Additive Manufacturing Technologies

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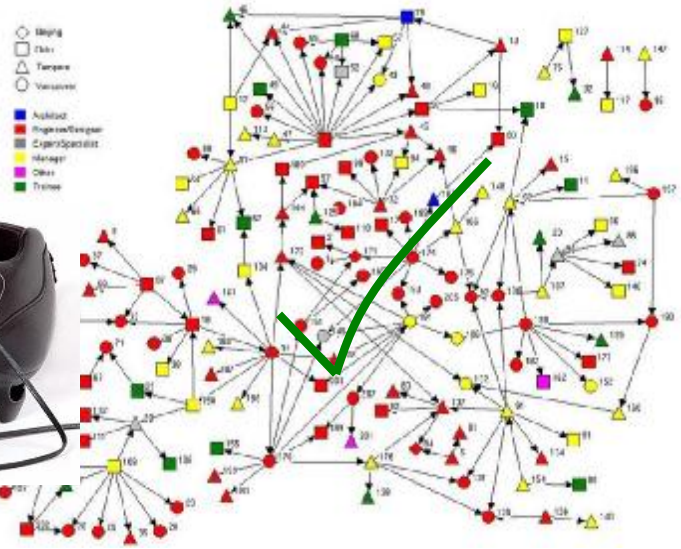
Additive Manufacturing

What if **anyone** could make almost **anything** they need, **anywhere**?



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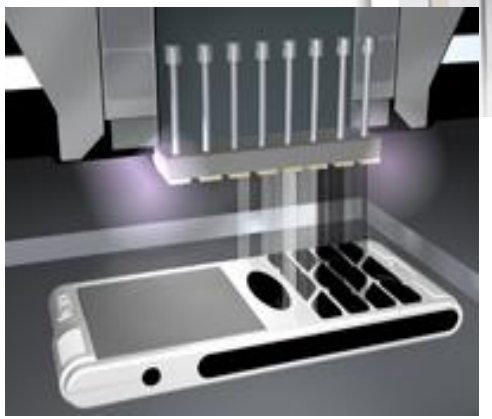
What if…

…all it took to set up an advanced manufacturing facility was **electricity**, access to some **raw materials**, and a **computer**?



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What if…

…an entrepreneur could **start selling** a new product **without** ever needing to buy a **machine**, purchase a **tool** or prove out a **mold**; and could **start shipping products the day after the design is finalized**?

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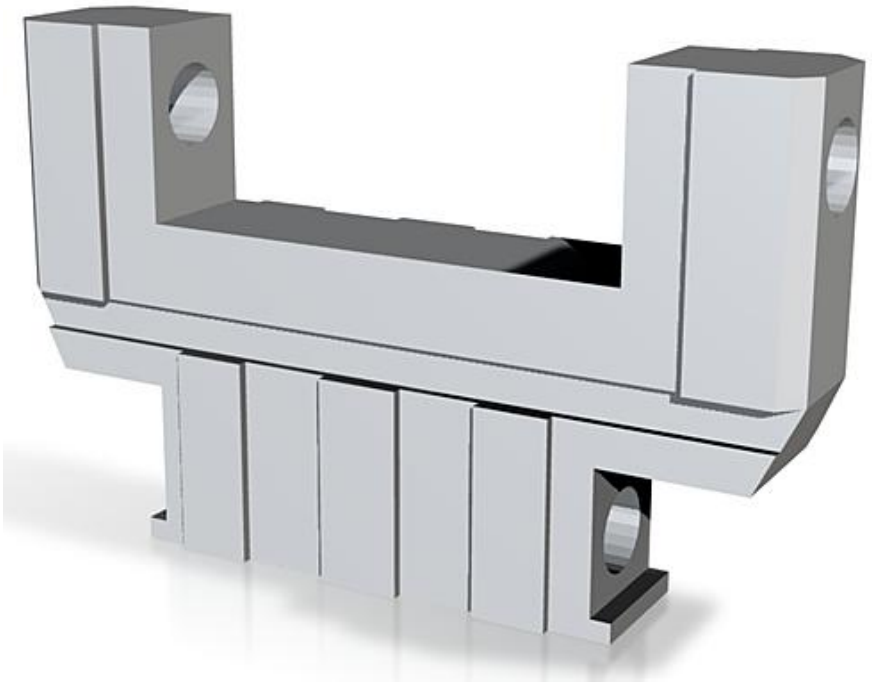
What if…

