Advanced Manufacturing – a new innovation agenda for US production

Outlook 2017 Conf.
Industrial Fabrics Association Int’l
May 22, 2017

William B. Bonvillian
Lecturer, MIT
Advisor, MIT Industrial Performance Center
What’s the Advanced Mfg US Context?

--- Recent Reports...
The US Manufacturing Problem:

1) Manufacturing is not Agriculture
2) Our Manufacturing Firms are Increasingly: “Home Alone”
3) Small, mid-sized, and start-up firms – most of U.S. manufacturing - can’t get financing to “Scale-Up” innovative production
4) Strong innovation capability = strong production capability
   • Emerging advanced technology fields
5) Manufacturing is part of the innovation system
6) What Germany can teach us: strong ecosystem
7) Jobs – How manufacturing scales jobs with production
8) Economic effects; social disruption

Response:

A New Manufacturing Innovation Model?

Elements: Manufacturing Institutes, Cross-Gov’t/Industry/Univ’s Collaboration, Technology Strategies, training, financing, etc.
Part I – The Diagnosis:

• Drawing from the reports --
• What is the US manufacturing problem?
Problem 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 reports tell us this manufacturing is not agriculture
• US lost 5.8 million manufacturing jobs from 2000 to 2010
  – We 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 we didn’t get the productivity gains we thought
  – Capital and plant investment down in 2000s
  – Major trade deficit: $800b manufactured goods
  – Job loss data: US manufacturing hollowing out
Problem Two: Home Alone

- The reports 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
  - We 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”
  - 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”
Problem 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
  - 2) **Main Street firms** – they do most of our manufacturing, there are 250,000 small and mid-size firms (under 500 ee’s)
    - They **have trouble getting production scale up funding**, they’re **thinely 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 that
    - So they turn to contract manufacturers abroad
Point: Venture Capital withdraws from “hard” technology

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

Energy/Industrial = 5%
Problem 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 Innovation is the key factor in growth
Problem Five: Production must be seen as part of the Innovation System

• Manufacturing not pictured in the US as part of the innovation process
  – 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
Problem Six: what Germany can teach the US

- 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
- Some German practices don’t apply, some do
Problem Seven - Behind it all -- Understanding the Hourglass --

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

<---- Production (12m jobs)

<---- Distribution, Sales, Life Cycle

AND: Value Chains run throughout
Problem Eight: The Economic Context: “Secular Stagnation” – Decline in Productivity and Growth

- Larry Summers – “secular stagnation” 2013 speech to IMF
  - Term from Alvin Hanson in 1938 describing lasting effects of the Great Depression
  - Summers – it’s more than the lasting effects of Great Recession
  - Krugman – part is slowing growth in working age populations in developed world
  - GDP growth stuck in the 2% level vs. historic 3% range of U.S.; middle income in decline
  - Productivity: 3+% in the IT revolution, now in the 1% range

  - The IT innovation wave is less significant than the 1870-1970 waves (internal combustion engine, modern communications, electricity, chemicals, pharmaceuticals, urban sanitation)
  - Productivity gains lower, real growth lower
  - Stagnating living standards ahead

- U.S. Limits technological innovation to “Frontier” sectors
  - IT sector: still only 4.6% of the U.S. economy
  - Legacy sectors: some 80% of the U.S. economy

- “Technological and related innovation” is the dominant causative factor in growth
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 – particularly white males.
  – Yet earnings per person for white male high school graduates:
    • fell by 9% between 1996 and 2014;
    • earnings for white male college graduates rose 22%;
    • 2014, income for white male high school graduates:
      – $36,787, compared to
      – $94,601 for college graduates.
Social Disruption, Continued

• full year employment - men with high school but not college degrees:
  – went from 76% in 1990
  – to 68% in 2013.

• The share of these men who did not work at all went from 11% in 1990 to 18% in 2013.

• 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%

• Restoring manufacturing was a frequently cited subject in the 2016 Presidential election.

• This was clear a signal of:
  – a loss to middle income ranks and growing 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
- Delinked innovation/production
- But: Manufacturing is part of Innovation System
- Germany: strong mfg. ecosystem tied to innovation
- Lost 1/3 Mfg. Jobs – manufacturing is largest job multiplier, far higher than services

Way out? Apply innovation
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: How far down the innovation pipeline does the Federal Government role go?

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”
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 breakthrough research not production
  • Time for the US to do both?
Idea: New Manufacturing Paradigms?

Are there new advanced manufacturing “Paradigms” –

• raise efficiency, compete with lower cost economies; could lead to restoration of mfg. leadership? – some non-fiber examples:

• **Energy Efficiency** – energy is “waste”

• **“Network centric”**
  – mix of advanced IT, RFID, sensors in every stage and element, new decision making from “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, syntthetic biology
  – Lightweighting everything

• **Nanomanufacturing**
  – fabrication at the nano-scale

• **Mass Customization**
  – Production of one at cost of mass production (ex.: 3D printing mfg, tied to computer controls, etc.)

