Additive Manufacturing

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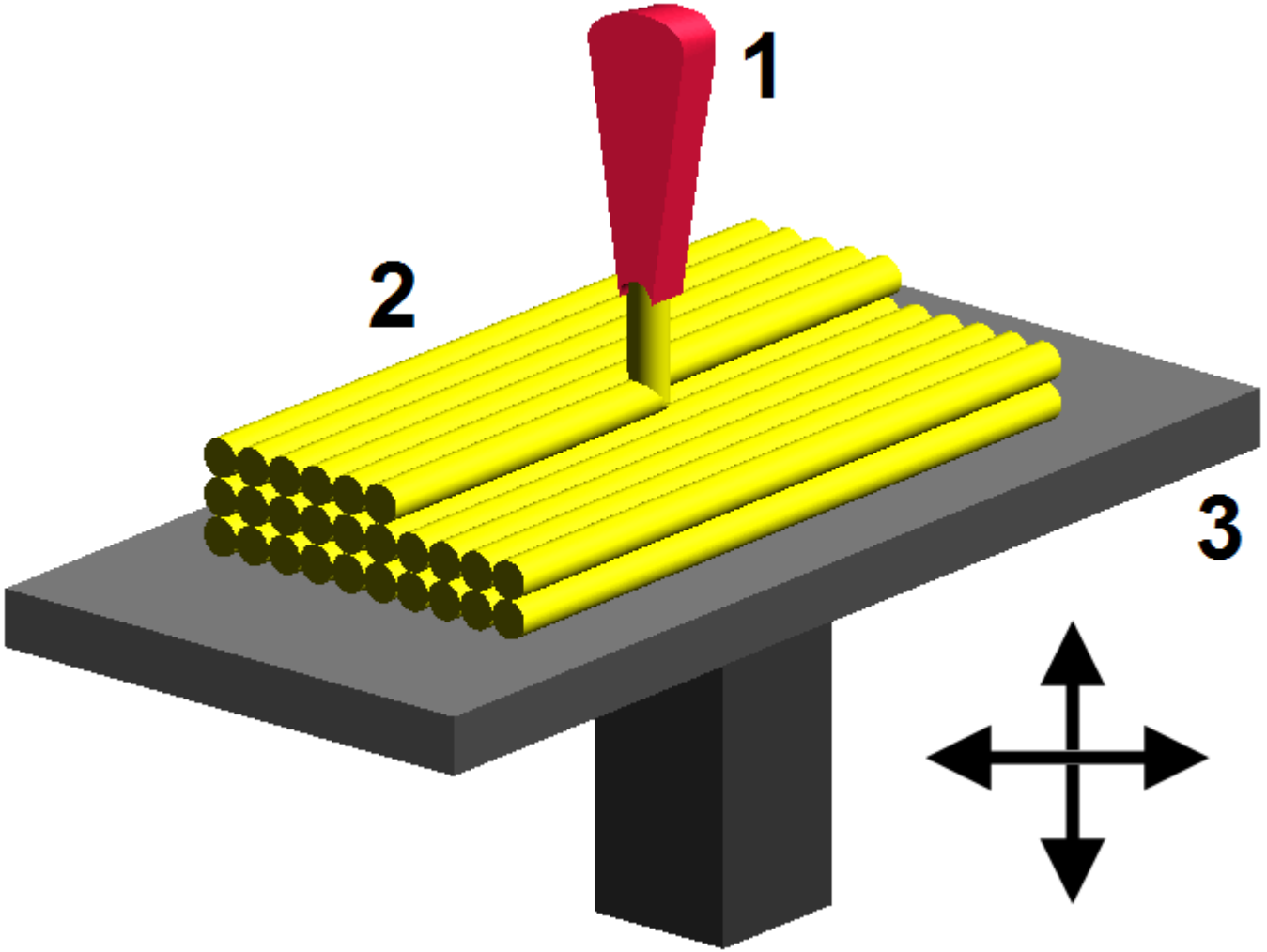
Introduction

