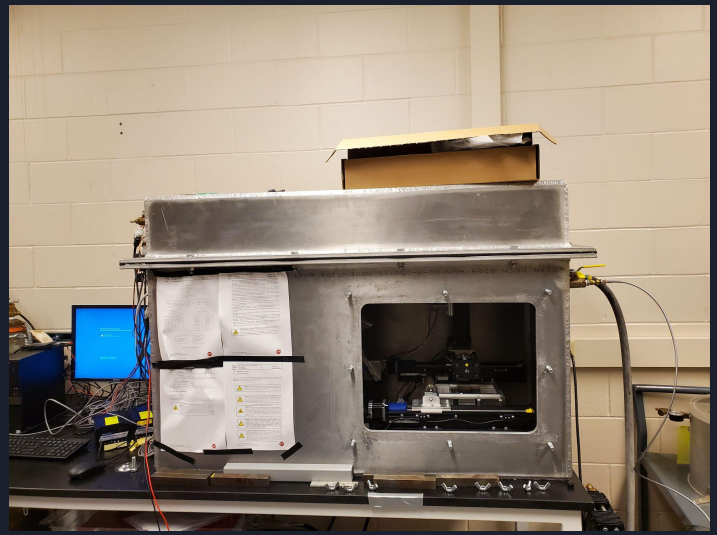
Metal Powder Bed Printer

Group SDDEC21-11: Colin Firth, Chris Johannsen, Tary Todd, Aaron Martin, Dale Young, Addison Ulrick

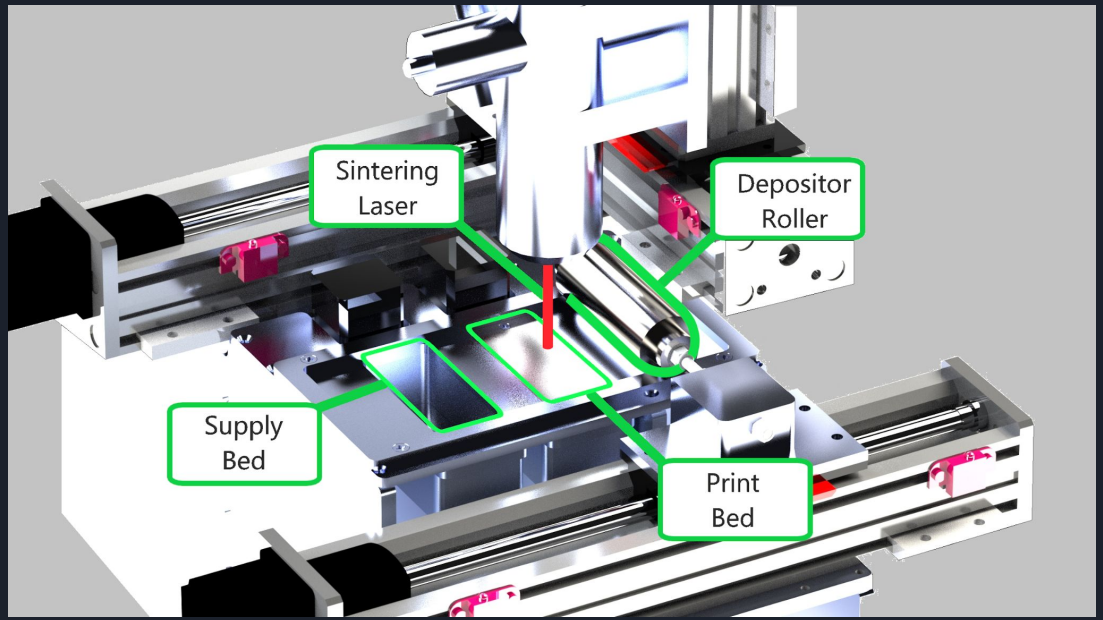
Advisor: Prof. Timothy Bigelow

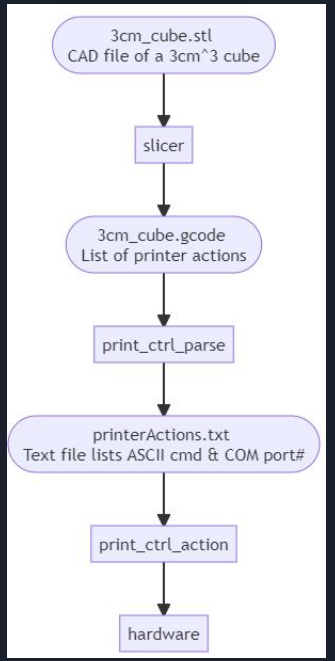
Project Statement

- The goal of this project is to get Iowa State's custom made metal powder bed 3D printer to print metal cubes by the end of 2nd semester. This project is for Professor Bigelow's lab in Applied Science Complex II for NDE research.



