3D Metal Printer with NDE Capability

sdmay18-05
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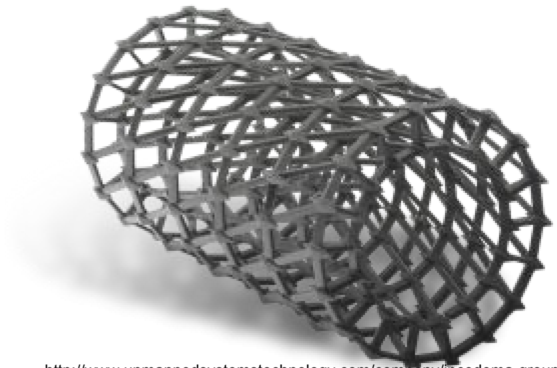
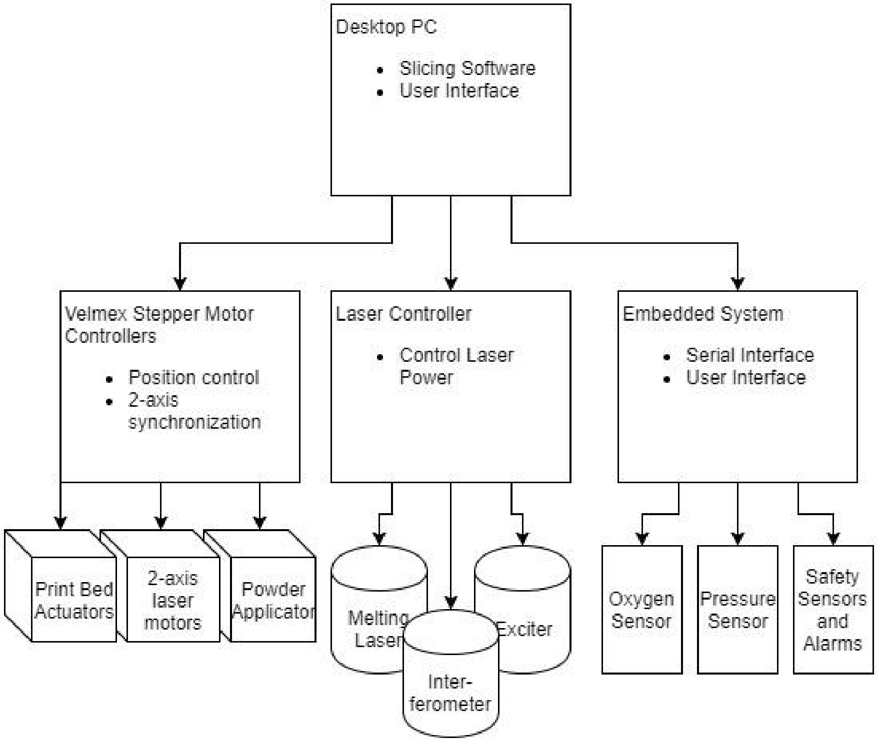
Problem Statement

To design and build an affordable Metal 3D Printer for NDE research.



http://www.unmannedsystemstechnology.com/company/incodema-group/

Conceptual Sketch



Functional Requirements

- 3 lasers
  - 1064 nm 200 W melt laser
  - 1064 nm ultrasound laser
  - 1550 nm laser interferometer
- Blade/roller to deposit powder from powder bed to print bed
- Powder bed which moves up in order to deposit a new layer of powder
- Print bed which moves down after each layer is sintered by the laser
- Collection bin which collects excess powder not deposited on the print bed
- Any place with powder must be enclosed in a sealed chamber which can withstand a vacuum and be filled with nitrogen or argon gas

***For full list of functional requirements please see our Project Plan located on our team website: http://sdmay18-05.sd.ece.iastate.edu/

Nonfunctional Requirements

- Volume of sealed chamber needs to be minimized
- System software should be easy to modify by future users
- Build speed

Technical/Other Constraints/Considerations

- Need to fit several moving parts into sealed gas chamber
- Constraints from manufacturer of laser head and stepper motor slides
- Environmental issues, particularly dust
- Evaluated many methods
  - Mirror
  - Moving mirror (galvo system)
  - Window

Market Survey

- Build Time Process Monitoring
  - NDE can be used as a per slice monitoring technique
- Commercial 3D Metal Printers
  - Some use a recoater instead of a roller to apply next layer of powder
  - Most machines have the laser rotate with a ball joint and larger machines also have the laser move across the print area with a 2 axis stepper motor system.
- Additive Manufacturing Software
  - Most open source software is used for plastic additive manufacturing.
  - Available 3D slicing software generates g-code which is an instruction language for a the majority of plastic printing machines.

