

ECE 342 FINAL PROJECT

Developer Guide

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1 System Overview

Our team developed a SpyderCam style payload positioning system that moves a payload around in an 8.5 by 11-inch area by using three strings that connect a central payload to pylons at the corners of an equilateral triangle. An Arduino AT MEGA2560 is used to control the stepper motors that allow for the payload to change position, the Arduino also is used to measure the sensor values from the RFID and light sensors on the payload. G-Code commands generated by a MATLAB GUI are used to provide the Arduino with instructions on where to move the payload.

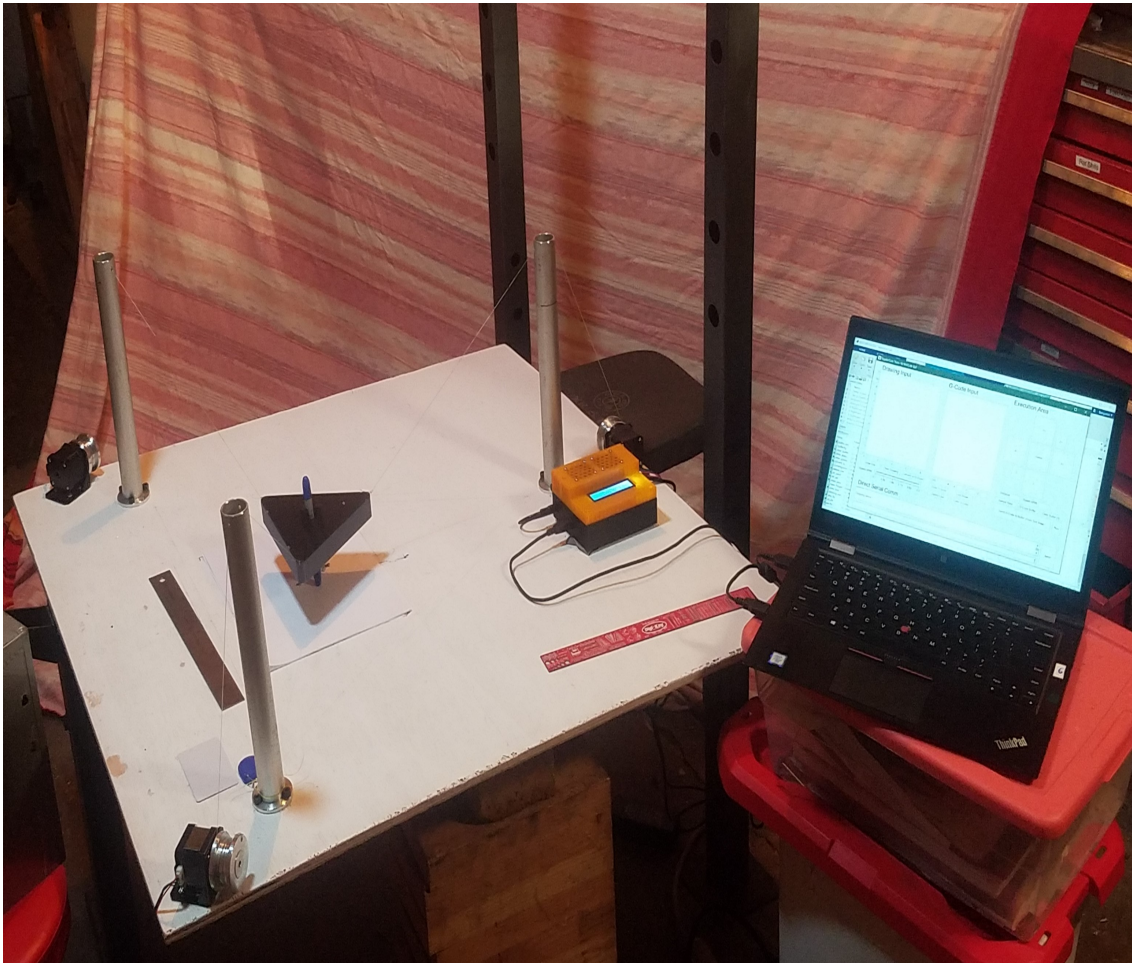


Figure 1: This is an image of what the completed project looks like.

