Next Generation 3D Printer

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Midpoint Report
Document

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1. Introduction

The capstone teams have entered the midpoint stage of the Spring Semester. This semester is the time where students must manufacture and assemble their capstone projects. During this semester, the team has ordered parts, manufactured and modified vital components, and began the assembly of the 3D printer for Novakinetics. This includes assembly of the frame, the gantry system, the electrical components, and the software end of the 3D printer. Up to the midpoint in the semester, the team has made progress towards completing the 3D printer. This paper will explain the progress made as well as give an estimate to what else needs to be done to complete the 3D printer.

2. Design

In (**Figure 1**) the preliminary design can be seen. In this design the X & Y gantry was supported by four guide rods and raised and lowered by four lead screws. The X-axis was controlled by a single stepper motor via a belt system, while the Y-axis was controlled by a single stepper motor with two shafts that connect to two separate belt systems to prevent binding. After consulting with Novakinetics, they expressed their desire to reduce the cost. With the preliminary design, the bulk of the cost was the four lead screws which cost $985 each. With this in mind, we began modifying the design to reduce the cost.

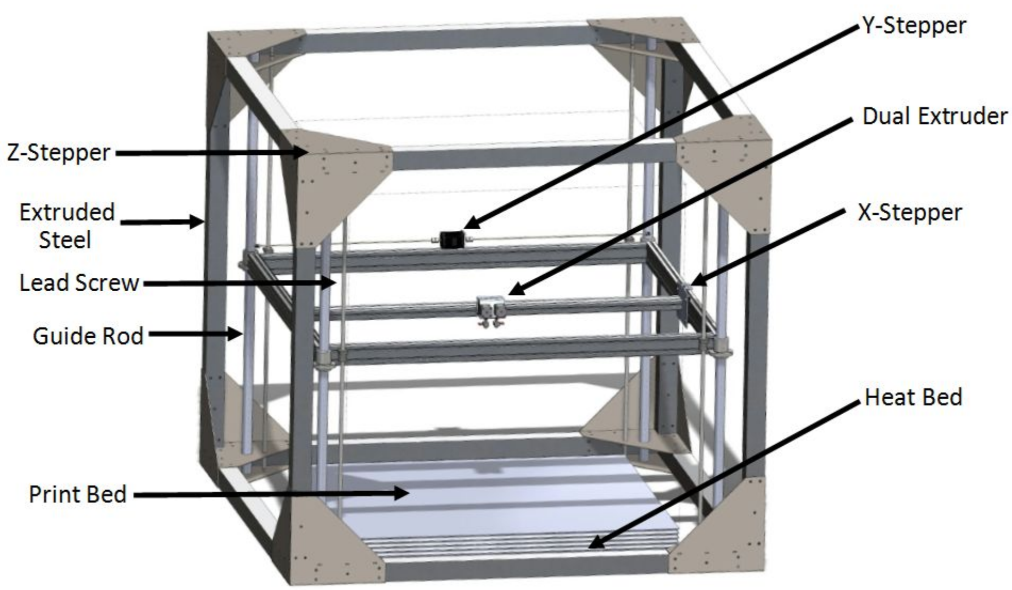

Figure 1 - Preliminary Design

In (**Figure 2**), the final design can be seen. The main difference between this design and the preliminary design is in how the print head is raised and lowered. In the preliminary design the print head was raised and lowered along with the entire gantry system, whereas in the final design the print head is raised and lowered via a Z-axis section of extruded aluminum. With this modification, the final design requires only one lead screw, which effectively reduced the cost by nearly $3,000.