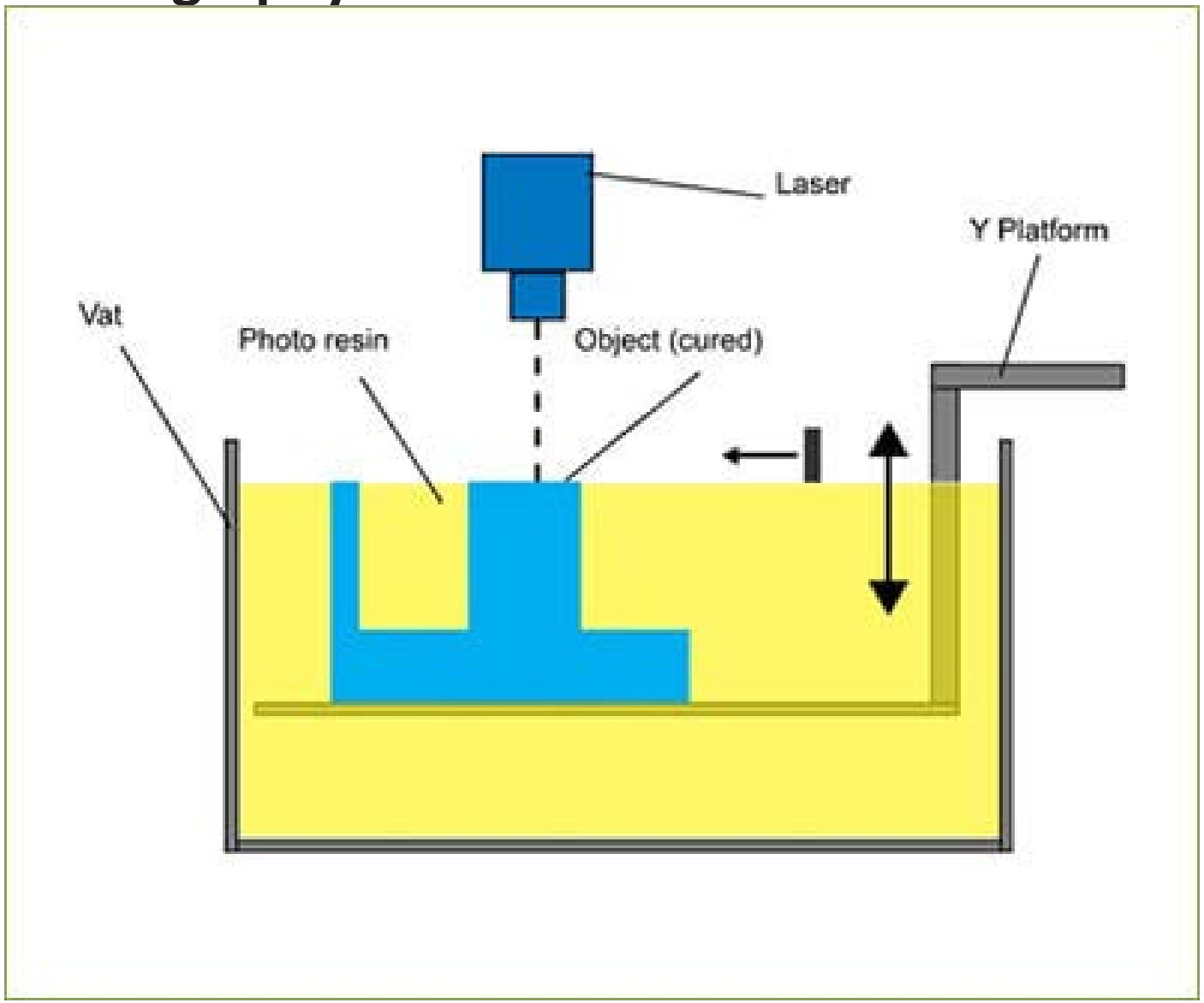
- Additive Manufacturing (aka 3D Printing)
  - Set of manufacturing processes that generally create an item by laying down many successive thin layers of a material.
  - Performed with little worker interaction
  - Based off of 3D CAD file
- Many different processes
  - Material Extrusion- Heated nozzle melts material as it comes out, allowing for layering in multiple directions by CAM software and hardening immediately after extrusion.
  - Stereolithography – Ultraviolet laser traces cross sections in a resin vat and builds layer upon layer, joining them together.
  - Powder Bed Fusion- High power laser fuse small particles of powder into desired mass based on 3D model. Done in a layered fashion similar to stereolithography.
- Need guidance in our hardware model to estimate the cost of additively manufactured parts

