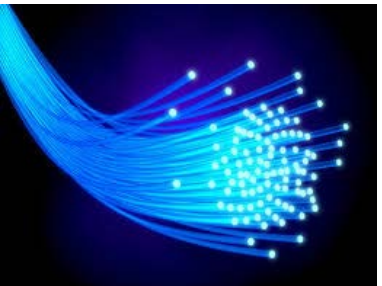
"Extended Pipeline" Model - DOD has a "Connected System"

INDUCED INNOVATION – INDUSTRY:

Development and Post-Development focused

The 4th Innovation Model:

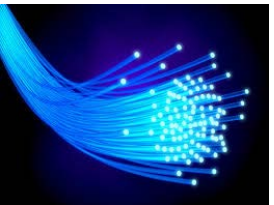
- "Manufacturing-Led" Innovation
  - Innovation system focus is on innovation in production technologies and processes
  - Examples:
    - US created mass production in late 19th century
    - Japan created "Quality Manufacturing" in 1970s-80s
  - Manufacturing-Led innovation systems:
    - Germany, Japan, Korea, and now China
- *BUT: END OF WW2: Because the US led in mass production, it just assumed production leadership*
  - *Focused its innovation system on research*
  - *not production*
    - Time for the US to do both?
    - *<u>But</u>* private sector led, cost-shared, collaborative



Idea: Scientists/Engineers Say There Are: New Manufacturing Paradigms

Are there new advanced manufacturing "Paradigms" –

- **Idea:** raise efficiency, compete with lower cost economies; could lead to restoration of mfg. leadership? – And innovation is its own reward, creates new opportunities -- some examples:
- **"Network centric"/Digital Production**
  - mix of advanced IT, RFID, sensors in every stage and element, new decision making fro "big data" analytics, **advanced robotics, supercomputing w/adv'd simulation & modeling**
- **Advanced materials**
  - "materials genome" – ability with supercomputing to design all possible materials with designer features -- Biomaterials, bio fabrication, syntehtic biology -- Lightweighting everything
- **Nanomanufacturing**
  - fabrication at the nano-scale
- **Mass Customization**
  - Production of one at cost of mass production (ex.: 3D printing, tied to computer controls etc.)
- **Distribution efficiency**
  - IT advances that yield distribution/supply chain efficiency,
- **Photonics, Advanced Composites, Biofabrication, etc.**



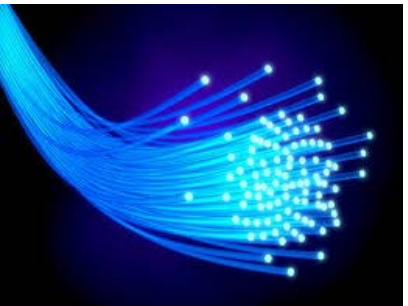
Example: 3D Printed Shelby Cobra at Oakridge w/Techmer PM composites

- concept to printed car, 6 weeks; 500 parts/24 hours to print

Used - BAAM (“Big Area Additive Manufacturing”) machine -- can print parts 500 to 1,000 times faster than current industrial 3D printers

Idea: Firm of the Future

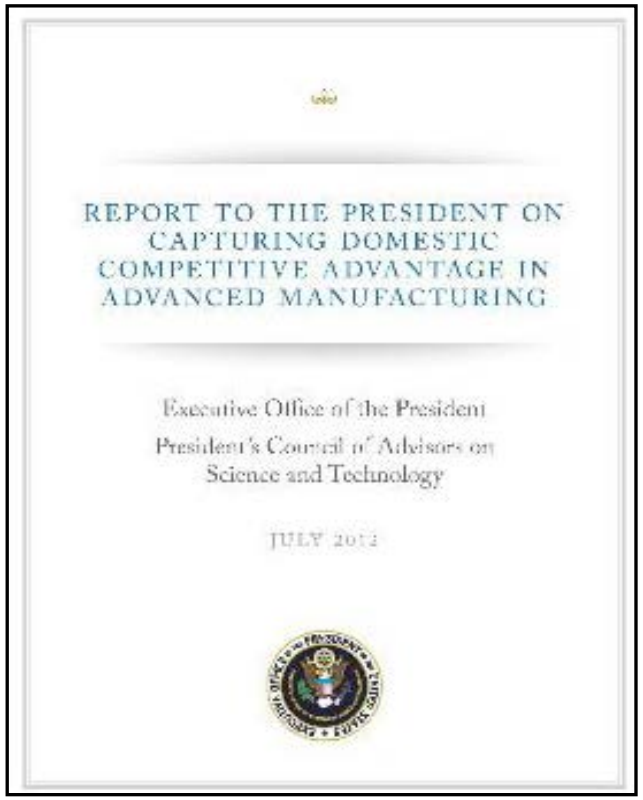
- US is nearly 80% services and only 12% manufacturing – why worry about manufacturing?
- The New Firm: will integrate production and services
  - An iPhone is hard technology that delivers services
  - Hard technology can allow services delivery around it
- Traditionally: goods are tradeable and can scale, services: face-to-face, personal & can't
- But: tie tradeable goods to services = tradeable services for scaleable growth
- So scale both
- BUT: Model requires ***manufacturing***



