Extremely Agile, Adaptive, Responsive and Robust Manufacturing

Rodney Brooks
Heartland Robotics
(formerly iRobot & MIT)
US Manufacturing Productivity Has Increased Faster Than Other Productivity

Source: Federal Reserve Bank of Chicago, Oct. 2007
US Manufacturing Output Increased 3.7% per Year with 60 Year Mostly Flat Employment

Source: Federal Reserve Bank of Chicago, Oct. 2007
U.S. Manufacturing Value Added Remains World’s Largest, But Growing Slowly

Source: U.S. Bureau of Economic Analysis
Volume

Non Consumer

Luxuries

Necessities

Value Add
US Manufacturing Since WW2
Labor Cost Increases Move Low Value Goods

Sources:
Low Cost Goods, E.g., Wal-Mart

- **2007:** Direct Wal-Mart imports from China, $32B
  (Financial Times Apr 7, 2008)
  - Approx 10% of all Chinese imports to the US, $321B (US Census Bureau)
- Hard to account exactly, but many other indirect imports sold by Wal-Mart not counted in this number
  - e.g., $900M by Hasbro (2008 Hasbro 10K with SEC)
  - many other US brand names, e.g., Black and Decker
- Leaves US with a significant trade deficit with China; $259B in 2007 (US Census Bureau)

- Trade is a driver of strategic pressures
Low End Manufacturing
Workers are “Robotic”
Each Does Simple Task
Robots?
World’s First Industrial Robot

- The Unimate (Unimation)  
  - by Joe Engelberger

- First installed in a GM factory  
  - 1961

- Later bought by Westinghouse  
  - then sold to Kawasaki
Computation and Sensing Expensive

- No computer
- No sensors
- Same motions repetitively
- Cost of systems integration is 10 times robot cost

Today’s industrial robots are much the same; they have not yet exploited the microprocessor/network revolution
Today’s Manufacturing Robots

- Unsafe for people to be around
- Engineered to be precise and repeatable, not adaptable
- Can only operate in very structured environments
- Their application is limited
- Integration cost is 5 to 10 times capital cost
## Distribution of # of US Manufacturing Companies By Revenue

<table>
<thead>
<tr>
<th>Min</th>
<th>Max</th>
<th># of Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0</td>
<td>$500,000</td>
<td>158,129</td>
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<tr>
<td>$500,000</td>
<td>$1,000,000</td>
<td>56,553</td>
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<td>$1,000,000</td>
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<td>$10,000,000</td>
<td>$100,000,000</td>
<td>31,712</td>
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<tr>
<td>$100,000,000</td>
<td>$100,000,000</td>
<td>44,294</td>
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<tr>
<td></td>
<td>$100,000,000</td>
<td>398,717</td>
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</table>
Transformation of Computers

Went from top-down model to bottom-up empowerment of individuals
Personal Computer and Internet Empowers

- Newer, nimbler, local services with global reach, e.g.,
  - graphics production
  - publishing (Web, and even paper)
  - language translation services
  - movie editing
  - music production

- Large scale decimation of existing models, being replaced by new
  - retailing
  - music recording
  - newspapers
Robotics Exponential Growth

1979
20m/6hrs

1992
2000m/6hrs

2005
200km/6hrs

The Cart, Stanford

Polly, MIT

Stanley, Stanford
Robots In Unstructured Environments
Uptake in Unstructured Environments

<table>
<thead>
<tr>
<th></th>
<th>June 2002</th>
<th>January 2010</th>
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<tbody>
<tr>
<td>Ground robots in US military</td>
<td>0</td>
<td>&gt; 7,000</td>
</tr>
<tr>
<td>Robots in people’s homes</td>
<td>0</td>
<td>&gt; 5,000,000</td>
</tr>
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</table>
Why Have Things Taken Off?

• Computation and sensors have gotten exponentially cheaper for the last 50 years

• Research in computer vision and in simultaneous localization and mapping have made major strides in the last ten years

• For certain tasks robots have passed a usability threshold that makes them useful to untrained people
Robots for Manufacturing Workers

• Safe to interact with at close quarters
• Easy and intuitive to control
• Robust and reliable
• Empower people to do things faster, easier, and better
New Robotics Capabilities...