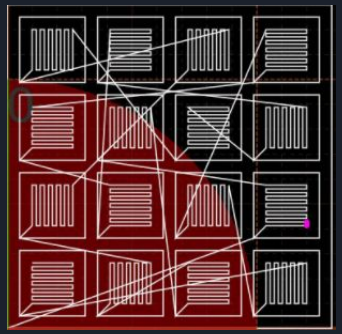
Conceptual Sketch

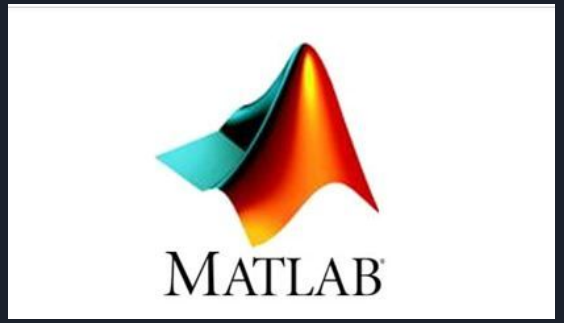




Functional Requirements

- Refactor and convert source code from C# to Matlab
- Adjustable voxel count
- Create a defect at a specific location in metal cube
- Be able to control the sintering laser
- Be able to print 3 cm^3 metal cubes



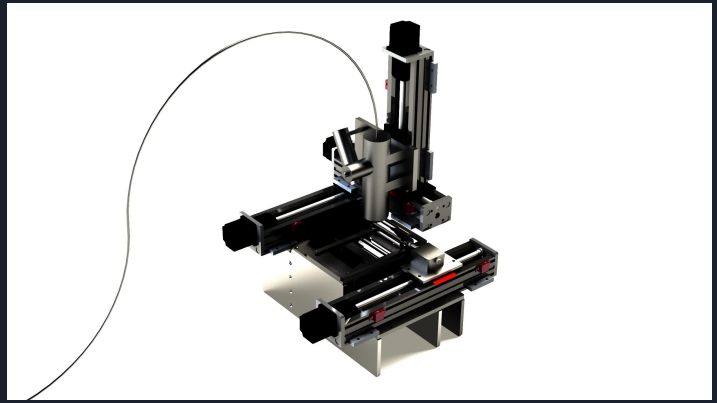


Non-Functional Requirements

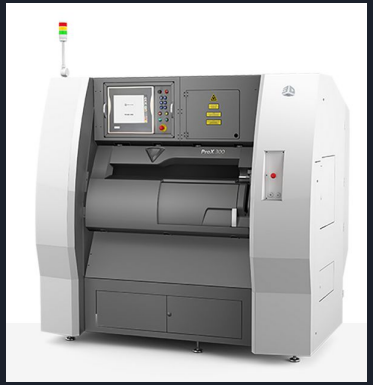
- Printer should be ability to print at an appropriate speed
- Laser will operate in safe conditions such as at an optimal temperature
- Printer will function reliable and under safe conditions generally
- Roller will move at an appropriate speed and uniformly spread out powder in the powder bed

Constraints

- Hardware systems for the project were already purchased in lab at ASCII
  - Had to work with the hardware given
    - Velmex motors
    - Laser system
    - Sensor system
- Software systems to be done Matlab



Market Survey



- Previous groups did some legwork
  - Similar printer in another lab on campus
    - Much larger (10x10x12” vs. 4x4x8cm)
    - Laser system used different mechanism (mirror vs. 2 axis motor)
  - Similar system from NDE paper in NIST journal[1]
    - Focus of paper is specific NDE technique, not the printing itself

- Hardware constraints such that we had to work with what was given
  - Outside work was too general or too specific to be very applicable

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4487290/

Potential Risks & Mitigation

- Safety Risks:
  - Nitrogen Environment
  - Aluminum Powder (inhalation risk)
    - Monitor sensor system
    - Use respirators
  - High Power Laser
    - Seal chamber
    - Follow training
- Project Progress Risks:
  - Components of project are dependent on each other
    - Communicate progress