Potential Risks & Mitigation

- Components may not survive the vacuum
    - Communicate with suppliers
- Stepper Motors for the powder beds may not be able to handle the weight of the powder
    - Lower max powder volume
- Nitrogen gas could leak from our machine
    - Safety sensors and proper ventilation
- Powder could get into the stepper motors
    - Stepper motors are enclosed

Resource/Cost Estimate

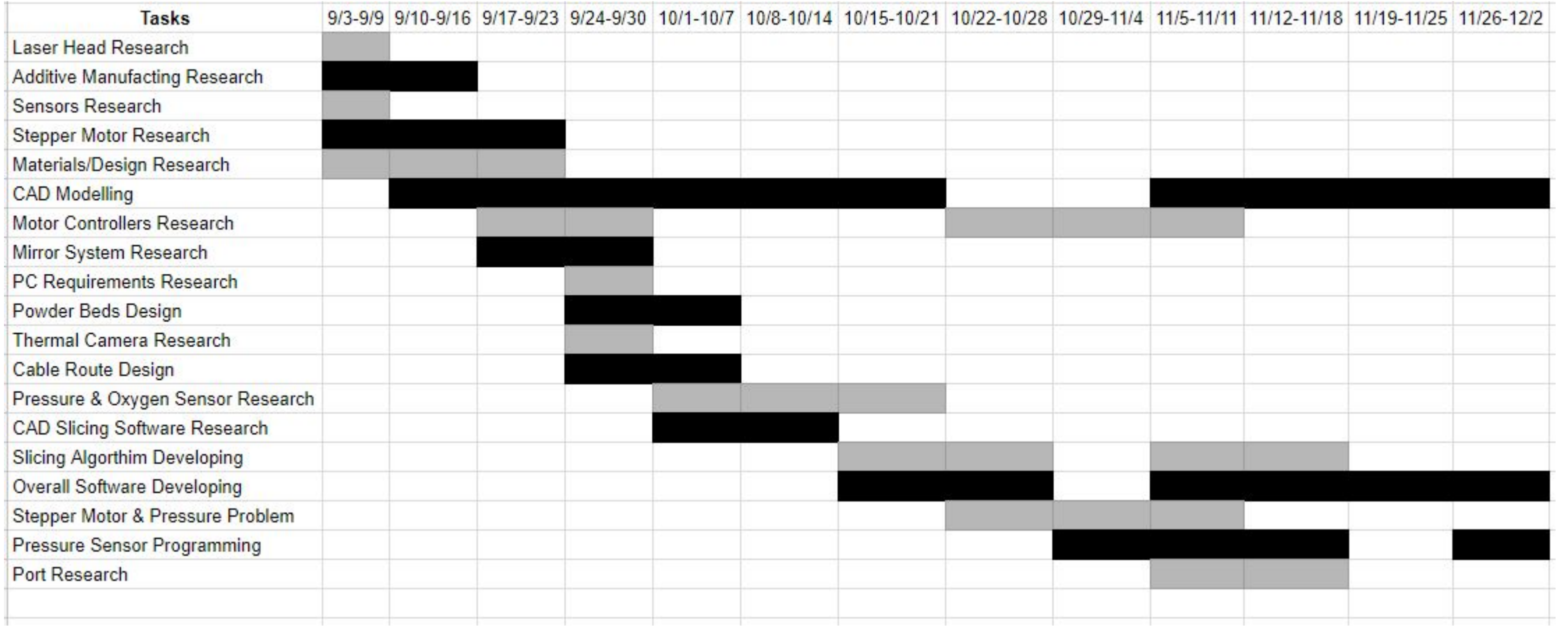
- External Oxygen Sensor - $109.00
- Internal Oxygen Sensor - $1840.00
- Internal Pressure Sensor - $19.90
- Arduino Uno Rev 3 - $27.95
- Desktop PC - $400
- 3 Velmex Motor Controllers - $3742.00
- Vacuum Electrical Pass Throughs - $1455.00
- Velmex Xslides - $ TBD
- Chemistry Machine Shop potential quote - $ TBD