• **Distribution efficiency**
  – IT advances that yield distribution efficiency (ie, supply chain)
Example: 3D Printed Shelby Cobra at Oakridge w/Techmer PM composites - concept to printed, 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

– 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: Industry-University-Gov’t: Developed Innovation Model, Basis for the Advanced Manufacturing Institutes

PCAST 2011
Recommends Advanced Manufacturing Initiative as national innovation policy

PCAST 2012
Recommends Manufacturing Innovation Institutes to address key market failure

PCAST 2014
Recommends strong, collaborative network of Manufacturing Innovation Institutes
The 2012 & 2014 Advanced Mfg. Partnership – 4 Basic Recommendations:

- Transformative Technologies – Technology Strategies Linked to R&D
- Implementing Manufacturing Institutes and networking them
- Demand-Driven Workforce Solutions
- Technology Scale-Up/Policy
New Model - Advanced Manufacturing

- **Advanced Manufacturing Partnership (AMP)** - idea:
  - need innovation-based efficiency gains to compete with low cost/low wage nations
  - Apply innovation capabilities to manufacturing
  - So: New Technologies/Processes/Business Models

- **“Advanced Manufacturing Institutes”** - 15 now planned
  - Collaborative–industry/univ/gov’t –in a way, Sematech model
  - Testbed role / Workforce education role
  - Around potential new technology paradigms
  - Cost shared between: federal gov’t/industry/state gov’t

- **Creating an Adv’d Manufacturing System – still to be undertaken:**
  - *Create the network for info-sharing; governance mechanism*
  - **Technology Strategies** around adv’d mfg. technologies
  - *Industry-Univ-Gov’t. - collaborative advice – advisory panel*
  - *Integrated adv’d mfg R&D across agencies* – feed-in to Institute
  - Seek a financing for $10 billion, streamlined effort
Institutes: Addressing the “Scale-up” Gap

Focus is to address market failure of insufficient industry R&D in the “missing middle” or “industrial commons” to de-risk promising new technologies.
The Institute Design
Creating the space for Industry & Academia to collaborate

National Network of Institutes

Academia
- Universities & National Labs
- Community Colleges

Institute For Manufacturing Innovation
- Prototype lab/shops
- Research facility
- Computer lab

Shared Use Facility

Industry
- Large Manufacturing Companies
- Small & Medium Enterprise
- Start-ups

Government
- Federal
- State & Local
- Economic Dev. Org.

Note: Complex model: Like standing up a country
Green shaded states have major participants in Manufacturing USA Institutes.
The First 9 Manufacturing Institutes:

- Additive Manufacturing (3D Printing) (America Makes)
- Digital Manufacturing and Design Innovation (DMDII)
- Lightweight and Modern Metals (LIFT)
- Next Gen Power Electronics (Power America)
- Advanced Composites Manufacturing (IACMI)
- Photonics (AIM Photonics)
- Flexible Hybrid Electronics (Next Flex)
- Advanced Functional Fibers (AFFOA)
- “Smart” Manufacturing – adv’d controls, sensors, platforms (CESMII)
The Five New Institutes – late 2016 early 2017

• Advanced Assistive Robotics (ARM)
• Regenerative Manufacturing (ARMI) – biofabrication, tissue engineering
• Advanced Biopharmaceuticals Production (NIIMBL)
• Advanced Chemical Processing (RAPID)
• Recycling and Remanufacturing (REMADE)

• DOD: 8 Institutes
• DOE: 5 Institutes
• NIST: 1 Institute
Institute Case Study: Composites Manufacturing


Institute of Advanced Composites Manufacturing Innovation
Each Institute has a clear mission based on a critical Industry need

Opportunity:
Lightweight composites:
• Major benefits to energy efficiency, renewable power generation – auto, aerospace, wind
• Problem: overcome barriers to deployment
• How: advanced technologies to make composites
• Means lower cost, faster production, using less energy
• readily recycled

• Big Idea:
• The Institute: world-class resources to partners
• develop new low-cost, high-speed, and efficient manufacturing and recycling process technologies
• promote widespread use of advanced fiber-reinforced polymer composites.

Focus on:
• cut overall manufacturing costs of advanced composites by 50 percent
• reduce the energy used to make composites by 75 percent
• increase the ability to recycle composites by 95 percent
• In ten years
Each Institute to creates value for industry participation in return for cost-share funding

- **Access to Shared RD&D Resources:** access to equipment, from lab to full-scale, to for demonstration -- reduce risk for industry investment

- **Applied R&D:** significant government, industry, and academic funding for innovative solutions to member challenges

- **Composites Virtual Factory:** access to end to end commercial modeling and simulation software for composite designers and manufacturers through a web based platform.

- **Workforce Training:** Provide specialized training to prepare current and future workforces for the latest manufacturing methods and technologies.
Each Institute is operated by a consortium - a partnership of Industry, Academia and Government -- institute evaluations – Deloitte, NAS,

A partnership of world-class companies including:

- Dow
- Ford
- GE
- BASF
- Dassault Systèmes
- Boeing
- Lockheed Martin
- Volkswagen
- Dupont
- Local Motors

Top universities including:

- The University of Tennessee
- Vanderbilt University
- Purdue University
- Mississippi State University
- Colorado State University
- University of Kentucky
- University of Louisiana
- Ohio State University
- University of Nebraska

Economic Development Council to leverage state support and investment

Collaboration of state development leaders seeding economies worth $2 trillion
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 into company plants –
Part III: 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
Of potential interest to IFMI members from the Institute Model:

- **Specific research projects** – new fiber breakthroughs
- **Process research** that is beyond the reach of individual companies
- A more intense **ecosystem for mutual gains** – link larger/smaller firms – new “commons” for shared assets
  - Horizontal platforms and vertical capability
- U.S. productivity falling – 1% level now, vs. 3+% in 90s – so focus on **productivity gains** which are real system gains
  - Ex.: Internet of Things/ GE’s “digital productivity” – the physical and analytical join – efficiency multiplier
- Facilitate **entry of startups** (new collaborators)
- Workforce training – technology disseminator
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
  -- community college role, adv’d engineering

• Lesson re Production Scale up
  – Gap in financing system – new “innovation orchards”models, substitute space for capital