Resource/Cost Estimate

- There should be zero cost for software related purchases
  - Free MATLAB student license
  - Free LabView student license
  - Microsoft Visual Studio: Community Edition is free for everyone
  - Velmex drivers are also free
- There should also be zero cost for hardware related purchases
  - Powder Bed Metal Printer was built by Dr. Bigelow and a previous Senior Design Team
  - Arduino was also purchased by a previous design team
- A $17 dollar purchase was made to replace a video adapter for the chamber camera

Project Milestones & Schedule

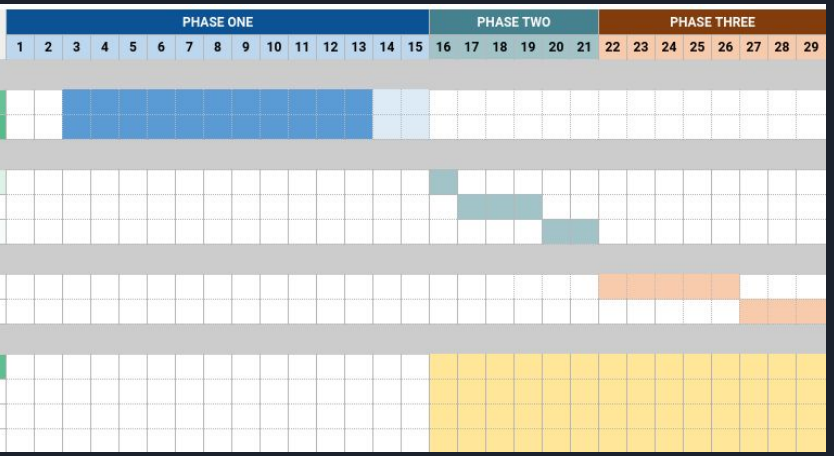
2.4 Project Timeline/Schedule

Action/Task	Completion Date
Finish porting code	5/7/2021
Be ready to test working sensors	5/7/2021
Finish laser control	12/17/2021
Ensure sensors are working	12/17/2021
Print metal cube	12/17/2021

Table 1: Project Timeline/Schedule

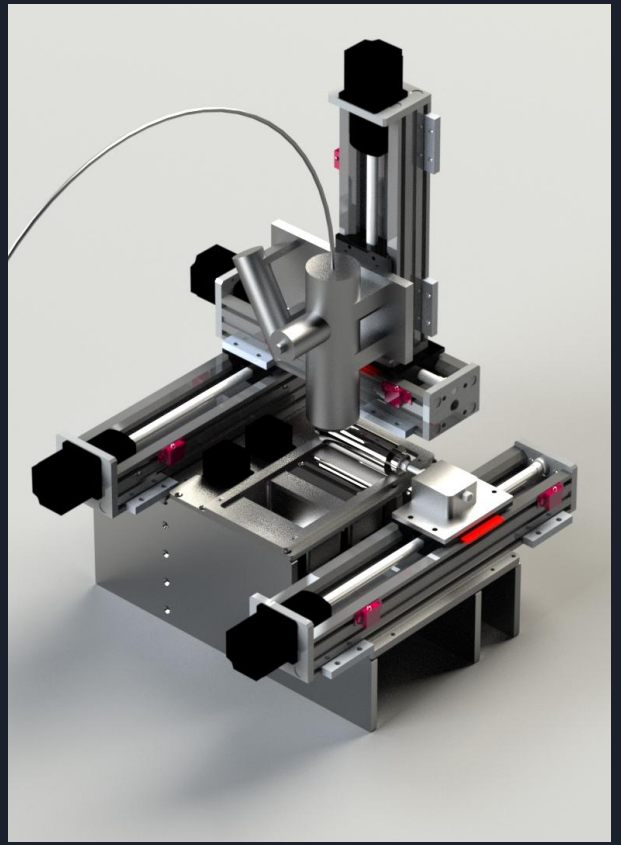
Project Milestones & Schedule

	TASK TITLE	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Port C# To MATLAB**				
1.1	Slicer Program	2/15/21	5/3/21	12	90%
1.2	gcode to VXM commands	2/15/21	5/3/21	12	100%
2	**Implement Laser/Sensor Control**				
2.1	Lab Safety Training	8/23/21	8/30/21	1	20%
2.2	Integrate Sensors	8/30/21	9/20/21	3	0%
2.3	Commands to control laser	9/20/21	10/4/21	2	5%
3	**Print 3D Metal Cube**				
3.1	Fully print 3D cube	10/4/21	11/1/21	5	0%
3.2	Print 3D cube with defect	11/1/21	11/22/21	3	0%
4	**Optional Objectives**				
4.1	Slicer GUI	8/23/21	11/22/21	14	95%
4.2	3D printer GUI	8/23/21	11/22/21	14	0%
4.3	Extra infill patterns	8/23/21	11/22/21	14	0%
4.4	Generalize slicer program	8/23/21	11/22/21	14	0%