Advanced Manufacturing Partnership:
A Industry-University-Gov't Public Private Partnership:

idea: need innovation-based efficiency gains to compete with low cost/low wage nations

– *Recommended an* Innovation Model = Advanced Manufacturing Institutes


REPORT TO THE PRESIDENT ON CAPTURING DOMESTIC COMPETITIVE ADVANTAGE IN ADVANCED MANUFACTURING

Executive Office of the President

President's Council of Advisors on Science and Technology

JULY 2012

PCAST 2012

Recommends Manufacturing Innovation Institutes to address key market failure


REPORT TO THE PRESIDENT

ACCELERATING U.S. ADVANCED MANUFACTURING

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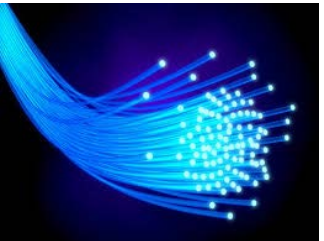
October 2014

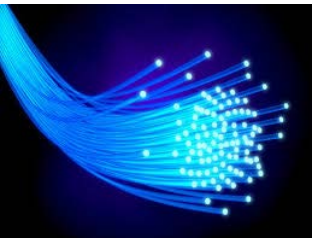
PCAST 2014

Recommends strong, collaborative network of Manufacturing Innovation Institutes



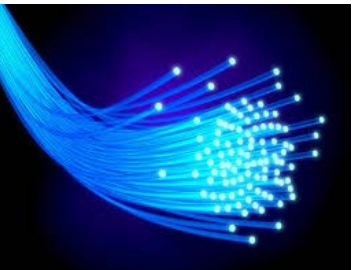
Critical Manufacturing Institute Role: **Workforce Training**

- Germany: Fraunhofer Institutes have a "Fraunhofer Academy"
- It trains apprentices for "mittelstat" small and mid-sized as well as large firms in the advanced technologies that its Institutes are creating
  - learning by doing, classroom and workplace
- *IT IS THE ADVANCED MFG. TECHNOLOGY DISSEMINATION MODEL*
  - The way advanced manufacturing technologies get into company plants –
  - *Learning walks on two feet*, not through plans



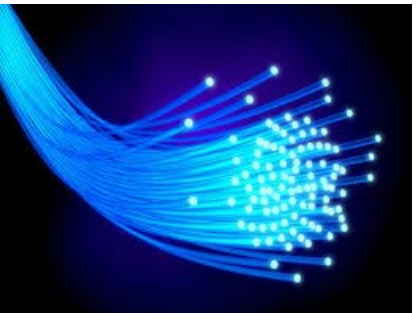
Have to do Advanced Manufacturing because our competitors are…

- Germany: Industrie 4.0
  - 60 Fraunhofer Institutes – annual funding $2 billion/year (Base federal gov't funding, regional gov't funding, industry funding and contracting, EU funds
  - Industrie 4.0 – estimated $4billion/multiyear project, gov't-industry funded
  - Strong apprenticeship program in all industries, gov't-industry costshared, supplemented by Fraunhofer Academy for advanced manufacturing skills
- China: "Made in China 2025"
  - Government's focus for last 25 years, build early stage research, now shifting to advanced manufacturing – "Made in China 2025"
  - Changing Places: China in 2000, 6% of world mfg. output; 2016, 24% of world mfg. output; U.S. in 2000, 26%, now 16% - China: unequalled rapid scaleup
  - $3 billion advanced manufacturing fund
  - 40 new Advanced Manufacturing Institutes by 2025 – led by advanced batteries (started in 2016, w/$400m) and digital production
  - 40 industrial parks just for robotics
- Also, India, Singapore, Britain, Korea, etc. planning initiatives



Linking Policy to the Problem Points

- Lesson from "home alone" – restore the ecosystem:
  - Manufacturing Institutes – like Germany's Fraunhofers?
- Lesson from "innovation/production connection"- reconnect:
  - Use the federal R&D system in adv'd mfg
  - Technology strategies for new adv'd mfg paradigms
    - Collaborative – industry-univ.-gov't
    - Focus on cross-sector technologies
  - Tie in R&D system to strategies, link to institutes
- Lesson re Workforce: need training for adv'd mfg -- commmunity college role, adv'd engineering



- Lesson re Production Scale up
  - Gap in financing system – new models required - substitute space for capital

Conclusion

- Advanced Manufacturing Institutes –
  - IDEA: Apply the still strong US Innovation System to Manufacturing
  - Manufacturing Institutes evolving
- Still need work on –
  - Connecting the R&D System to the Institutes
  - Creating the Network
  - Workforce training
  - Scaling-up Startups
  - And have to integrate the various technologies for entirely new production floor systems