VANDAL FORGE
3D METAL PRINTER

Senior Design 2016-2017
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Problem Statement

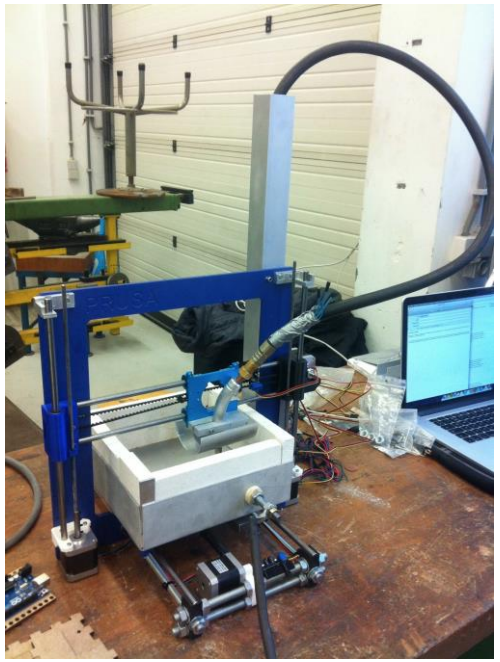
- Additive Manufacturing vs. Conventional Methods
- 3D plastic printers have become ubiquitous.
- 3D metal printers are very expensive.

Mission Statement

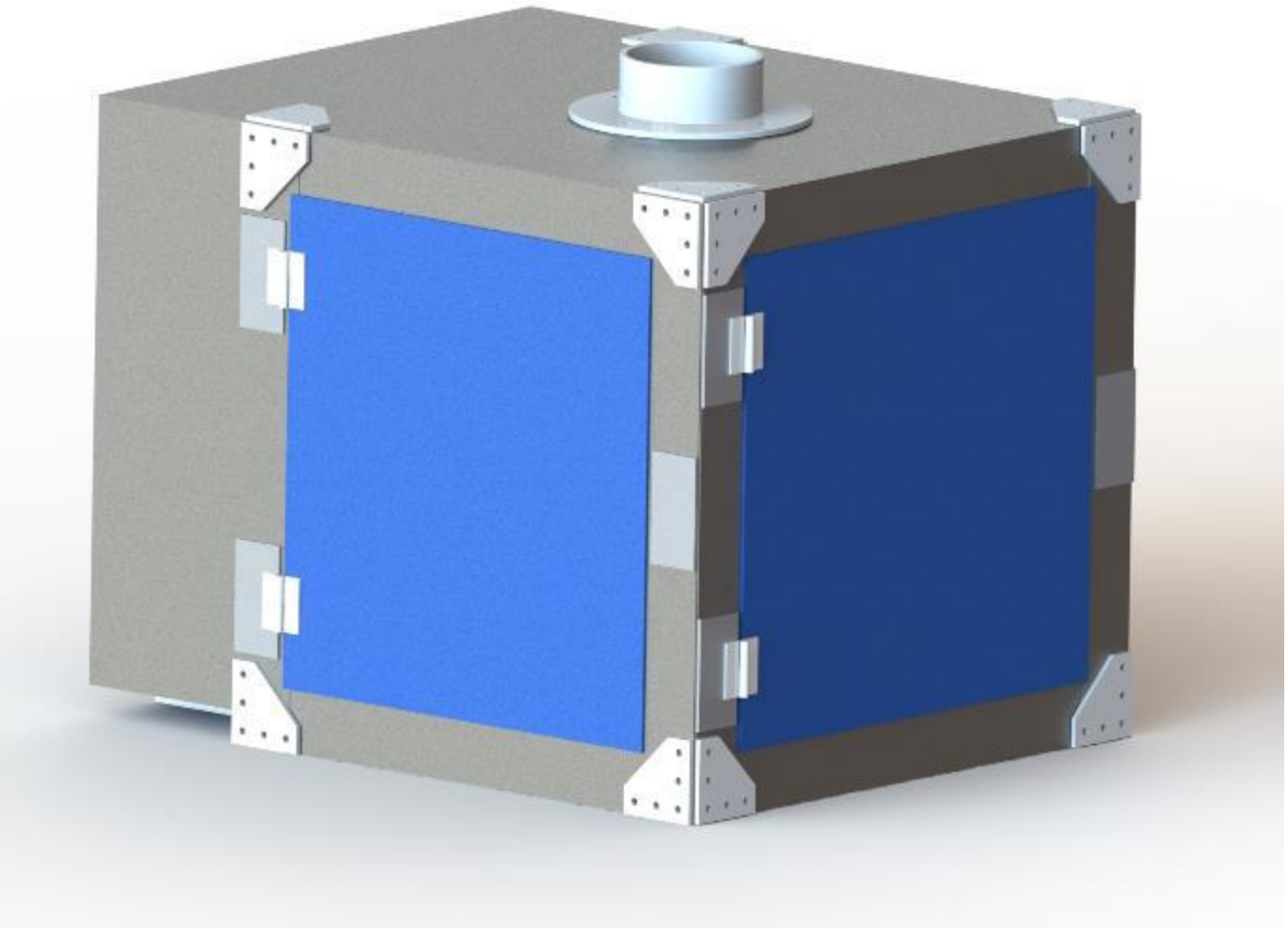
- Develop a prototype 3D metal printer using MIG welder technology in order to prove the concept and research the possibility of large-scale manufacturing in order to bring 3D metal printing to academia and the home user.

Inspiration

- University of Michigan
  - Delta Style Printer
  - Under $1,500
  - Open Source
- Delft University of Technology
  - Prusa i3 Model Printer
  - Inexpensive
  - Open Source



Design Overview



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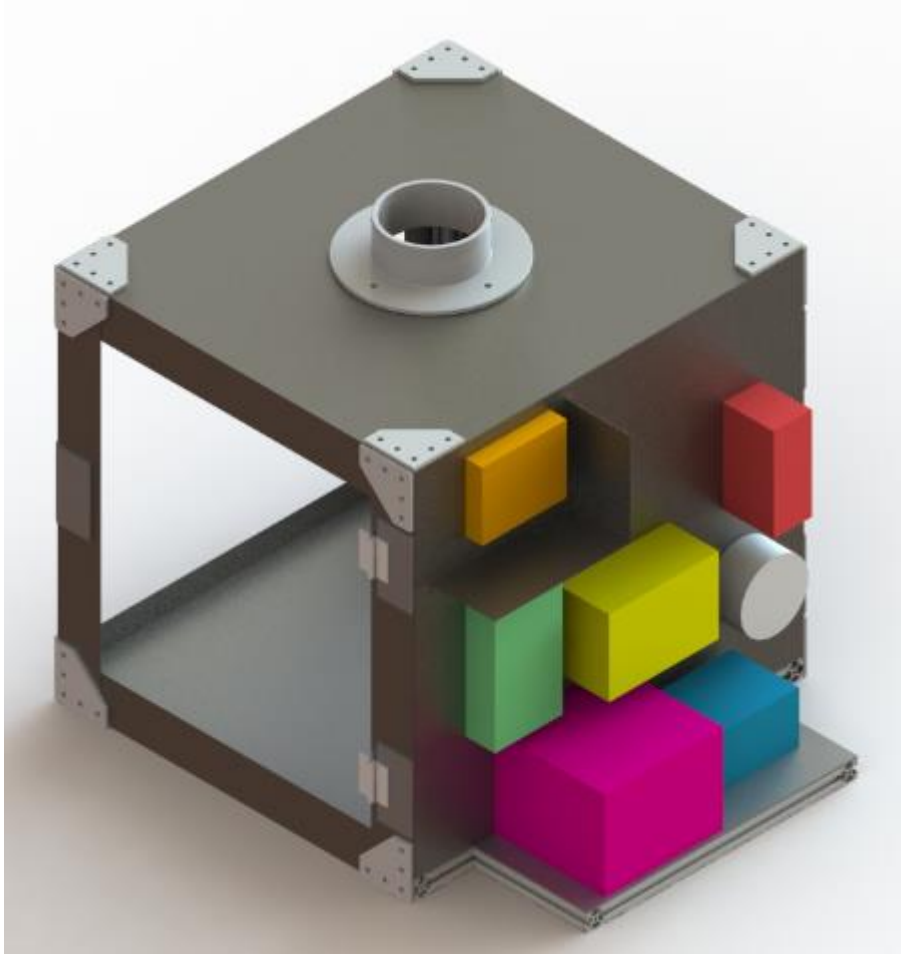