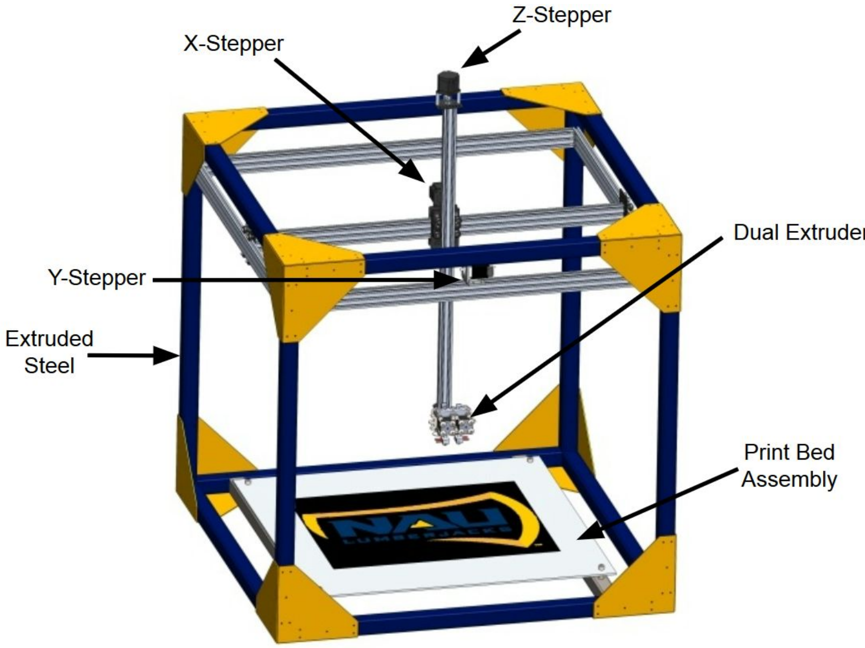

Figure 2 - Final Design

Once Novakinetics approved of the new design, sourcing of materials and components began. With all of the materials and components selected, the team made a series of purchase orders to begin the manufacturing process.

3. Manufacturing

To begin the manufacturing process, the 3D printer was divided into sections that could be manufactured separately and then assembled to achieve the final product. The sections of manufacturing are the print bed, the frame, the gantry system, and lastly the electrical components.

3.1 Print Bed

The manufacturing of the print bed is fairly straightforward. The process begins with a 38x38x⅜ inch plate of 6061 aluminum as seen in (**Figure 3**).

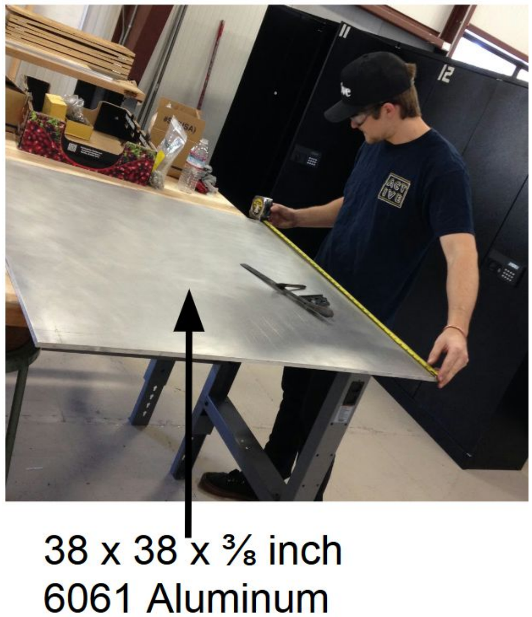

Figure 3 - Aluminum Plate

With this plate of aluminum, four half inch holes are drilled in the corners (**Figure 4**) to allow the aluminum plate to be fastened to two sections of two inch square steel tubing. This is done by using half inch bolts along with high stiffness springs which provide dampening and allow the print bed to be leveled.

