Production in the INNOVATION ECONOMY

Trends in Advanced Manufacturing Technology Innovation

May 31, 2013

60th Meeting of the Board on Science, Technology and Economic Policy (NAS), Washington D.C.

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Personal Observations on Manufacturing

1. Superplastic Forming versus High-Speed Machining

   New mfg technology must be cost-competitive

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

RUAG
Aerospace

BOEING®

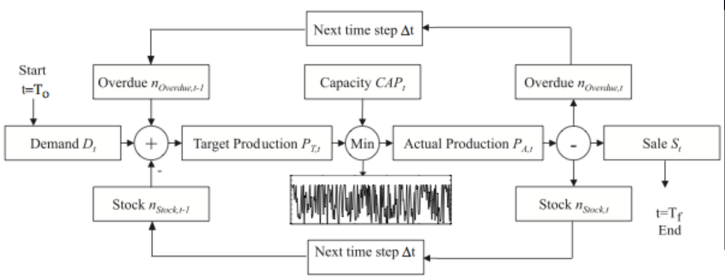
1. F/A-18 Program Experience

   Must fit into Global Supply Chain

2. Flexibility in Component Manufacturing

   Importance of Product Variety and Intermediate Volumes

MARCEL EMMENEGGER PHOTOS
RUAG Aerospace teammates perform a full-scale fatigue test on Swiss F/A-18Ds (left) and conduct maintenance, repair and upgrade work on F/A-18C/Ds. The Swiss firm was named a Boeing 2003 Supplier of the Year.



MIT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Hauser D., de Weck O.L., "Flexibility in component manufacturing systems: evaluation framework and case study", *Journal of Intelligent Manufacturing*, 18 (3), 421-432, June 2007

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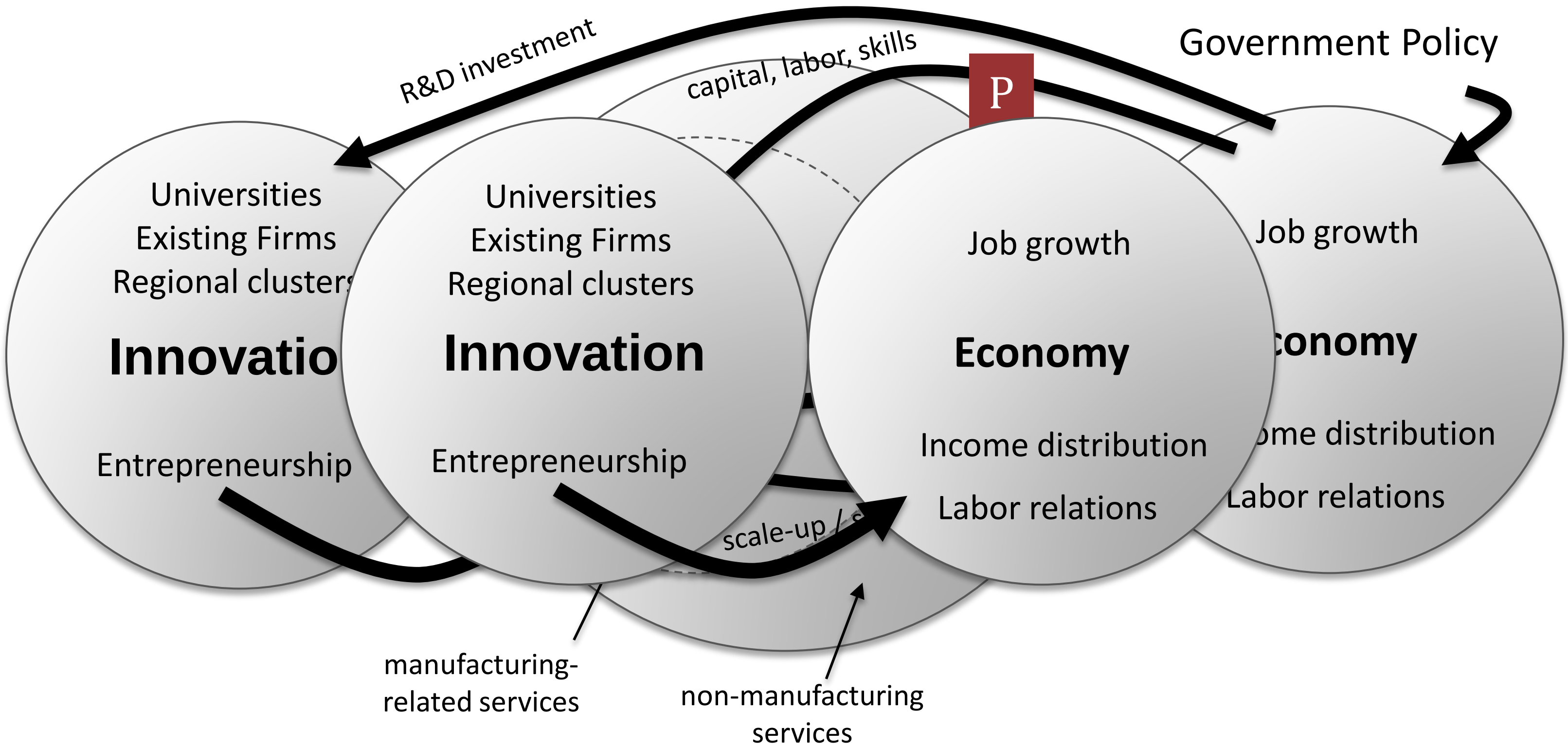
PIE Study Architecture:
Innovation←→Production is a Complex System



