



# Desktop 3D Printer

SENIOR DESIGN SPRING 2015

JACOB AINSWORTH, DERICK DISHER, DERRECK MORREAL

# Table of Contents

## Contents:

Introduction .....	p. 3
Background .....	p. 3
Problem Statement.....	p. 3
Objective.....	p.3
Solution.....	p. 3-9
Cost Analysis and Sections .....	p. 9-10
Calculations .....	p. 11-12
Conclusion .....	p. 13
Illustrations .....	p. 13-14
References.....	p. 15

## Introduction

3D printing is becoming an industry standard for prototyping. And while the technology continues to grow at an increasing rate for industry, the consumer market is not getting near the same amount of attention. 3D printing is something that we believe will one day be part of our everyday lives. We think this should be sooner more than later.

## Background

Each of our group members have been fascinated with 3D printing since the day that we learned about it. A machine that could accept electronic files of solid models and then convert them into real life objects seems to be a machine that could only be possible in a star trek episode. Thanks to 3D printing technology, that is no longer the case. Now our goal is to embrace that amazing technology and give people the opportunity to own a personal 3D printer capable of producing prints comparable to printers that are much more expensive.

## Problem Statement

There are currently a few 3D printers that can be purchased for home use, but these printers are not nearly as user friendly as we think they should be. Most are quite expensive, take lots of work to maintain, and have limited build capabilities in terms of size and resolution.

## Objective

Our goal is to create a 3D printer that compared to its competition will have the following improved qualities.

- Increased print size
- Increased resolution
- Reasonably Priced
- Reduce time required to print
- Easy to assemble
- Reduce Maintenance

Specifications	
Build Volume	300mm x 300mm x 300mm
Print Resolution	100 microns Vertically
Print speed	150mm/s
Frame material	Aluminum extrusion

## Solution



## Construction

While our printer has a great number of various parts, the design can be easily separated into 3 separate sections. These are:

1. Frame
2. XY Carriage
3. Z Carriage



*Figure 1 - Frame*

## Frame

The frame is constructed of black anodized aluminum extrusion. This special type of extrusion is known as t-slot extrusion. T-slot extrusion is slotted for easy assembly and modification. Not only is this easy to assemble, and render the printer able to be easily expandable in terms of accessories; It is also much sturdier than the wood and plastic frames of other printers in this price range. The added rigidity allows the printer to move faster without flexing, which can cause the railing system to bind and prevent movement.

