Team 19
CNT Reinforced Ceramics 3D Printer
Final Presentation

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Contents

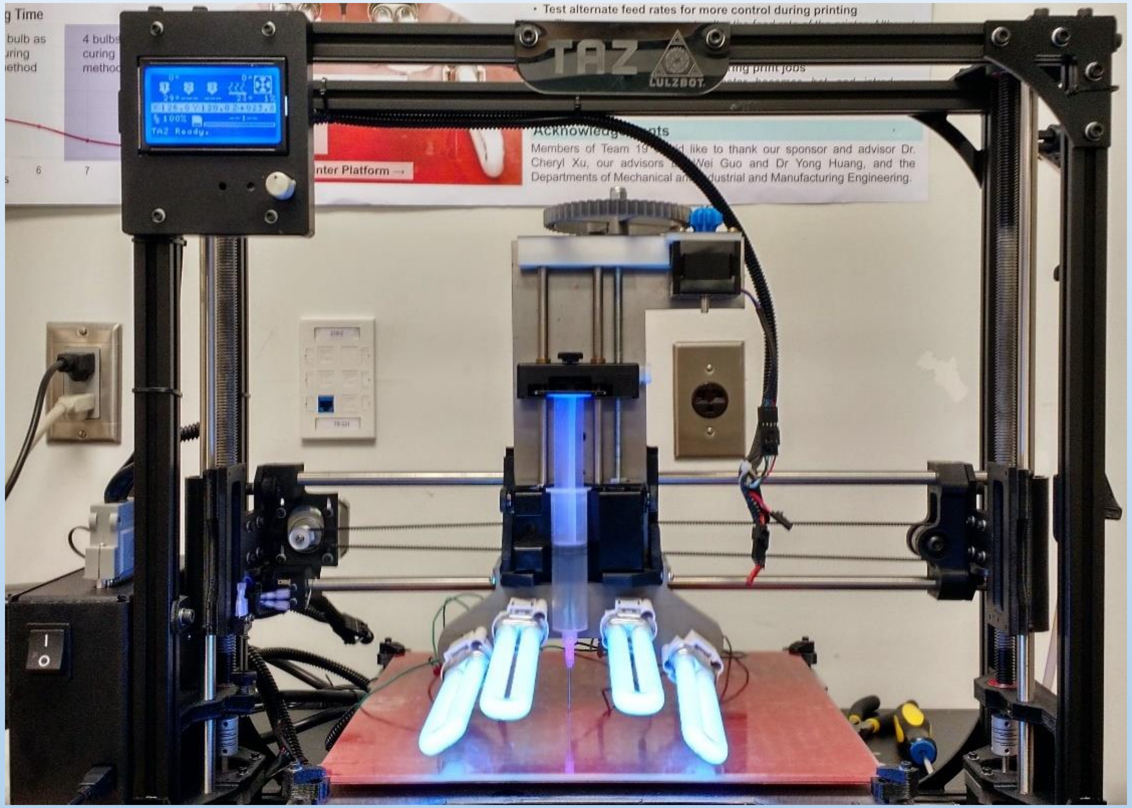
Motivation

- **Sponsor funding contingent on results**
  - Start up funds for project
  - Used to gather funds in future
- **Materials science advancements**
  - New material for advanced applications
  - Applications follow new materials
- **3D printer advancements**
  - Outdating previous industry manufacturing methods

Sonya Peterson

Objective

Develop a new manufacturing process for a liquid ceramic-polymer material reinforced with carbon nanotubes by **retrofitting a 3D printer** with both an **extrusion system** capable of depositing the material, and a **curing system** which will solidify the material for further pyrolysis.

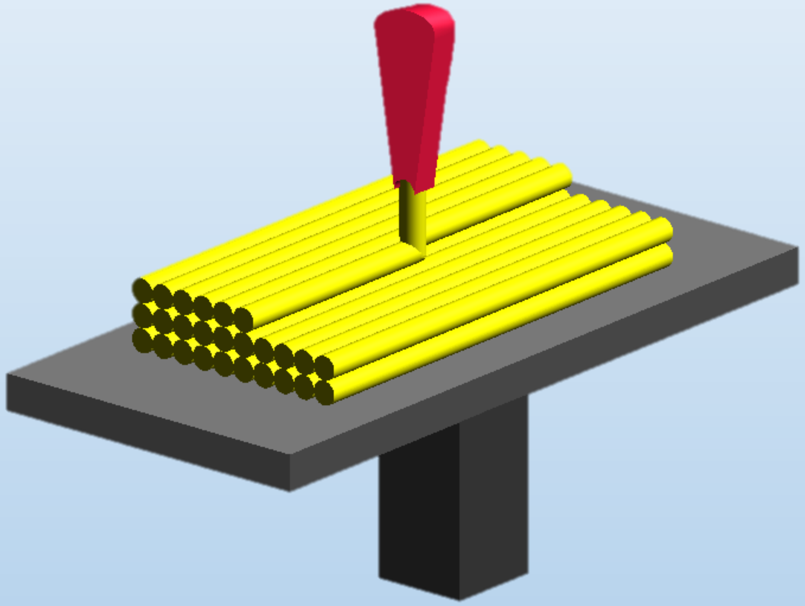


Scope

- Modify existing 3D printer to meet customer specifications
- Fabricate custom hardware
- Install support systems
- Develop optimal material composition
- **Not** required to build or assemble base 3D printer
- **Not** required to develop new software
- **Not** responsible for post-processing of material
- **Not** responsible for performing material property tests