Material Extrusion

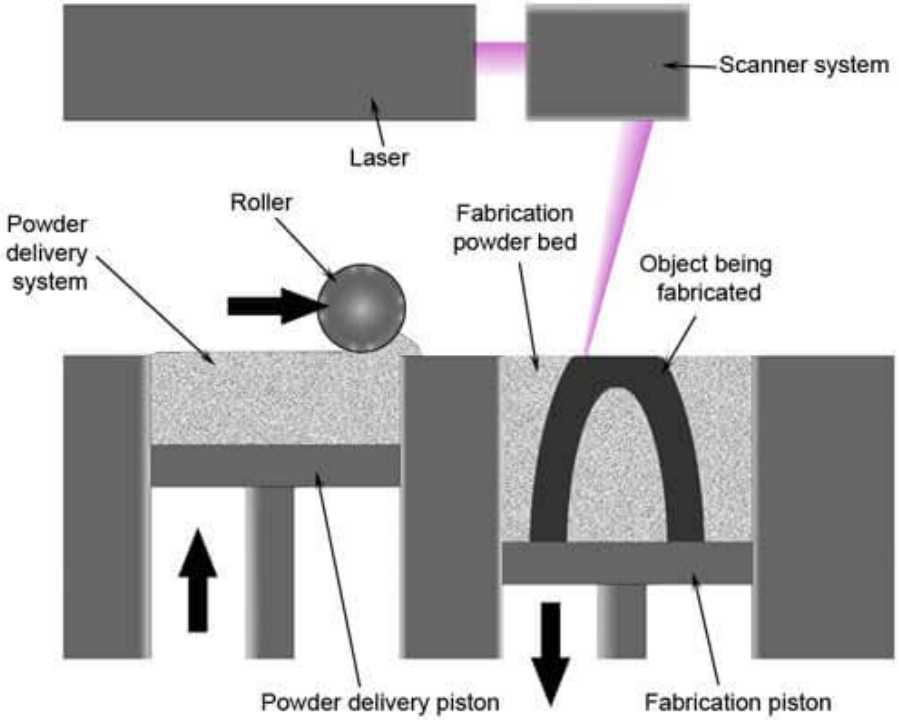


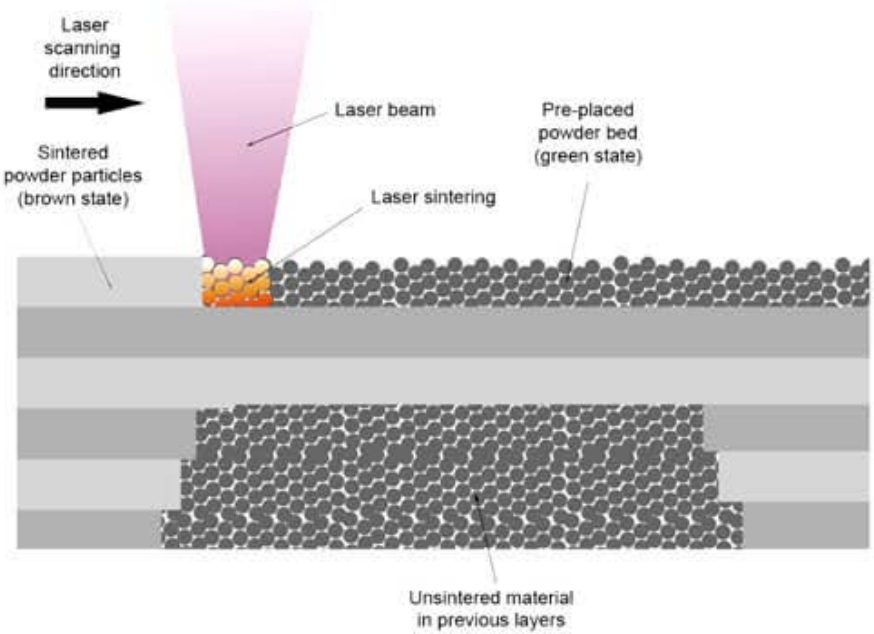
Fused deposition modelling (FDM), a method of rapid prototyping: 1 – nozzle ejecting molten material (plastic), 2 – deposited material (modelled part), 3 – controlled movable table.

Stereolithography



Powder Bed Fusion





Why 3D Printing?

- Additive Manufacturing use has been growing:
  - Used in medical, aerospace, and automotive industries
  - Multi-billion dollar worldwide industry (expected $21 billion by 2020)
- Additive has benefits over subtractive methods:
  - Rapid Prototyping
  - Rapid Manufacturing
  - Reduced Waste Material