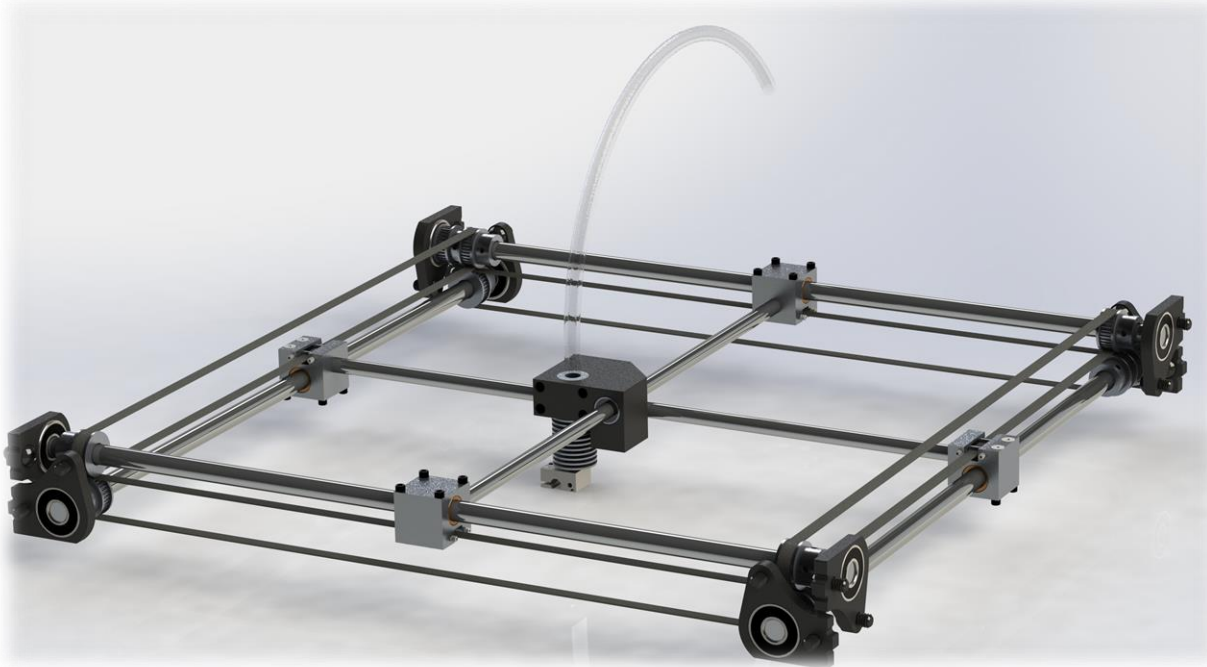


Figure 2 - XY Carriage

## XY Carriage

The XY Carriage is what allows the printer to locate in both the X and Y directions. Our design uses self-lubricating bronze bushings that slide on chrome plated steel rods to move the hot end quickly and quietly compared to the ball bearings that the competition uses.

The Hot End is one of the most important parts of a Fused Deposition 3D Printer. Fused Deposition printing works by stacking layer over layer of plastic repeatedly until those many layers build up to become a 3 dimensional object. The Hot End is the part that actually extrudes the plastic. It works just like a hot glue gun, heating up the plastic and positioning it with the nozzle. The hot end consist of the following components (shown in figure 4):

1. Aluminum Heatsink
2. Stainless Steel Heat Break
3. Aluminum Heater Block
4. Brass Nozzle

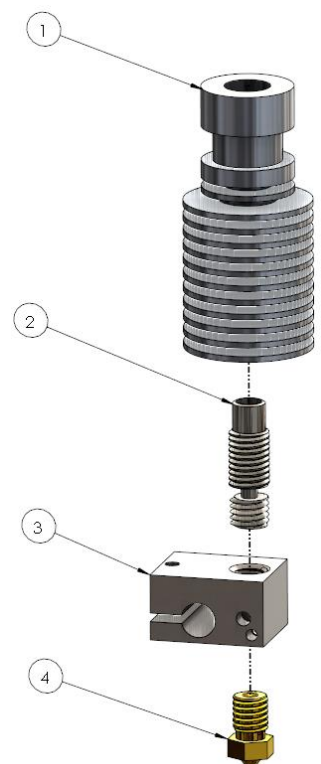


Figure 3 - Hot End

## Heatsink

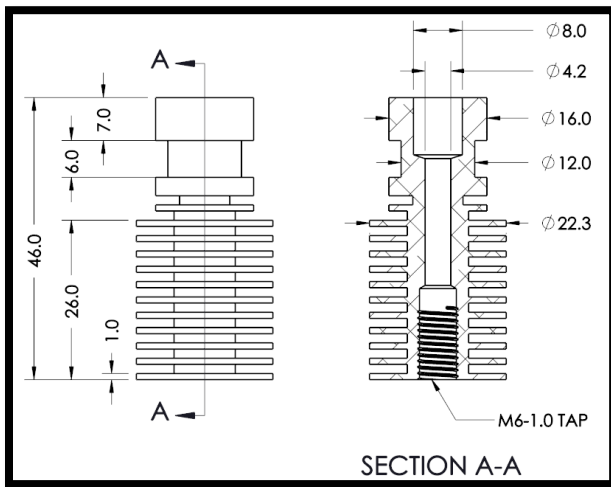


Figure 5 - HeatSink

The heat sink (Figure 5) is responsible for dissipating most of the heat that comes from the heat block. The thin fins allow air to flow through and pull the heat out. This reduces the chances that the plastic will melt in the hot end and jam the printer. In this design the heatsink also serves as the mounting point for the hot end.

## Heat Break

The heat break (Figure 6) has several functions. It first serves to help the heatsink in dissipating heat. It leaves gaps between the heat block and the heatsink, making it harder for the heat to run up the hot end. It is constructed of stainless steel which has lower thermal conductivity than aluminum. As a result the heat from the heat block is less prone to travel through it; acting as a break.

This design also makes the complete hot end much easier to manufacture, by separating the turning operations and milling operations into separate parts.