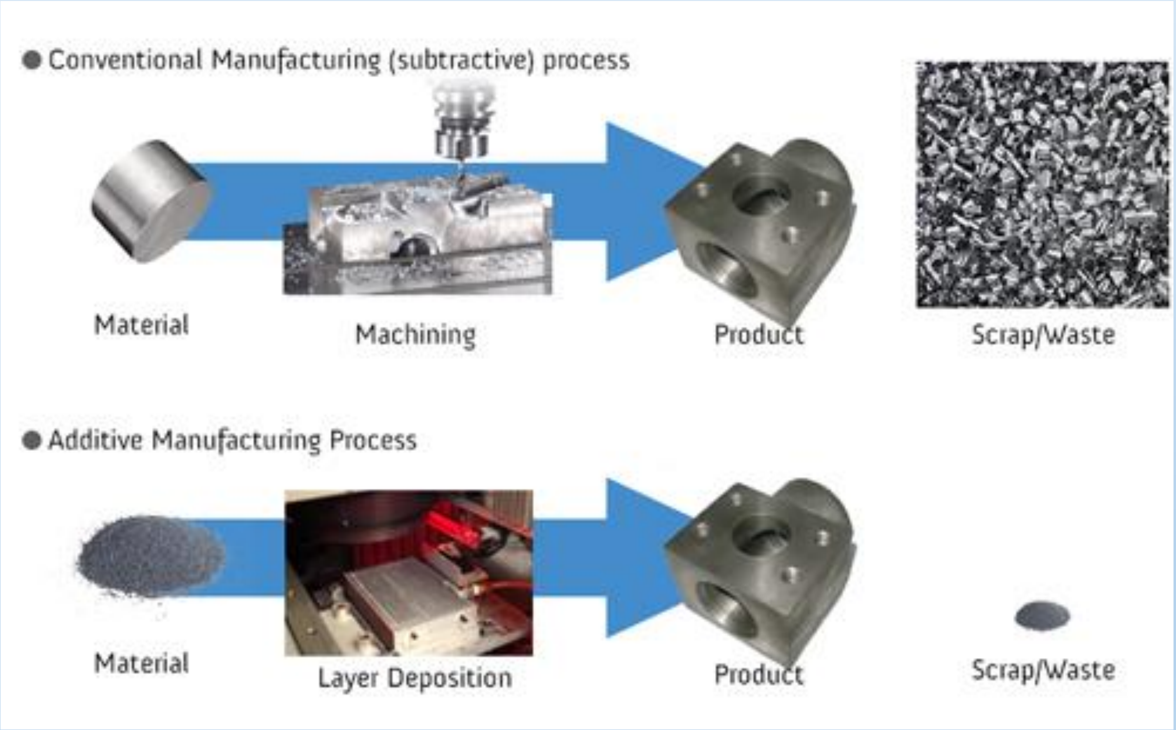
Design Requirements

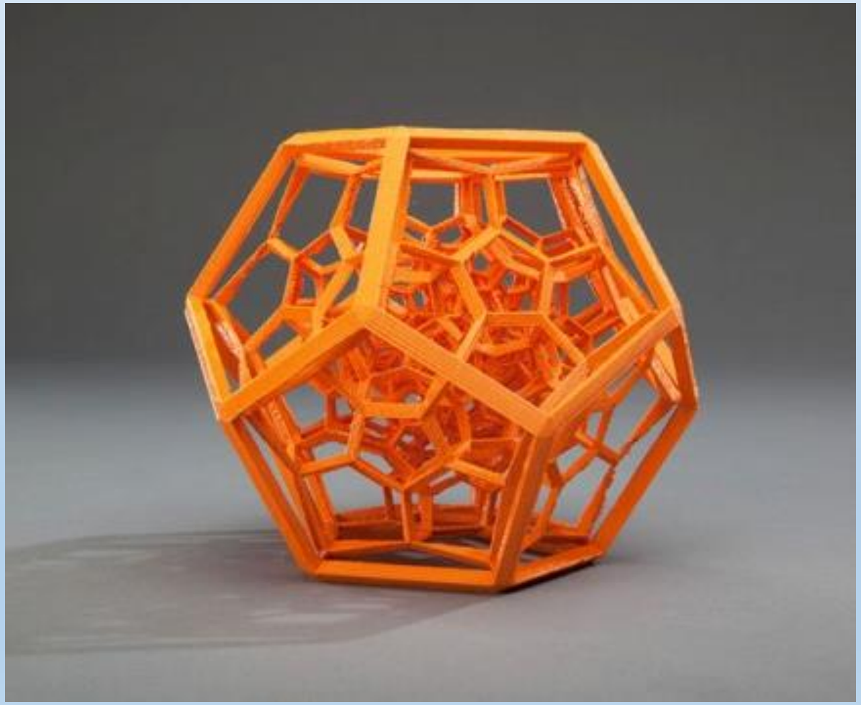
- Minimize curing time
- Maximally use commercial components
- Object must consist of multiple layers
- Printer should be durable
- The material requires an extrusion type process as opposed to other 3D printing methods such as sintering or resin printing