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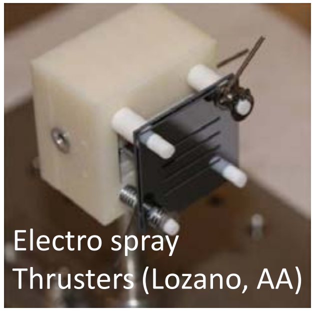
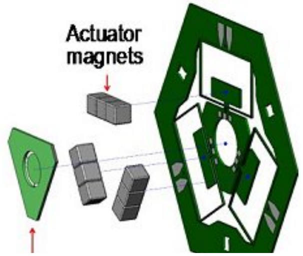
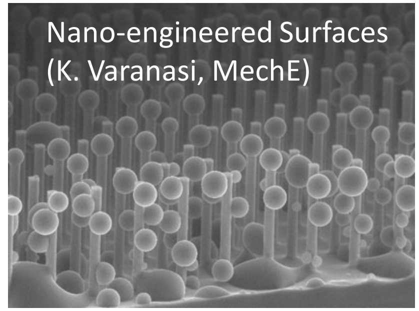
Innovation in Mfg Technology: Internal Scan at MIT (examples)

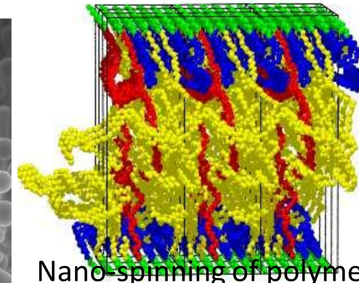
30+ Labs

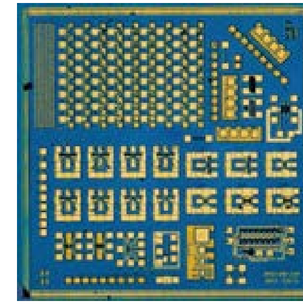

Electro spray Thrusters (Lozano, AA)

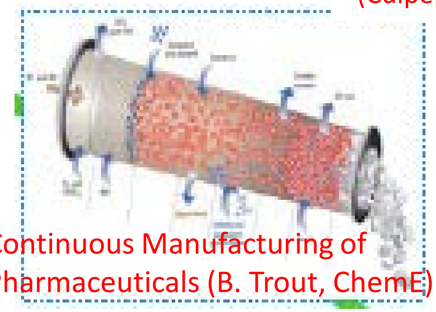


MEMS Compliant Actuators (Culpepper, MechE LMP)


Nano-engineered Surfaces (K. Varanasi, MechE)