… part of your watch broke and you didn't want to buy a new watchband, so you used a free sketching tool to design a replacement, which you uploaded on a website and had **shipped to your house a couple days later, in the material of your choosing, for less than $5?**



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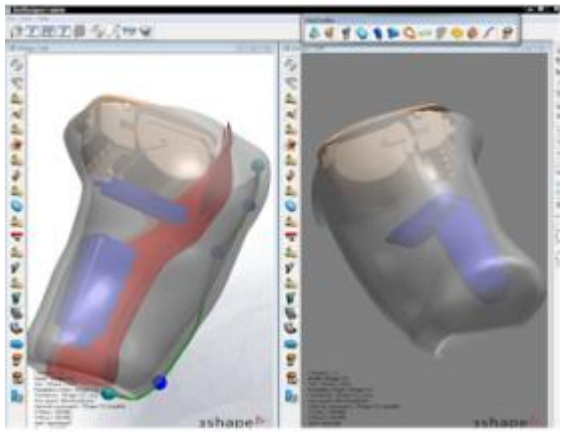
What if…

…you **automated** the **manufacture of hearing aids** so that you simply **scanned** the ear, **printed** out a custom-fitted hearing aid, **inserted the electronics**, and **shipped them** by the millions?



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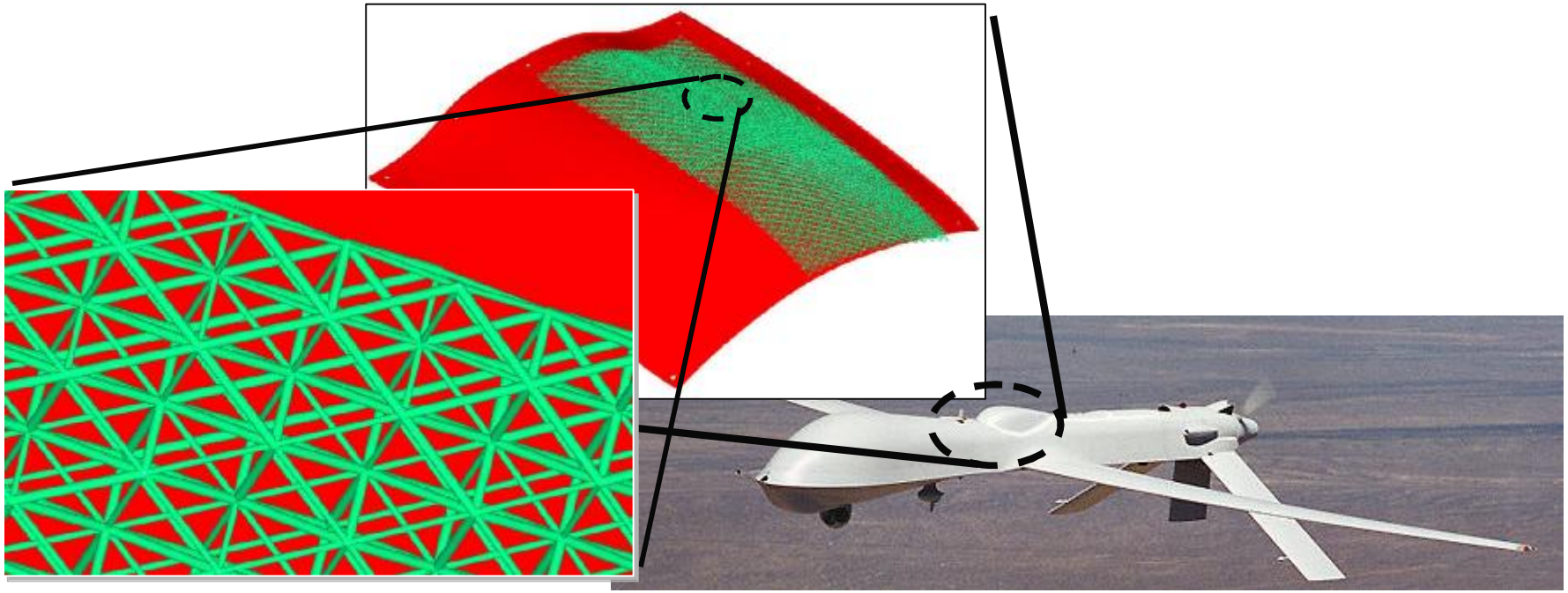
What if…