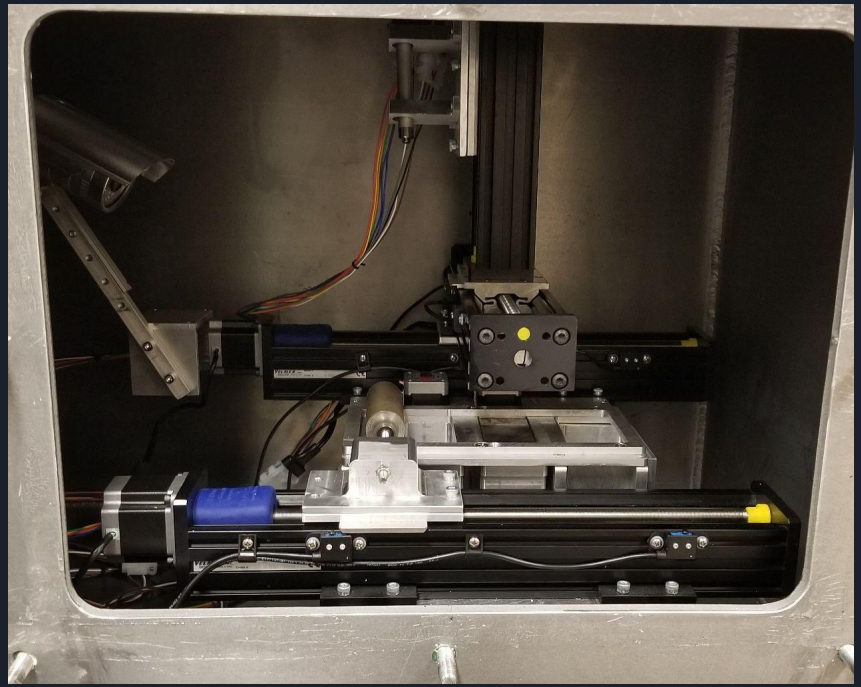
Test Plan

- Manual Unit and Integration Testing
  - Slicer and Printer Control
  - Manual verification of plaintext output files
    - Testing G-code with toolpath simulation
    - Testing Motor Code with Velmex COSMOS
- System Usability Testing
  - In-person verification at ASC2
- Future Testing Plans
  - MATLAB Unit Tests



Hardware Platforms

- Laser Operations
  - SPI Lasers 1064 nm 200W
  - 700 TVL Color Day/Night Camera
- Motors
  - 6x Stepper Motors
  - 1 step = 0.00025 mm
  - Velmex Motor Controllers
- Sensors & Safety
  - Arduino Uno
  - SEEED Studio Grove High Accuracy Barometer
  - AMI 2001LC Trace Oxygen Analyzer