Total = TBD

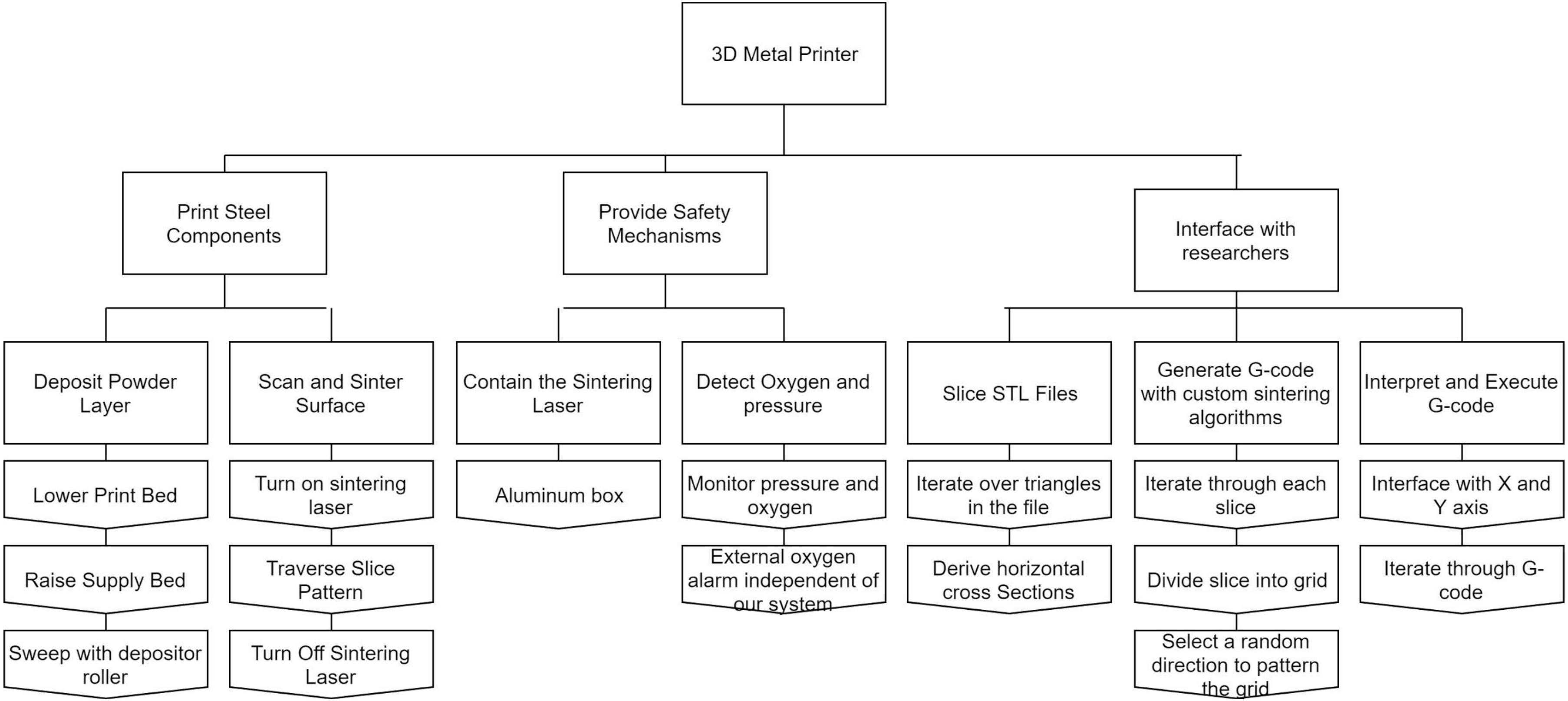
-This estimate does not include previously purchased items for this project or ISU resource that are free to students.