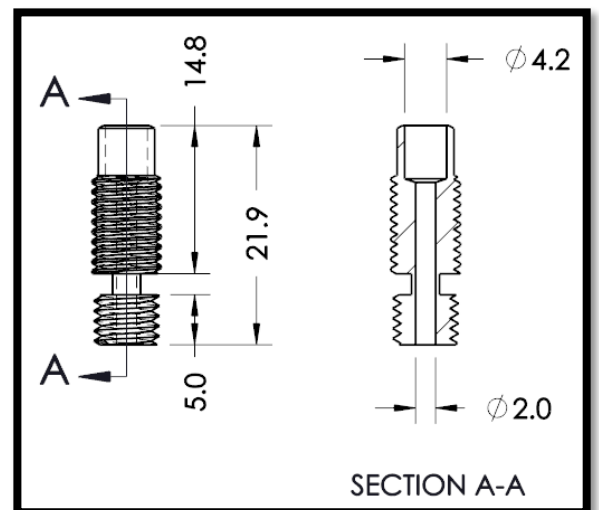


Figure 6 – Heat Break

## Heat Block

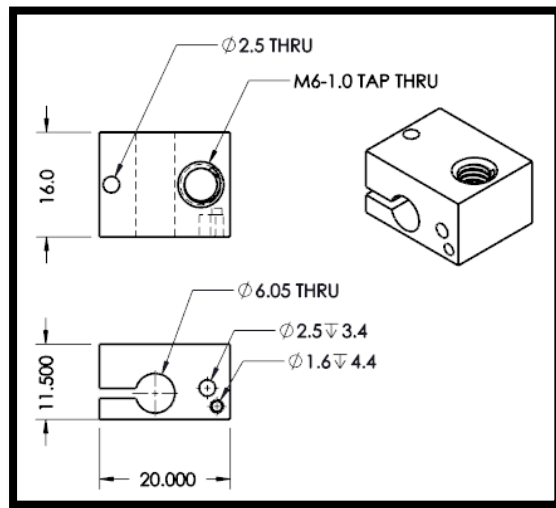


Figure 7 - Heat Block

The heat block (Figure 7) is where the thermistor, heating element, and nozzle all mount up to. The thermistor is a special type of resistor that allows you to read the temperature up to 300 degrees Celsius. This allows us to heat up the nozzle to the appropriate temperature depending on the material.

## Nozzle

The nozzle (Figure 8) is where the plastic will come out. It is made of brass, a great conductor, which means that most all of the heat that we generate within the heat block is transferred directly to the nozzle. When the plastic hits the tip, it is instantly melted and is forced through the small hole. This part can be easily replaced with other nozzles that have different sized holes for whatever your need is.

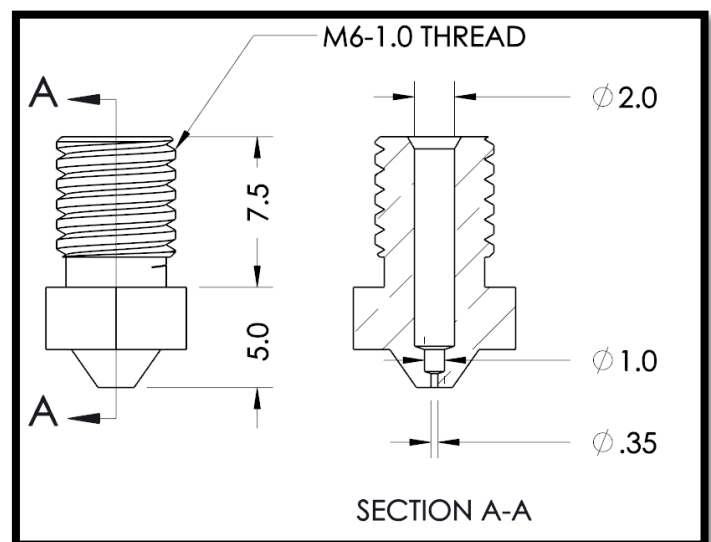


Figure 8 - Nozzle



*Figure 9 - Z Carriage*

## Z Carriage

The Z carriage is responsible for moving the bed in the Z axis (up and down). It also holds the heat bead which is a device that keeps the printing surface warm, preventing the part from warping. The actual printing surface is made of surface ground 6061-T6 Aluminum that sits on top of the heat bed. Because the printing surface is made from aluminum, which has a high thermal conductivity, heat can be easily transferred from the heat bed to the part.

In each corner of the printing surface there is a bed level adjustment to help get the bed initially level. To further insure that bed is perfectly level we've added a proximity sensor to the printing head that will take measurements before each print and adjust the program accordingly. The bed itself rides along a linear lead screw and carriage design from PBC Linear.