Background 3D Printing

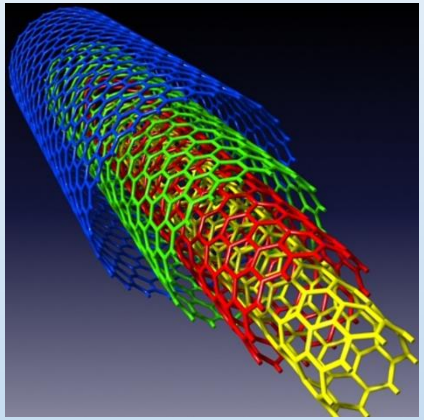
- Additive vs traditional manufacturing

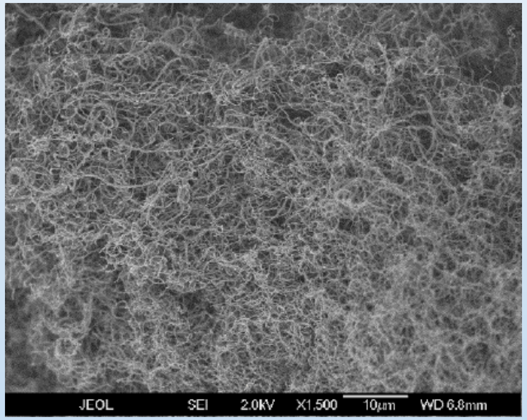




Background Carbon Nanotubes

- Carbon nanotubes (CNTs) are one atom thick layer of carbon atoms rolled into a cylinder
- Increases strength, elasticity, and electrical and thermal conductivity
- Applications in aero and astrospace, defense, and automotive industries
- Project use: improve properties and add viscosity

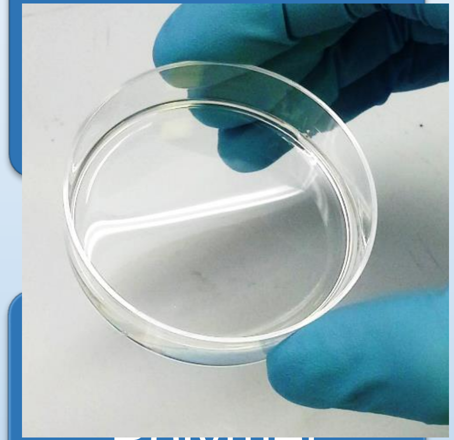




Basak Simal

Background Polymer Ceramics

- Polymer with inorganic fibers within the matrix
- Curing Liquid → Solid at ~200° C
- Pyrolysis Polymer → Ceramic at 1000° C
- Increased electrical and thermal conductivity, corrosive, abrasive, oxidative, and crack and creep resistant
- Applications: strengthening and reinforcing ceramic matrices and high temperature coating



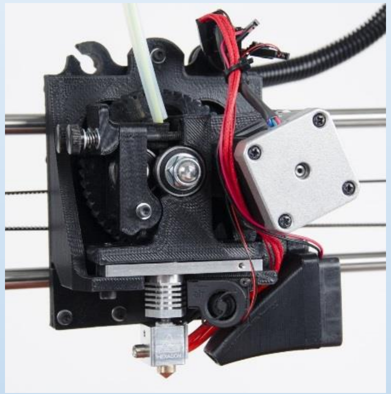
TAZ 4

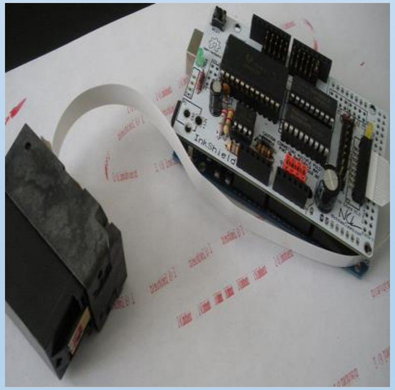
- Established firmware & hardware
- Extruder head clearance
- Open-source software
- Sponsor preference

Ernest Etienne

Design Process
Extrusion System

- Retrofit TAZ 4’s standard extruder head
- Concept Generation
  - Ink Shield
  - Nozzle
  - Syringe Pump
- Syringe pump superior extrusion method

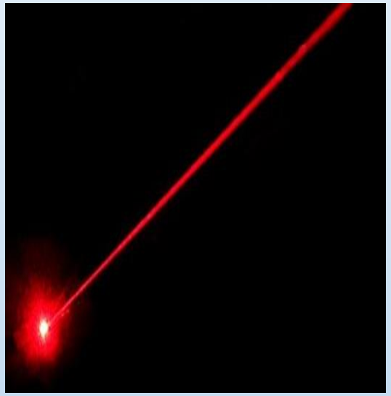




Design Process

Curing System

- Expand TAZ 4’s capabilities
- Concept Generation
  - Heat
  - Laser
  - UV Cure
- UV Cure chosen for curing system