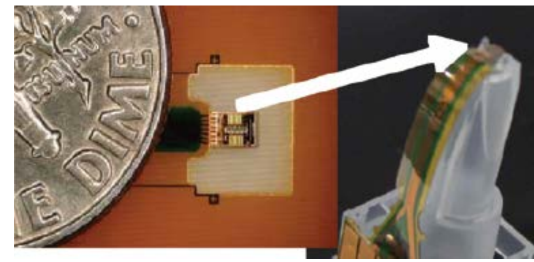

Nano-spinning of polymers (G. Rutledge, ChemE)


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

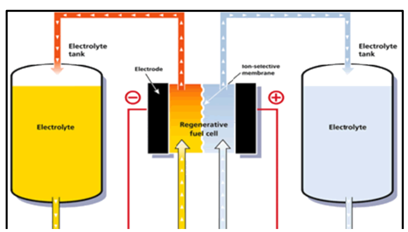

Continuous Manufacturing of Pharmaceuticals (B. Trout, ChemE)

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)

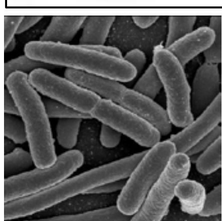

Liquid Metal Batteries (Don Sadoway, DMSE)

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 $
- Found a **grouping** of 7 manufacturing technologies that reflects major research thrusts in advanced manufacturing research