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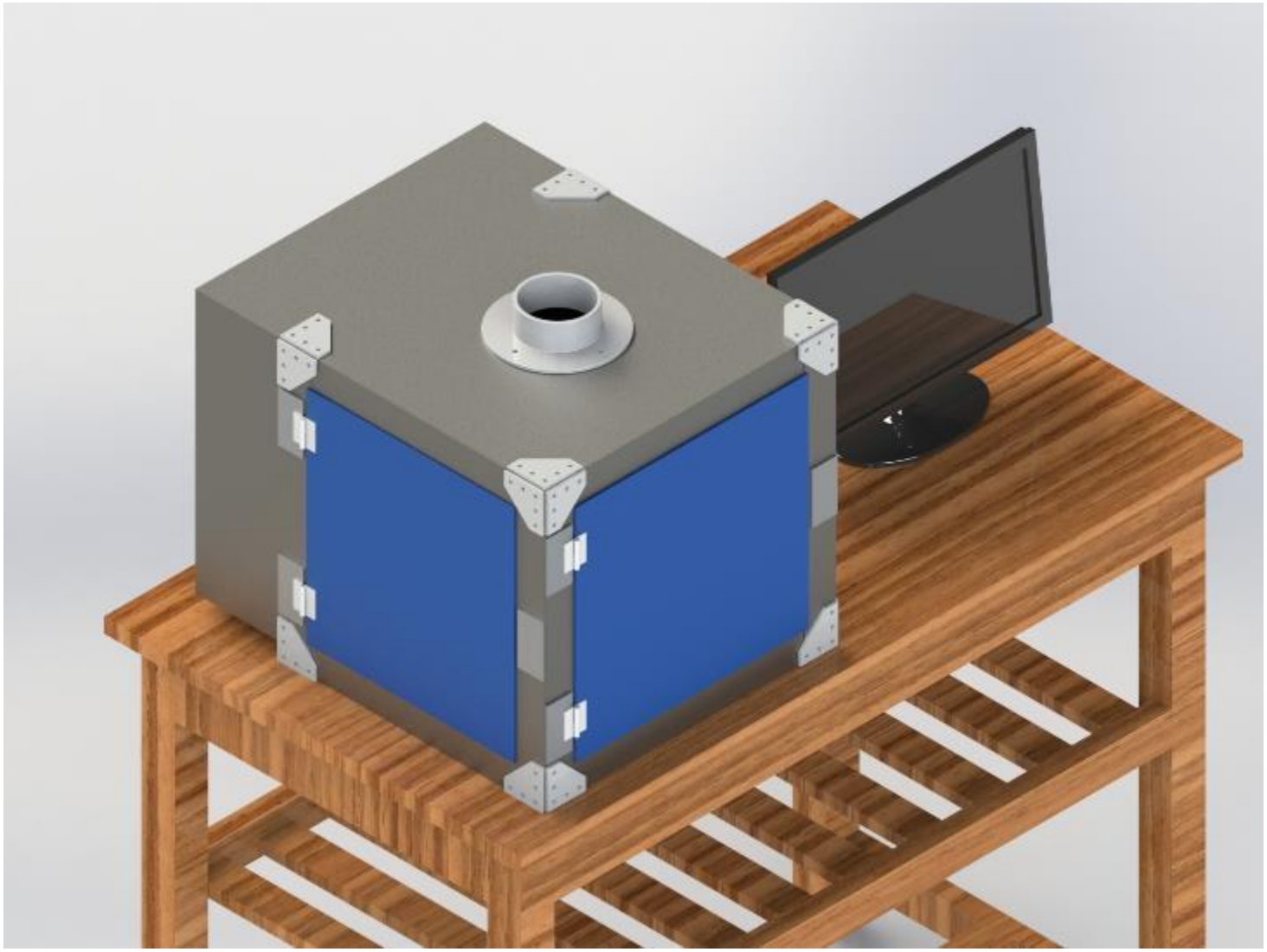
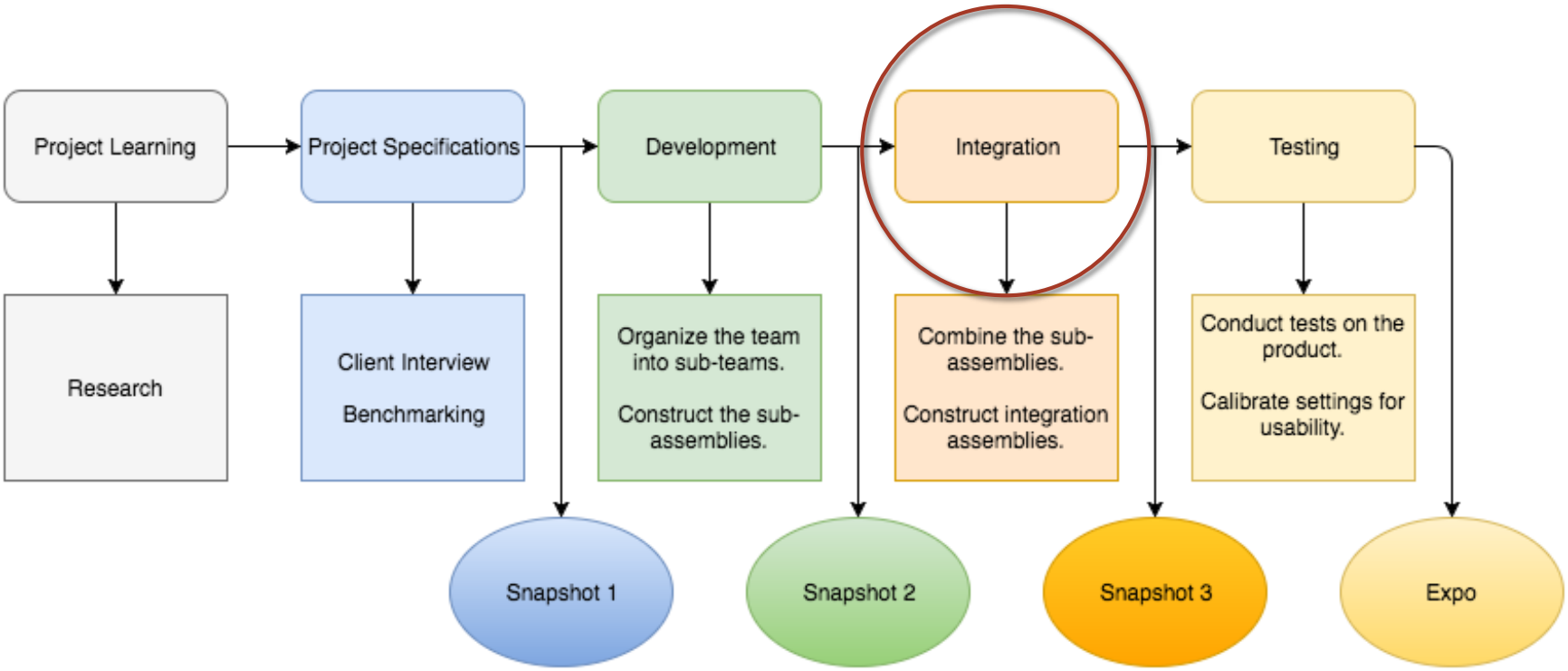