Project Milestones & Schedule

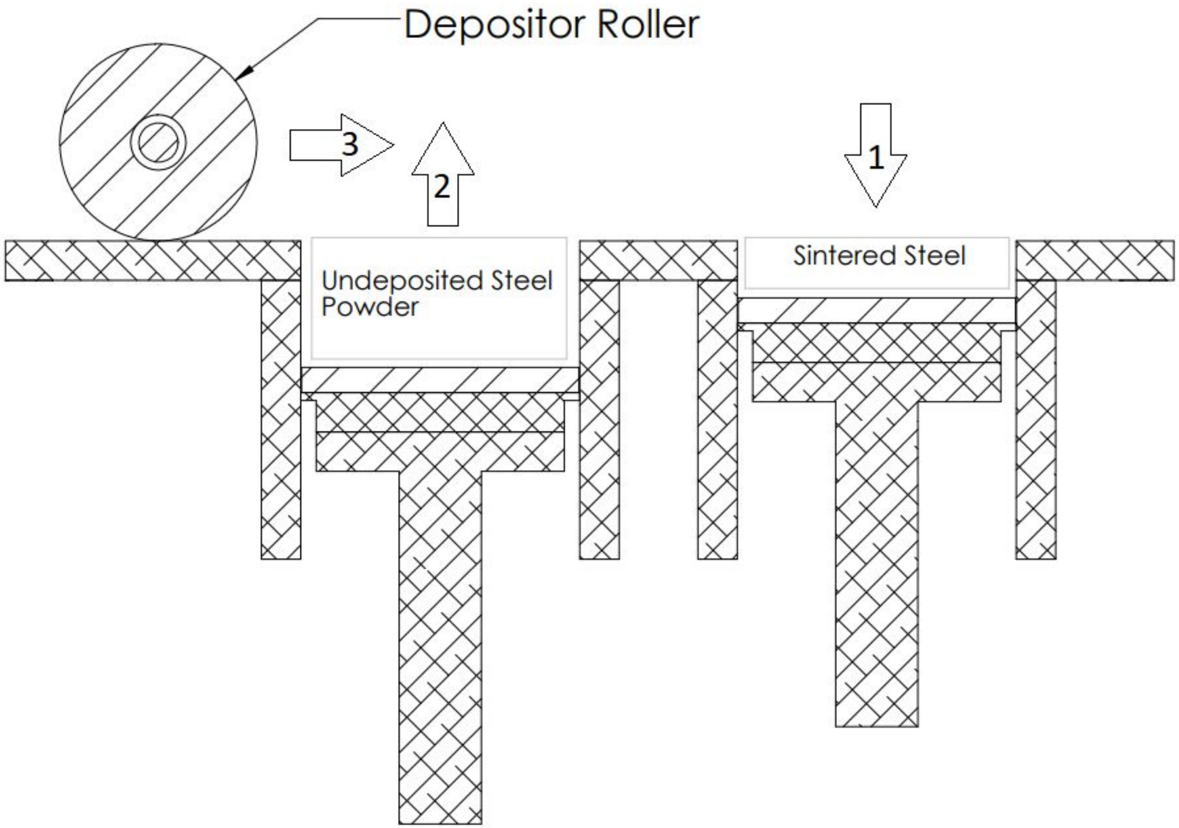
- Completed Milestones: Mechanical Design, Several Parts Ordered, Slicing Framework