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

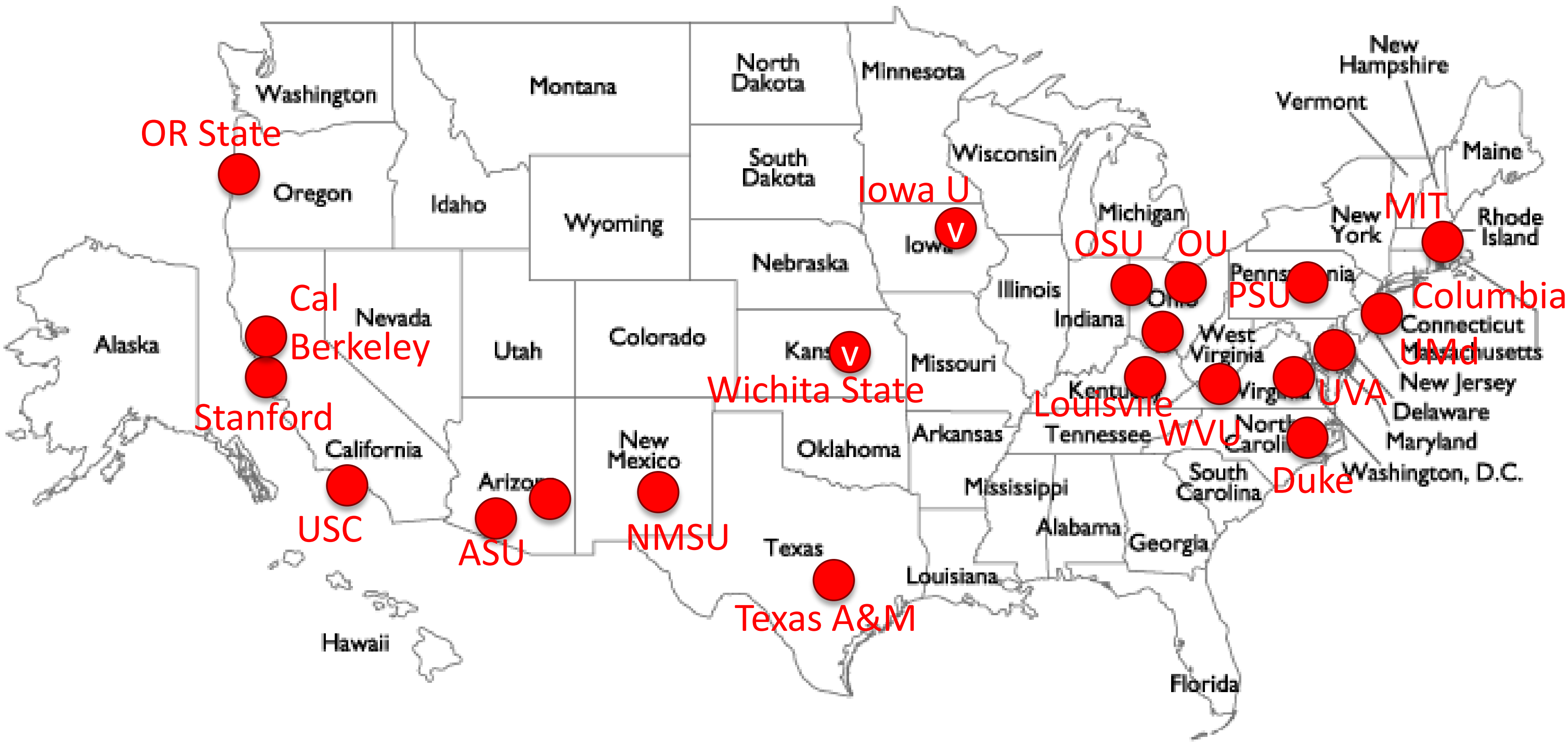
Distributed Supply Chains / Design

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

External Survey: Distribution of respondents



N=29 Responses
Response Rate = 34.1%

Response period: 4/19-8/20/2012

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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 core and competently used can offer benefits in productivity, flexibili... consumer preferences						
Additive manufacturing /free fo... processes Application of additive manufac... 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 prototypin... additive manufacturing The worl... 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 ability to b... laminates 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 manufactu...
- 3D ICs for semiconductors
- Fiber-composite materials
- Nano-etching

