Production in the INNOVATION ECONOMY

Production in the Innovation Economy (PIE)

A new MIT study on the current state and future of innovation and manufacturing in the U.S.

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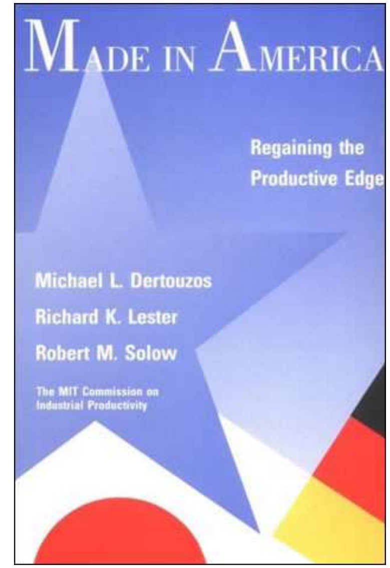
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

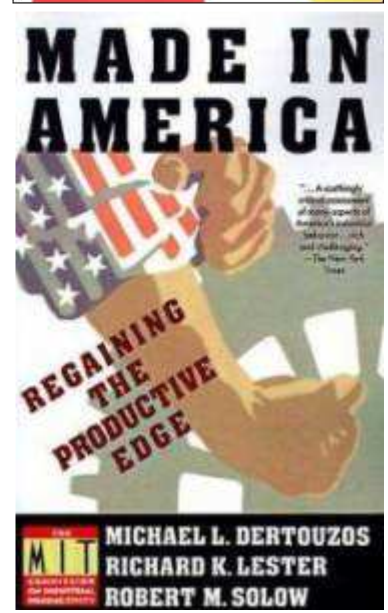
Made in America Study (1986-89)

- In the mid-1980s MIT conducted a major three year study on U.S. Manufacturing
  - Led by Dertouzos, Lester and Solow
- Prompted by success of Japan
  - producer of lower cost and higher quality products thanks to lean manufacturing and kaizen
- Analysis by 8 manufacturing sectors:
  - semiconductors, computers, and office equipment; automobiles; steel; consumer electronics, chemicals and pharmaceuticals; textiles; machine tools; and commercial aircraft
- Central Message:
  - **Need to increase industrial productivity and performance of U.S. manufacturers**
  - **Reorganization of human resources and technology within firms**