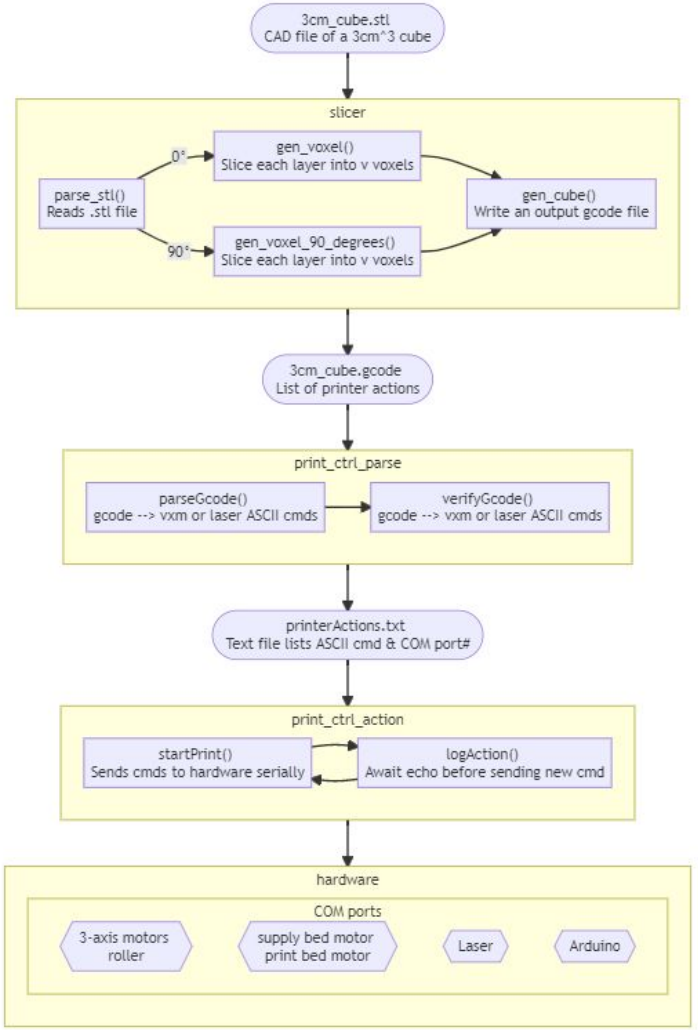


Software Platforms

- Previous:
  - C# in Visual Studio
  - NI LabView
  - Velmex COSMOS
- Current:
  - MATLAB 2020
  - C/C++ for Arduino
- Other:
  - .gcode
  - VXM Motor Control Commands
  - SPI Lasers Control Commands
- SPI Lasers PrismView

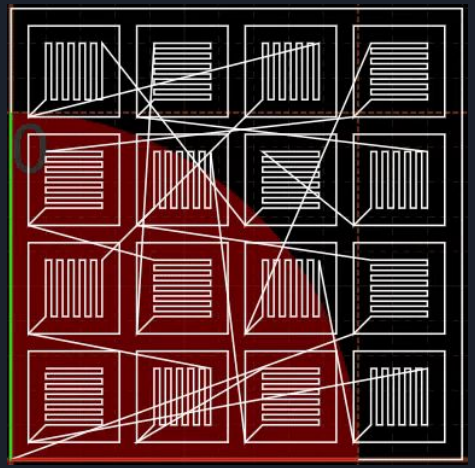
Detailed Design: Overview

- Text-based UI:
  - MATLAB Console
- 3 Functional Modules:
  - Slicer
  - Printer Control
  - Laser Control



Detailed Design: Slicer Module

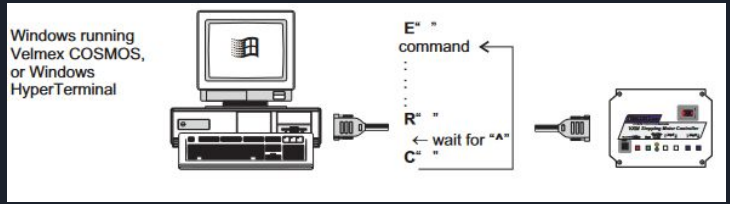
- Slicer Program
  - 3D object/Cube specs → CNC toolpath
- .gcode file
  - G01 - Linear Motion (mm)
  - M200 - Layer Change Operation
  - M201/M202 - Laser On/Off Command
- Infill Pattern
  - 0° & 90° Checkerboard
  - Randomized Voxel Print Order

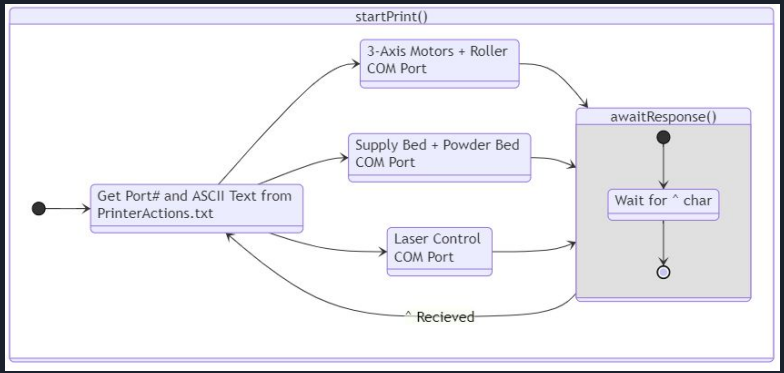


```
Width: 30 Length: 30
M200 0.1
M201
G01 Z0.0000
G01 X0.0000 Y0.0000
G01 X13.0000 Y0.0000
G01 X13.0000 Y13.0000
G01 X0.0000 Y13.0000
G01 X0.0000 Y0.0000
G01 X9.8750 Y3.6250
G01 X12.5000 Y3.6250
G01 X12.5000 Y6.2500
G01 X9.8750 Y6.2500
G01 X9.8750 Y3.6250
;0 degree voxel,3,1,0
M201
G01 X10.3750 Y4.1250
```