1.1 System Block Diagram

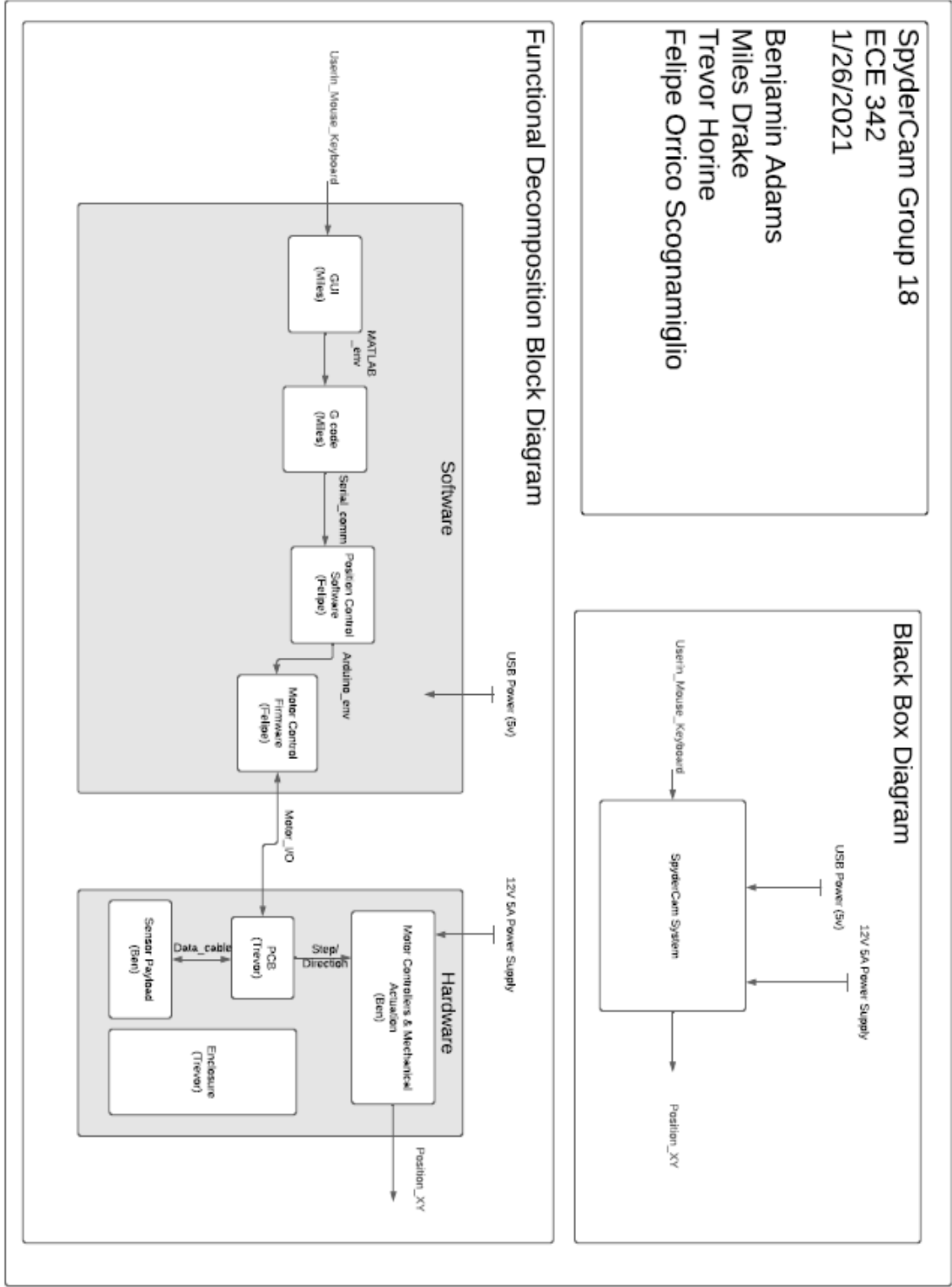


Figure 2: This is the block diagram of the whole system.