Hard Cover

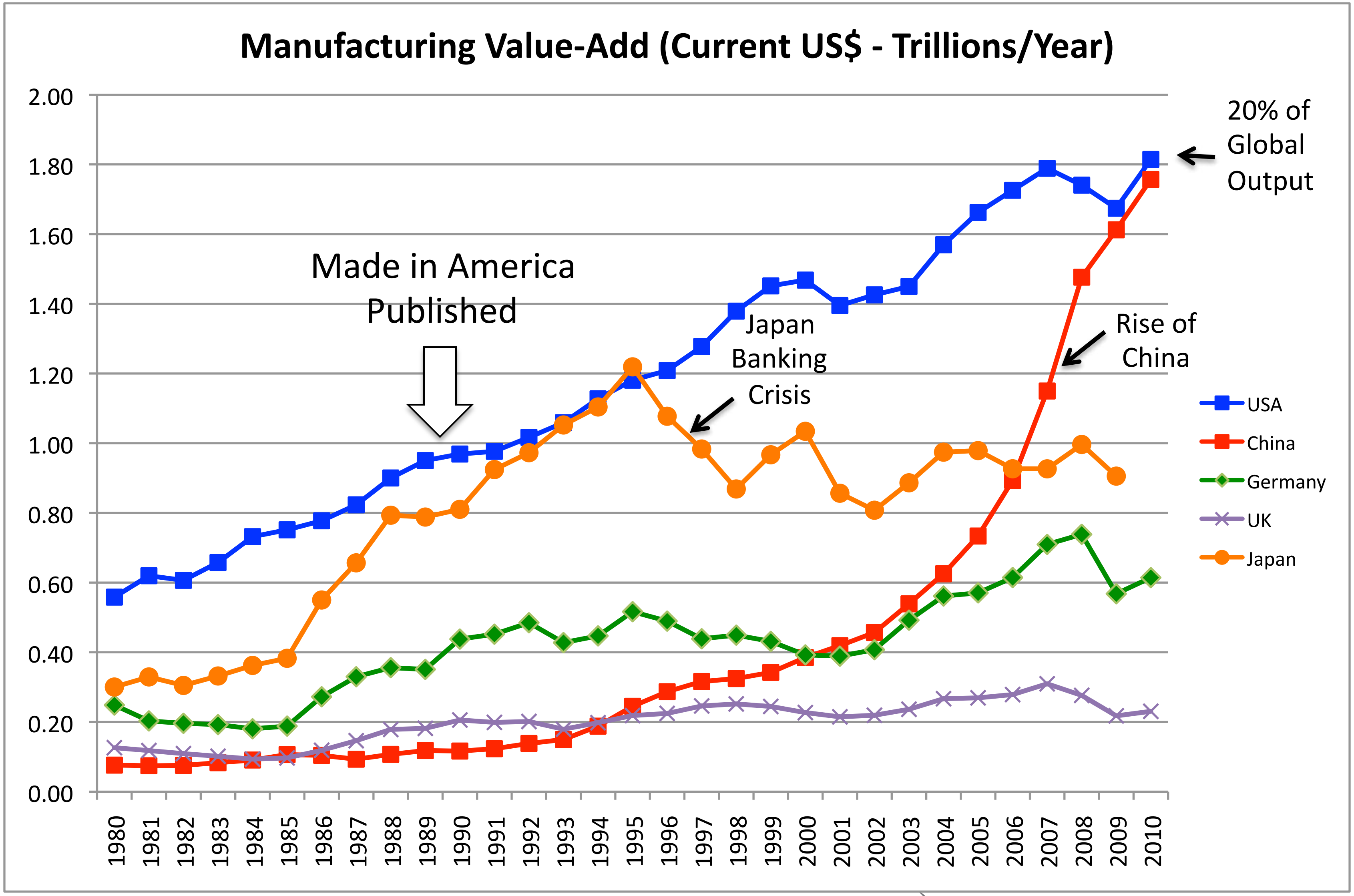
57,000 sold in two years



Soft Cover

Translated in to 8 languages
300,000 sold in total

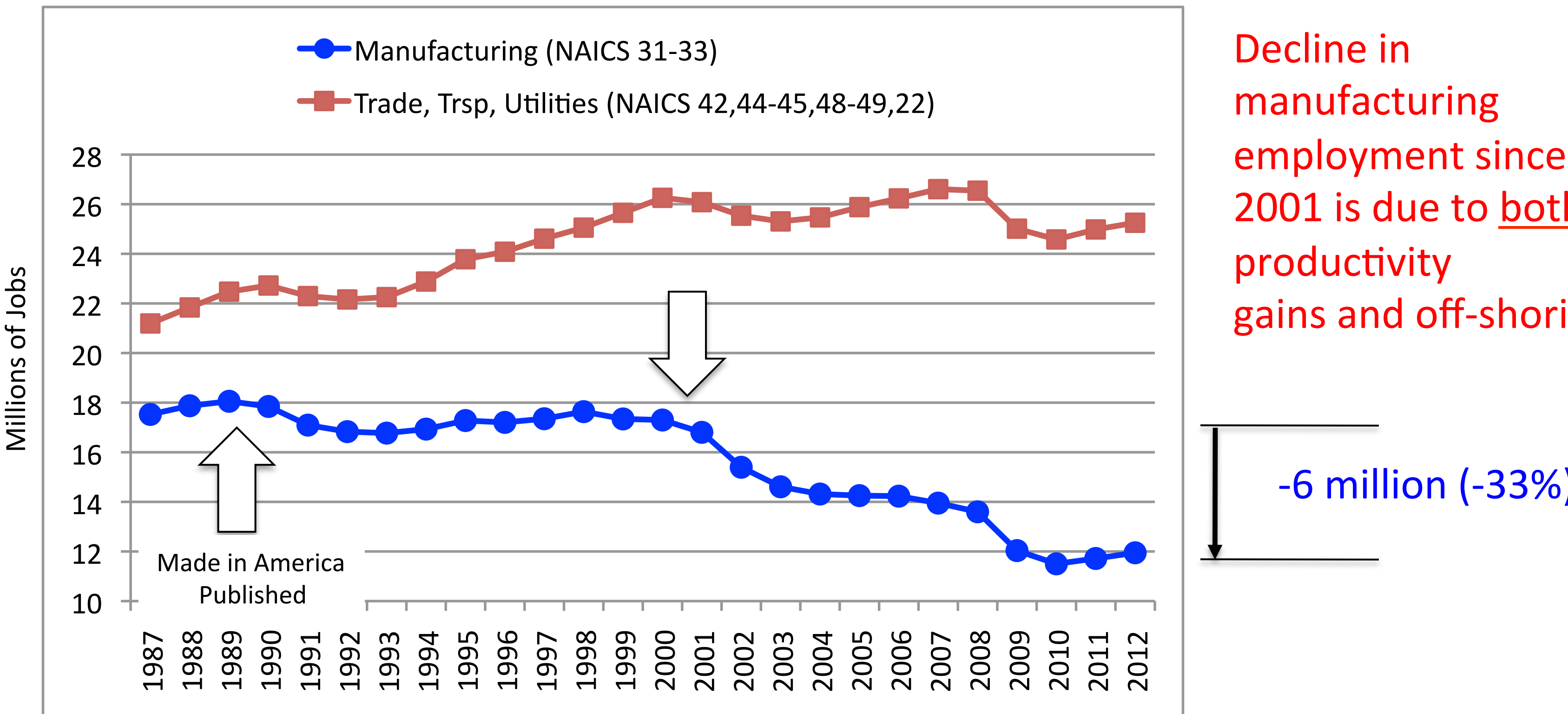
U.S. manufacturing value-add on the rise



Source of Data: World Bank http://data.worldbank.org/

Sharp decline in manufacturing employment

- Number of U.S. manufacturing jobs has declined steeply since 2001:
  - Reduction by about 1/3 from 18 to 12 million jobs since 1989 (-6 million)
- Number of jobs in goods-related services such as wholesale, retail, warehousing and logistics and utilities has increased since 1989 (+ 4 million)