…you wanted to **control** the overall **geometry** of a part, which is made up of a **truss** network, where each truss has an **optimized thickness** and could have an individually **controllable microstructure or material**?



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What if…

…all of these things were already happening and most people had no clue?

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•All of this is possible and is currently being done with Additive Manufacturing Technologies

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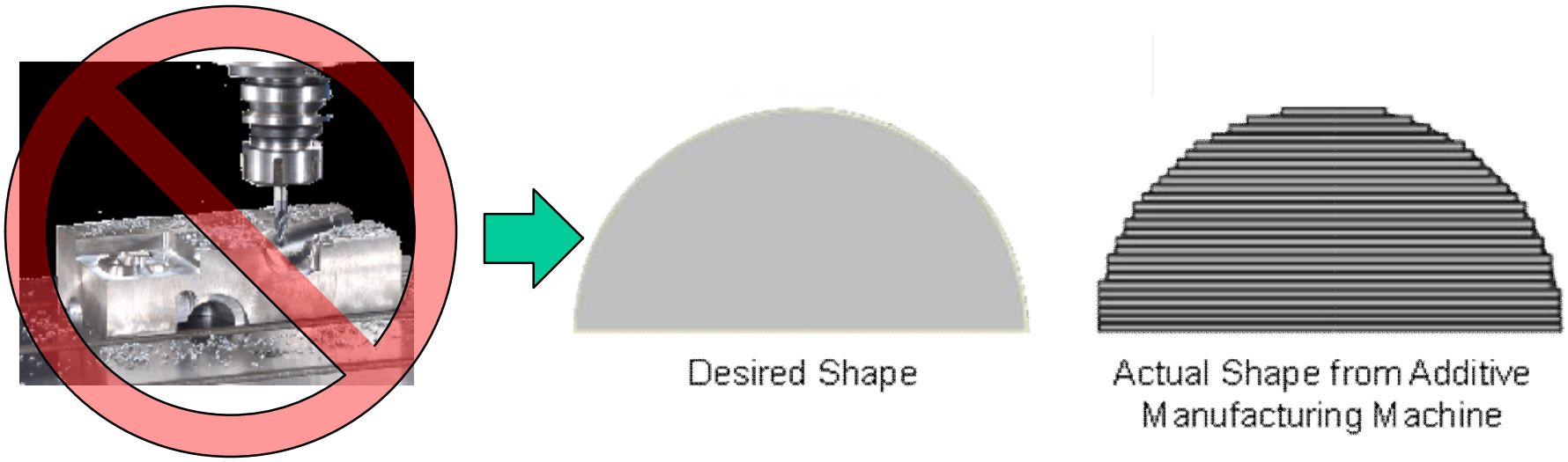
What is Additive Manufacturing?