Experiments

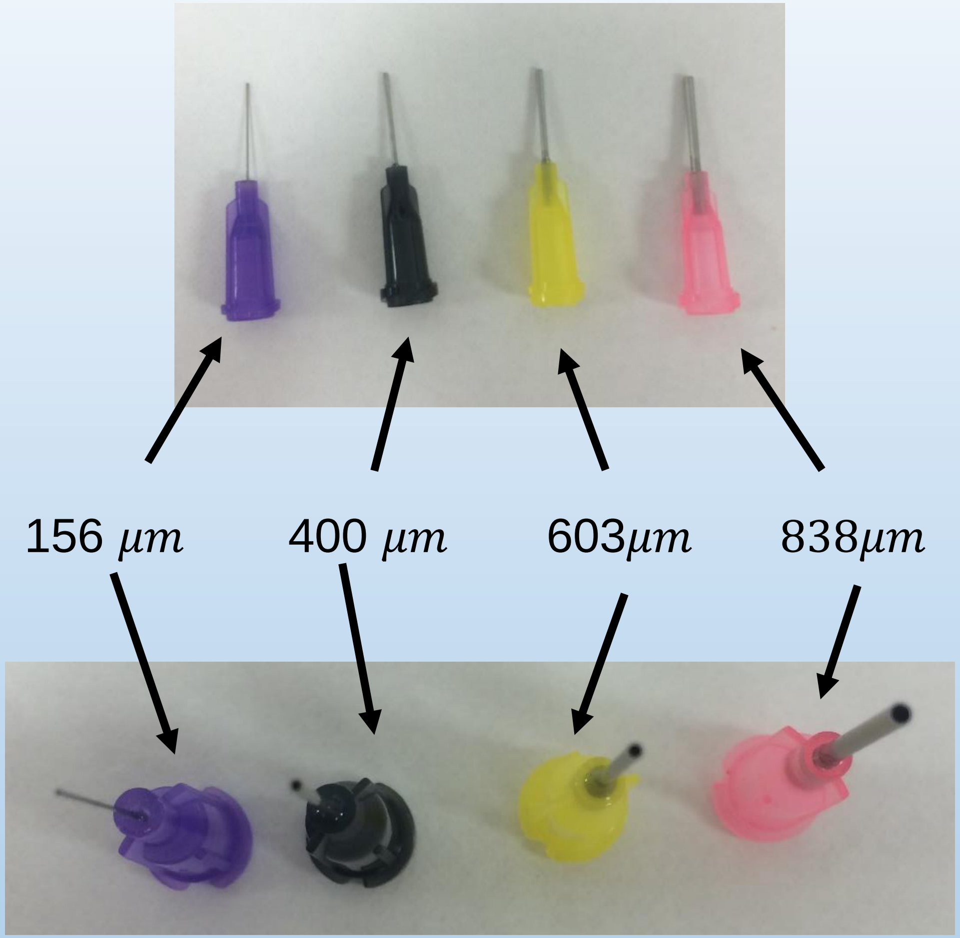
- Testing apparatus
- Constant
  - Needle distance from plate (3mm)
- Variables
  - Needle gauge
  - Print stage travel speed
  - Flow Rate (mL/min)

Experiments

- Extrusion of polymer mixed with carbon nanotubes
  - CNTs increase viscosity
  - Determining a desirable mass fraction of CNTs
  - Flow control

Experiments

- Initial gauge caused high pressure build up
- Increase resolution
  - Varying the needle gauge
  - 400 μm needle had best resolution ~0.8 mm line width



Experimental Formula

- Theoretical Calculation for viscosity
  - Poiseuille's Law
  - Linear force of pump 15-35lbs.
  - $\Delta P = \frac{8\mu LQ}{\pi r^4}$; $\mu = \frac{\Delta P \pi r^4}{8LQ}$
  - Viscosity determined 45,000 – 295,000 cP

Material	Viscosity (cP)
Water	1
Milk	3
SAE 10 Motor Oil	85-140
Pure Polymer	50-200
Honey	10,000
Ketchup	50,000
Sour Cream	100,000
Peanut Butter	250,000
Slurry with 2% CNT	45,000 - 295,000