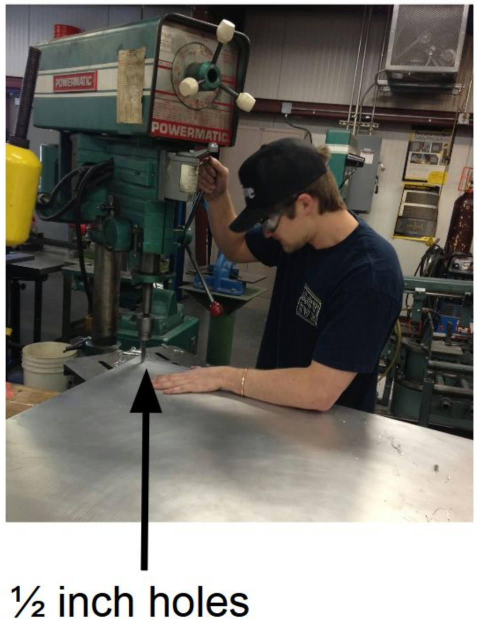

Figure 4 - Print Bed Drilling

With the holes drilled into the print bed, the 24 inch by 36 inch heat bed is installed with adhesive. This heat bed is capable of reaching temperatures in excess of 230C, which is well above the print temperature of 100C that it will be operating at.

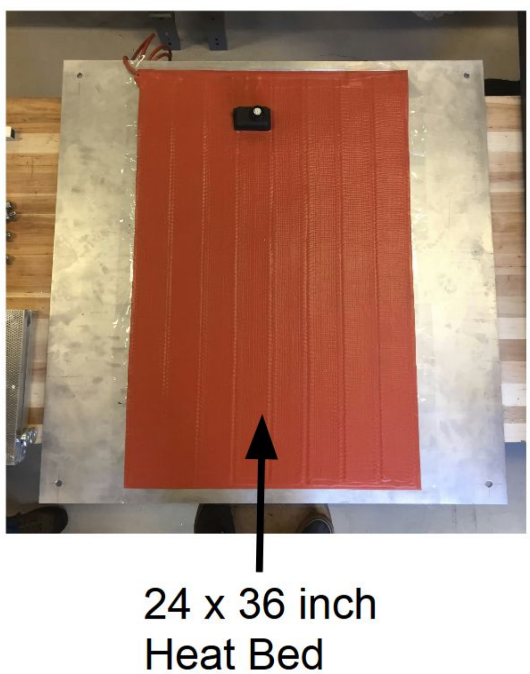

Figure 5 - Aluminum Plate With Heat Bed

One issue that was encountered with the print bed was a slight warping of the aluminum plate. The team plans to address this by installing braces to apply tension and flatten out the surface. With the print bed assembly completed, manufacturing of the frame proceeded.

3.2 Frame

The manufacturing of the frame was broken down into three different stages. The first stage consisted of acquiring all necessary materials. The materials needed for this stage were 12 2”x2”x1/8” square steel tubes, 24 six gauge steel gusset plates, and all hardware (nuts, bolts, casters, etc). After acquiring the materials, stage two began.

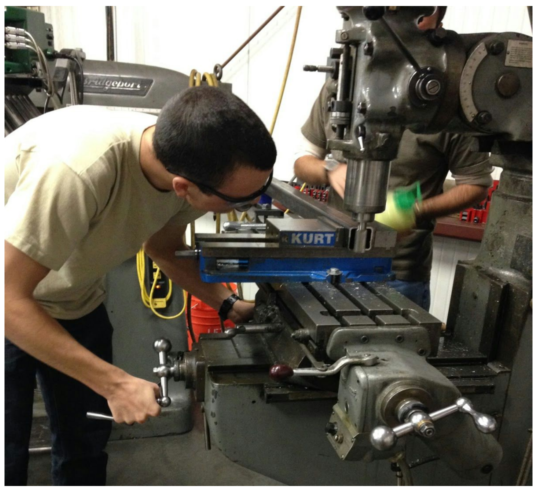

Figure 6 - Face Milling

In stage two of manufacturing the frame, the main focus was the fabrication of the parts of the frame. This included tasks such as drilling holes, facing ends, deburring edges, and cleaning the parts. This was perhaps the most time consuming of each of the three stages. For all of the beams, approximately 250 through-holes needed to be drilled and each end needed to be faced down to specifications. (**Figure 6)** shows the end mill set up for the facing operation and (**Figure 7)** shows the deburring operation, which was one step in the process of cleaning each part.