- The process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies



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Additive Manufacturing Layer-by-Layer

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Seven AM Process Categories

- Based upon a recent balloted categorization by the ASTM International Committee F42 on Additive Manufacturing Technologies

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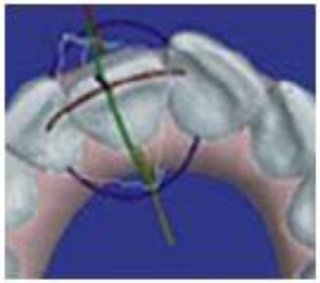
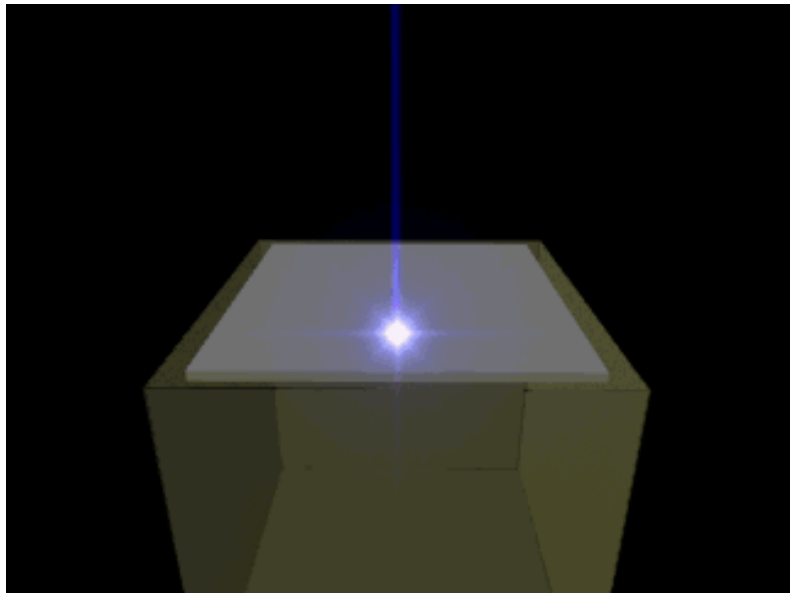
Photopolymer Vat Processes

- An AM process in which a pre-deposited photopolymer in a vat is selectively cured by light-activated cross linking of adjoining polymer chains.





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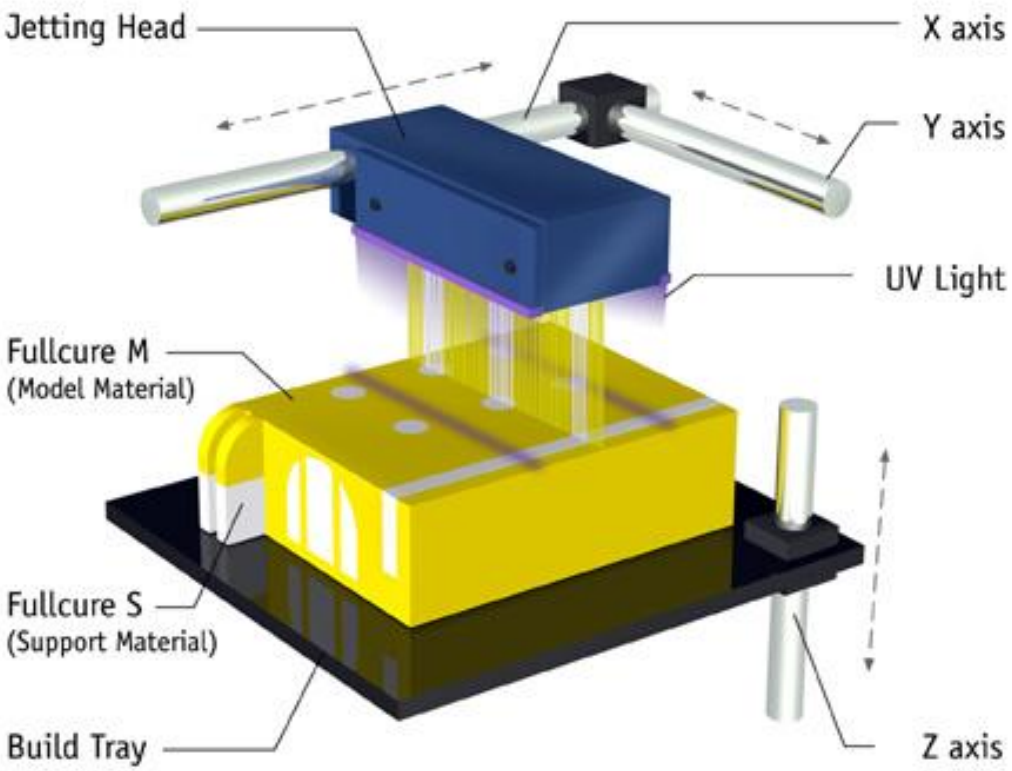
Material Jetting