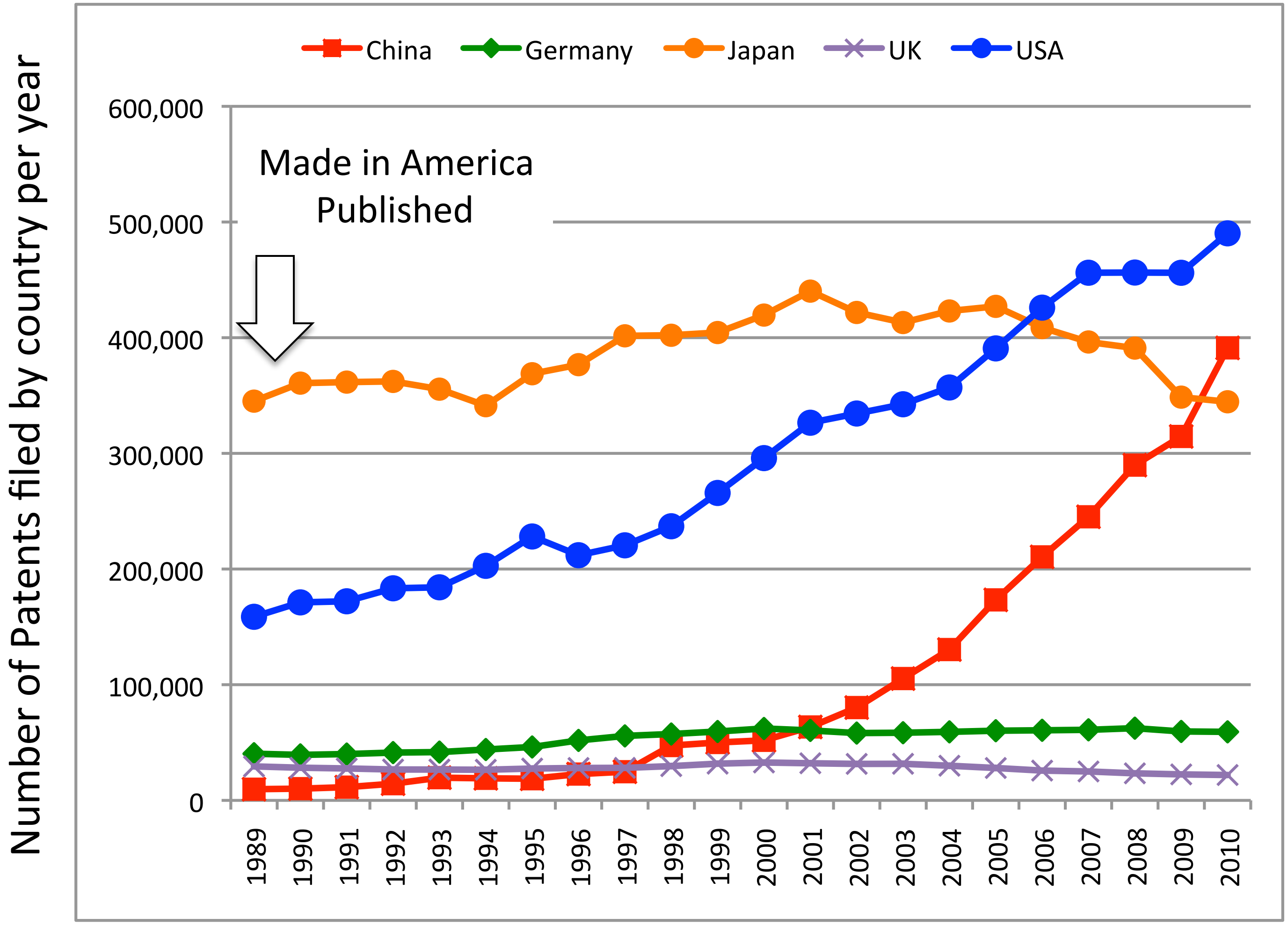


Decline in manufacturing employment since 2001 is due to both productivity gains and off-shoring

Source of data : U.S. Bureau of Labor Statistics (BLS) http://www.bls.gov

All the while we continue to be "innovation nation"

We have overtaken Japan since 2005 but China is catching up fast



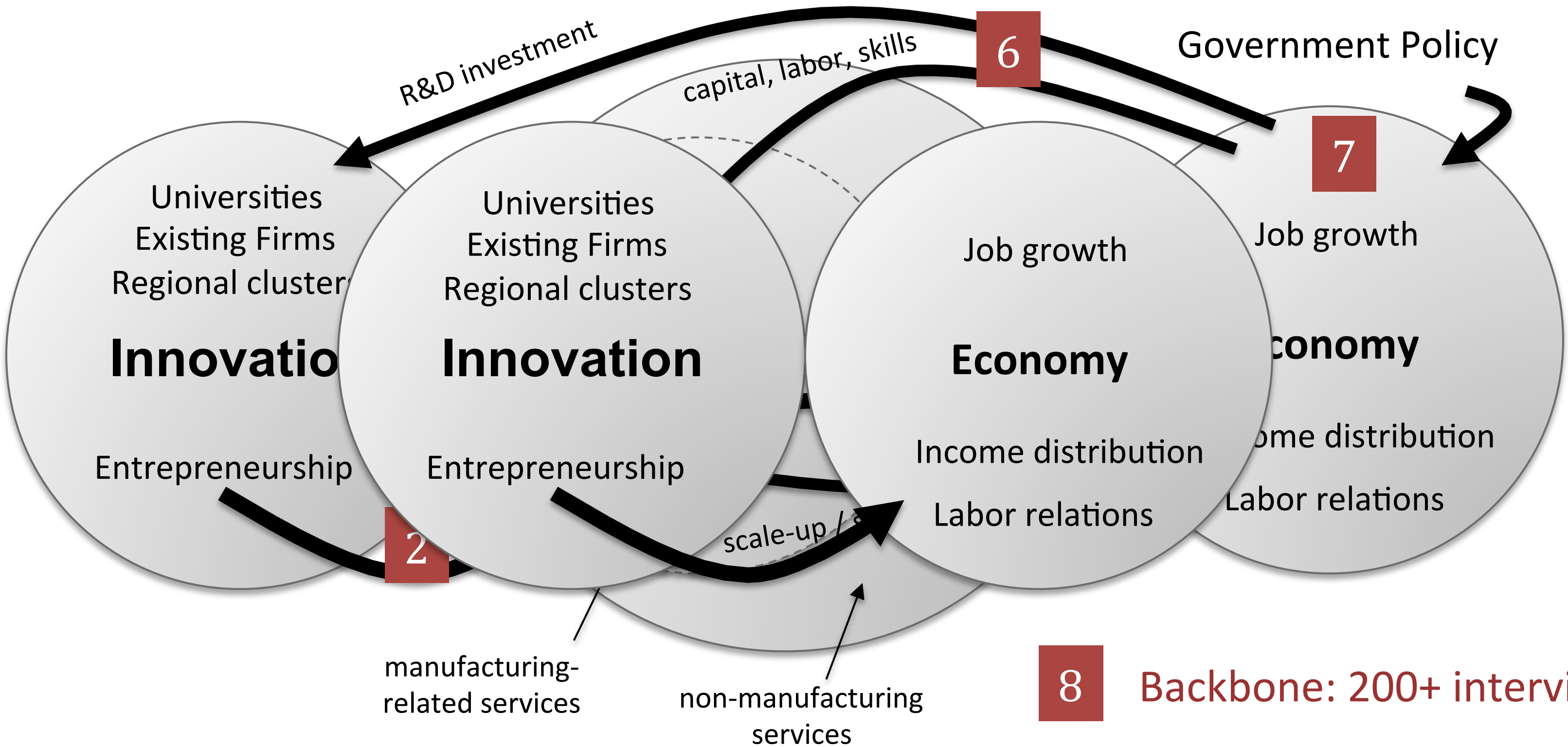
Source: WIPO Statistics Database, December 2011

Key Questions at the Heart of PIE

- **What might happen if we became a nation of "pure innovators" and focus almost exclusively on R&D, design and services such as logistics and leave the physical implementation/manufacturing to others?**
  - **Would this be sustainable long term?**
  - **Most of us believe that manufacturing has a special role to play, but what exactly is advanced manufacturing?**

- **How can we harness more value as a nation from our innovations?**

PIE Study Architecture:
Innovation←→Production is a Complex System



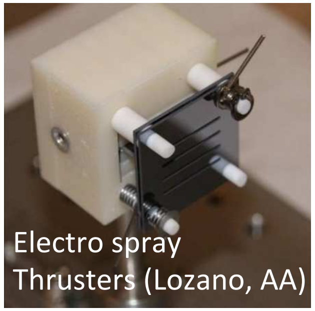
8 Backbone: 200+ interviews

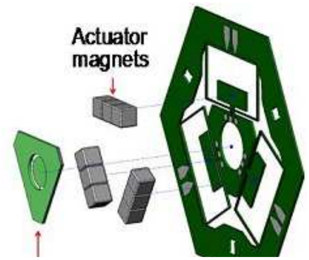
PIE Research Modules

1. Innovation in Manufacturing: Prospects of new manufacturing technologies (e.g. nano-manufacturing, robotics …)
2. Scale-Up: How do innovations transition from the lab to startups and large-scale industrial production? Financial models?
3. Scale-Down: How to create smaller scale competitive manufacturing? *"How to break the tyranny of bulk"*
4. Skills and Training of the U.S. workforce. What do firms need? What institutions can provide this? What is the role of the community college system?
5. Labor Market Puzzles: Polarization of U.S. workforce and its implications. Productivity spillover effects of manufacturing?
6. Public Policy and Firm Strategies: Comparative research on public policies related to manufacturing in US, Germany, Japan, China …
7. Cross-Border Partnerships: Who benefits from cross-border contracting between U.S. firms and foreign investors and firms (e.g. China, Mexico …)
8. Backbone – Firm Interviews and surveys. Interviews in 200 "high impact" firms in all size categories. Quantify factors driving production location decisions.
   - **200+ Interviews conducted to date and several more scheduled**