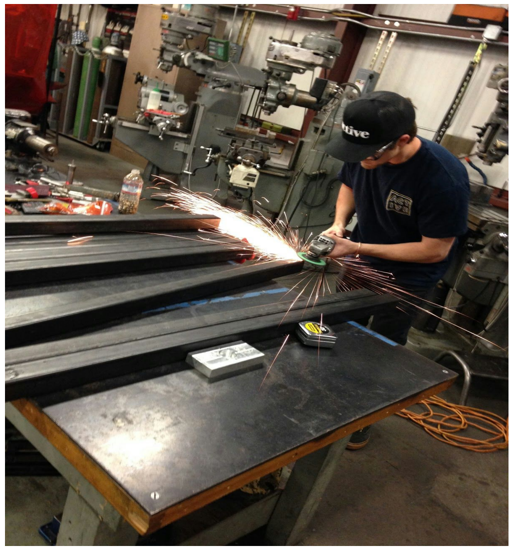

Figure 7 - Deburring

Once the parts had been fabricated, the assembly of the frame, Stage 3, could begin. As can be seen in Figure 2, the frame is a cubic structure that is composed of 12 beams and 24 gusset plates, each held together by nuts and bolts. Also, due to the large number of bolts required for assembly, a specific process was needed to follow in order to assemble the frame correctly. First, the top and the bottom four beams were assembled separately and on the ground by the use of the gusset plates on each corner. They were then connected together with the four vertical beams, which completed the cubic shape.

Once the frame had been assembled, some tweaks needed to be made. First, due to tolerances, the frame wobbled slightly when placed on the ground. To fix this, the bolts were loosened then strategically tightened while ensuring the frame was as square as possible. Also, since the frame weighs a significant amount at this point, it was necessary to install casters onto the bottom to allow for transportation of the frame. The final assembly of the frame can be seen in (**Figure 8**).

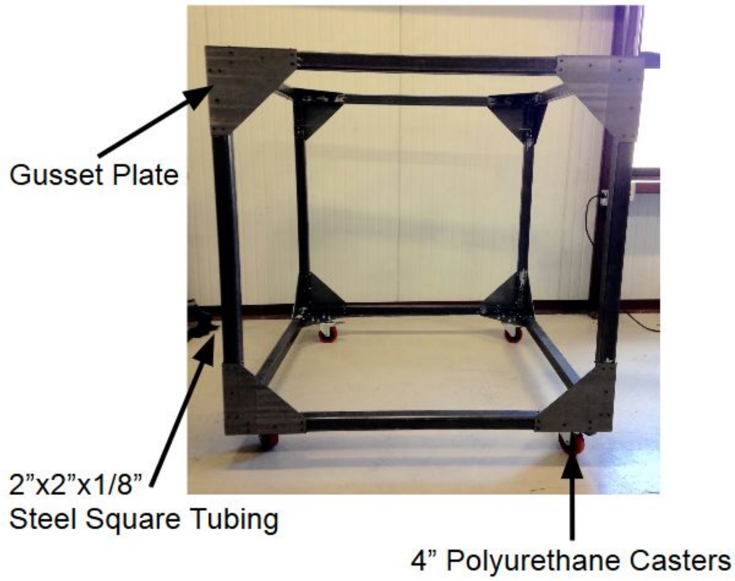

Figure 8 - Final Frame Assembly

3.3 Gantry

In Fall 2015, the team decided to go with the v-slot gantry setup. The V-slot beams used are made of extruded aluminum and are the support structure of choice when it comes to accurate and precise movement as well as interchangeability. The profile of the V-slot extruded aluminum allows for mounting of different components. The team decided to use this because it is lightweight and capable of interchangeability as well as capable of accurate movement. Openbuilds Parts Store was the vendor of choice for the Gantry system because they had very good support for custom 3D printer builds and parts could be individually bought. This allowed the team to get creative with the design as well as be able to support it effectively in the future with replaceable parts. The size of the V-slot extruded aluminum was chosen to be 20mmx60mm. (**Figure 9)** shows the profile of the V-slot extruded aluminum.