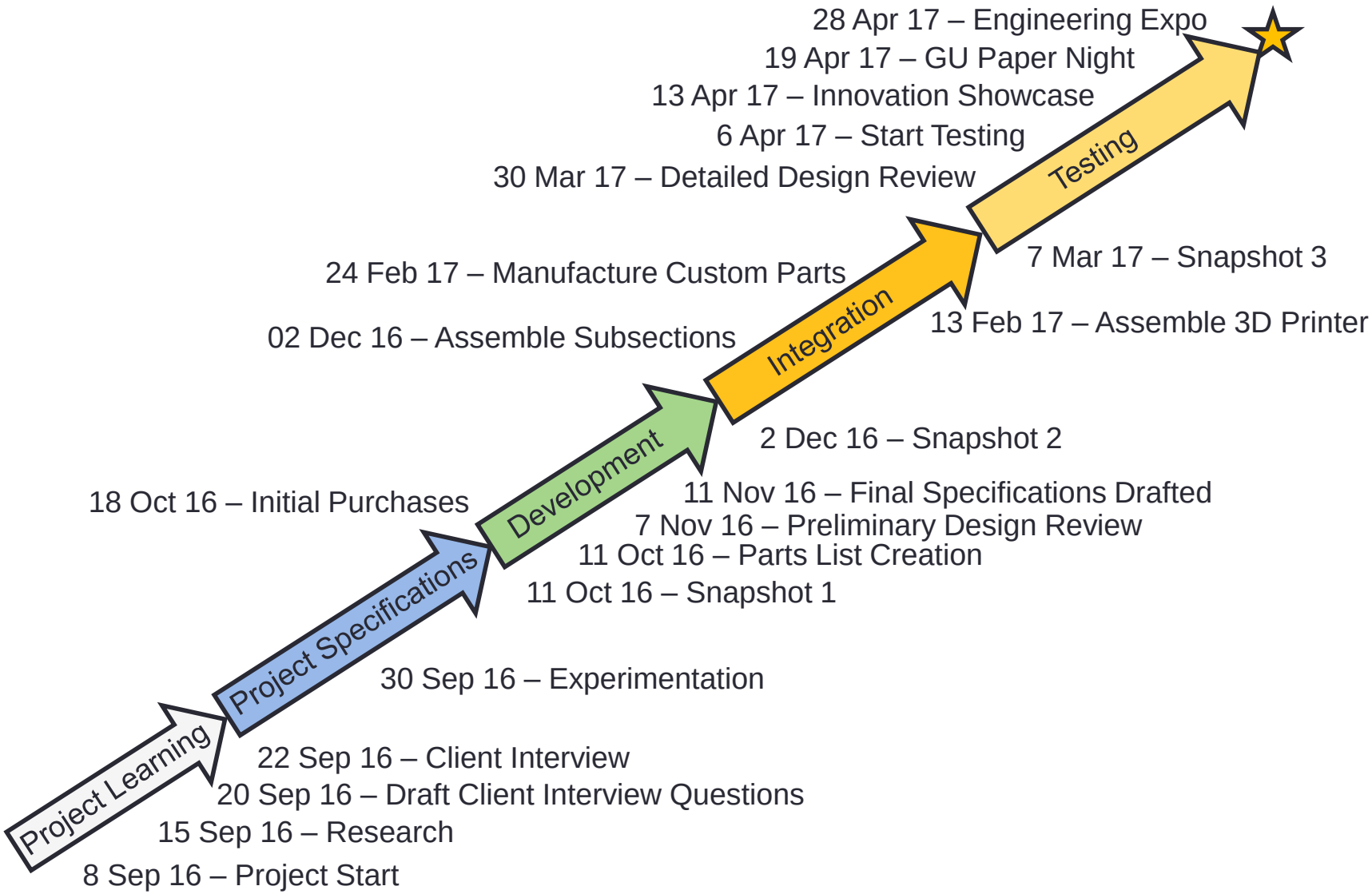
Product Specifications

- Print Volume – Comparable to 3D plastic printers.
  - 9.84” x 8.3” x 8”
- Resolution – Comparable to 3D plastic printers.
  - Typical 3D Printer Nozzle – 0.016” – 0.032”
  - Welding Wire Diameter – 0.023”
  - Target Resolution – 0.029” – 0.035” (125% - 150% of 0.023”)
- Input Voltage – Typical wall outlet.
  - 120 V (North America)
- Total Size – Fit on a standard size desk.
  - 28” x 23” x 22”
- Cost – Comparable to high-end 3D plastic printers.
  - End user cost: $3,500-$5,000
  - Manufacturing cost: $1,000