- An AM process in which droplets of build material are selectively deposited
  - Wax or Photopolymers



The Objet PolyJet Process

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Binder Jetting

- An AM process in which a liquid bonding agent is selectively deposited to join powder materials.
  - Capable of printing colored parts
  - Can bind plastic, metal, ceramic & sand to form parts & molds

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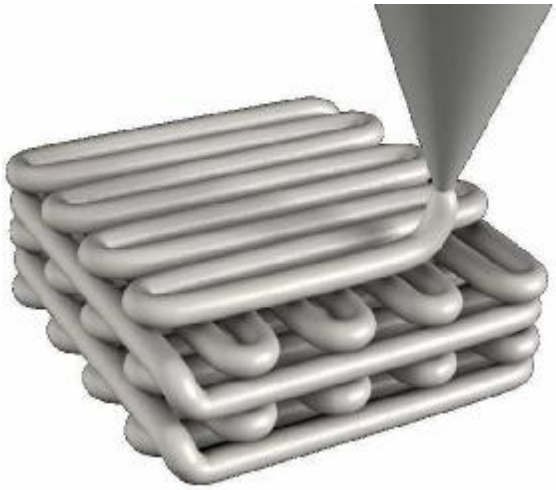
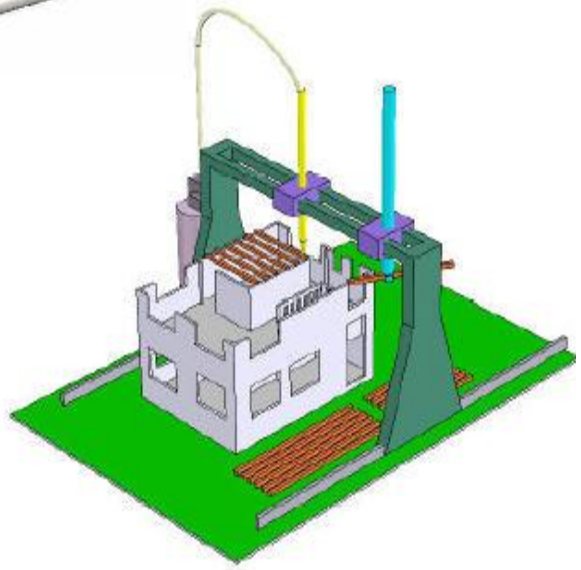
Material Extrusion

- An AM process in which material is selectively dispensed through a nozzle or orifice
  - Parts from microns to meters in size
  - Machines from $700 to above $100,000
  - Office & Home friendly
  - Mostly for prototyping form & fit





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Powder Bed Fusion

- An AM process in which thermal energy selectively fuses regions of a powder bed
  - CO_2 lasers used for polymers; fiber lasers and electron beams used for metals