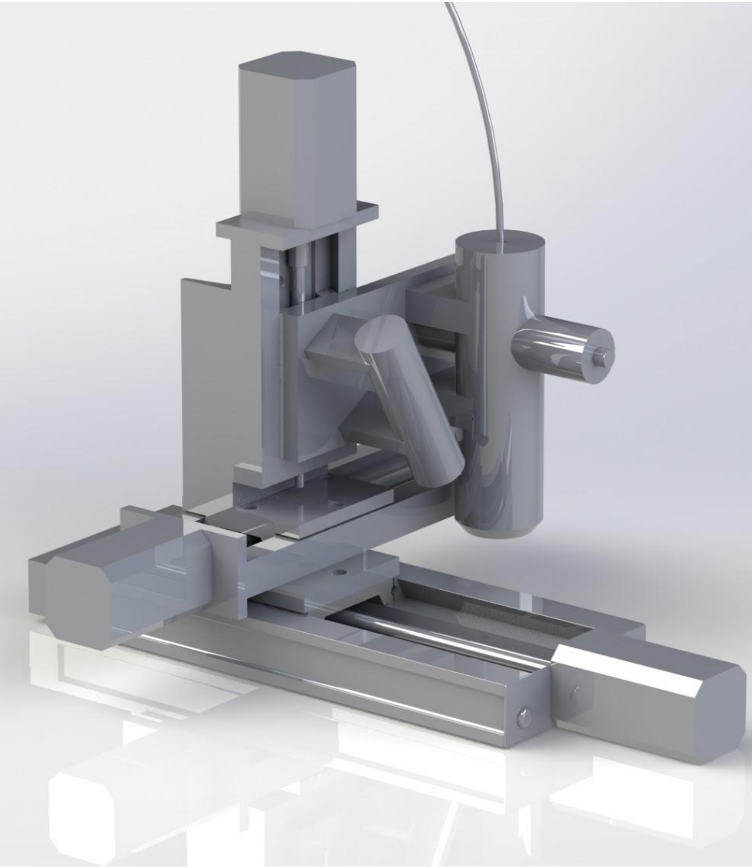
Functional Decomposition



Detailed Design: Deposit Powder Layer



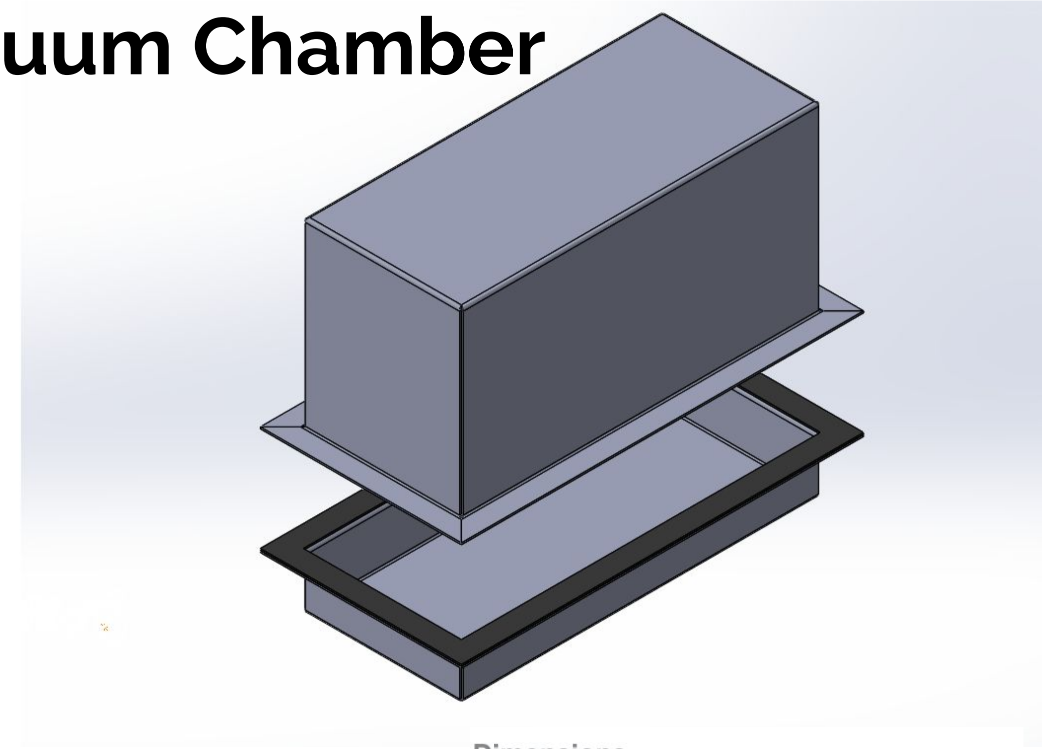
Detailed Design: Scan and Sinter Surface

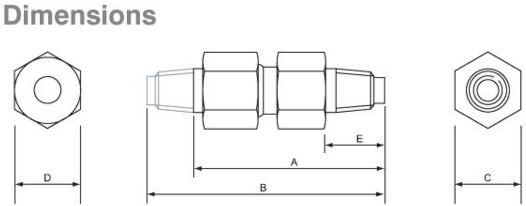


Detailed Design: Vacuum Chamber

Features

- Wire pass throughs for signals
- Pass throughs for fiber optics
- Pass throughs for Oxygen Sensor
- Removable panel for accessibility