Experiments

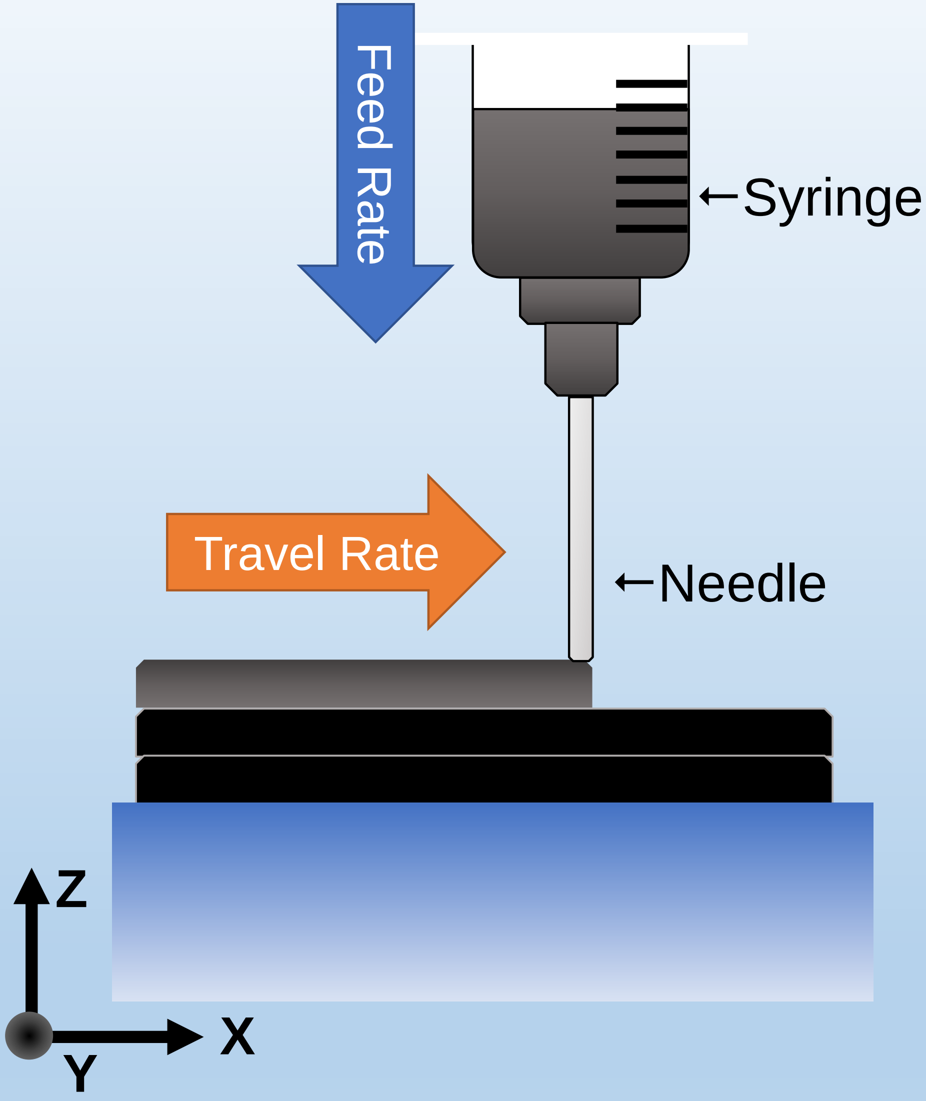
Conclusion

- 2% mass fraction of carbon nanotube added to polymer
- 400 μm produced best resolution
- Flow rate set constant 0.5 $\frac{mL}{min}$
  - Enhanced flow control

Functional Results

Speed and print time

- Liquid material printing possible at speeds of conventional printing
- Finer results can be had with speeds at 33-80% of maximum
- Lower speeds reduces inertia of print material, reducing error due to overshoot, allows for more consistent extrusion