2 Electrical Specifications

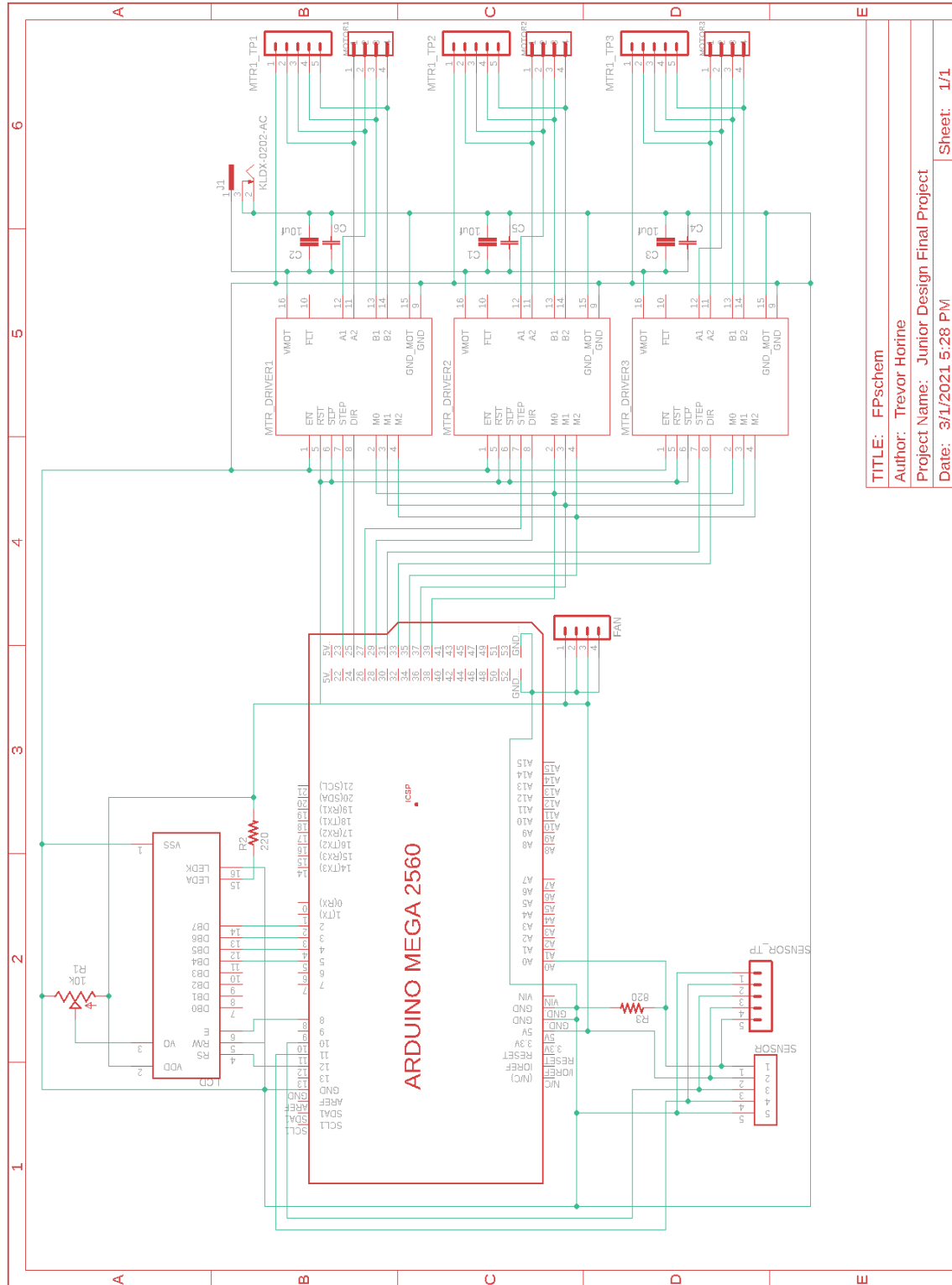
The Arduino AT MEGA 2560 is powered off the USB that is also used for serial communication with the computer and MATLAB script that provides G-code commands for the system to perform. In addition, the system also has a 12 volt five amp power input that supplies the higher voltage and current that is required to drive three stepper motors used to move the payload around. With the exception of the outputs from the DRV8825 stepper motor drivers to the motors the rest of the system uses five volt logic.