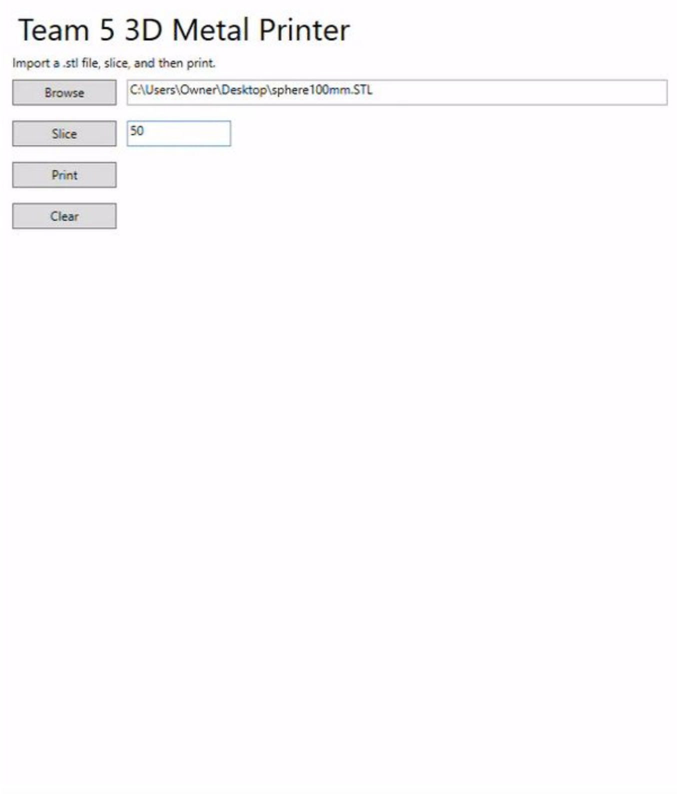
Detailed Design: Sensor Selection

- Internal Oxygen Sensor
  - AMI 2001LC Trace Oxygen Analyzer
  - Required sensitivity on ~1000ppm level
- External Oxygen Alarm
  - BW Honeywell Clip 2.0
  - 19.5%/volume alarm
- Internal Pressure Sensor
  - Seeed Studio Grove High Accuracy Barometer

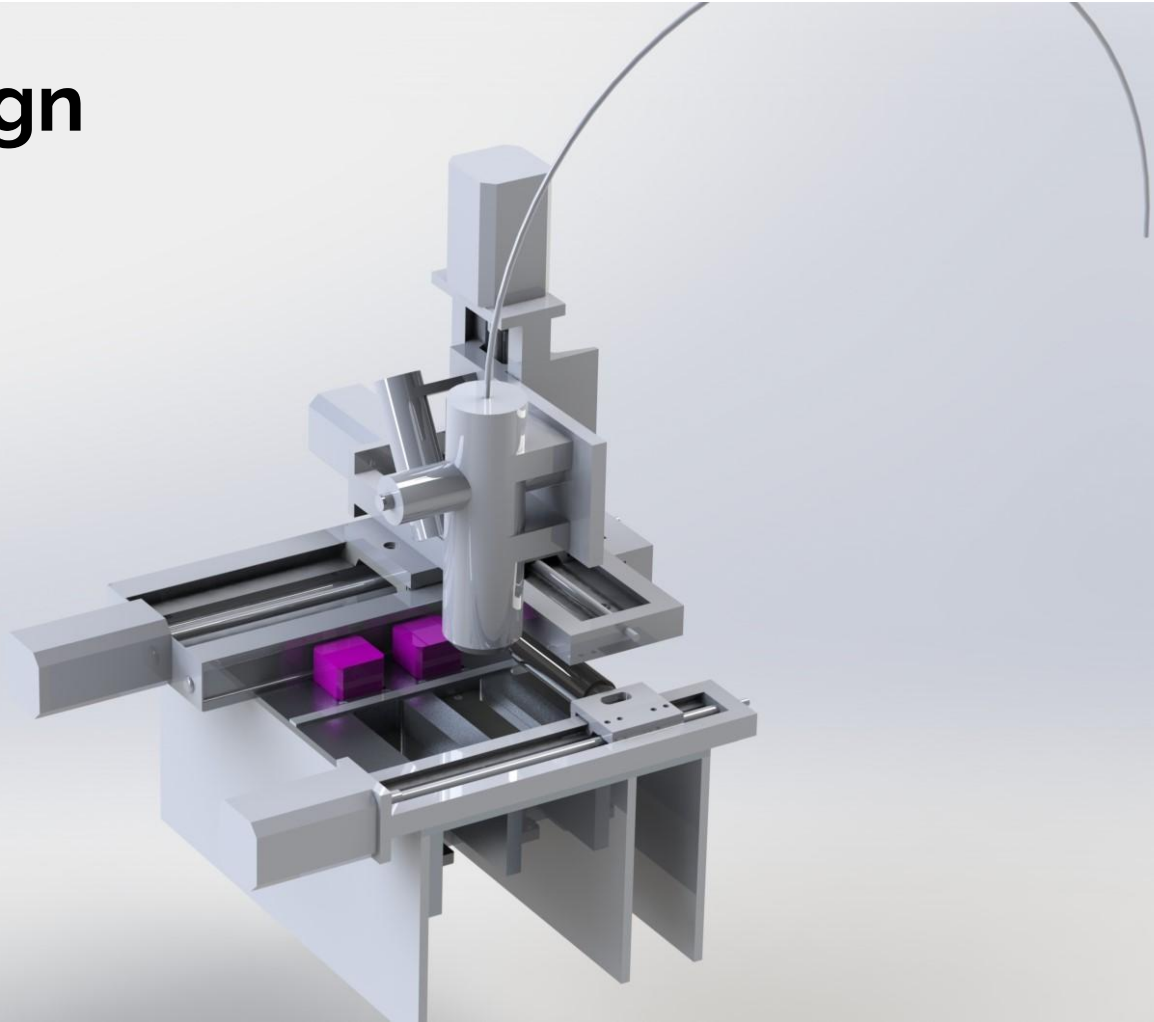
Internal oxygen sensor. Source: AMI user manual