## Cost Analysis & Parts List

Item Number	Description	Vendor	Qty	Price	Total
1020	1"x2" Aluminum Extrusion	Neff	68	\$0.28	\$19.18
-	8020 Cut to length	Neff	12	\$1.17	\$14.04
1010	1"x1" Aluminum Extrusion	Neff	216	\$0.17	\$37.58
3343	10s DBL End Fastener	Neff	8	\$1.59	\$12.72
3381	End Fastener	Neff	8	\$0.90	\$7.20
2284T51	(4) 2284T51 1/4-20 Leveling Feet	McMaster	1	\$2.74	\$2.74
8662K23	Black Delrin Rectangular Bar, 1/4" Thick, 2" Wide, 2' Length	McMaster	2	\$7.57	\$15.14
8662K41	Black Delrin Rectangular Bar, 1/2" Thick, 1" Wide, 1' Length	McMaster	1	\$7.13	\$7.13
8662K73	Black Delrin Rectangular Bar 1-1/4" Thick, 2" Wide, 1 ft. Length	McMaster	1	\$25.62	\$25.62
91251A112	(100) Black-Oxide Alloy Steel Socket Head Cap Screw, 4-40 Thread, 5/8" Length	McMaster	1	\$8.12	\$8.12
91255A537	(50) Alloy Steel Button-Head Socket Cap Screw, Black-Oxide, 1/4"-20 Thread, 1/2" Long	McMaster	1	\$7.53	\$7.53
8910K401	Low-Carbon Steel Bar, 1/8" Thick, 2-1/2" Width, 1' Length	McMaster	1	\$5.67	\$5.67
91292A033	(25) Type 18-8 Stainless Steel Socket Head Cap Screw, M3 Thread, 35MM Length, 0.5MM Pitch	McMaster	1	\$3.30	\$3.30
94669A743	Metric Aluminum Unthreaded Spacer, 6MM OD, 30MM Length, M3 Screw Size	McMaster	8	\$1.29	\$10.32
PSFJ8-400	8MM Linear Shaft	MISUMI	2	\$12.00	\$24.00
PSFJ10-430	10MM Linear Shaft	MISUMI	4	\$14.81	\$59.24
SHBZ10-25	10MM Bronze Bushing	MISUMI	4	\$6.44	\$25.76
-	(5) NEMA 17 Stepper Motor	eBay	1	\$49.99	\$49.99
GT2 16	GT2 16 Tooth 5mm Bore	eBay	4	\$3.99	\$15.96
SHF12	(2) 12mm Linear Rod Rail Shaft Support	eBay	1	\$11.00	\$11.00
6000RS	(10) Sealed 10mm/26mm/8mm Deep Groove Radial Ball Bearings	eBay	1	\$14.77	\$14.77
LM8UU	(2) linear motion ball bearings 8x15x24	eBay	2	\$4.75	\$9.50
3382	(30) 8020 T Slot Hardware 1/4-20 Economy T Nut	eBay	1	\$11.55	\$11.55
-	12" X 12" Heatbed PCB	eBay	1	\$53.00	\$53.00
Mega 2560	SainSmart Mega2560 + A4988 + RAMPS 1.4 3D Printer KIT	eBay	1	\$43.99	\$43.99
-	(5) Mechanical Limit Switch	eBay	1	\$13.99	\$13.99
LCD12864	smart controller Graphic Matrix LCD module RAMPS 1.4 Megareonics Rambo	eBay	1	\$19.00	\$19.00
UGA040D-A10-0420-LS100	PCB LINEAR ACTUATOR	Kendall Electric	1		\$248.53
1020	1"x2" Aluminum Extrusion				
SY124010L	40mm Fans	Amazon	4		\$7.70
	Aluminum Heatsinks	Amazon	2		\$5.80
NTC 3950	100k Thermistor	Eaby	1		\$3.45
	30 Amp Relay Board	Ebay	1		\$19.50
	12V 30A 360W PSU	Ebay	1		\$29.99
UJ12A3-4-Z/BX	Inductive Prox	Ebay	1		\$2.59
	Base Mount Bowden Extruder	Ebay	1		\$91.99
	GT2 Timing Belt	Ebay			\$19.00
	gt2 timing belt loop	ebay	2		\$3.98
	gt2 timing belt loop Large	ebay	2		\$7.58
	1/4-20 drop in t slot nuts	ebay	22		\$19.00
	1/4-20 t slot nuts	ebay	38		\$10.90
98032a429	(100) No. 4 Flat washer	McMaster	1		\$2.04
2191A27	Ball Nose Plunger m5x0.8	McMaster	1		\$4.85
90295A370	(100) Nylon Flat Washer	McMaster	1		\$6.41
47065T92	80/20 End cap	McMaster	2	\$1.50	\$3.00
92005A116	(100) M3 pan head machine screw	McMaster	1		\$2.60
91255A535	(50) Alloy Steel Button Head Cap Screw 1/4-20 X 3/8"	McMaster	1		\$7.75
86825K11	.25" thick MIC6 Cast Aluminum	McMaster	1		\$44.67
1561T14	(3) High Load Compression Spring	McMaster	2	\$6.75	\$13.50
91239A327	(50) M6X25mm Button Head Socket Cap Screw	McMaster	1	\$7.83	\$7.83
98381a306	(25) 1/8" diameter, 5/16" LG Dowel Pin	McMaster	1	\$5.61	\$5.61
94355A216	(50) 4-40 X 5/16" Set Screw	McMaster	1	\$7.57	\$7.57
92210A110	(100) 4-40 X 1/2" Flat Head Socket Cap Screw	McMaster	1	\$3.99	\$3.99
					\$1,107.87