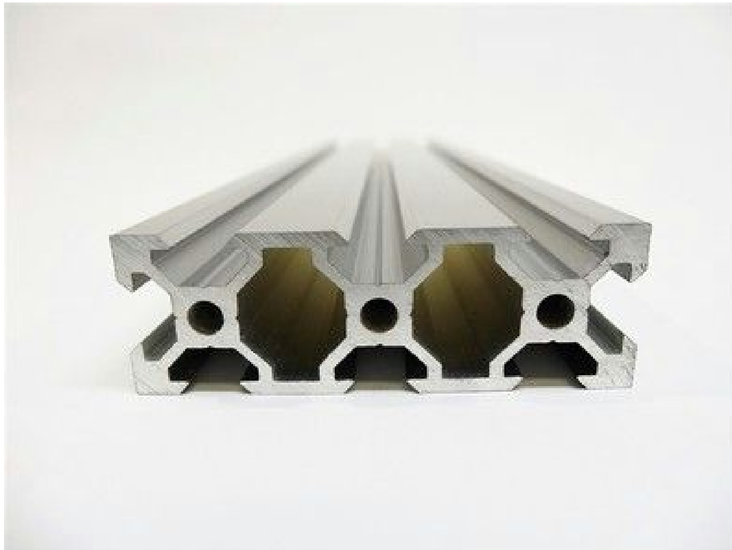

Figure 9 - V-Slot Extruded Aluminum Linear Rail

When four of these extruded aluminum linear rails are connected at ends, they create a large square area where a systematic x and z system can be placed. (**Figure 10)** shows four V-Slot extruded aluminum linear rails connected together to create the main structure for the gantry and (**Figure 11)** shows the roller plates that will be used to move the X and Z movement apparatus around.

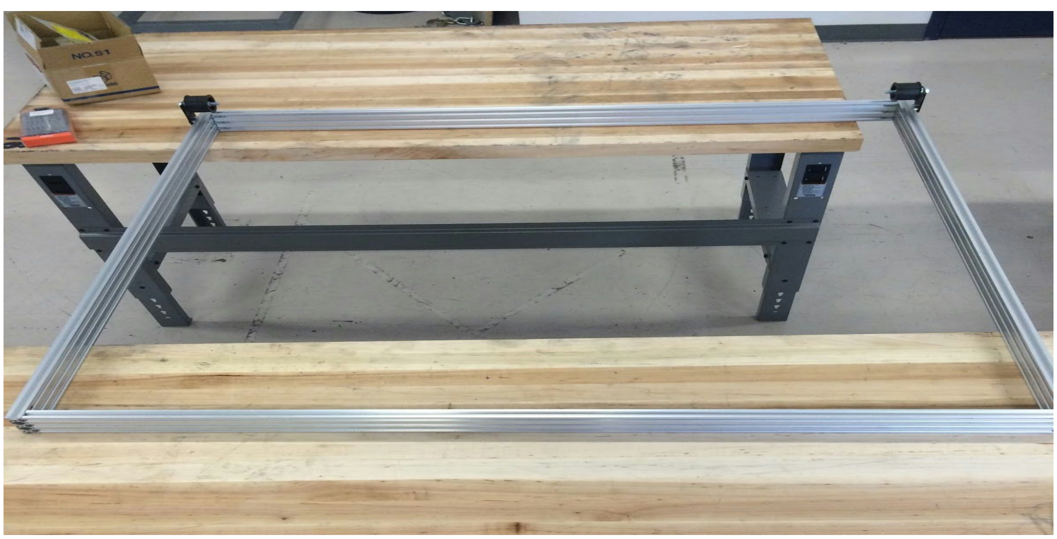

Figure 10 - Gantry Rail Setup

Figure 11 - Polyurethane roller wheel

Polyurethane wheels with roller ball bearings were then attached to aluminum plates to create a moving structure within the gantry. The gearing system that will drive the Y movement of the 3D printing apparatus will be placed on this supporting gantry structure. This involves a polyurethane belt, a drive gear, and an idler pulley situated on each side of the X and Z moving apparatus. A dual axial Nema 23 Stepper motor will drive this belt and drive system which will move the X and Z directional apparatus with precision.