Detailed Design: Slicing STL files

Current GUI software:



Overall Design



HW/SW/Technology Platforms used

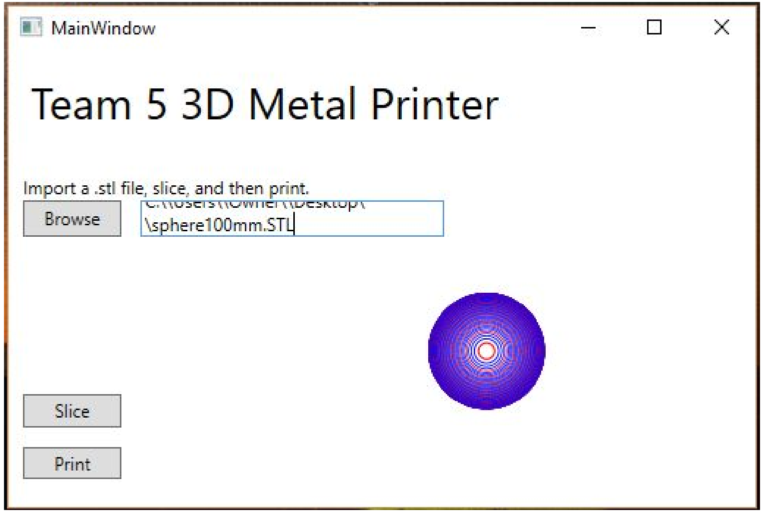
- GUI software - C#, Visual Studio, STL file input, g-code
- Stepper motor controllers - Velmex hardware, serial commands
- Sensor acquisition and communication - Arduino
- CAD software - Solidworks, GrabCAD

Testing and Evaluation

- Broken into two parts
  - Software testing plan
  - Hardware/system testing plan
- Performance metric testing
  - Quantitative and qualitative metrics

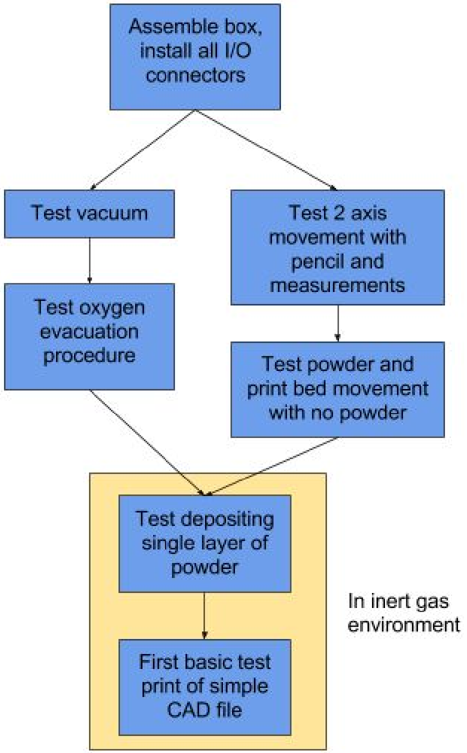
Software Testing Plan

- Software broken up into testable pieces
  - CAD -> Slices -> Line Segments -> Grid -> g-code -> Serial Commands
  - Each piece tested independently
  - Visualization software
- Testing also done at unit level
  - Not formal unit tests yet