2.1 System Interface Table

Interface Definitions	
Userin_Mouse_Keyboard	PS/2 Keyboard Interface Vcc = 5.0V
MATLAB_env	Internally Defined MATLAB Variables Floating-point precision
Serial_comm	Protocol: UART 115200 baud G-Code Commands
Arduino_env	Internally Defined Arduino Variables See ATMEGA 2560 DS
Motor_I/O	10 Digital Pins Vmin = 0V Vmax = 5V
Step/Direction	Vmin = -0.5 V Vmax = 7.0 V
Data_cable	6 Pin High Speed UART (115200 Baud) Vmin = 0V Vmax = 5V
USB_Power	V = 5 V I = 0.5 A P = 2.5 W
Motor_Power	V = 12.0V I = 1.5 A (nominal) I <= 1.1 A (Actual)
Position_XY	x/y payload position spanning 23.00" equilateral triangle Lateral Deviation $\leq 0.25"$ per 10" travel

Figure 3: This is the interface table for the system.

2.2 Schematics



TITLE: FPSchem

Author: Trevor Horine

Project Name: Junior Design Final Project

Date: 3/1/2021 5:28 PM

Sheet: 1/1

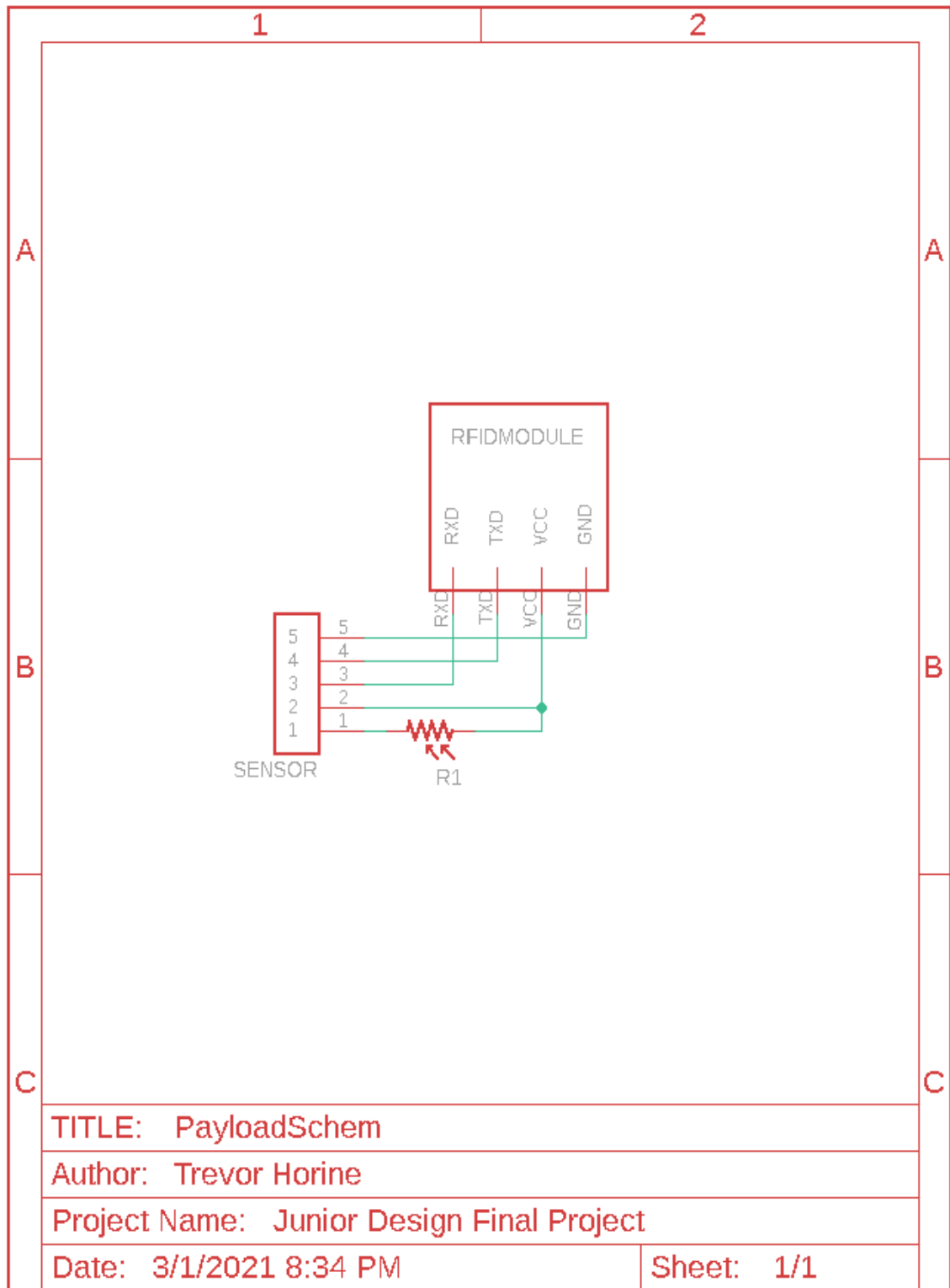


Figure 5: Detailed schematic of the payload that connects to the SENSOR connector in Figure 4.