  - Can produce complicated geometry that can't be achieved through traditional
    - *Spiral channels*
    - *Internal Vias*
    - *Internal Supporting Features (honeycomb/lattice structures) – Reduces weight while maintaining strength*
  - Can reduce logistical footprint, as spares can be created on-demand.
  - Reduced part counts

Research Approach

- Partnered with Lehigh University's Enterprise Systems Center

- Worked closely with vendors in the industry

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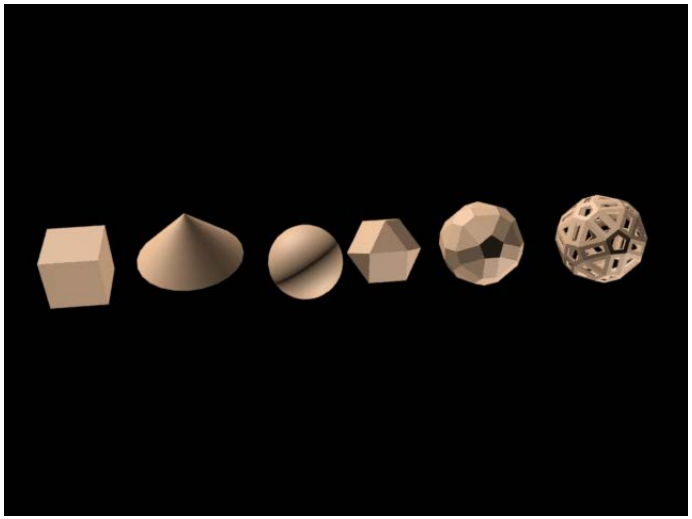
Results - Intricacy Experiment

- Tested hypotheses regarding how shape/intricacy of item affects build time
- Shape/intricacy not found to be a significant driver