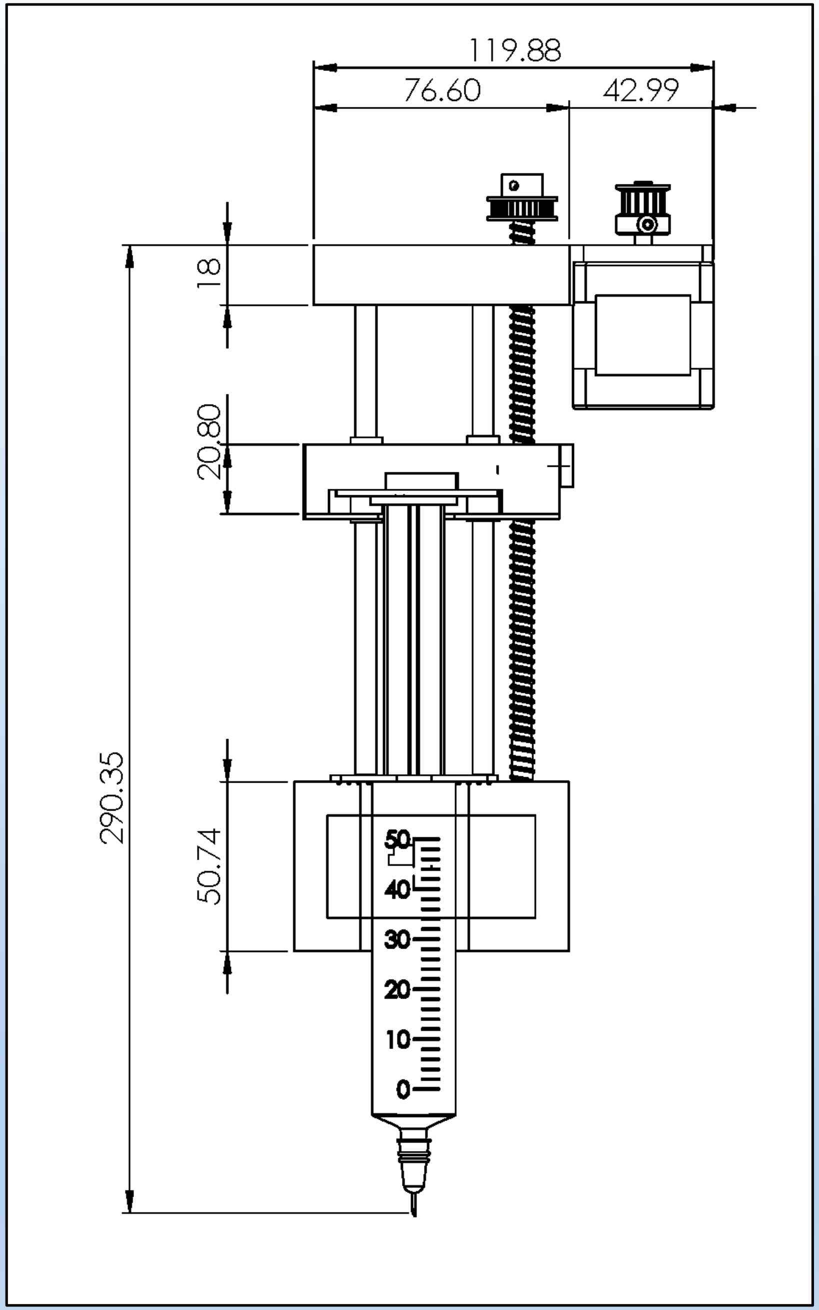


Cody Evans

Functional Results

Syringe Pump

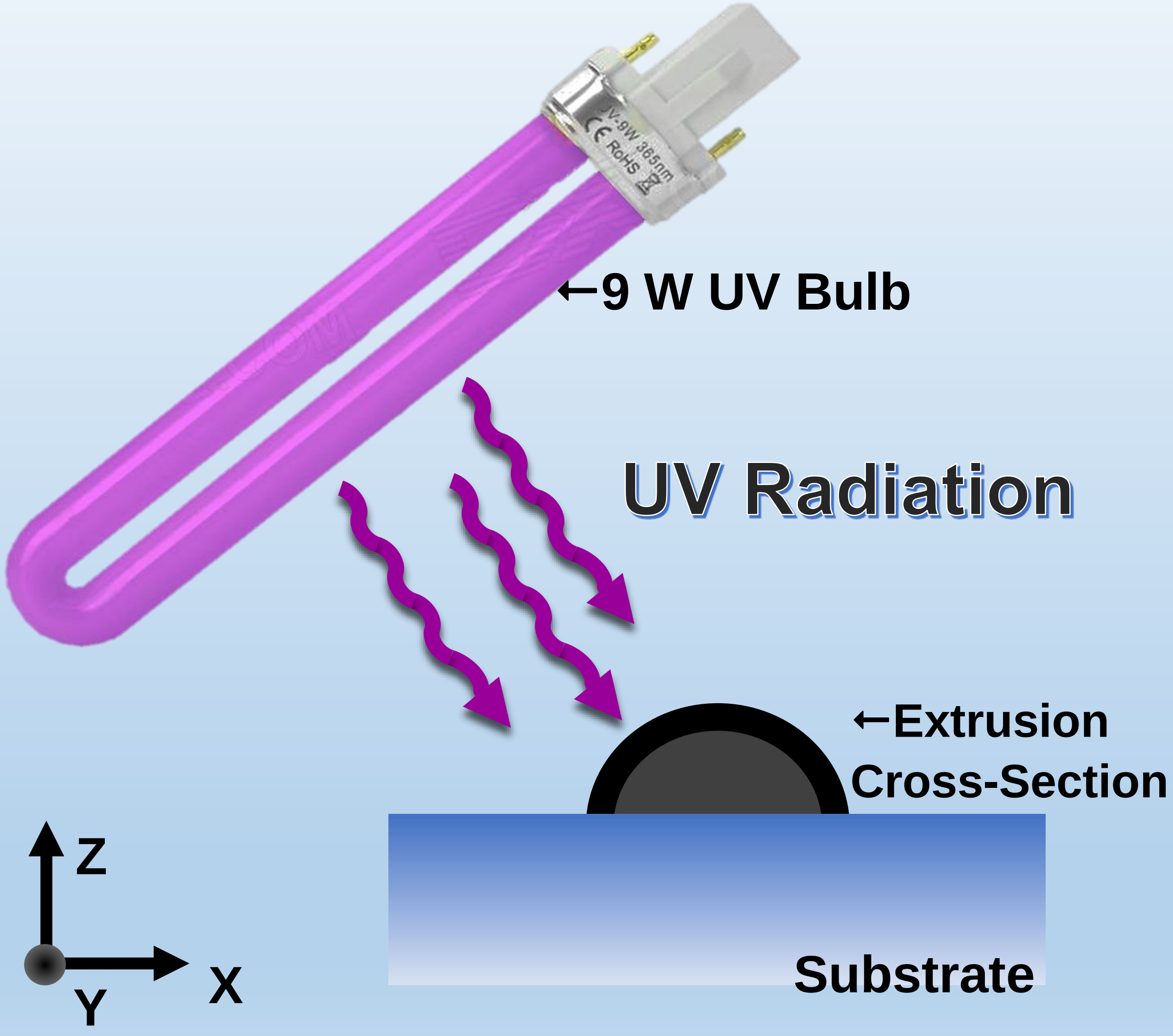
- Multiple syringe and needle combinations
  - Tested range: 400 to 838µm (micron) needles
  - Min. line width: 0.6mm
  - Min layer height: 0.5mm
- Allows user to premix material
- Variable flow rate control via stepper motor