## Calculation Results

The results of our calculation show that if we proceed with using the 1020, 80/20 brand extruded aluminum the printing platform will not deflect enough to jeopardize our target resolution of 200 (0.0078") microns or better.

From the Torque calculations we were able to determine that the specific motors that we bought, NEMA 17 stepper motors, are able to produce enough torque to raise and lower our table with an entire spool worth of plastic on it. This calculation also provides us with enough information that we can make the decision to maintain a 1:1 gear ratio between the motor and the lead screw.

This will greatly reduce time of programming.

## Testing and Calibration

Calibrating the printer has posed to be the most work out of the whole project. Even at this time there are still many improvements that can be made to the firmware.

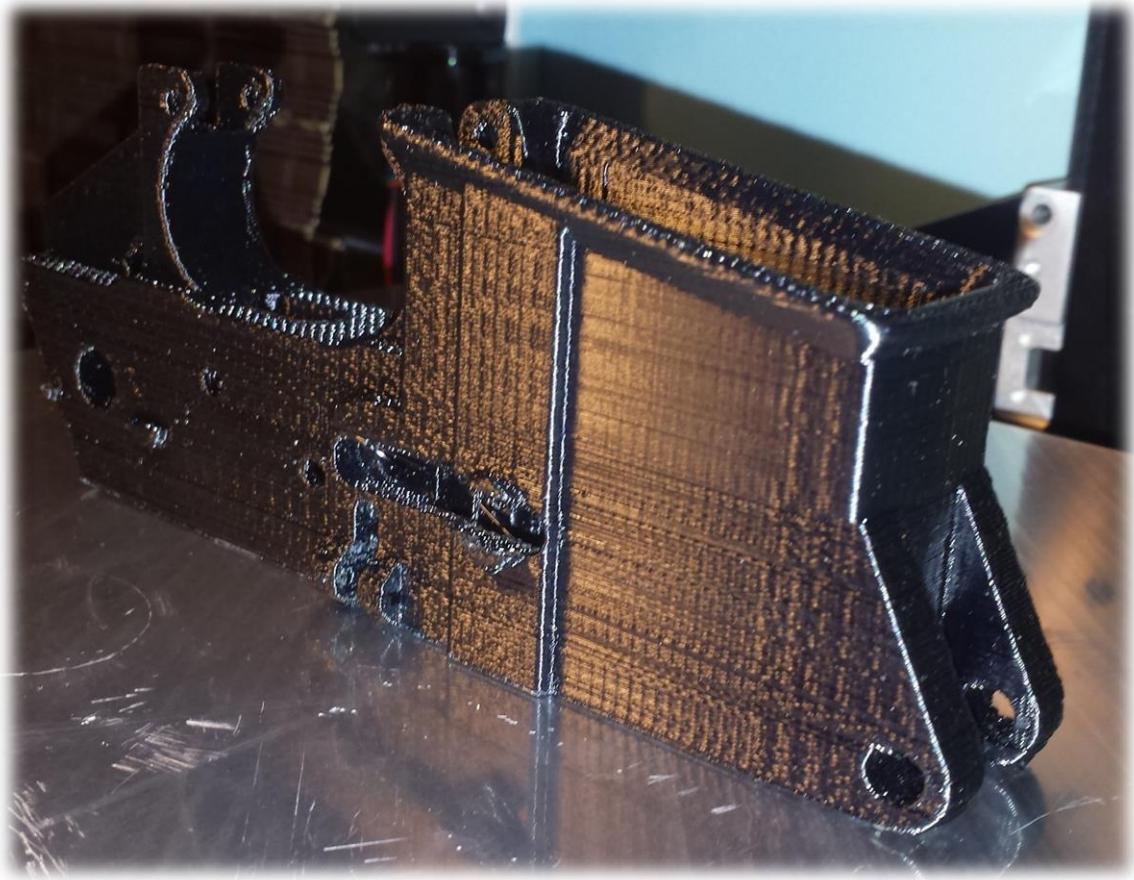
The Firmware for the print board is all edited in what is called the Arduino IDE. The firmware that we are using is named Marlin. Marlin is an open source code that is made for 3d Printers. It is highly customizable and is used in hundreds of 3d printers on the market today.