• Will revolutionize low end manufacturing and change
  – balance of payments
  – who the manufacturing powers can be
  – how the supply chain works
  – what the nature of manufactured goods are like

• Will trickle up to high end manufacturing
  – provide better and more dependable low end components
  – change the nature of high end manufacturing
Analogy: MFG.COM

Monday, January 10, 2011; Open RFQs

- **Today's Total**: 77,047,396 USD
- **Machining**: 44,079,452 USD
- **Home Textiles**: 11,431,188 USD
- **Assembly**: 9,529,887 USD
- **Casting**: 2,705,277 USD
- **Stamping**: 1,962,198 USD
- **Molding**: 1,933,214 USD
- **Fabrics & Trim**: 1,290,046 USD
- **Extrusions**: 1,174,859 USD
- **Fabrication**: 1,153,028 USD
- **Apparel**: 1,148,559 USD
- **Pumps, Valves & Fittings**: 201,738 USD
- **Forging**: 169,911 USD
- **Tube Modification**: 109,475 USD
- **Tool, Die & Mold Making**: 86,925 USD
- **Industrial Equipment**: 47,427 USD
- **Fasteners & Hardware**: 21,011 USD

This is a partial listing of recent awards

- **Telecommunications** buyer in Carpinteria, California United States of America to a **Stamper** in Deerfield, Illinois United States of America
  - January 7, 2011 11:05 PM
- **Consumer Products** buyer in La Canada, California United States of America to a **Machine Shop** in Mentor, Ohio United States of America
  - January 6, 2011 7:17 PM
- **Government Military** buyer in Warrington, Pennsylvania United States of America to a **Machine Shop** in Nunica, Michigan United States of America
  - January 5, 2011 10:41 PM
- **Automotive** buyer in Atascadero, California United States of America to a **Machine Shop** in Palmetto, Florida United States of America
  - January 4, 2011 7:49 PM
- **Government Military** buyer in Roseland, New Jersey United States of America to a **Machine Shop** in Frederick, Maryland United States of America
  - January 4, 2011 4:37 PM
- **Oil & Gas** buyer in Houston, Texas United States of America to a **Machine Shop** in Clarksville, Tennessee United States of America
  - December 27, 2010 4:52 PM
## Only Possible Now

<table>
<thead>
<tr>
<th>Enablers</th>
<th>Result</th>
</tr>
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<tbody>
<tr>
<td>• Universal availability of Internet</td>
<td>• Tiny (1 person &amp; up) entrepreneurial companies (high school level education often) can engage in national marketplace</td>
</tr>
<tr>
<td>• Web standards and browsers</td>
<td>• Small run prototyping and manufacture can turn around complex projects from office in 48 hours</td>
</tr>
<tr>
<td>• High-end 3-D CAD and spreadsheets for personal computers</td>
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<tr>
<td>• Overnight shipping services</td>
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</tbody>
</table>
What would worker empowering robots lead to, besides bringing low-end manufacturing back to US?
E.g., Plausible New Manufacturing Process

- Franchised “factory pavilions”, all over the country
- Entrepreneurial “micro companies” lease space
- Name brand franchise bids on building multi-10K lots of goods for national product brand
  - standardized drawings and manufacturing documents
  - requestor actually wants multi-100K but also wants to minimize warehousing and cross country transport
- Within pavilion micro companies bid on supplying parts, assembly services, packout, etc.
- Locally manufactured goods get to distribution center/retailer within days
E.g., Another Plausible Trend

• Like locavore food, locavore style & production
• Revitalization of craft
  – with appropriate flexible automation, craftspeople could manufacture at scale
  – craftspeople could become the champions of local community, and leaders in local style
• Regional strengths and craft communities could grow and become regional identities
• International airports worldwide could have unique stores!!!
A New Vision For American Manufacturing

Smart and productive:

- skilled workers producing both high value and mass market products
- robots take over the simple cases of the simple tasks freeing workers to be smart
- robotics and STEM education intertwine to support each other

Industrial revolutions:

1. muscles replaced by mechanically distributed power (UK - 1780)
2. electrical power allowing redistribution (USA - 1900)
3. computational intelligence between workers and work (USA?? – 2010)