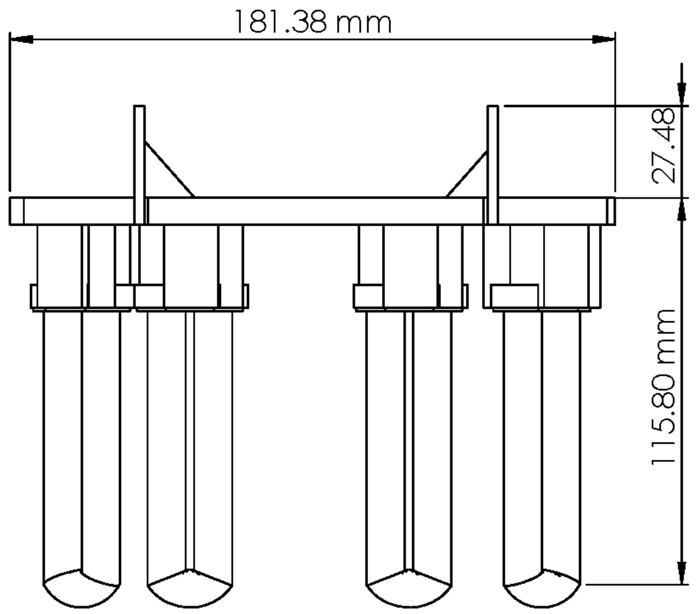


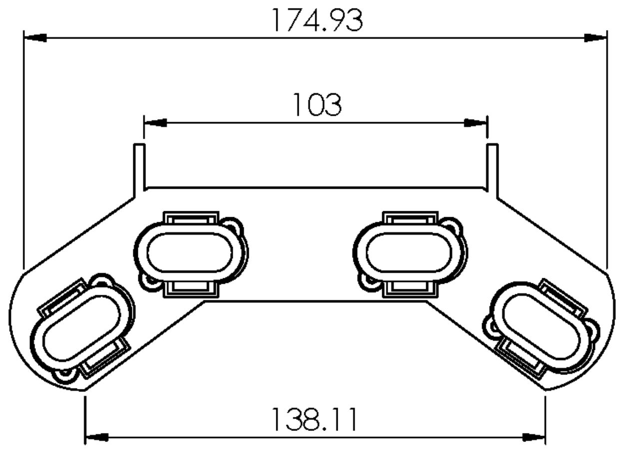
Functional Results

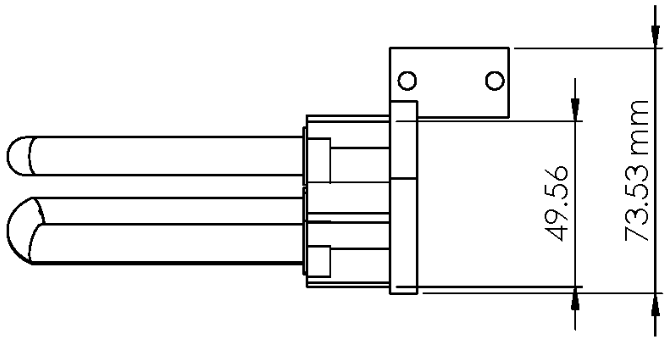
Ultraviolet Lamps

- Curing induced via UV radiation in the presence of UV sensitizer
- Layer solidification begins after 2-3 minutes
- Layer fully cures in 10 minutes




181.38 mm
27.48
115.80 mm


174.93
103
138.11

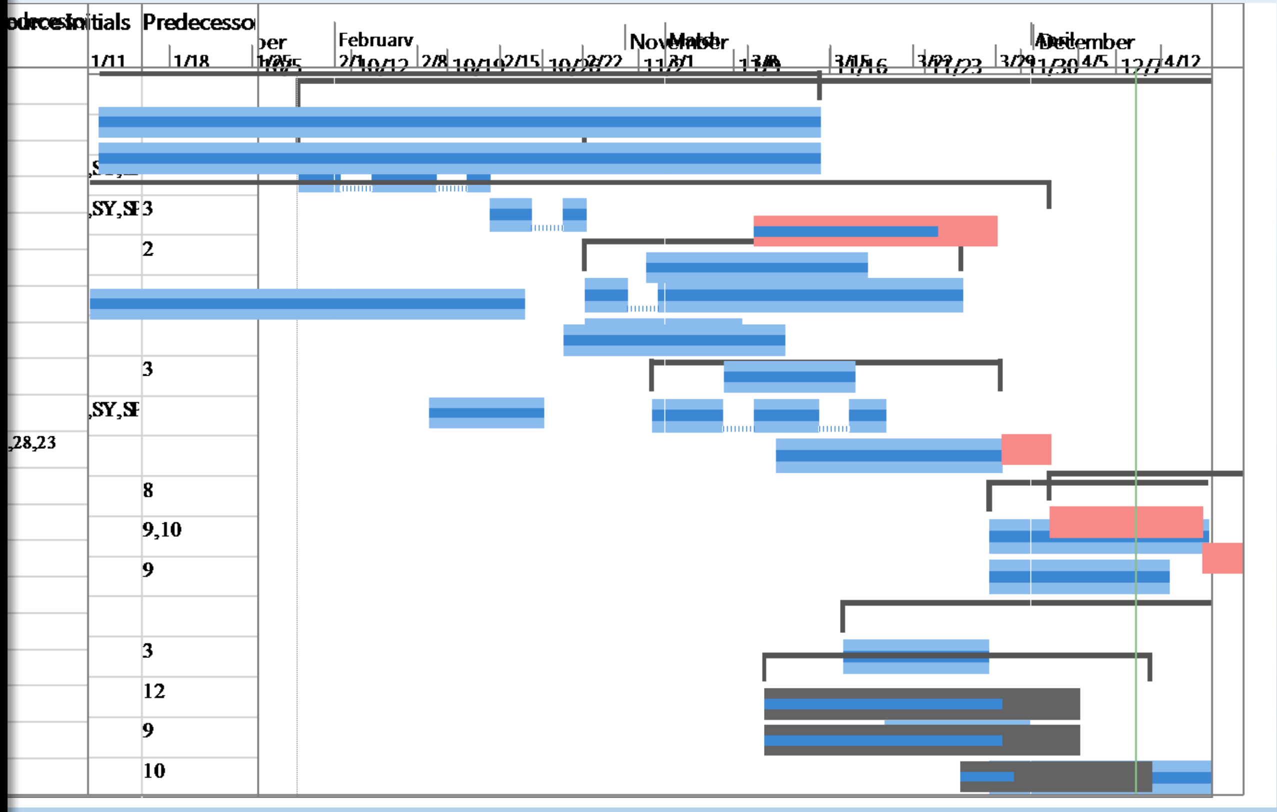

49.56
73.53 mm

Safety Environment and Health

- 3D printing hazards
- Ultraviolet radiation hazards
- UV curing reagent hazards
- CNT disposal and exposure risks
- Precursor disposal and exposure risks