Design Process

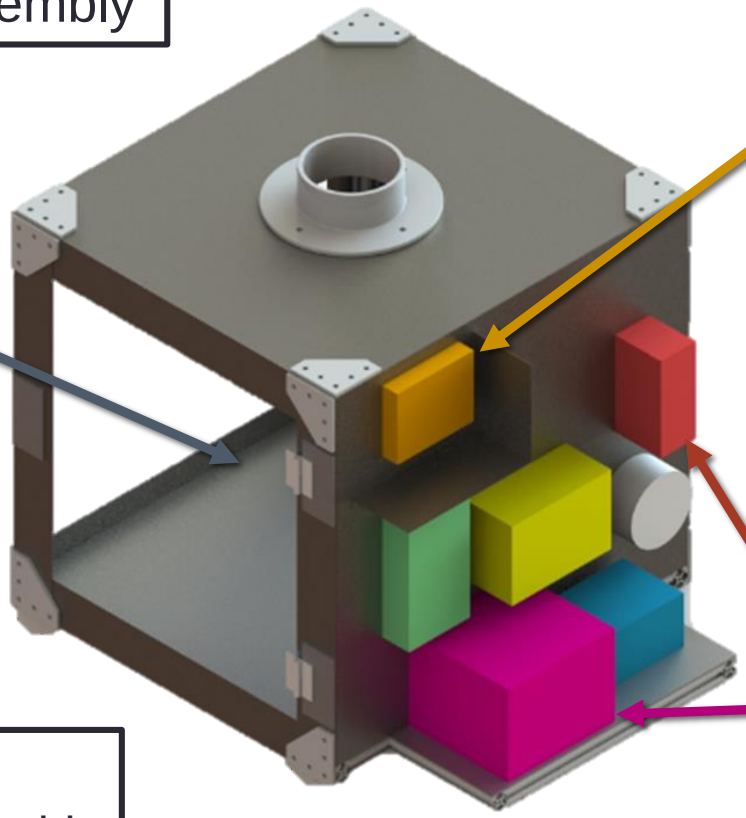


Project Schedule



Key Components

3D Plastic Printer Assembly

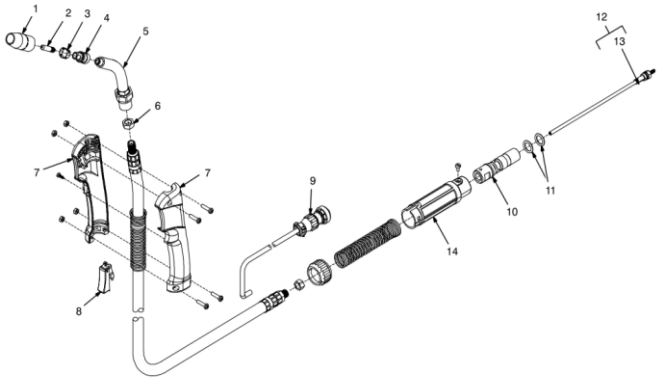


Controller
- Schematics
- Firmware
- Printing Process

Welder
- Gas Assembly
- Wire Feed Assembly
- Power Supply
- Machined Parts

Integration
- Wire Cutter Assembly
- Print Bed Assembly

Welder



Gas Assembly

- Gas Tank
- Regulator
- Gas Block
- Nozzle

Wire Feed Assembly

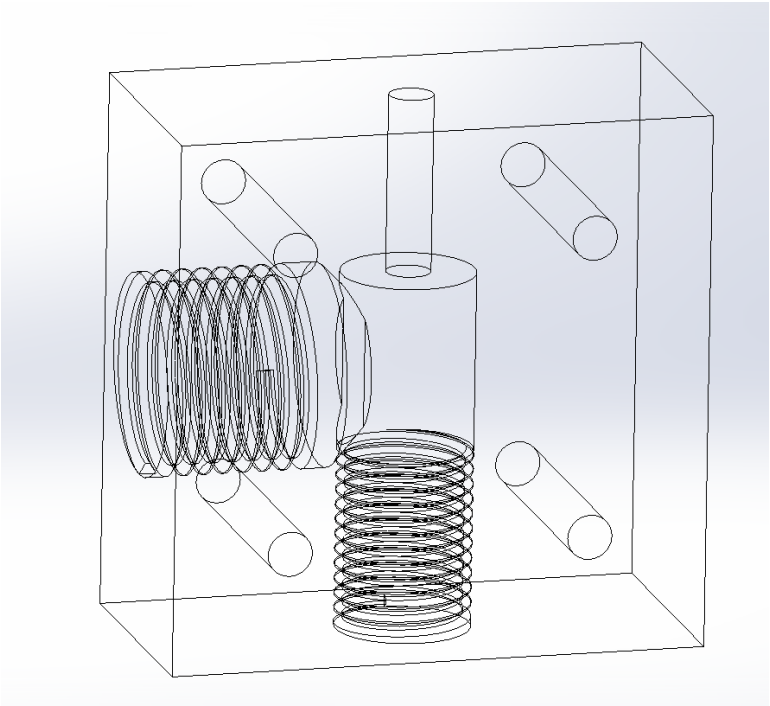
- Spool
- Wire Feed
- Gun Liner
- Gas Block
- Contact Tip

Power Supply

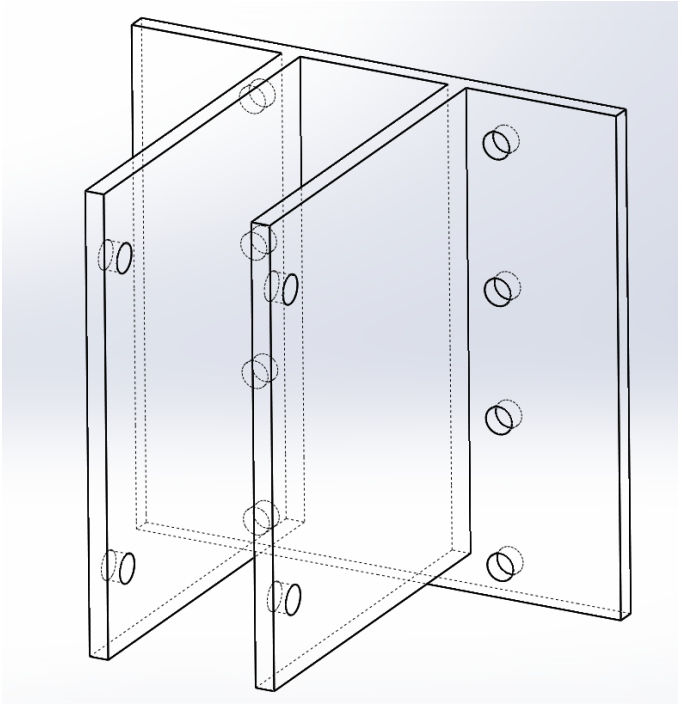
- Forney Welder
- 120V 95A
- Welding Cable
- Gas Block
- Contact Tip