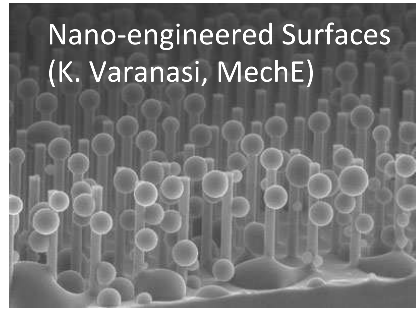
Innovation in Mfg Technology: Internal Scan at MIT (examples)

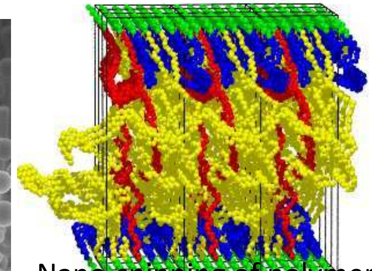
30+ Labs

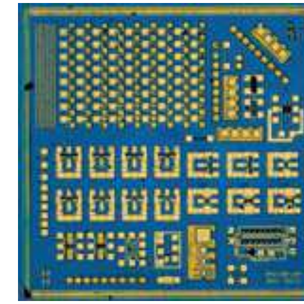

Electro spray Thrusters (Lozano, AA)

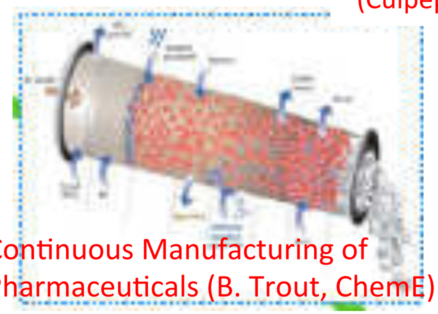


MEMS Compliant Actuators (Culpepper, MechE LMP)


Nano-engineered Surfaces (K. Varanasi, MechE)

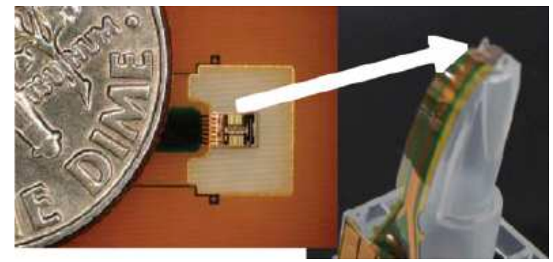

Nano-spinning of polymers (G. Rutledge, ChemE)


InGaAs Group III-V SCs (J. del Alamo – EECS)


Continuous Manufacturing of Pharmaceuticals (B. Trout, ChemE)

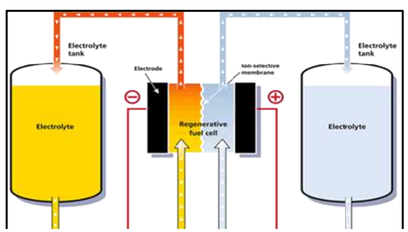
Layer-by-Layer Assy of Bio-materials (R. Cohen, ChemE)


Julie Shah AA/CSAIL – Human-Robot Collaboration



MEMS-manufacturing (M.A. Schmidt, EECS)

Nanophosphate Li-Ion Batteries (YM Chiang, DMSE)



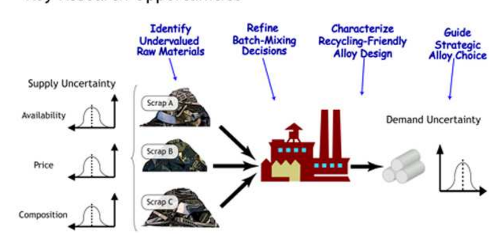
Continuous Flow Batteries (YMC)


Liquid Metal Batteries (Don Sadoway, DMSE)

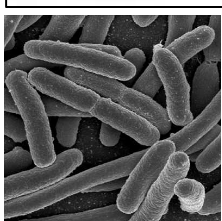
RFID-technology Auto-ID

EPCglobal

Sarma (MechE), Williams(CEE,ESD)



Aluminum Recycling under comp. uncertainty J. Clark, R. Kirchain (MSL, DMSE/ESD)


Biofuels from E Coli (K. Prather-Jones, ChemE)


Peter Schmitt (MAS) 3D Printing of mechanisms


Organic Photovoltaic's (Bulovic/Gleason) EECS,

Summary of Findings from MIT Scan

- There is "critical mass" of manufacturing related PIs at MIT (order 150 PIs) distributed across the Institute
- Research is generally motivated by real problems in industry, non-incremental, and funded by mix of federal and private research $; some collaboration but not strategically managed
- Found a **revised grouping** of 7 manufacturing technologies that seems more logical and in tune with major research thrusts

Nano-engineering of Materials and Surfaces

Synthesis of multi-functional materials at the nano-scale from the ground up

Additive Precision Manufacturing

Building up components by adding layers of material in complex 3D shapes

Robotics, Automation and Adaptability

Using robotics to substitute for or complement human labor in new ways

Next Generation Electronics

Next generation circuits using non-Si materials, using mask-less processes and flexible substrates

Bio-manufacturing / Pharmaceuticals

Continuous manufacturing of small molecules, turning cells/ organisms into programmable factories