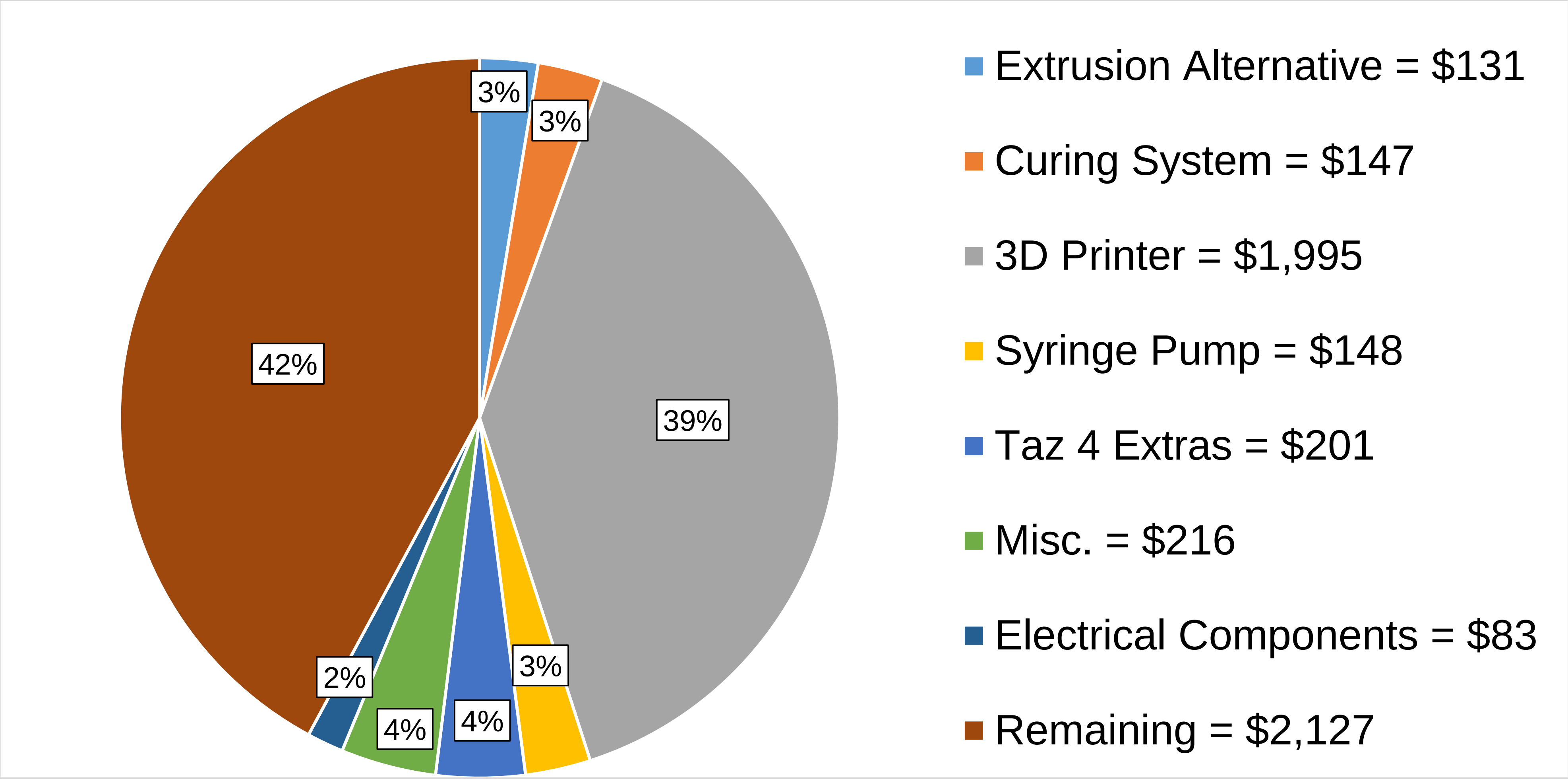
Gantt Chart

ID	Task Name
19	1.6 Testing
20	1.6.1 Droplet Size and Flow Rate
21	1.6.2 Curing Time
22	1.7 Fabrication & Assembly
23	1.7.1 Curing Array
24	1.7.2 Syringe Pump Mechanism
25	1.7.3 Inkshield Device
26	1.7.4 Machined Components
27	1.7.5 3d Print Components
28	1.7.6 PC and software setup
29	1.7.7 Mount custom hardware
30	1.8 Refinement
31	1.8.1 Testing w/ Nanopowder
32	1.8.2 Test analysis
33	1.8.3 Improvement plan
34	1.8.4 Rework
35	1.9 Project Closure
36	1.9.1 Create operation manual for users
37	1.9.2 DFMA Report, Economic Analysis
38	1.9.3 Write Final Report

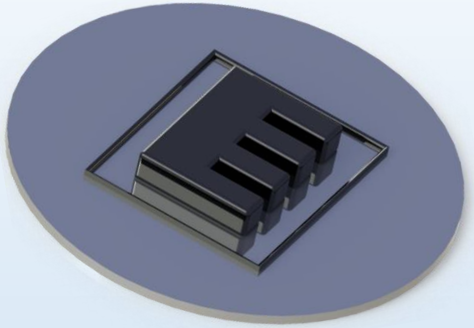


Daphne Solis

Budget Allocation



Achievements

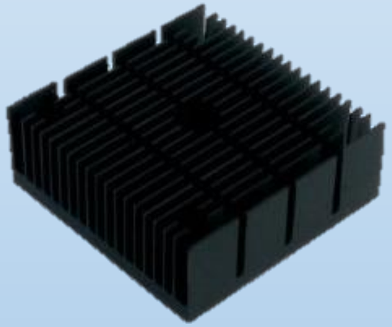


- Successfully extrude the material mixture
- Implemented a material curing system
- Modified printer profile and G-code
- Made custom print head quickly interchangeable
- Used project management tools to control budget and schedule
- Realized the product formation process
- Printed solid parts conforming to sponsor specifications

Recommendations for Future Work

- CNT alignment
- Material mixture refinement
- Curing array improvements
- Gear set and stepper motor modification
- Establish material property tests

LED Emitter



Heat sink

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Questions?

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