Detailed Design:
Printer Control Module

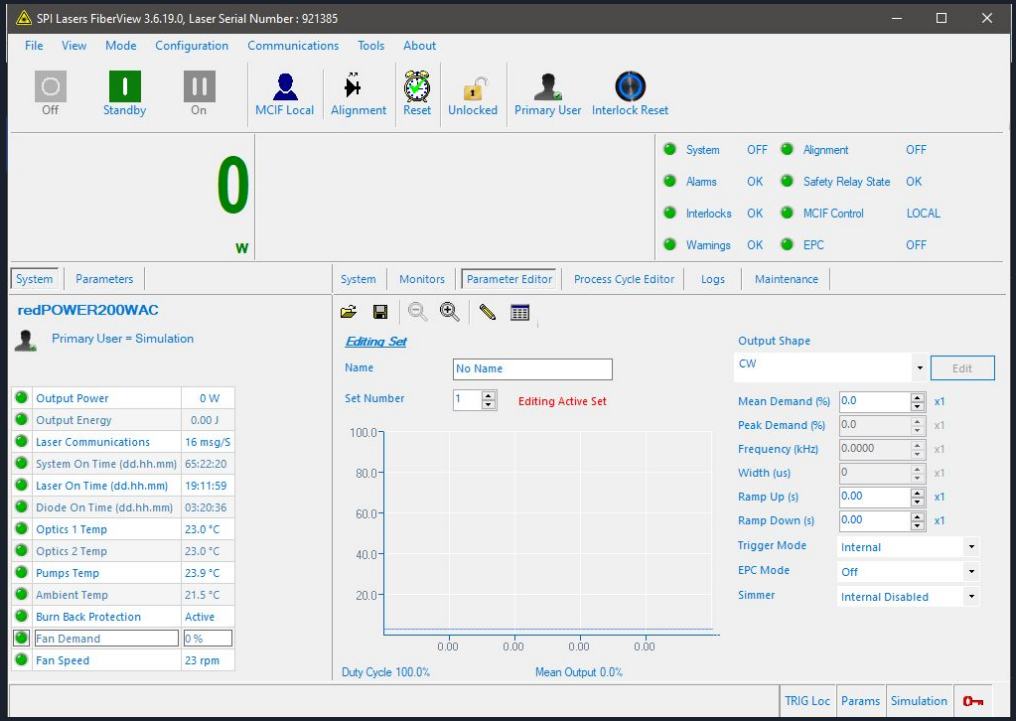
1. Map gcode to motor or laser cmd
   - `G01 X1.0 Y-1.0`
   - `"axis,  F, C, (I2M 400, I3M-400), R,\r"`
2. Write to corresponding COM Ports
   - PrinterAction Object → Text to send to a serial port
   - Await response



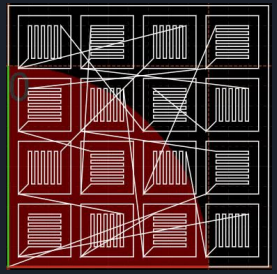


Detailed Design:
Laser Control Module

- Sensor Suite powered by Arduino
  - Chamber O2 Sensor
  - Chamber Barometer
  - Room O2 Sensor
- 200W Sintering Laser
  - FiberView Software
  - Serial Port Communication
- Chamber Camera

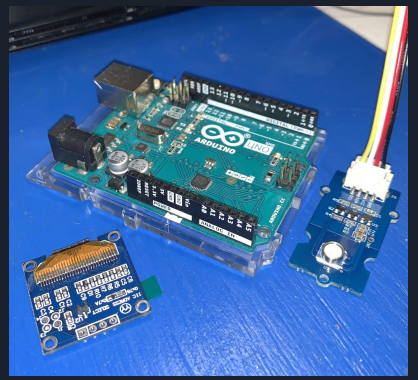


Prototype Implementations



Prototype Voxel Tracing

- Initially we were unsure on what pattern to use when Voxel tracing, whether it be diagonal tracing, straight-line tracing, etc.
- The team decided on straight-line tracing as this was the main recommendation from Dr. Bigelow.