Distributed Supply Chains / Design

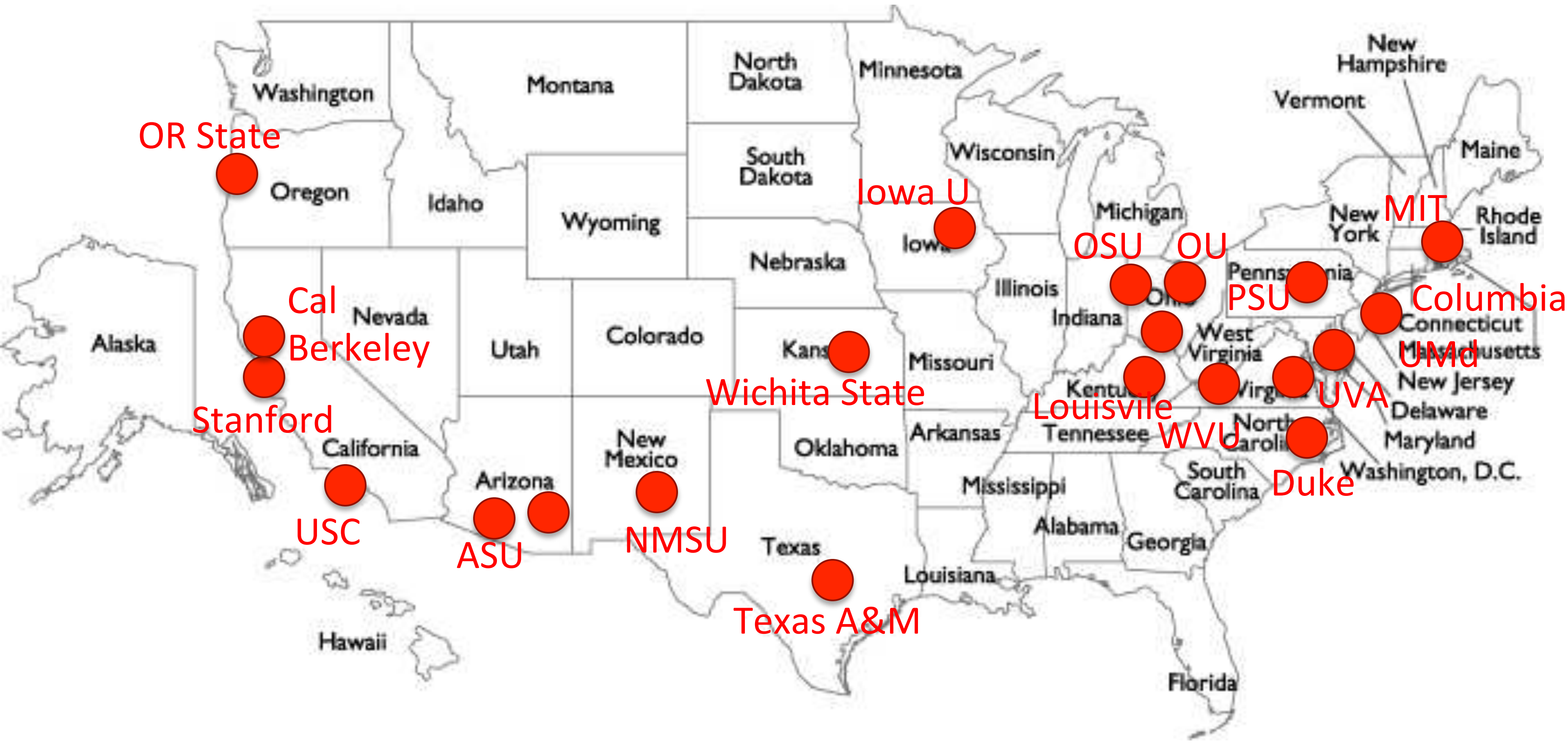
Enabling flexible and resilient decentralized supply chains, new approaches to web-enabled mfg

Green Sustainable Manufacturing

New manufacturing processes that use minimal energy, recycle materials and minimize waste and emissions

Distribution of survey respondents

An external survey was administered early in 2012, similar to AMP survey but mainly directed to larger set of US universities and organized around the 24 technology themes



N=29 Responses
Response Rate = 34.1%

Response period: 4/19-8/20/2012
Thanks to Darci Reed and Jagruti Patel for administering

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"Unbiased" Upstream Innovations → New Manufacturing

Which technologies or innovations have the potential to lead to significant new manufacturing and production in the future ? List three to five promising ones and explain.

Unbiased Innovation List

Additive/Precision Manfacturing	Materials/Nanotechnology	Robotics, Automation, and Adaptability	Electronics	Green/Efficient Manufacturing	Biomanufacturing	Supply Chain and Design
3-D printing at home / / Consumer based mfg will reduce logistics costs	Nanotechnology	Reconfigurable systems in manufacturing - to increase the efficiency of manufacturing	extreme ultraviolet nanolighography: will allow next generation electronics	Solar energy-electricity conversion technologies	Cell stems and their applications to all kinds of treatments induing cancers.	Community based design - can harness the collective thinking of people not necessarily from one location
3D printing						
Rapid protot						
additive manufacturing - if corre and competently used can offer benefits in productivity, flexibilit consumer preferences						
Additive manufacturing /free for processes Application of additive manufact methods to real materials, i.e. st Al, Ti etc to manufacture parts satisfying functional requiremen right now this capability is limite few materials and to prototyping additive manufacturingThe world is entering a critical scarcity of raw materials. waste must be curtailed.	Nanofabrication					
addtive manufacturing: will allow mass customization, fast turnaround, reduce waste	Composite Automation -- more moving to composites and aut to kee prices in check					
Rapid prototyping integrated into CAD packages to enable a complete desktop engineering environment - design and fabricate a mechanical device without ever leaving your chair.	Composite structures with com / The abiilty to b aminates materials will systems					
Medium-scale rapid prototyping "foundries" (similar to MOSIS in the micro-electronics arena) - farm out automated prototype fabrication using standardized parts/modules.	carbon fiber					
Development of machine tools for machining and forming, i.e. presses, precision hard machining milling machines, EDM and laser machining devices, tool and die technology. Without machines and tools/dies, it is not possible to have a modern large volume production	Low-cost carbon fiber producti enable widespread deploymen cost-sensitive applications such as automobiles, wind energy, oil and gas					

Additive / Precision Man

- 3D-Printing at Home
- Rapid Prototyping integrated into CAD
- EDM, Injection Molding
- MOSIS-like foundries
- Laser-based manufacturi (fast control, short pulse
- Al, Ti, Ni sintering/forming

Robotics and Autom

- Intelligent smart aut
- Embedded sens
- Reconfigurable robo
- Huma
- Wirel
- Netw
- Tele-

Green / Efficient Manufacturing

- New energy sources: solar PV, CSP
- US natural gas, waste-2-energy
- New battery storage technologies
- ors vs. batteries
- within plants
- & recycling

Supply Chain Design

- Community-based Design
- Decentralized supply chains
- Cloud computing for CAD/CAE/CAM

