A Possible Scenario for the Future of Manufacturing in the US

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1. Intro: Motivation.

2. Reengineer Engineering: Why?

3. From Rapid Prototyping to Additive Manufacturing (AM).

4. Future directions:
   - Multi-length scales
   - Multi-materials
   - Multi-physics----Desktop integrated manufacturing Machines or DIMPS.

5. Reengineer Engineering : How ?
1. Intro: Motivation

- Micro devices (MEMS). Medical diagnostics on a CD /CD Player: invented at UCI, developed in IMTEK Germany but manufactured by Samsung in Korea.
1. Intro: Motivation

- Nano devices (NEMS). Suspended wire nano sensors: invented at UCI investigated with an international research ring led by UCI. But what about IP and who will manufacture it?
1. Intro: Motivation

- Something contradictory here: precipitous job losses despite major US tech discoveries!
- Government investment in R&D is leading to more and more profits elsewhere because we do not make things anymore!
- IP is more valuable closer to the final product implementation so we are also not capturing that anymore.
1. Intro: Motivation

“......the loss of the manufacturing base is not a simple linear loss, it becomes irretrievable exponential as times goes on.

History has shown that it is the manufacturing capability that drives the economical growth and creates wealth. Assuming that we can still market and design new products without manufacturing excellence is naïve.” (M. Madou in WTEC report).

Testimony on Capitol Hill on the State of Manufacturing in the US April, 2005.
2. Reengineer Engineering: Why?

- Education:
  - Lack of skilled US technicians for technology companies (not enough links between 2-and 4-year colleges).
  - Students cannot apply what they have learned well enough.
  - The science of making things got lost in many areas.

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**REASONS WHY U.S. EMPLOYERS ARE HAVING DIFFICULTY FILLING JOBS**

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of technical competencies (hard skills)</td>
<td>48%</td>
</tr>
<tr>
<td>Lack of workplace competencies (soft skills)</td>
<td>33%</td>
</tr>
<tr>
<td>Lack of available applicants/no applicants</td>
<td>32%</td>
</tr>
<tr>
<td>Looking for more pay than is offered</td>
<td>27%</td>
</tr>
<tr>
<td>Lack of experience</td>
<td>24%</td>
</tr>
<tr>
<td>Qualifications/certifications - skilled trades</td>
<td>18%</td>
</tr>
<tr>
<td>Qualifications/certifications - professional</td>
<td>16%</td>
</tr>
<tr>
<td>Professionalism</td>
<td>14%</td>
</tr>
</tbody>
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Enevate's R&D laboratories have developed new materials and battery architectures for higher energy capacity with compatibility to existing Li-ion energy management systems.
2. Reengineer Engineering: Why?

- Systemic:
  - Push for outsourcing.
  - Little interest in making real things – virtual companies.
  - Loss of manufacturing base = loss of innovation/IP.
  - Middle class is disappearing in lockstep with loss of manufacturing.
  - Popular cultural bias against science.
2. Reengineer Engineering: Why?

- Future Threats:
  - If the US doesn’t make the next best thing anymore we will also eventually lose our position as leaders in engineering education.
  - Private industry is NOT picking up the slack in government funding.
  - Further radicalization of politics and more poverty.
  - Our tax dollars are funding IP leakage if foreign students do not remain in the US.
  - Security concerns: where will drones come from next?

2. Reengineer Engineering: Why?

- President Obama’s Advanced Manufacturing Partnership (AMP) is a national initiative that enlists the cooperation of industry, academia and the federal government. New institutes so far are on 3D printing (America Makes), lightweight metals and digital manufacturing.
3. From Rapid Prototyping to Additive Manufacturing (AM)

- Some other names for Rapid prototyping:
  - 3D printing
  - Layered manufacturing
  - Digital manufacturing
  - Additive Manufacturing (AM),
  - Etc.

- Common features:
  - Part is produced in multiple layers
  - X, Y, Z stages
  - Platform that moves in the Z direction.

[Image: DEUS EX MACHINA]

[Image: The Economist]

[Image: Researchers create world's first 3D-printed bionic organ]

[Image: 6 billion dollars]

The value of products that are expected to be turned out by the world’s additive manufacturing in 2020.

[Image: 30 percent]

The annual growth of the world’s additive manufacturing industry.

3. From Rapid Prototyping to Additive Manufacturing (AM): 3D Printing (3DP)

- Layer of powder is: first spread across build area.
- Inkjet-like printing of binder over the part cross-section
- Repetition of the process with the next layer.
- Can produce multi-colored parts.
- Useful only for presentation media.
- Market Leader: Z-Corp [now part of 3D Systems]

Arthur Olson’s team at the Scripps Research Institute in La Jolla, California, produces models of molecules; some are shown here partway through the printing process.