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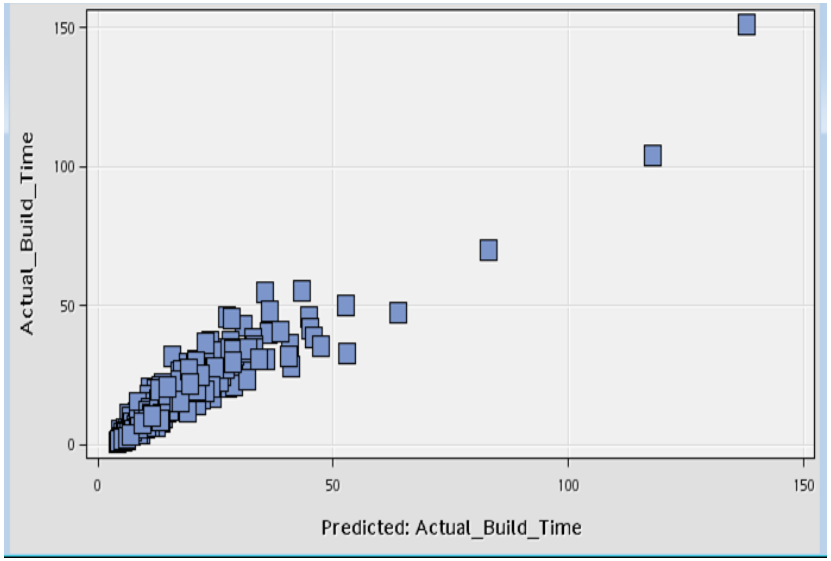
Results

- Build Time Estimate
  - Build Time = f(Height, Volume, Surface Area)
  - Based on 691 data points from ProtoCAM
    - *4 different printers, all Stereolithography. Printer was not a significant driver.*
  - Conversion for Metal (DMLS) build time estimate based on 11 data points from Picatinny Arsenal.
  - Metal Equation validated by Imperial 3D SMEs.
- Gathered data on
  - Common industrial 3D printers, total ownership costs
  - Common 3D printed materials (plastic and metal)
  - Printer-to-Material Compatibility



Results

- Additive Manufacturing direct costs composed of:
  - Amortized Machine Cost
  - Material Cost
  - Postprocessing Cost