Materials and Nanomanufa

- Large area graphene produ
- Roll-to-roll manufactur
- 3D ICs for semiconductors
- Fiber-composite materials
- Nano-etching

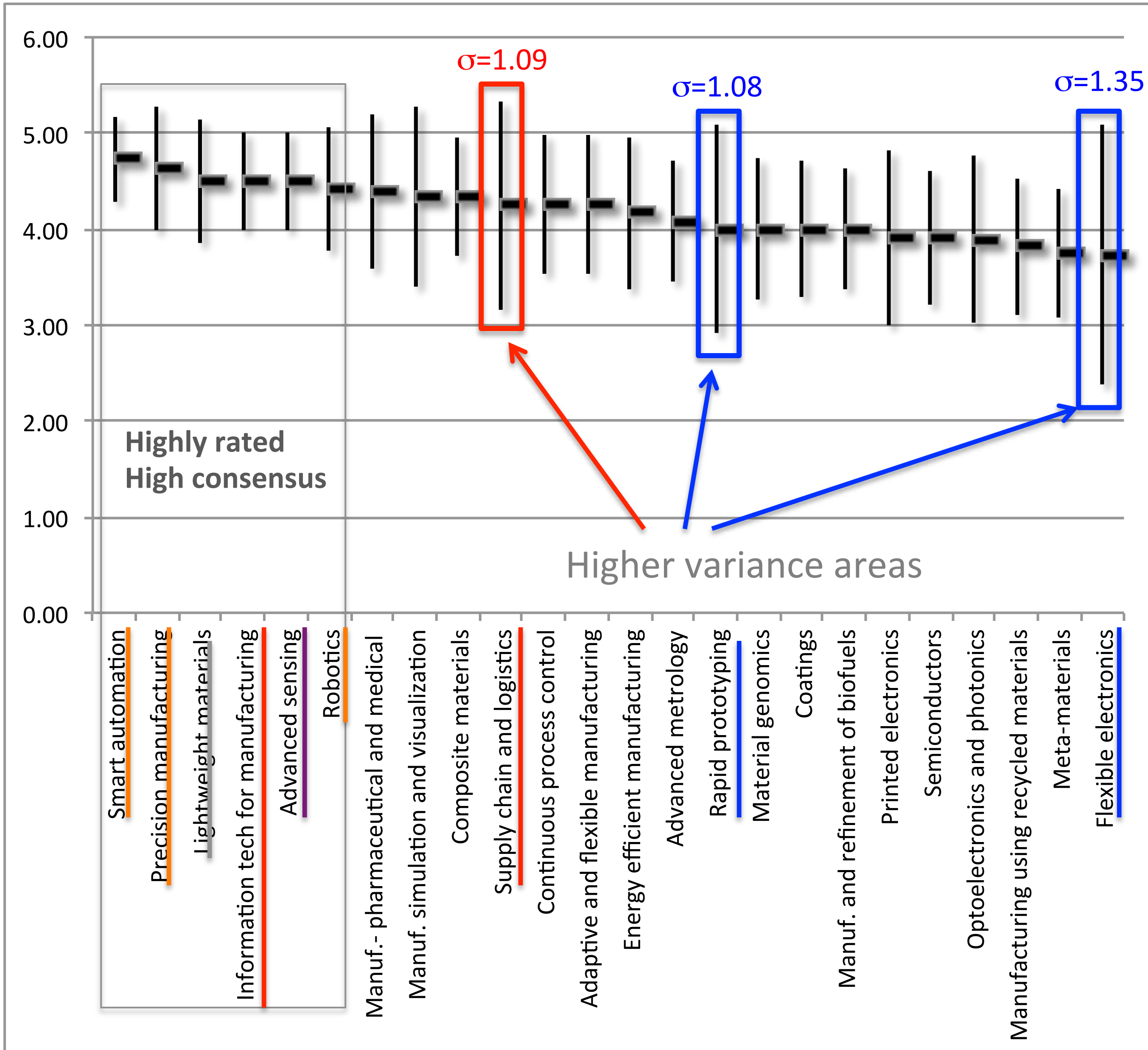
Electronics

- UV Nanolithogra
- Multifunctio
- Computer intert
- Wireless revolut
- Flexible substrat

Biomanufacturing

- Stem cell-based mfg
- Human organ engineering
- Regenerative medicine
- Tissue manufacturing