Even though the firmware is already written, there are still thousands of variables that must be tweaked to work for our printer. Variables such as Steps per unit moved, Acceleration, and Jerk all have huge impacts on the quality of your print. It's a huge challenge to find the right pieces to the puzzle. Most would think that if the quality does not look good, then you can just slow it down. But if you slow the printer down too much, then you will have strings and blobs from the hot end being in one place too long. The calibration process will never end as there always seem to be edits that give a positive results.

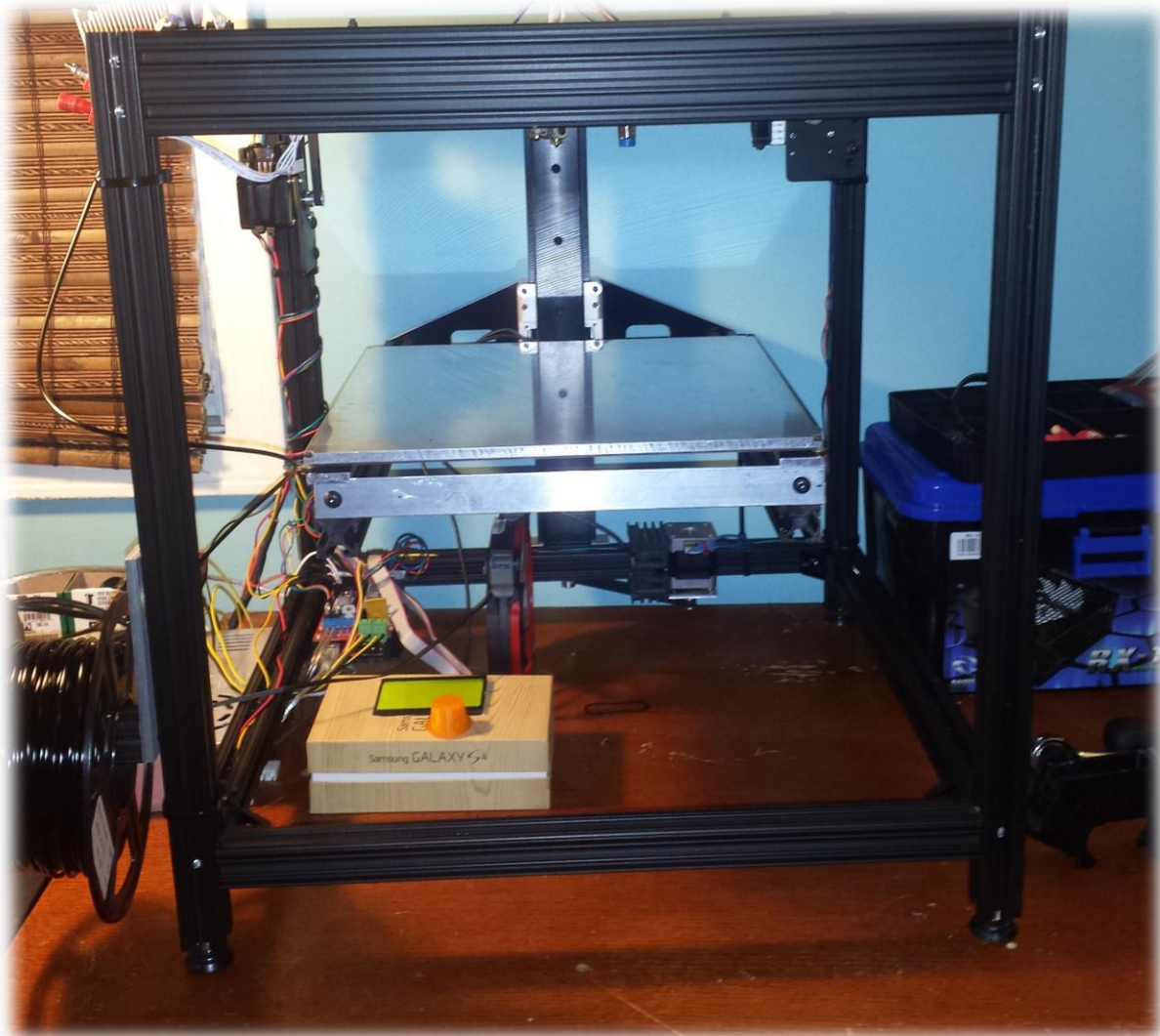
Retraction Speed	15mm/s	15mm/s	15mm/s	15mm/s
Retraction Length	2mm	4.5mm	4.5mm	4.5mm
Print Temp	200°C	200°C	190°C	190
Print Speed	30mm/s	30mm/s	30mm/s	30mm/s
Layer height	.3 mm	.3	.3	.3
INFILL	20%	20%	20%	30%