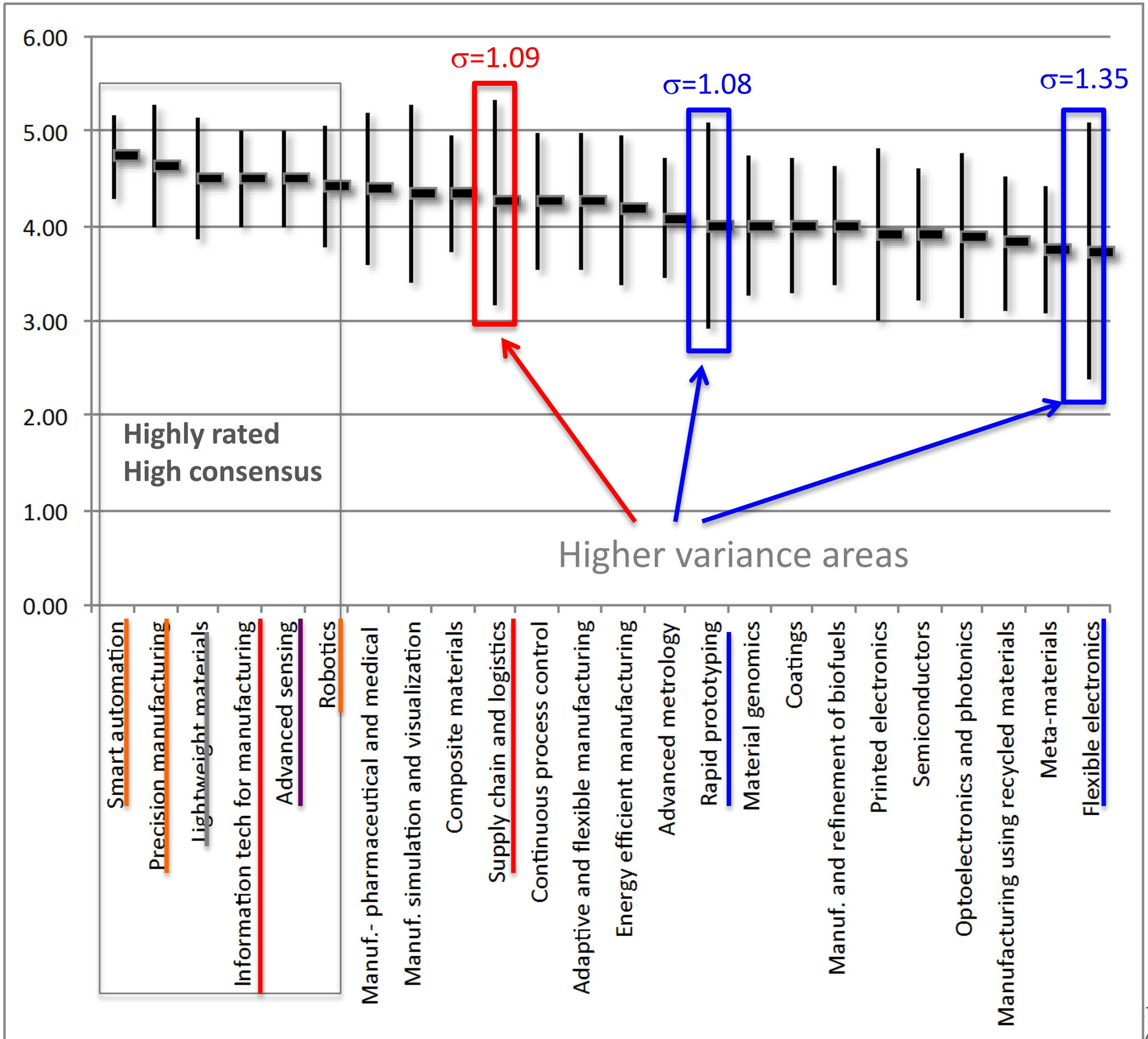
Electronics

- UV Nanolithogra
- Multifunctio...
- Computer interf
- 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

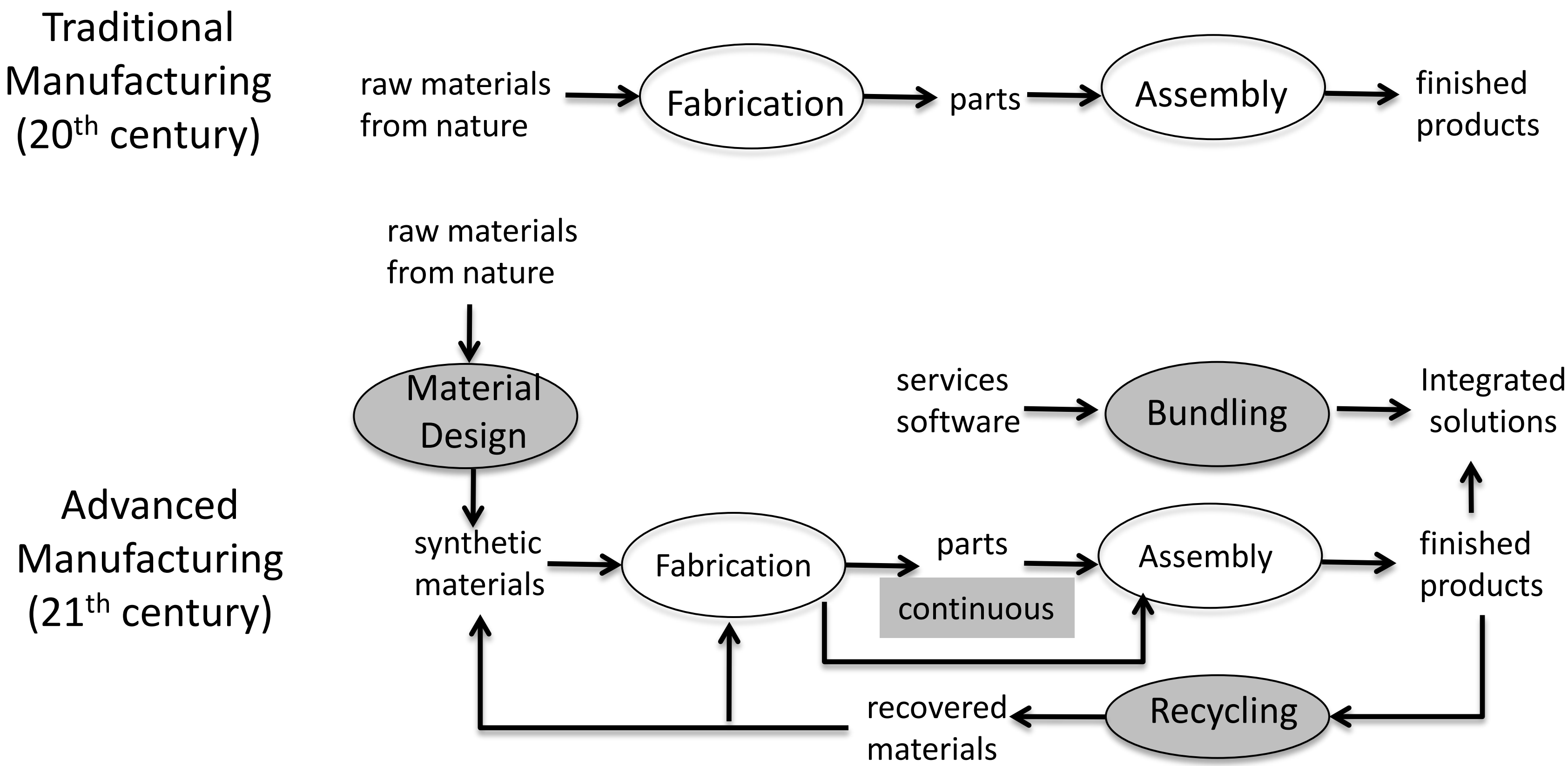
General agreement that research in automation/robotics is very important.