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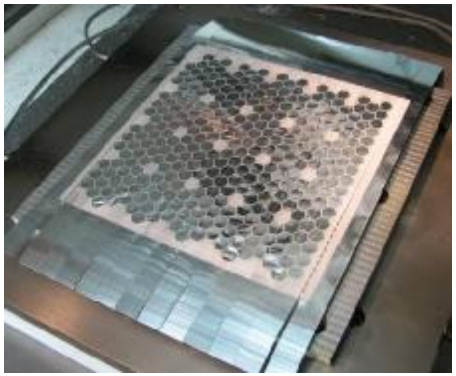
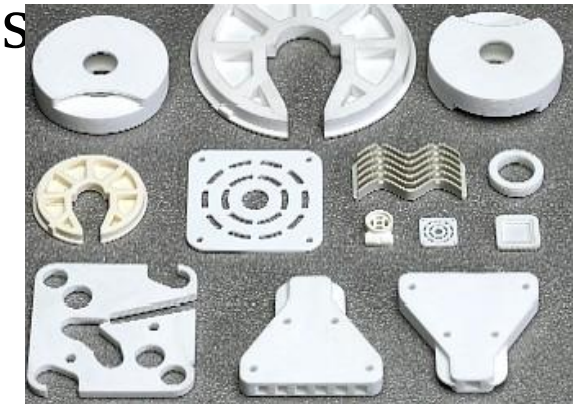
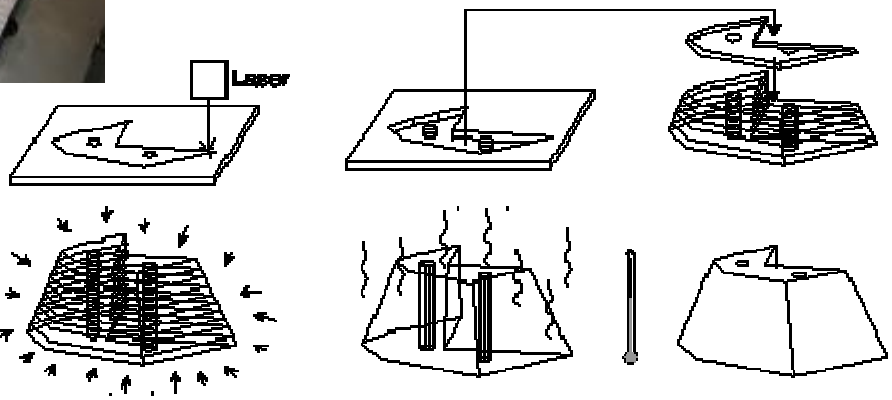
Sheet Lamination

- An AM process in which sheets of material are bonded to form an object.
  - Paper
    - Using glue
  - Plastic
    - Using glue or heat
  - Metal
    - Using welding or bolts



- CAMLEM process for ceramics





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Directed Energy Deposition

- An AM process in which focused thermal energy is used to fuse materials by melting as they are being deposited

–Wire & Powder Materials

–Lasers & Electron Beams

–Great for feature addition & repair

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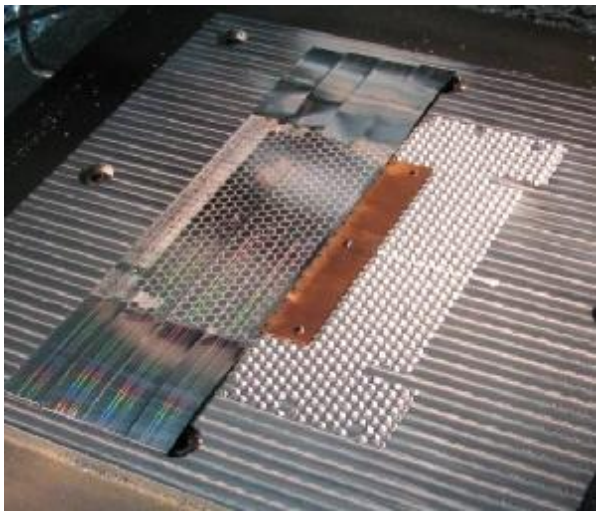
Engineering Implications

- More Complex Geometries
  - Internal Features
  - Parts Consolidation
  - Designed internal structures
- No Tools, Molds or Dies
  - Direct production from CAD
- Unique materials
  - Controllable microstructures
  - Multi-materials and gradients
  - Embedded electronics



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Business Implications

- Enables business models used for 2D printing, such as for photographs, to be applied in 3D
  - Print your parts at home, at a local “FedEx Kinkos,” through “Shapeways” or at a local store
- Removes the low-cost labor advantage
- Entrepreneurship
  - Patents expiring
    - New Machines
  - Software tools
  - Service providers