Sensor Prototyping

- As work on the laser progresses, the need for new and updated sensors may arise.
- In order to ensure that the sensors will work in tandem with the printer, prototyping and tests will have to be done with each additional sensor.

Current Project Status

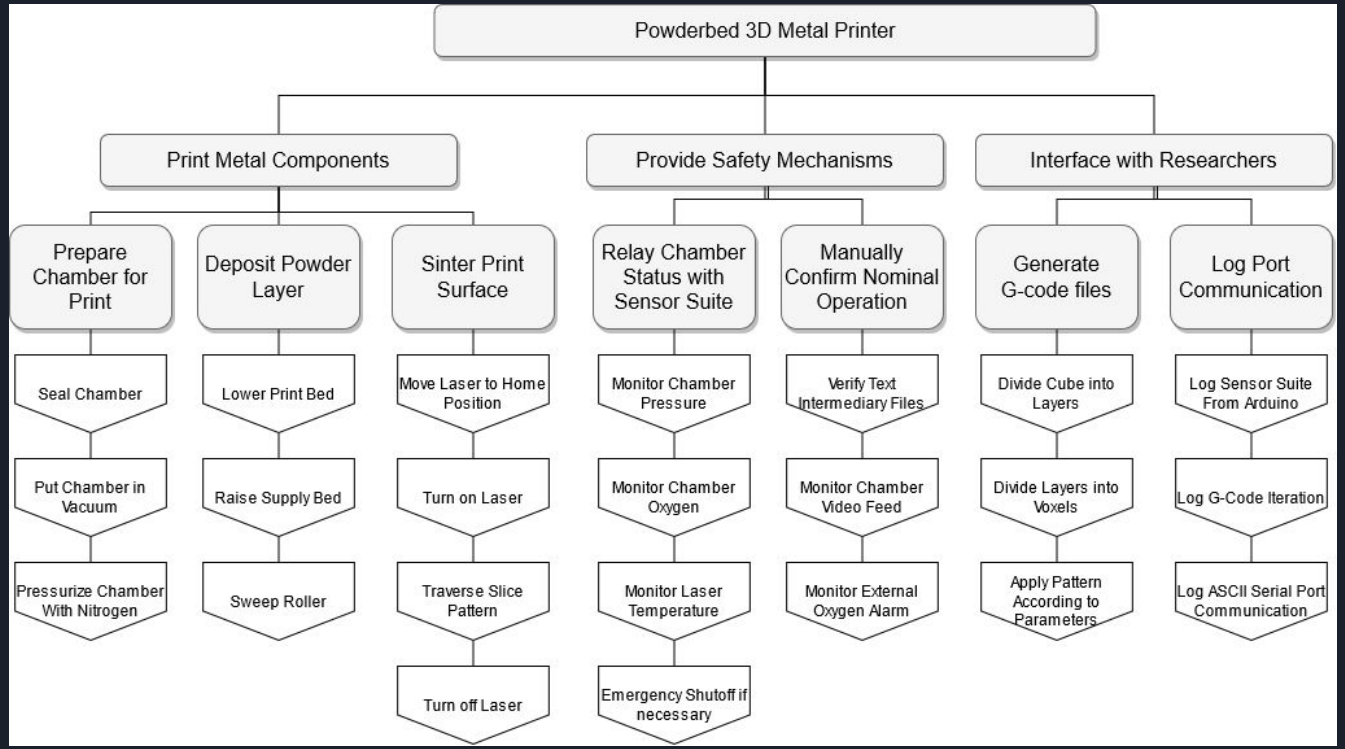
Completed Tasks:

- Code translation from C# to MATLAB
- Motor functionality with voxel algorithm
- Systems for pressure and temperature sensor

Tasks To-Do:

- Integrating new code with the laser system
  - Ensuring that the laser reads and runs with our inputs
- Finish required training to properly use the laser unsupervised