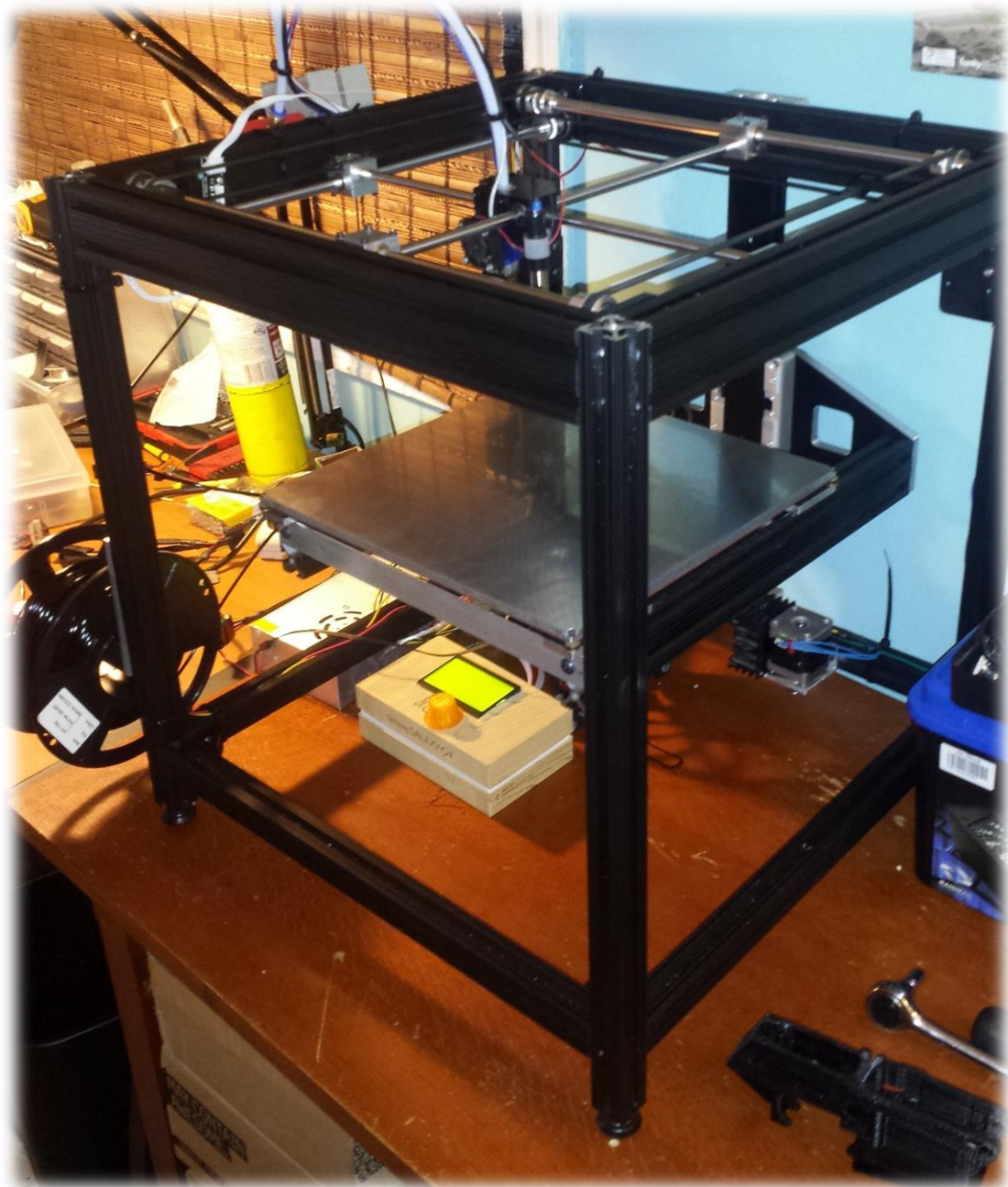
## Conclusion

During the past semester our group was able to design and assemble a fully functional 3D printer. Our printer is capable of accepting files from numerous software's and convert them into 3 dimensional objects, something that just 20 years ago would have been unheard of in a household environment. We would like to continue to work and maximize efficiency and cost, without sacrificing the resolution that we desire. We also plan to use our printer to produce various parts for itself, for example, housing for the controllers, possible HMI, and all other exposed electronics. This project has been both inspiring and rewarding.