3 User Guide

3.1 Setup

The following sections describe the initial setup and running of separate components of the Spydercam Project.

3.1.1 Hardware

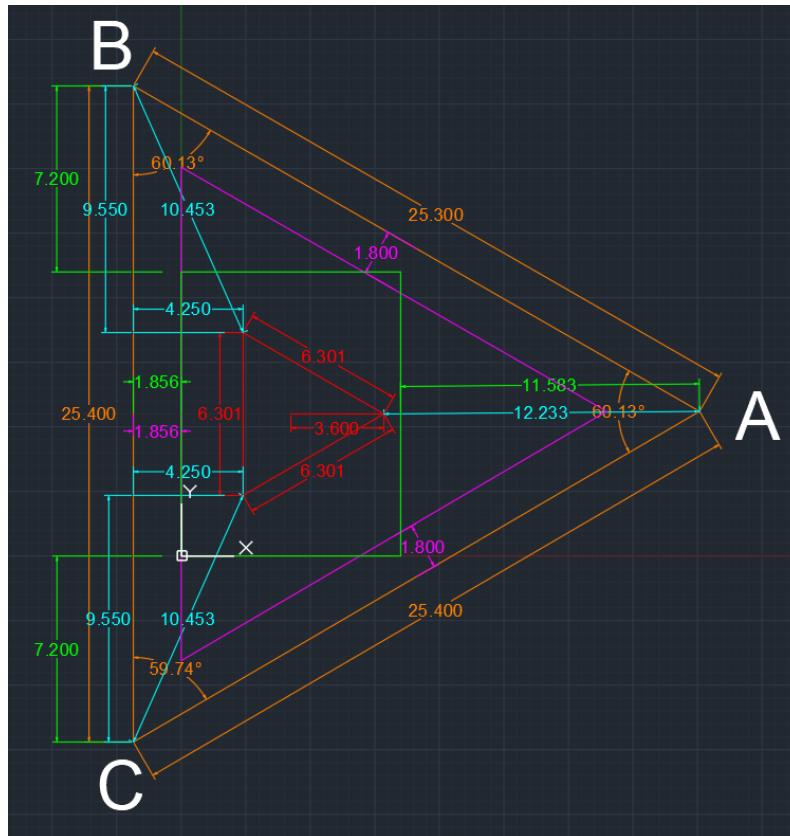


Figure 6: CAD image of relative hardware measurements with a triangular payload

Begin by setting up the pylon mounts and pylons in accordance with Figure 6 (note that different payloads can be compensated by changing software parameters (see section 3.1.2, but the pictured payload does not alter other dimensions)). Dimensions pictured are from the point where the thread leaves the pylon, so some basic shop math is required. Once positioned, the pylon feet will balance the pylon, allowing for easy positioning before installation. Carefully mark all of the bolt hole positions in the pylon feet, then drill 5/16" holes to allow the insertion of 1/4 – 20" socket-headed cap screw. Install 1/4 – 20 screws, washers, and bolts, and tighten. Carefully position the nema 17 motor mounts outside of the triangle, allowing for a clear trajectory for the thread to travel, and bolt down after making sure that motor cables are long enough to reach the microcontroller box. After wiring up the stepper motors, the microcontroller enclosure can be mounted to the frame. Finally, care should be taken in accurately positioning any paper inside the drawing area. Paper can be easily secured with double-sided tape, and marking the paper registration makes the reloading of paper more efficient.

The final hardware should look like Figure 7.