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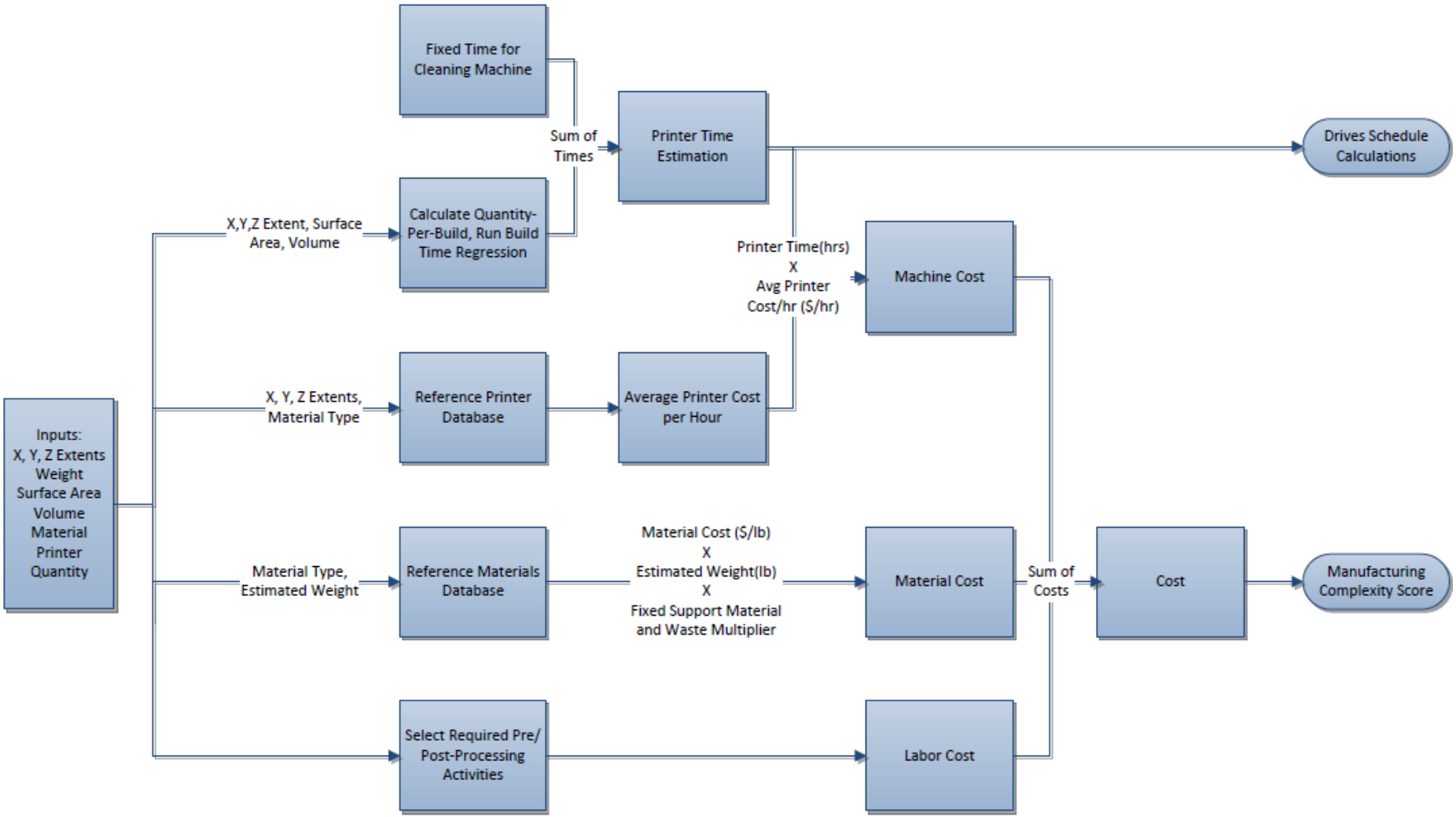
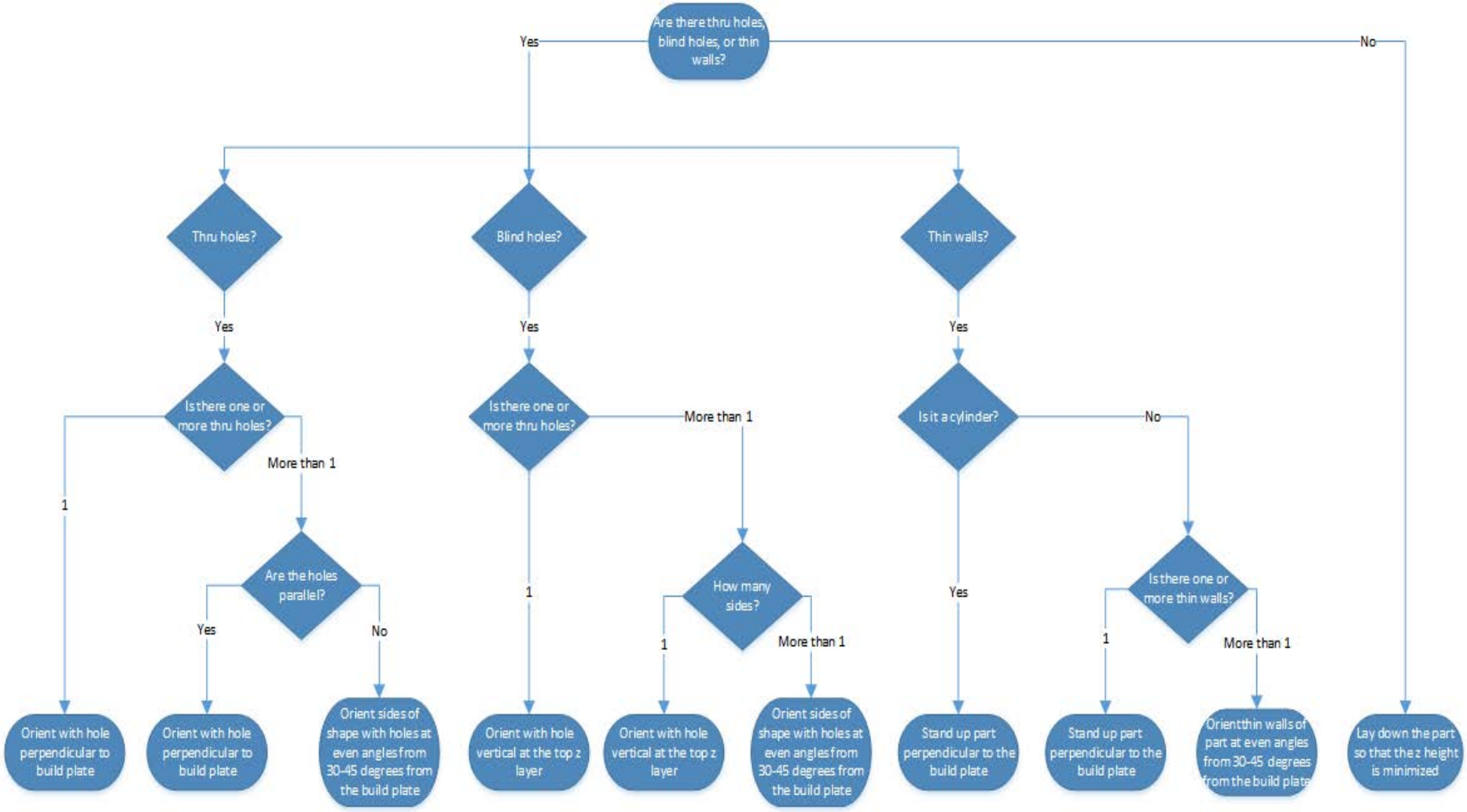
Results