Functional Decomposition



Project Member Contributions

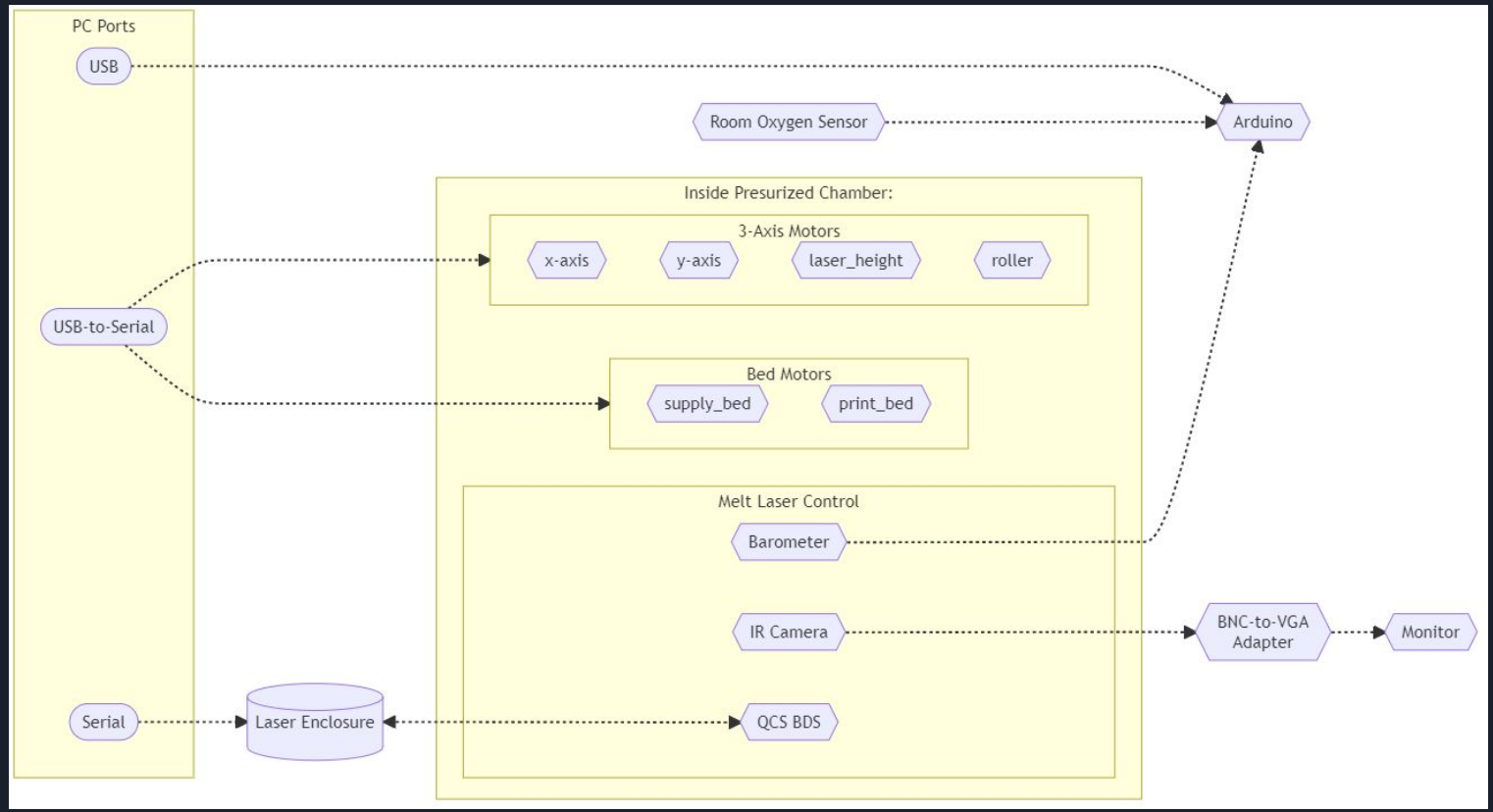
- We divided up our team into three separate groups of two, in order to focus on individual aspects of the project all at once.
- The three teams we chose, which follow our functional modules, are:
  - Printer Control: Aaron Martin, and Tary Todd
  - Slicer and Motors: Colin Firth, and Chris Johannsen
  - Laser and Sensors: Addison Ulrick, and Dale Young

Plan for Next Semester

- As we stand, we have full functionality of the motors and sensor systems
- The main plan going forward is to learn more about how to function the laser system
- Following that, we plan on combining everything together, and printing a cube
- Optional objectives include creating GUIs for the systems, generalizing the slicer system, and being able to print more than just cubes.

Q/A

Hardware Overview



Chassis Rendering