Quantitative Assessment of Mfg Technologies

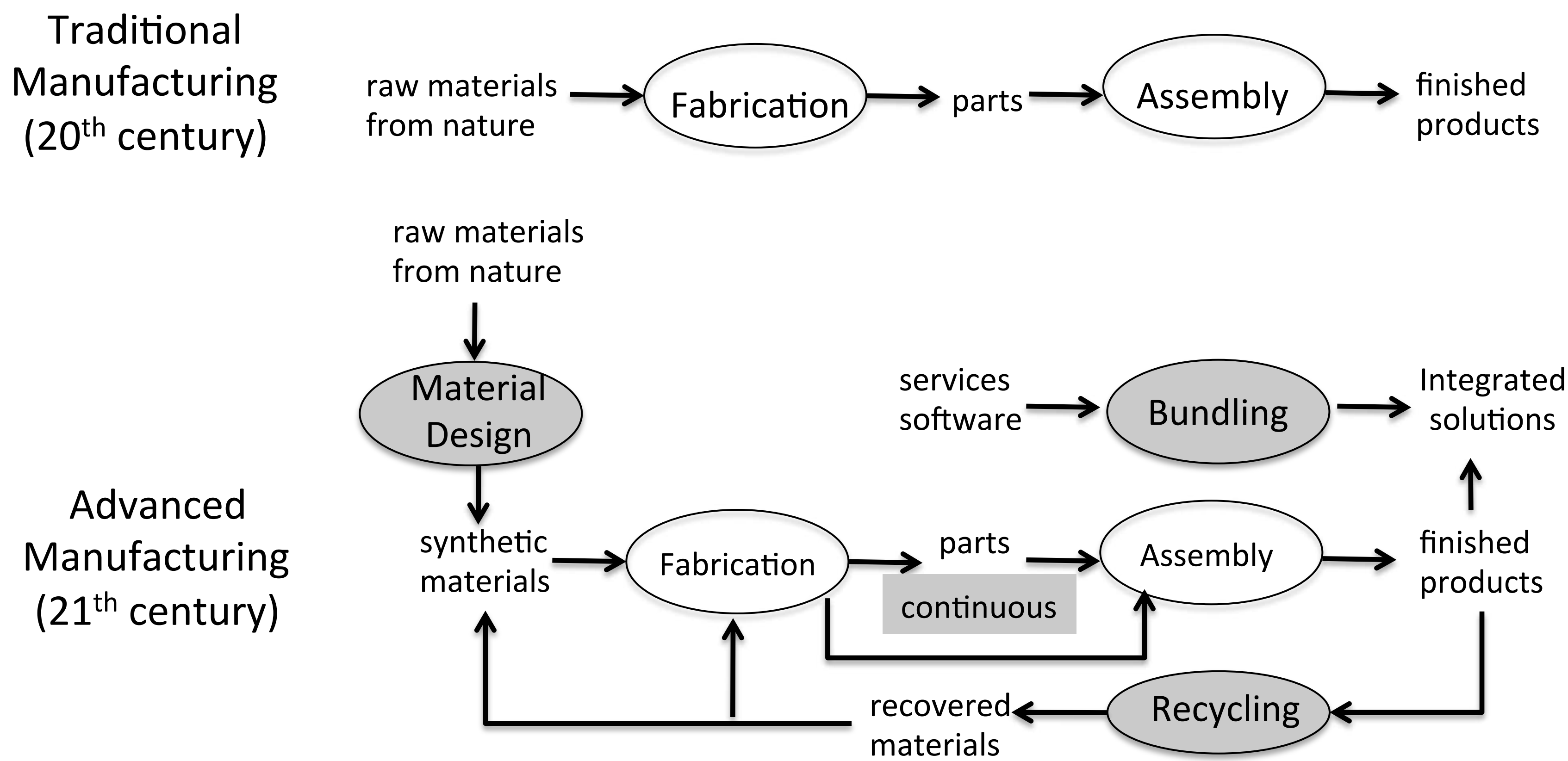


std dev
> 1.0 points

General agreement that research in automation/robotics is very important.

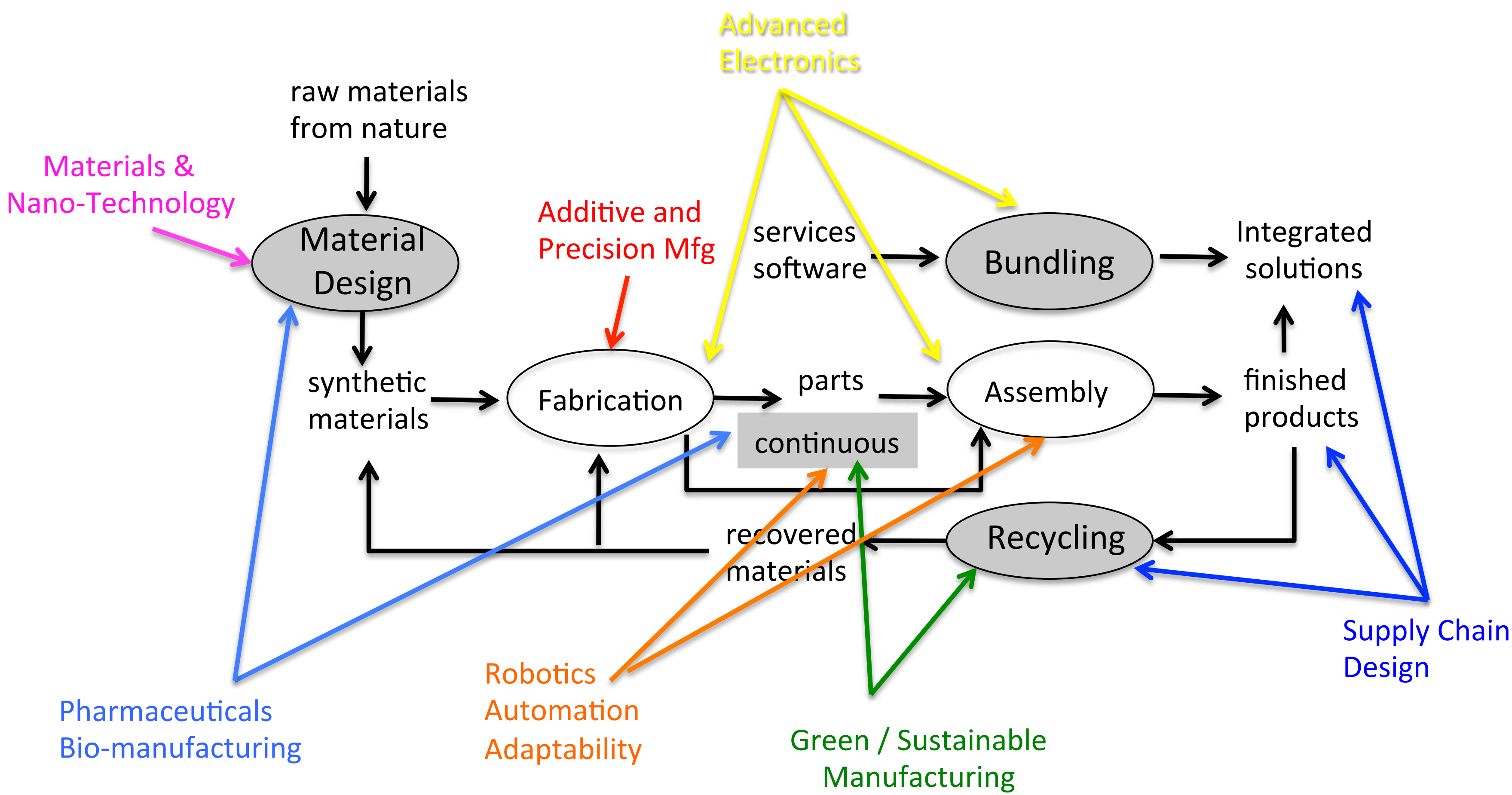
Some areas of large variance, e.g. Rapid Prototyping

What is Advanced Manufacturing?



Advanced Manufacturing is the creation of integrated solutions that require the production of physical artifacts <u>coupled</u> with valued-added services and software, while exploiting custom-designed and recycled materials using ultra-efficient processes.

Where/how do the 7 technology areas impact this expanded view of advanced manufacturing?