Welder – Machined Parts

Gas Block



Print Carriage



3D Plastic Printer Assembly

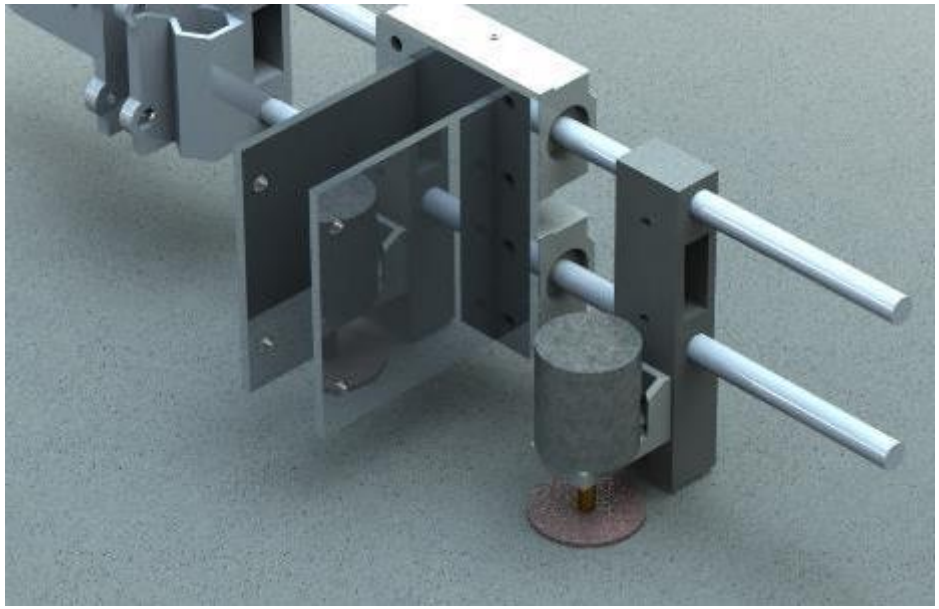
Prusa i3 Steel Kit

Prusa i3
+ Very Common
+ Simple
+ Reliable
+ Lots of online support
- Lots of plastic parts
- Vibration-prone
- Rubber Belts

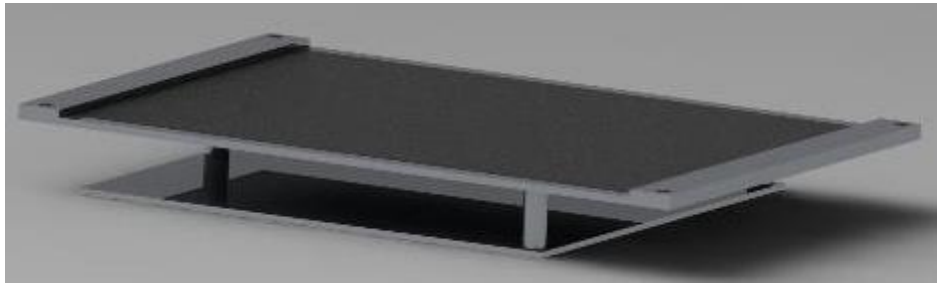
P3Steel
+ Simple
+ Reliable
+ Stable
+ Few plastic parts
- Rubber Belts
- Heavier

Integration

Wire Cutter Assembly

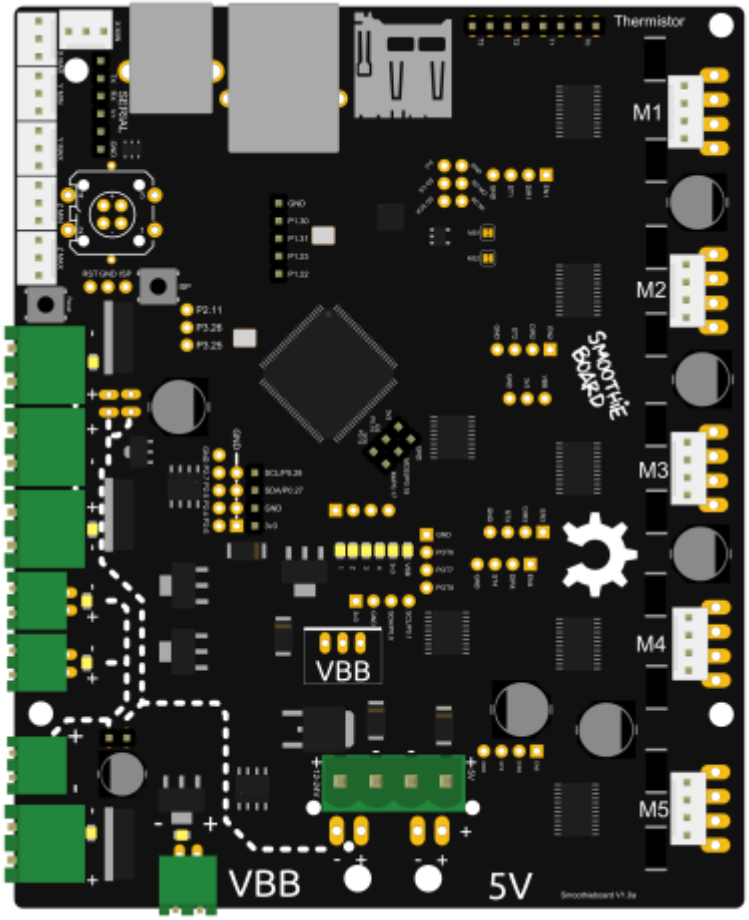


Print Bed Assembly



Controller

PCB	SmoothieBoard
MCU Included	Yes
Bits	32
CPU	ARM-Cortex M3 LPC1769
CPU MHz	120
Stepper Motor Connections	5
Stepper Motor Drivers Included	Yes
Endstop Inputs	6
Power	5V/0-24 V
External Fan Support	Yes
MicroSD	Yes
Interfaces	SPI, I2C, PWM, DAC, GPIO
LCD Support	Yes
Debugging Support	GDB