Using the Polyurethane wheels and mounting plates, a V-slot extruded aluminum linear rail was mounted through the middle of the square frame. This will allow the framework for the X and Z directional apparatus to be made. (**Figure 12**) shows the square framework with the the square framework with the X and Z movement apparatus attached to it using the polyurethane roller plates.

Figure 12 - X and Z movement apparatus

This is the final design for the gantry which was assembled in the machine shop. As you can see in (**Figure 12**), the Z movement is determined by a lead screw design and guided by a plate with 6 polyurethane roller wheels guiding the aluminum rail. Each stepper motor provides movement in the X, Y, or Z direction respectively. The Gantry, once it was completed, was then placed into the Frame of the 3D printer.

3.4 Electrical

Work on the electrical system started with the acquisition of a Dell desktop from property surplus. The desktop is used to slice the models from solidworks files into G-code. This is handled with the Repetier-Host program that the group installed in the Dell. The slicer program that comes with Repetier is called Slic3r. Both Repetier and Slic3r are established programs in the 3D printing community and offer support and expandability for future upgrades. Another reason why Repetier was selected was because of the easy implementation with the selected control board.

The selected control board is the Azteeg X3 pro. This control board supports expandability for upgrades in printer design such as adding more steppers to change the configuration of the printer. The Azteeg X3 pro is also compatible with the Repetier-Host program through the utilization of the Repetier firmware. Ounce the team received the Azteeg control board the firmware was flashed to the board.

The firmware files are of importance especially for this project because it allows the user to select advanced features. One of these features is changing the number of print heads from the default of one to two. Learning how the firmware works was also key to understanding how the control board works in general. The coed is written in the Arduino IDE and makes for easy understanding.

After the firmware was installed on the board the motor drivers needed to be setup. The purchased NEMA 23 motors have a maximum current rating of 2 amps. In order to prevent damaging the stepper motors the current was limited on the drivers through the use of a turnable trimmer. This trimmer can be seen in (**Figure 13**) below. After the current limits were all set for the X, Y, & Z steppers heat sinks were then added to the top of the drivers. Another heat sink was attached on the bottom of the board across all of the MOSFETS used to control the extruders and other accessories.

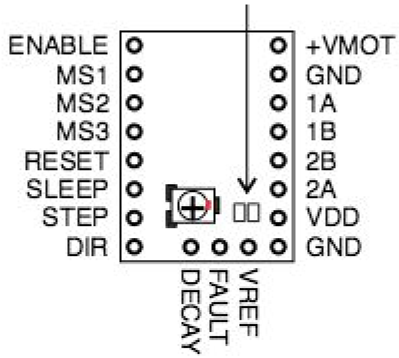

Figure 13- Diagram of Stepper Driver

At this point the electronics could now be tested. For testing purposes the team got 2 12V ATX power supplies along with a generic 12V computer fan. Testing started by first following the wiring diagram found below in (**Figure 14**). Once everything was wired the control board was turned on and then connected to the Repetier-Host program. The fan was positioned to provide maximum air flow over the heat sinks. Basic setting were inputted into the configuration section of the Repetier-Host program. This allowed us to move the steppers and determine everything was working properly.