## Illustrations

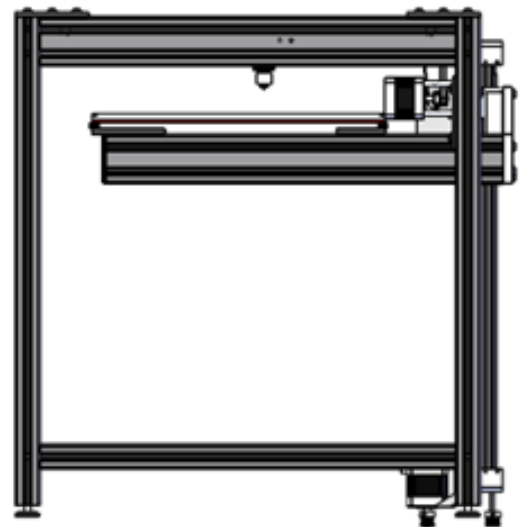
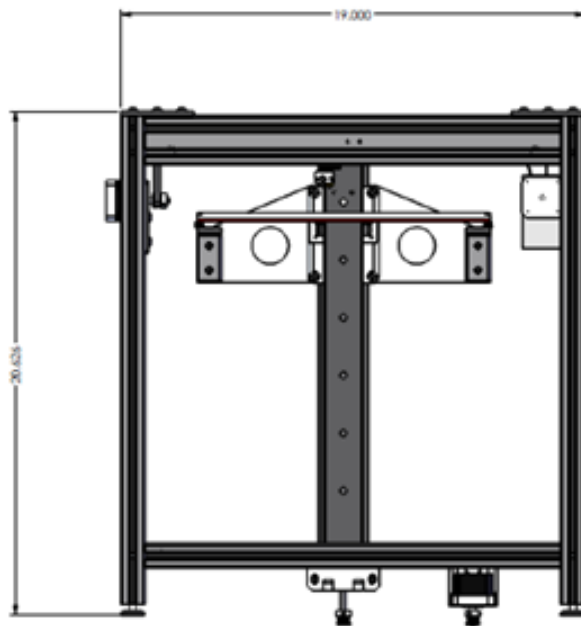
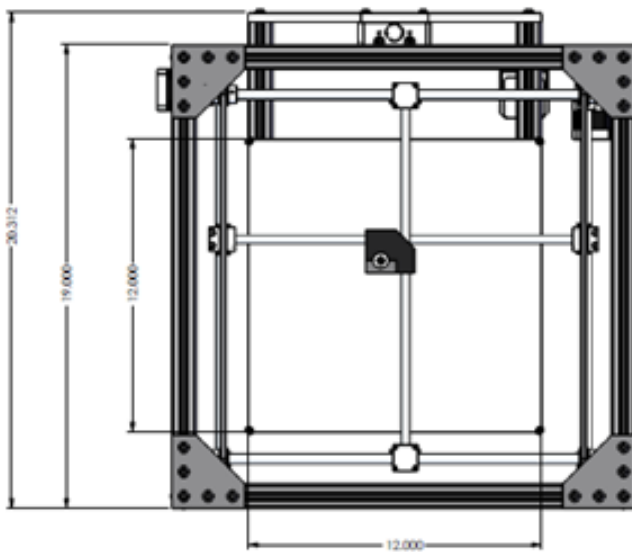






*Left: .2mm Layer Height. Right: .1mm Layer Height*





## References

Dupen, Barry. Applied Strength of Materials for Engineering Technology. Fort Wayne: IPFW, 2014. PDF.

<http://motion.schneider-electric.com/products/nema17.html>

"E3D Online." E3D Online. N.p., n.d. Web. 26 Apr. 2015.

5 Considerations for Scanning, Printing, and Subtractive Machining Design." Design World. N.p., 09 Apr. 2013. Web. 26 Apr. 2015.

"Reprap Development and Further Adventures in DIY 3D Printing." Reprap Development and Further Adventures in DIY 3D Printing. N.p., n.d. Web. 26 Apr. 2015.

"RepRap Options." - RepRapWiki. N.p., 22 Apr. 2015. Web. 26 Apr. 2015.