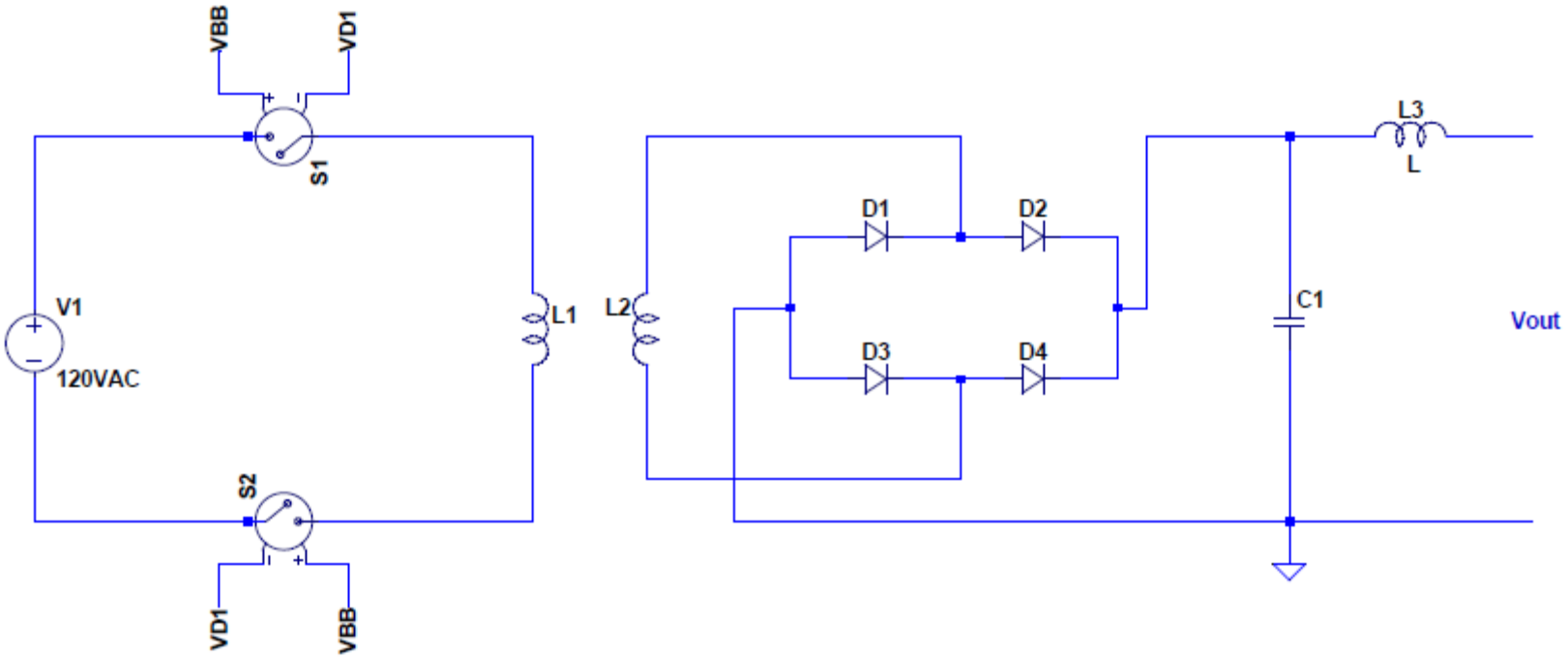


Controller - Firmware

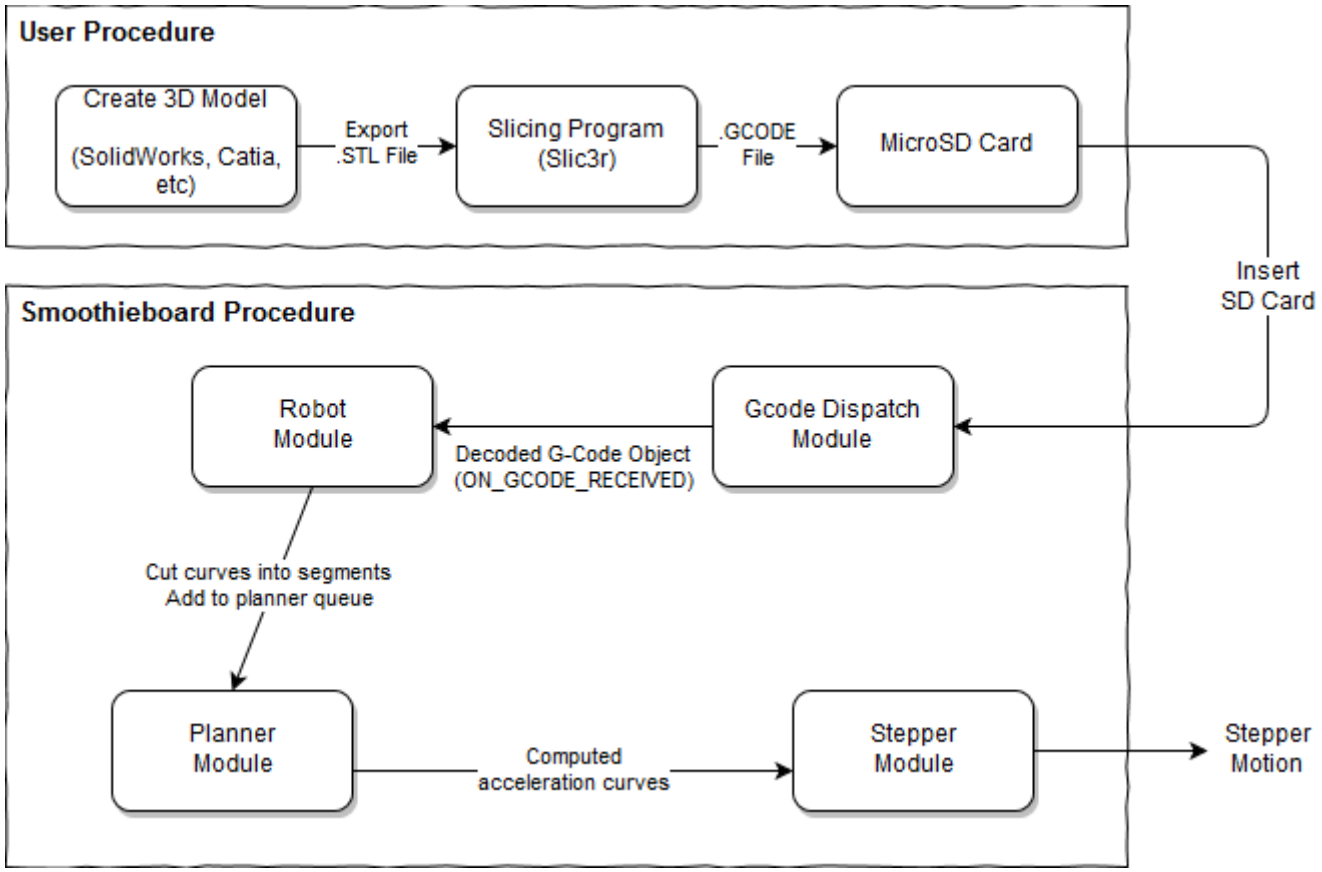
- Existing SmoothieWare functionality
  - Open source modular event-driven real-time OS
  - G-code interpreter (GcodeDispatch)
  - CNC Printer Controller: Robot, Planner, Stepper, Endstops
  - Modules: Switch, SerialConsole, Panel, etc.
- Additional firmware development
  - New modules created
    - PWM controlled DC motor wire feed
    - Relay, Wire cutter
    - Gas flow stepper motor control
    - Custom G-Code enhancement