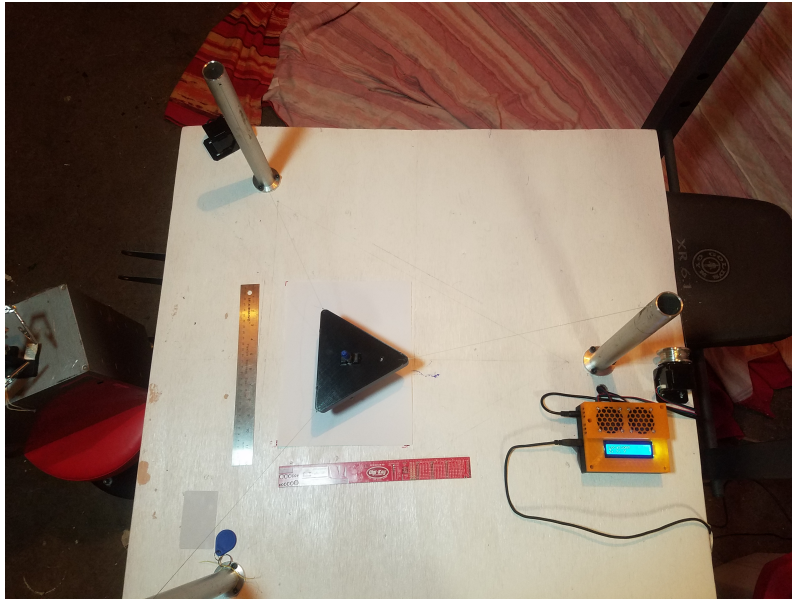


Figure 7: Final Hardware- top view

3.1.2 Software - Arduino

Before installing the Arduino software, be sure that the payload dimensions in lines 56-60 match the payload that you are using. After this is verified, load the provided Arduino code and libraries to the Arduino Mega using the Arduino IDE. After the program has loaded, the LCD display will request you to input some current values so that it knows where the payload is located, more precisely, it requests X, Y and Z (i.e. current payload X and Y location with relation to the C-edge of the paper, and the current height of the payload from paper-level to the top of the payload (where the threads are attached)). After all requested values are input, the Arduino side of the setup is complete, and it is ready to receive G-Code inputs to move the payload or perform another task.

3.1.3 Software - MATLAB

To set up the MATLAB GUI for this system, load spyderGUI.m (8.2) into MATLAB. Replace the value "COM3" on line 38 to the name of the serial port being used on your computer. Plug in the Arduino to the specified serial port using a USB cable and then run the program. If the serial device is not properly connected, MATLAB will throw an error and exit the program. If this is the case, reconnect the Arduino and confirm that the proper serial port is specified. Once the main GUI window opens up, setup is complete and MATLAB is ready to send commands. Before sending any G-Code, the direct serial communication section of the GUI should be used to send the initial location values of the payload, as stated in section 3.1.2 above.

3.2 Operation

Operation of the SpyderCam is viable in two different ways. It is possible to control the hardware by inputting commands straight to the Arduino or through the MATLAB GUI.

3.2.1 MATLAB

The MATLAB portion of the system serves as a graphical user interface (GUI). Its purpose is to take instructions from the user, send those instructions to the Arduino, then receive and display sensor and location data from the Arduino. There are four different ways that a user can enter instructions into the MATLAB GUI: By typing a sequence of G-Code, by making a drawing, by pressing incremental movement buttons, or by sending serial commands directly to the Arduino. The layout of the GUI can be seen in Figure 9.

The main focus of this GUI is the drawing input area. After making a line drawing in this area, the user can convert it to G-Code which will be sent to the G-Code text input box. From here, it can be edited using the options listed below the text area, or simply edited directly by typing in the box. Once the sequence of G-Code is ready to be executed, it can be sent to the G-Code buffer (shown in Figure 10), which will send commands to the Arduino one at a time. It sends a command, then waits for a package of location and sensor information to be returned from the Arduino as discussed in section 4.1. The 'G' at the end of the information package lets the buffer know that it's time to send another command. The information received is parsed and plotted in the sensor data window, shown in Figure 11.

In addition to the main program flow described in the previous paragraph, the direct serial communication area can be used to send commands to the Arduino regardless of whether a 'G' has been sent back. This is useful for sending M6 or M2 commands, which need to interrupt a current process. Received serial data from the Arduino will also appear in this section of the GUI.

3.2.2 Arduino

Operating SpyderCam with the Arduino is quite simple. After the setup is complete, all that needs to be done is to send commands through Serial to the Arduino. Those commands are in standard G-Code format and you can find a full list of them in Figure 8.