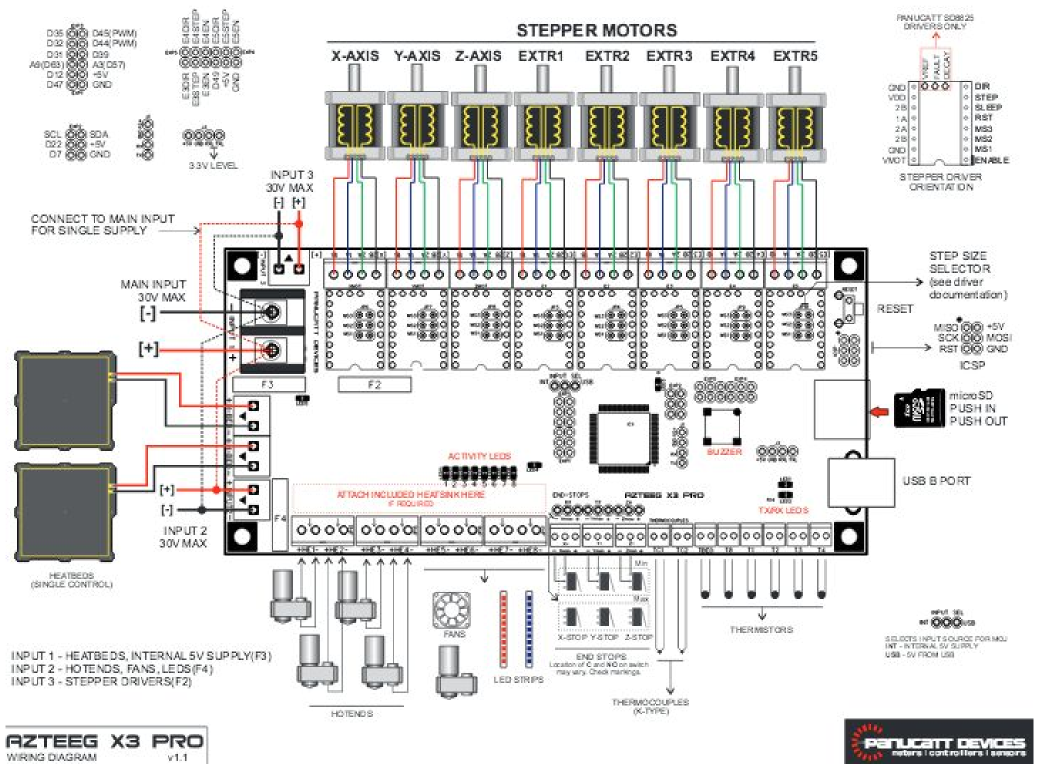

Figure 14 - Azteeg X3 Pro

After testing the electronics it became clear that there was a need for a control box in order to clean up and organize the wiring. To do this a chassis was need in order to protect the control board and organize the wiring. An Apple G5 computer was selected to make up the chassis. All of the Apple components were stripped out of the G5 except for the built in 12V 14 Amp with dedicated fans were left in place and will be utilized to supply power to the Azteeg board. Specifically it will be supplying power to the Azteeg's logic board. Standoffs were built into the case and allowed up to mount the Azteeg stood off the back surface of the case. This will allow for good airflow around the board and heatsinks. A terminal block assembly was then installed on the bottom in order to facilitate clean wiring between the Azteeg board and all the accessories such as stepper motors, end-stops, and thermistors. This will prove useful in troubleshooting the machine as well as general maintenance and replacement of broken parts. the completed control system can be seen below in (**Figure 15**).