Controller - Schematic

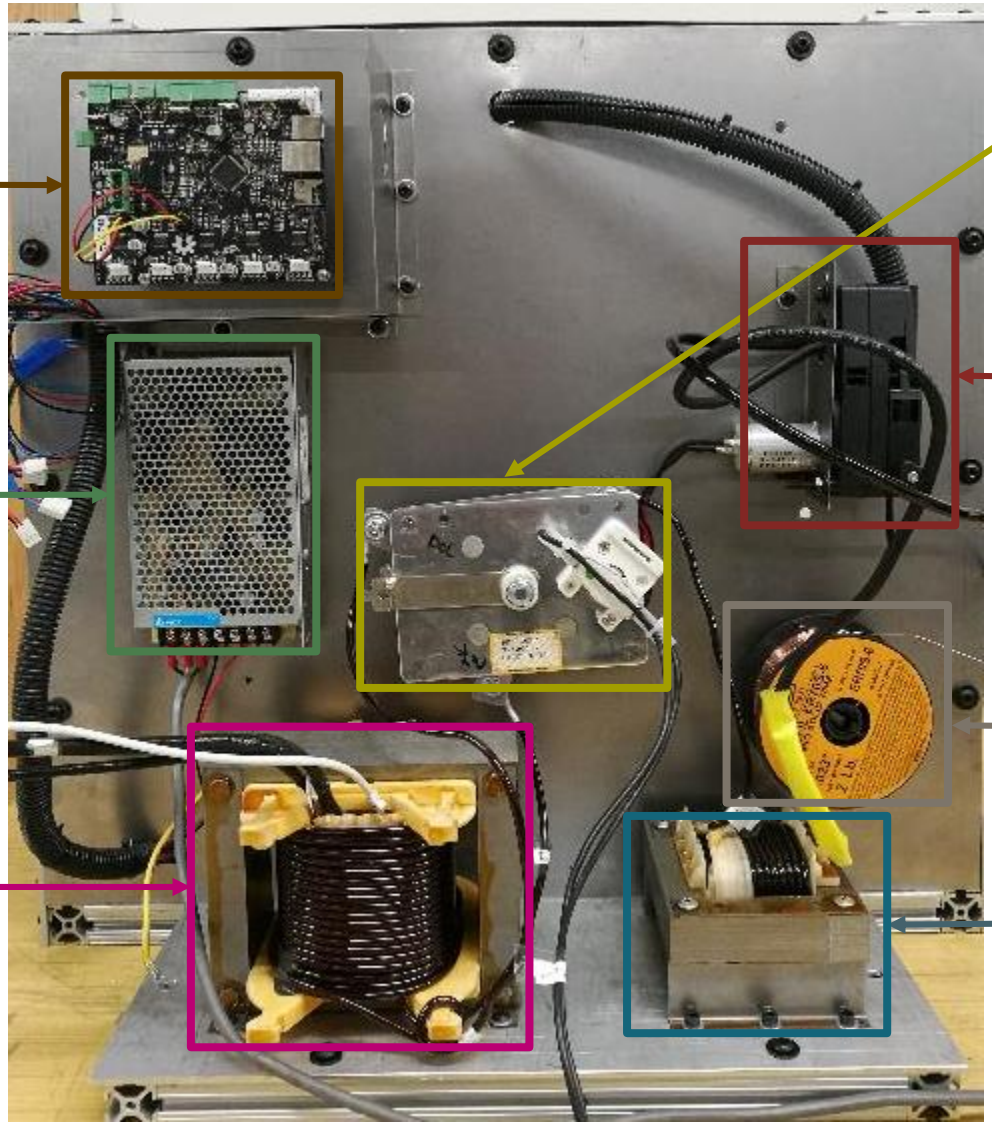
Welder On/Off Circuit



Controller - Printing Process



Parts View


Controller
Rectifier
Wire Feed Motor
Controller/Motor Power Supply
Wire Spool
Transformer
Inductor