Results

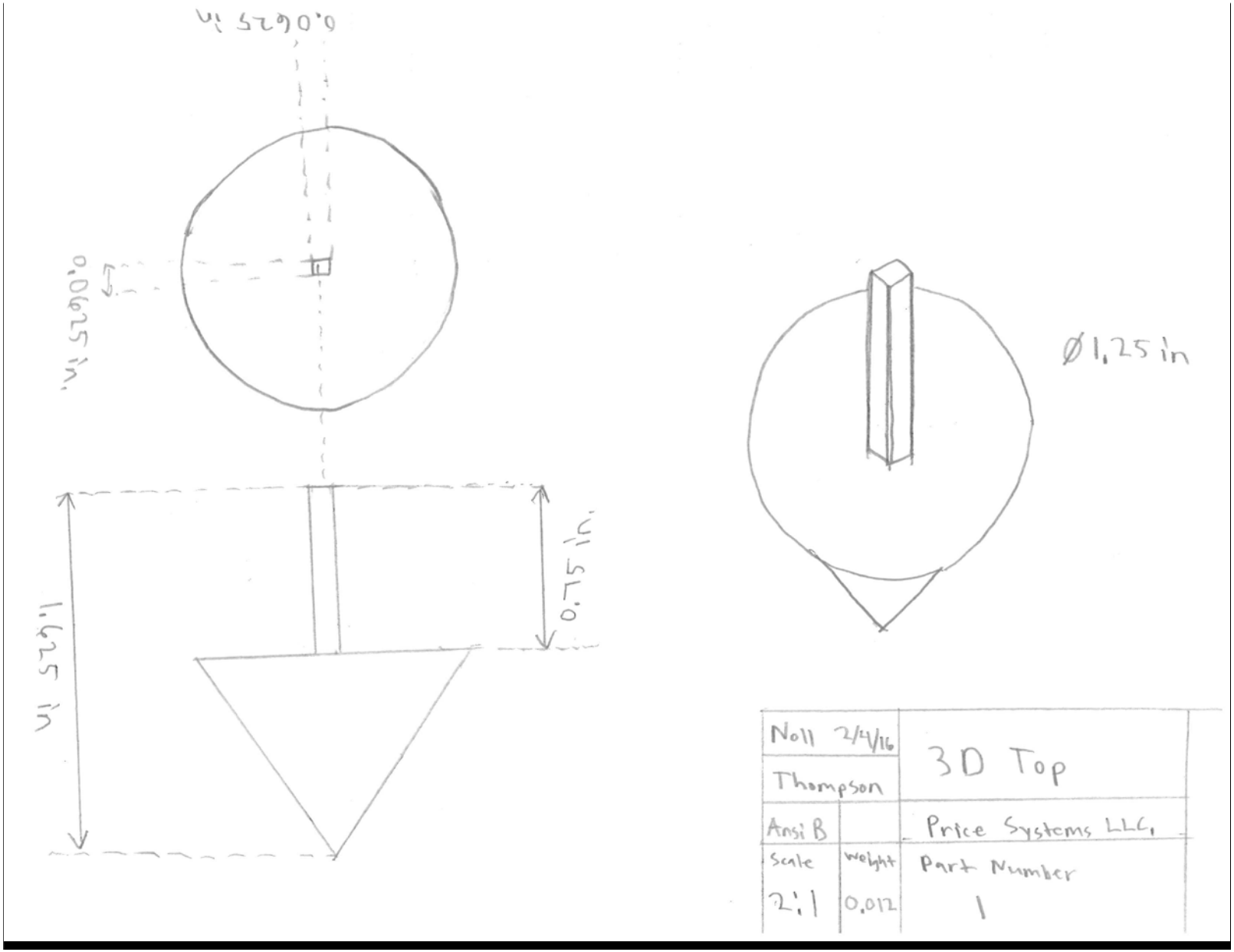
- Build tray orientation guidance



Results

- Post-processing costs research with Imperial 3D SMEs
  - Post-processing activity checklist
  - Cost baselines per activity

Demo



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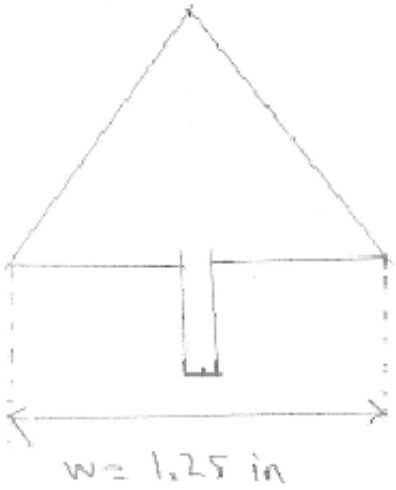
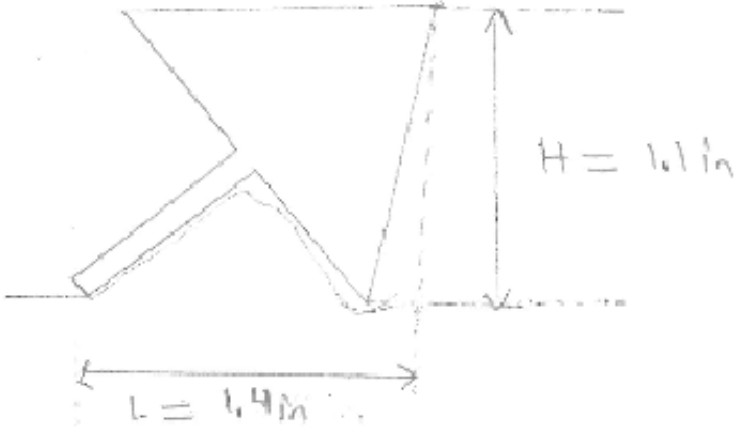
Demo





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Future Work

- Collect Build Time data for additional AM machines.
- Research Development Cost/Schedule Impacts
- Review with interested customers
  - Validate the model structure, especially post-processing
  - Validate completeness for A&D market
  - Validate results
- Address more material types
  - Composites
  - Sands
  - Ceramics
  - Chocolate?

Questions?

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