4 Design Artifacts

4.1 Arduino Code

The Arduino code Block contains two sub-blocks: Motor Control Firmware (MCF) and Control Software (CS). Those two sub-blocks work together to translate G-Code input into correct payload movement. The CS receives the G-Code input from Serial and collects all necessary values from it. It then interprets that information and sends a move request to the MCF. The MCF upon receiving a move request will calculate the target thread lengths and the amount of steps that each motor has to perform in order to achieve the correct displacement. It will then communicate with the stepper library AccelStepper to calculate the necessary speeds for each of the motors so that they reach each of their individual displacements at the same time. The CS is also responsible to reporting back values to MATLAB such as sensor data and current thread lengths and payload position.

G/M-CODE	VAR 1	VAR 2	Var 3	VAR 4	Definition
G0	X	Y	Z	-	Takes Payload to X, Y at max speed
G1	X	Y	Z	F	Takes Payload to X, Y at F speed
G20	-	-	-	-	Mode: Inputs in Inches
G21	-	-	-	-	Mode: Inputs in Millimeters
G90	-	-	-	-	Mode: Absolute Coordinates
G91	-	-	-	-	Mode: Incremental Coordinates
M2	-	-	-	-	End Program
M6	-	-	-	-	Tool Change
C1	-	-	-	-	Send Payload location to Serial
C2	-	-	-	-	Send thread lengths to Serial

Figure 8: Table of available G-Code commands within the Control Software

After any command from Figure 8 is sent to the Arduino and executed, the Control Software will send back information to MATLAB in the following format:

X<x-location>**Y**<y-location>**Z**<z-location>**A**<thread-len-a>**B**<thread-len-b>**C**<thread-len-c>**L**<light-level>**R**<rfid-data>**G**

The letter ‘G’ that is sent after the information indicates that the software is ready to receive another command. When a C1 or C2 command is executed, the format is different in the way that the information is sent to MATLAB. It will include a ‘#’ to indicate the end of the transmission cycle of the information requested.

4.2 MATLAB Code

The Drawing Input section of the MATLAB GUI allows the user to control the SpyderCam by entering a line drawing. MATLAB converts this drawing into G-Code by creating commands which move to the start of each line, lower the pen onto the paper, move along the path created by the line, then raise the pen and continue to the next line. The G-Code is all written in standard G-Code notation.

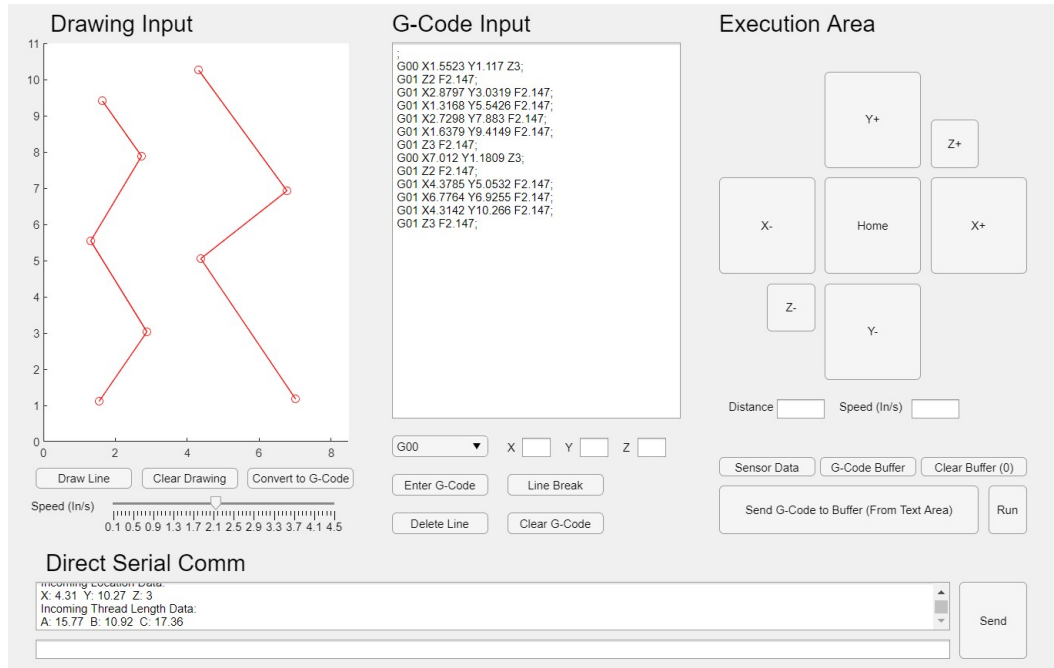


Figure 9: MATLAB GUI. Sections from left to right are: Drawing input area, G-Code text box, Execution area. The direct serial communication area is at the bottom.