Hardware/System Testing Plan

- Several layers of precedence
- Plan to start as soon as hardware ready

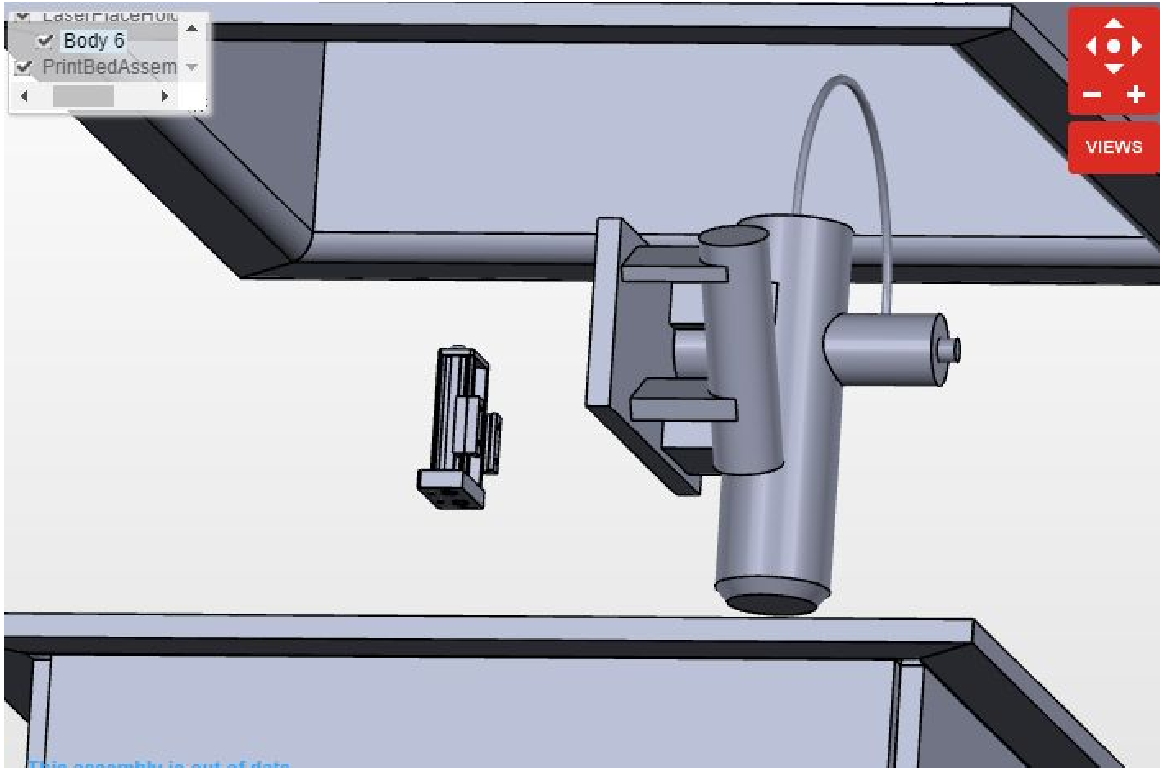


Performance Testing

- Key metrics:
  - Ease of use
  - Safety
  - Ease of modification/adaptation
- Other metrics:
  - Print speed
  - Print accuracy

Prototyping

- Current prototyping done in CAD software
- Allows early detection of interference, component interaction



Task distribution/Team composition

- Kevin Oran:
  - Responsible for Solidworks and majority of mechanical design, research
- Caleb Toney:
  - Responsible for sensor integration, research, wiring/connectors
- Jett Ptacek:
  - Responsible for software design and integration, research
- Ben Pieper:
  - Responsible for software design and integration, research
- Rachel Shannon:
  - Responsible for sensor integration, research, wiring/connectors

Project Status

- Hardware:
  - Hardware design finalized
    - Enclosure to be manufactured by January
    - Lasers, sensors recently arrived
    - Velmex slides and motors quote requested
- Software:
  - Early GUI complete
  - Slicing algorithm complete excluding edge cases

Moving Forward

- Hardware:
  - Design finalized
  - Assemble printer upon receipt of parts
- Software:
  - Refine slicing algorithm
  - Refine UI
  - Software Implement 2-axis stepper motors
  - Software implement powder and supply beds, roller
  - Software implement sensors and alarms
- Testing:
  - Extensive testing of hardware and software implementations

Questions?