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

Main challenges to university-based U.S. Manufacturing Research

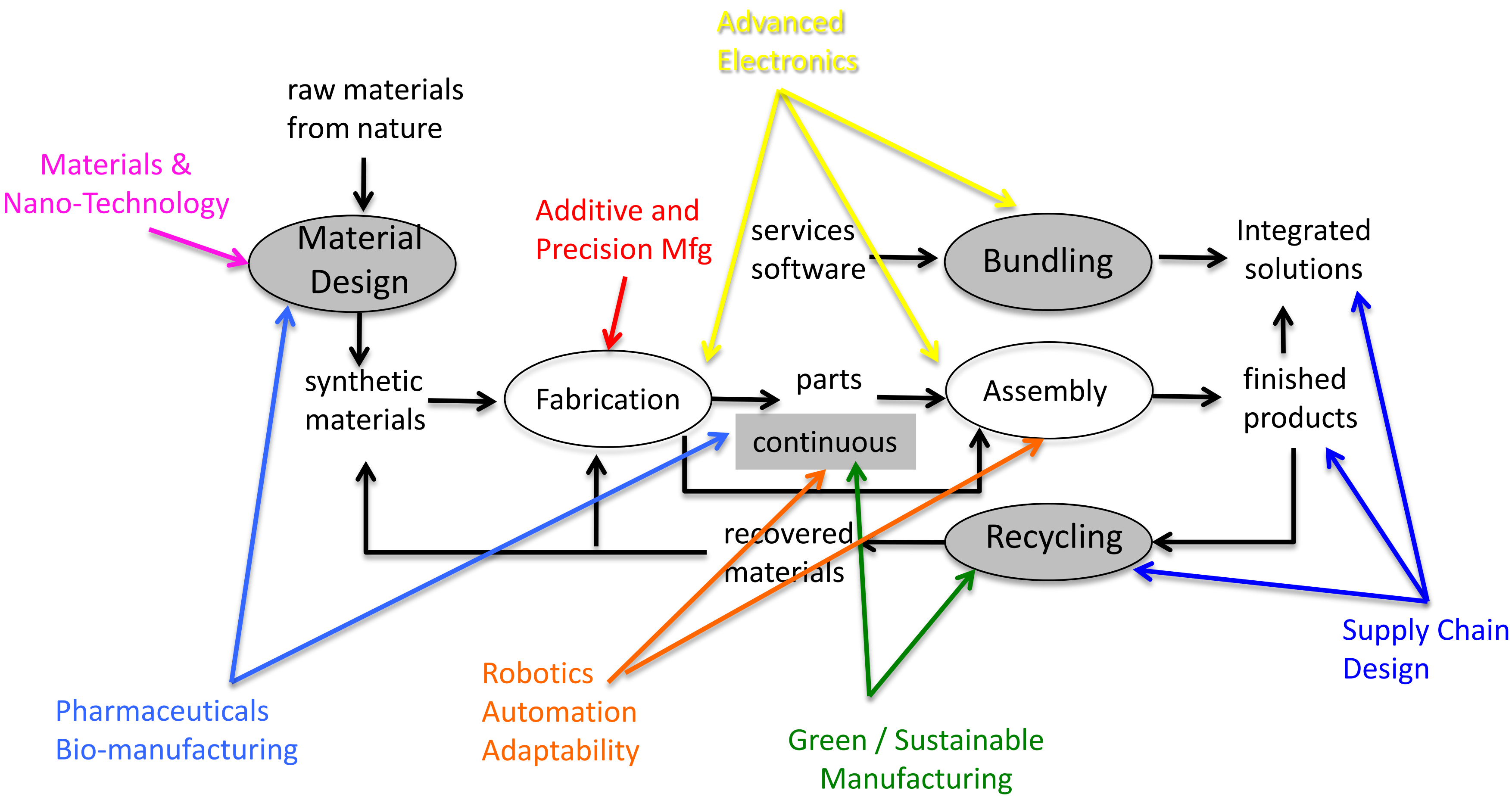
- Limited Resources
  - Financial resources to create and maintain sophisticated manufacturing research infrastructure at universities are often too large
  - Driven by changing federal funding priorities (e.g. NSF, DARPA …)
  - Sub-critical mass of faculty and students interested in manufacturing, tend to gravitate more towards other areas
- Collaboration with Industry
  - Use of industry facilities to build prototypes and test ideas, but gives IP rights mainly to sponsor
  - Industry wants quick answers, while faculty and students want to publish and do longer term projects (mismatch in timescales)
  - Need to develop joint value proposition (cost/benefit)
- **Opportunity to strengthen the university-industry interface**