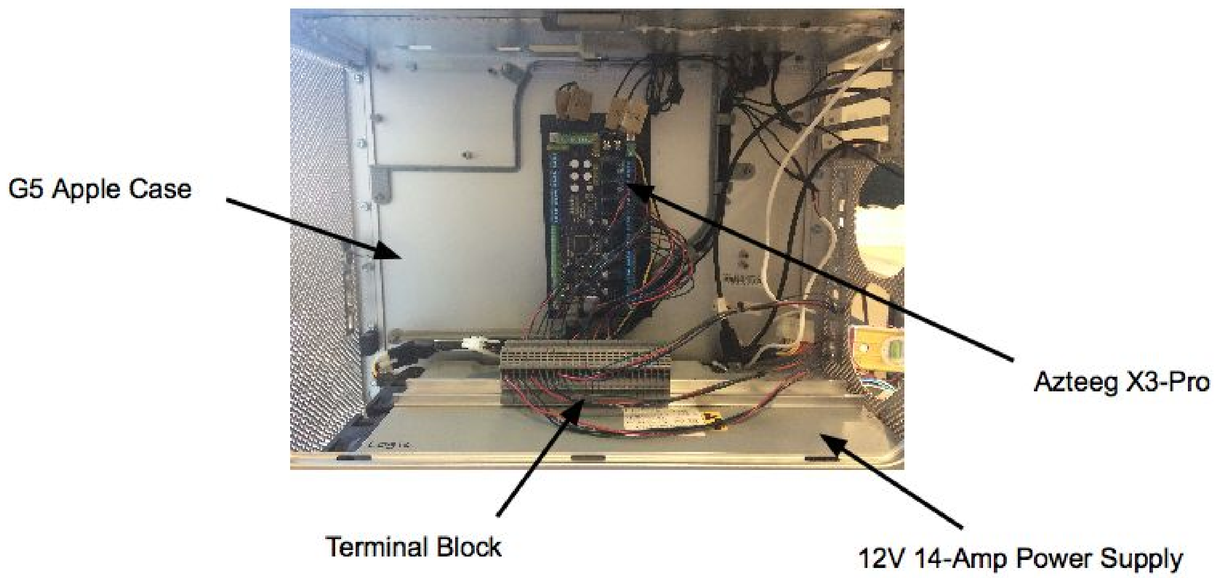

Figure 15 - Layout of The Control System

3.4 Next Steps

The next steps the team must still complete include movement calibration and troubleshooting of the stepper motors, installation of both a printhead and feed system, and lastly powder coating of the 3D printer. In regards to the movement calibration and troubleshooting of the stepper motors, stepper motors must be programmed and calibrated in order to ensure that the number of steps properly correlates to a linear movement. The installation of the printhead will simply require the manufacturing of a bracket to secure it to the Z-axis, while the feed system will be designed to hold a spool of filament. In order to powder coat the 3D printer, the team will disassemble the frame and send it over to Novakinetics to be painted and then it will be reassembled. Powder coating of the 3D printer will prevent corrosion and deterioration.

4. Conclusion

The client is Novakinetics, a company based in Flagstaff that specializes in aerospace composite parts. They are currently in need of a more efficient manufacturing process in order to reduce the lead time for molds and tooling. This can be achieved using 3D printing by optimizing the process for large scale printers while maintaining affordability. The objectives therefore are to increase the print speed, maximize accuracy, reduce maintenance, make it safe to operate and easy to use, as well as economic. Using functional diagrams and relative weight matrices, individual components of the 3D printer which met the team's established objectives were selected. With a CAD model and Bill of Materials of the 3D printer completed, parts were ordered and the manufacturing, programming and assembly process of the 3D printer began.

To begin the manufacturing process, the team divided the 3D printer into sections that could be manufactured separately and then assembled to achieve their final product. The sections of manufacturing include the print bed, frame, gantry system, and lastly the electrical components. In regards to the mechanical components of the 3D Printer, after configuring the frame, gantry and print bed, such components were then fastened together and the mechanical assembly portion of the team's 3D printer was completed. In consideration to the electrical components of the 3D printer, a control system enclosure was assembled and programing and calibration of the stepper motors has begun. After updating the Bill of Materials and summing all of the individual component prices, the overall cost of the team's 3D Printer came out to be roughly $2500.00 including shipping and tax fees. This total amount is still a rough estimate as the team still needs to order some more components such as filament. The next steps the team still needs to accomplish in order to complete their project in time include the movement calibration and troubleshooting of the stepper motors, installation of both a feed system and the printhead, and lastly a powder coating of the 3D printer to prevent rust and deterioration.

5. References

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