Adam Gardner, Molecular Graphics Lab at TSRI
3. From Rapid Prototyping to Additive Manufacturing: Stereo-lithography (SLA)

- Chuck Hull of 3D Systems, who pioneered rapid prototyping in the mid-1980s.
- Prototypes and parts are built from a liquid photopolymer. A laser solidifies the resin voxel by voxel in one layer at the time.
3. From Rapid Prototyping to Additive Manufacturing: Fused Deposition Modeling (FDM)

- The fused deposition modeling (FDM) technology was developed by Scott Crump in the late 1980s and commercialized in 1990 by Stratasys Inc.

- A spool of thermoplastic wire is continuously supplied to a nozzle.

- The nozzle heats up the wire and extrudes a hot, viscous strand (like squeezing toothpaste of a tube).

- A computer controls the nozzle movement along the x- and y-axes, and each cross-section of the prototype is produced by melting a plastic filament (ABS) that solidifies on cooling.
3. From Rapid Prototyping to Additive Manufacturing: Fused Deposition Modeling (FDM)

- FDM is moderately fast and inexpensive and functional parts are feasible.
- Industrial large equipment. Current market leader Stratasys, Inc.
- Do it Yourself FDM rapid prototyping systems (e.g., FAB@Home, RepRap and Cubify).

"Ribbon Tetris" (Carlo Séquin)

Courtesy, Dr. Robin Richards, University College London, UK

Stratasys Dimension SST 1200
4. Future Directions

- In Aug 2012 Tech Consultancy did put 3D Printing at Peak of “Hype Cycle.” We believe that they are somewhat right.

- In our proposed scenario we stress that 3D Printing alone will not be the answer for the future of manufacturing in the U.S. Too limited by:
  - Length-scales achievable
  - Limited types of materials
  - Limited types of processes (only additive!)

- What is needed are multi-length scale, multi-physics and multi-materials manufacturing stations: desktop integrated manufacturing machines (DIMPS).

4. Future Directions: Multi-Length Scales

- Challenge building fractal-like objects.
- Example combine μ-SLA with 2 photon-SLA
4. Future directions: Multi-Materials

- Prototyping (84 %)
  - Concept models
  - Architectural models
  - Disney characters
  - Movies—or is that real and thus manufactured?
  - Etc

- Manufacturing (16 %)
  - Implants and custom medical devices
  - Aerospace parts
  - Pilot scale production of lab equipment
  - Molds .. A Stradivarius?
4. Future Directions: Multi-Physics

- Desktop manufacturing stations have been the goal of at least three disparate communities: 1) materials scientists for additive manufacturing, 2) micro-technology scientists for mask-less lithography, and 3) mechanical engineers for micro-manufacturing centers.

- However, these stations only execute a limited set of processes in narrow application domains and lack shared standards, specifications, or algorithms.
With PCs as a model we aim to: (1) formulate a unifying computer language able to describe manufacturing processes from the many different process domains; (2) develop an effective suite of software tools to interactively assist in synthesizing new hybrid processes; (3) use computer algorithms and simulation tools as well as the results from process hybridization experiments to evaluate the performance and correctness of the newly synthesized processes; and (4) organize hybridized processes in a process-planning software tool to initiate the building of DIMPS.

DIMP (see http://dimps.eng.uci.edu).
5. Reengineer Engineering: How?

- Building on US Strengths:
  - Flexibility, risk taking, diversity, imagination, space, resources.
  - Back this up with the best education for a larger group of people.

- Invest in Education, New Manufacturing Materials and Building the Next Generation of Manufacturing Tools/Methods.

- Distributed or point of need manufacturing (PC analogy) as a first trial model (bottom-up approach—Maker community, DIY, Desktop Factories, etc).
5. Reengineer Engineering: How?

- Engage with local manufacturing industry.
- Rethink UCI’s Innovation strategy (see Innovation Institute).
- K to gray: connect four year colleges with community colleges that are in turn better integrated with K-12. Be involved in the education of the next generation of technicians.
- Give our students international exposure to cultures that do still appreciate engineering (Korea, Germany, Sweden, Switzerland, Japan).
- Promote scientist participation in politics again and get them compensated as well as financial sector workers.

10/24/2014
5. Reengineer Engineering: How?

- Materials and Manufacturing Technology Concentration—Make that into an Advanced Manufacturing Department.
- Integrate RapidTech (NSF-Advanced Technological Education Center) with manufacturing activities all over campus; business school and all entrepreneurial activities around campus.
- Advanced manufacturing course ENG 165/265.
- This is a good time for universities to reinvent themselves. Engineers did not cause the financial crisis!
5. Reengineer Engineering: How?

- Give as broad a group of people as possible access to Rapid Prototyping, CNC Machining, IC Clean-rooms, etc: unleash creativity (IP in manufacturing is more potent!).
- Shorten the design to prototyping/product loop. Distributed manufacturing on desktop machines (DIMPS).