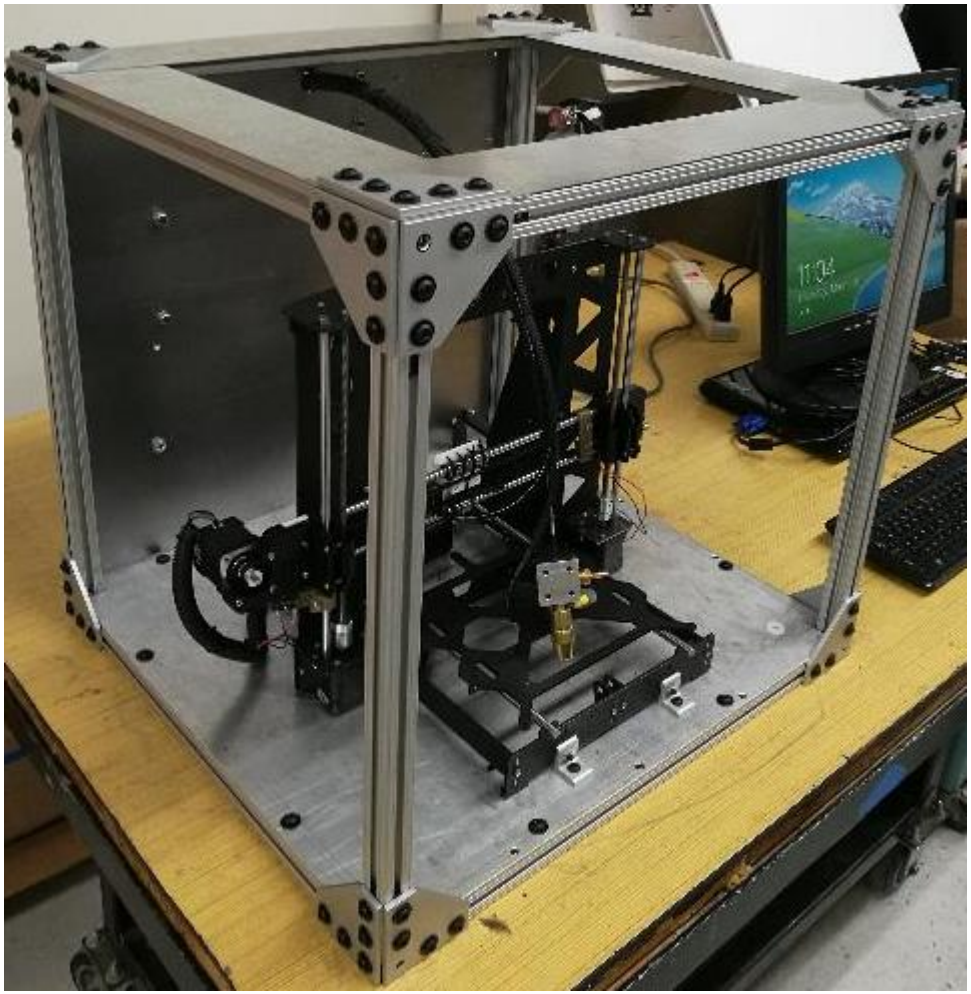
Bill of Materials

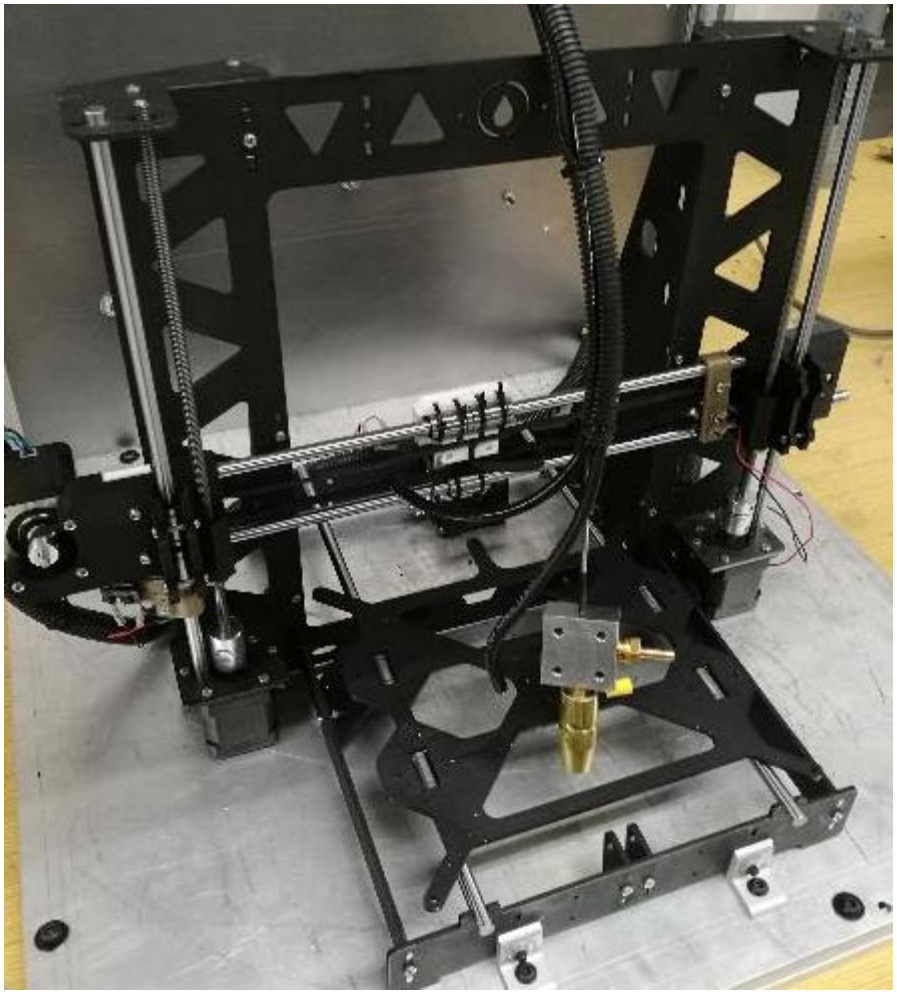
Section	Quantity	Part	Unit Price	Total Price
CNC	1	5PCS Nema 17 Stepper Motors	$65	$65.00
CNC	3	3 TriGorilla 3D Printer Endstops	$9.99	$29.97
Welder	1	GOCHANGE 12V Wire Feed Motor	$24.90	$24.90
CNC	1	2PCS Flexible Couplings	$5.73	$5.73
CNC	2	6PCS LM8UU Linear Ball Bearings	$7.90	$15.80
CNC	1	2 Aluminum GT2 16T Pulley and Belt	$9.56	$9.56
CNC	3	2PCS 8x500mm Linear Shaft	$17.83	$53.49
CNC	1	Acme rods, screws, nuts, nyloc, washers	$55.40	$55.40
Both	1	Smoothieboard Microcontroller	$175.47	$175.47
Welder	1	MIG TIG Flow Regulator	$34.80	$34.80
Welder	1	.023 inch Carbon Mig Welding Wire	$10.59	$10.59
CNC	1	Delta Electronics 24V Power Supply	$27.39	$27.39
Both	1	Tilman Welding Curtain	$33.99	$33.99
Welder	1	Anderson Metals Brass Hose Fitting	$4.86	$4.86
CNC	1	Mercury SC8LUU Linear Ball Bearing Block	$16.88	$16.88
Both	1	SBR Rubber Sheet	$8.99	$8.99
Welder	1	Mig Consumable Kit	$35.85	$35.85
Welder	1	Forney Flux Core Welder	$228.17	$228.17
CNC	1	Prusa i3 Frame + shipping	$91.58	$91.58
				$928.42

Potential Issues

- Heat
  - Need to keep exterior temperature low enough to touch.
- Safety
  - Need to prevent possibility of touching hot objects or exposure to UV.
- Power
  - Need to keep current draw within typical circuit range (~15 amps).
- Cost
  - Need to decrease manufacturing cost per unit in order to decrease end user cost.

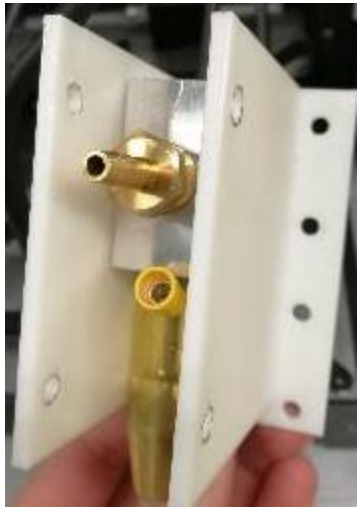
Progress



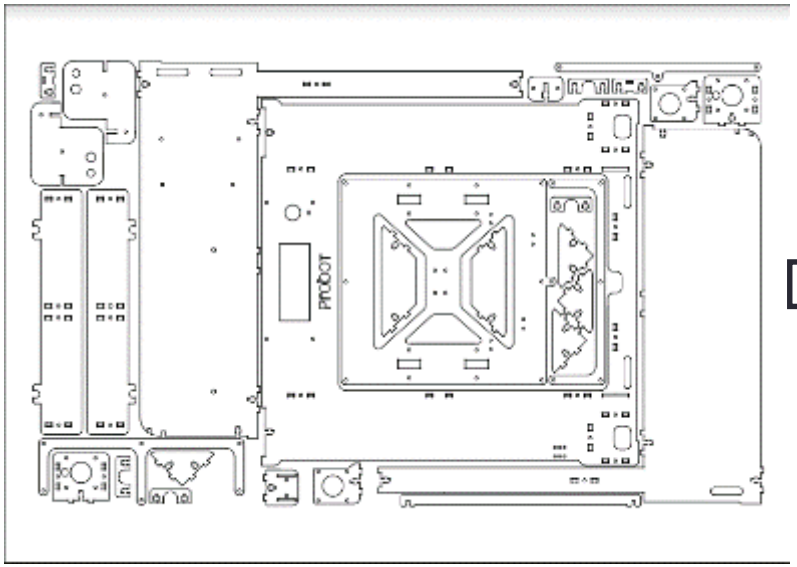


Progress – Tasks to Completion

- Assemble the frame.
  - Assemble door frames.
  - Manufacture sheet metal cover.
  - Add top panel and hose flange.
- Manufacture print head carriage.
- Manufacture print bed.
- Manufacture gas flow motor mount.
- Manufacture wire cutter mount.
- Develop the printer firmware.
- Wire the power circuit.



Future Plans



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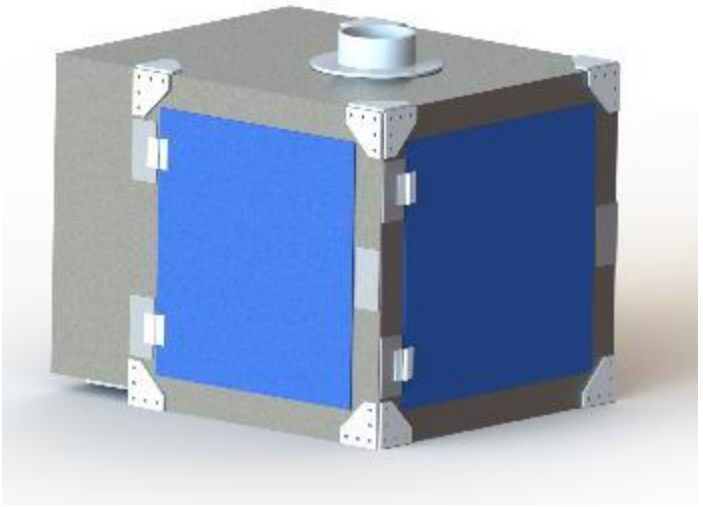

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