What is Advanced Manufacturing?



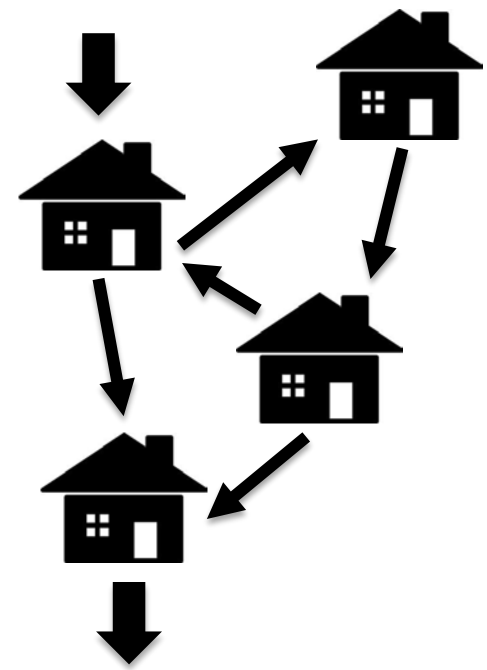
Advanced Manufacturing is the creation of integrated solutions that require the production of physical artifacts <u>coupled</u> with valued-added services and software, while exploiting custom-designed and recycled materials using ultra-efficient processes.

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



A vision for distributed manufacturing

- Much manufacturing today is still concentrated in **large factories**
  - Finished goods are transported over large distances to consumer markets
  - Large cost and environmental impact
- Many of the new technologies enable a potential future that allows for "breaking the tyranny of bulk"
  - Distributed manufacturing "on demand"
  - Flexible capacity through local networks
  - Digitally enabled design democratization
- Degree of decentralization will vary by sector and relative economics of energy, transportion and local labor



Opportunities and Policy Implications

- New product capabilities and classes of products that currently do not exist. Examples: non-Si based semiconductors, new drugs and fuels from biology, miniaturized propulsion for μ-sats ..
  - **Need a commitment to long term federally-funded research in manufacturing with a well-coordinated portfolio across agencies**
- "Programmable" manufacturing processes that do not rely on capital-intensive tooling and fixtures *Will they catalyze distributed manufacturing?* Examples: 3D Printing, maskless nano-lithography, etc…
  - **Create opportunities for smaller firms and universities to demonstrate these capabilities using realistic market-driven requirements**
- Technologies that enhance productivity and flexibility in existing manufacturing processes. Examples: RFID tracking of parts, human-robotic collaboration and flexible automation …
  - **Establish mechanisms for collaboration between industry, academia and public research institutions (e.g. NNMI)**

For more information, please visit:

http://web.mit.edu/pie

September 20, 2013 Release of PIE Study at MIT