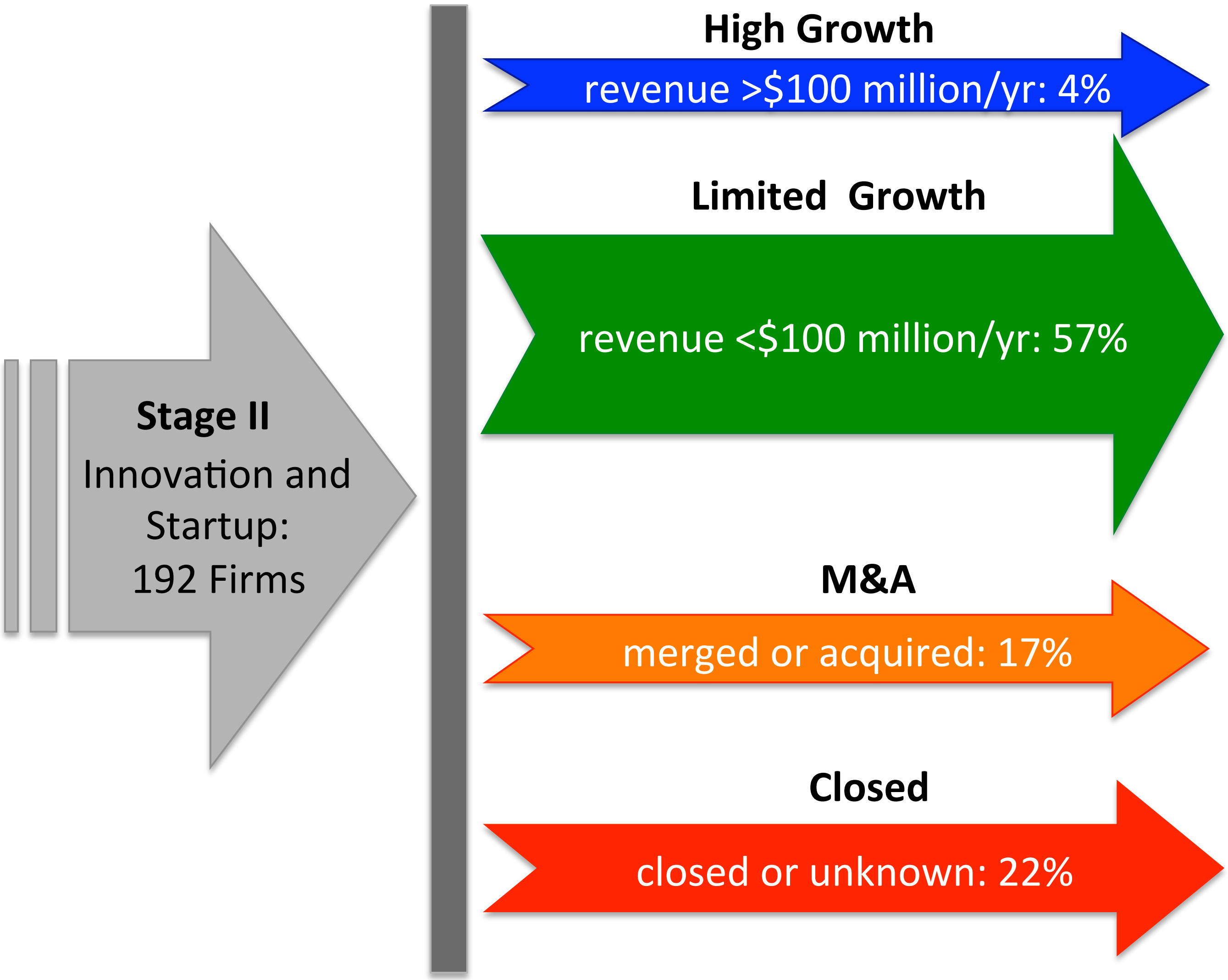
Module 2: MIT-licensed start-ups founded 1997-2008

Total Number of Firms: 192	
Active	61%
Merged or Acquired	17%
Closed	15%
Unknown	7%

Industries	
Biopharma	30%
Medical Devices	13%
Software	13%
Electronics	22%
Semiconductors	7%
Robotics	3%
Other	12%

- 78% of start-ups founded 4-15 years ago are active or acquired
- Of this subset, 66% are headquartered in MA, 14% in CA, 3% outside the US, and the rest in other states
- 80% of active firms have annual revenues below $5 million
- **142 out of the 192 firms (or 74%) produce a physical product**

Sample of Research Questions by Type of Firm: Four Primary Growth Trajectories



What factors enabled organic growth?

What factors can enable stronger or more sustained growth? Capital, skills, market access?

After the acquisition, what happened to the company/technology?

What factors contributed to the closing of the company?

Module 8 Backbone: PIE Initial "Proof of Concept" Models for Innovative U.S. Manufacturing

- While the U.S. has lost significant manufacturing activities, especially since 2001, **there appear to be specific opportunities for strong innovation-driven manufacturing**, specific "proof of concept" models we found are …
  - **Established large domestic manufacturers** who introduce smart automation and become "ultra-productive", but also have foreign plants

    TIMKEN Where You Turn — *bearings*

    DUPONT — *chemicals*
  - Small **entrepreneurial firms** (both startups and spinoffs) who **scale-up** manufacturing - at least in part in the U.S. - thanks to innovations

    A123 SYSTEMS

    QD VISION

    ATLAS DEVICES Rapid Access Solutions
  - **Mid-size manufacturers** who specialize in specific niches and emphasize flexibility, responsiveness and customization and value-added services

    SynQor® Advancing The Power Curve® — *DC power supplies*

    MARLIN Marlin Steel Wire Products Engineered Solutions Fast Since 1968 — *Steel wire baskets*

PIE Initial "Proof of Concept" Models for Innovative U.S. Manufacturing (cont.)

- **Market and regulation-driven manufacturing** that favors U.S. as a base of operations such as in defense (ITAR) and pharmaceuticals / bio (FDA)

NORTHROP GRUMMAN
Military systems

biogen idec
Pharmaceuticals
Transforming Discovery into Care

- **Foreign-owned manufacturing firms** who see the U.S. as an attractive market for domestic production and for export

MICHELIN
Tires

SAINT-GOBAIN

- **Bulk-manufacturing of commodities** where transportation costs can be on the same order as manufacturing costs due low value-density (\$/kg or \$/m^3)

P&G 3M

PIE summary and (some) initial findings

- U.S. Manufacturing employment has declined but manufacturing it is critical to our future, because of its **broader effects** on the economy and on innovation
- Renewed interest in manufacturing at the national scale and regional scale (e.g. PCAST, AMP, NIST …) and at MIT
- MIT has launched the PIE Study as a major initiative
  - Empirical study to establish better understanding of link between upstream innovation, manufacturing and global markets
  - Over 200 interviews conducted so far, surveys and modeling research
- Expect **February 2013 release at NAS in Washington D.C**.
  - Identify some of the most promising innovations in advanced manufacturing and the key aspects of this linkage
  - Policy recommendations both at the federal and state/regional level
- Major deliverable and book in September 2013

For more information, please visit:

http://web.mit.edu/pie