Pharmaceutical Manufacturing in China

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Web 2.0 + AM = **Factory 2.0**

- User-changeable web content plus a network of AM producers is already enabling new entrepreneurial opportunities
  - Shapeways.com
  - Freedom of Creation
  - FigurePrints
  - Spore
  - …and more

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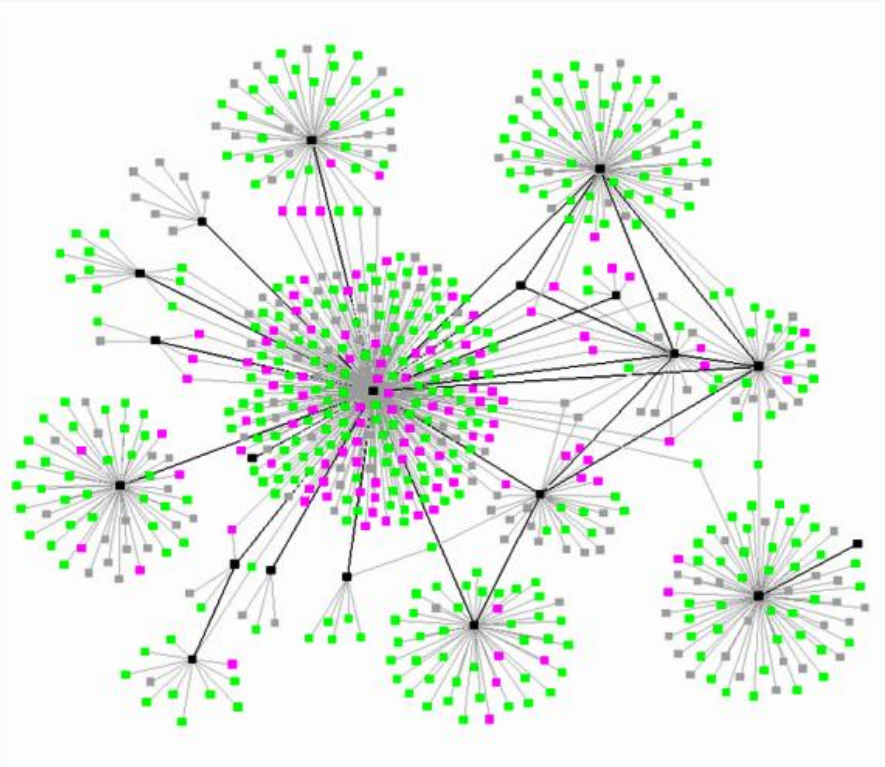
Impact on Logistics

- Eliminates drivers to concentrate production
- "Design Anywhere / Manufacture Anywhere" is now possible
  - Manufacture at the point of need rather than at lowest labor location
  - Changing "Just-in-Time Delivery" to "Manufactured-on-Location Just-in-Time"



Big Picture Possibilities

- Additive Manufacturing has the potential to:
  - Make local manufacturing of products normative
    - Small businesses can successfully compete with multi-national corporations to produce goods for local consumption
    - Parts produced closer to home cost the same as those made elsewhere, so minimizing shipping drives regional production
  - Reverse increasing urbanization of society
    - No need to move to the “big city” if I can design my product and produce it anywhere
  - Make jobs resistant to outsourcing
    - Creativity in design becomes more important than labor costs for companies to be successful

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Research Challenges

- Current AM machines are based upon the "prototyping" market
- Manufacturing machines require
  - Specialized machines for high-volume production
    - Different size envelopes & optimized for maximum speed
  - More materials (particularly polymers)
  - Better repeatability
  - Closed-loop control
  - In-process quality monitoring

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Conclusion

- Additive Manufacturing is poised to transform the production of “physical goods” in much the same way that the internet transformed the production of “informational goods.”

- Many people recognize these opportunities and are starting new businesses, designing future products and funding research focused around additive manufacturing capabilities

Questions?

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