G-Code which is sent to the buffer will appear in the G-Code buffer window. G-Code is sent from the buffer to the Arduino and subsequently removed from the buffer upon receiving a 'G' character through serial. The G-Code buffer window is shown in the figure below.

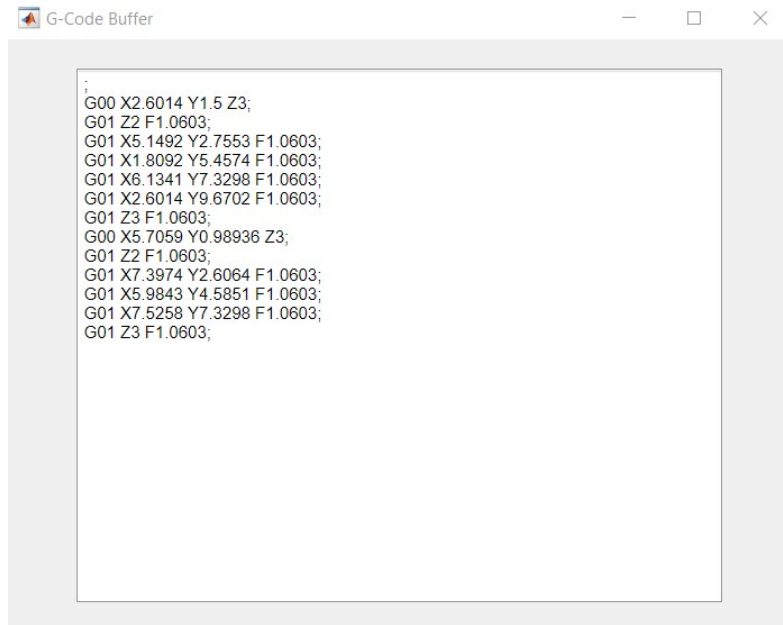


Figure 10: MATLAB GUI G-Code Buffer. This window shows a list of G-Code which is queued to be sent to the Arduino.

When the Arduino reaches its current destination, it sends back a packet of location and sensor information as described in the previous section. The information is then parsed and displayed in the Sensor Data Window, shown in the figure below.

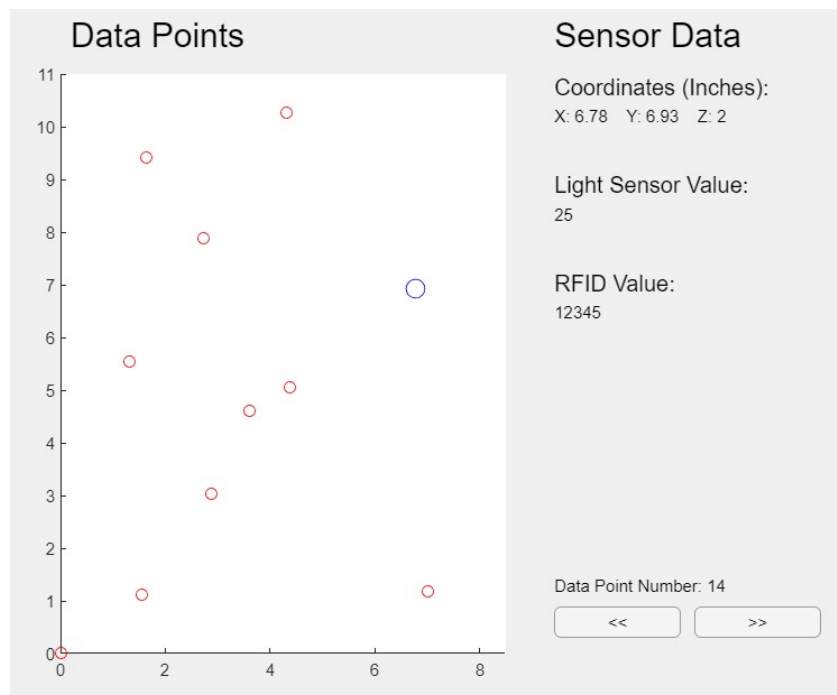


Figure 11: MATLAB GUI sensor data view. Each data point is contains a packet of sensor and location data received from the Arduino

4.3 Mechanical Subsystem

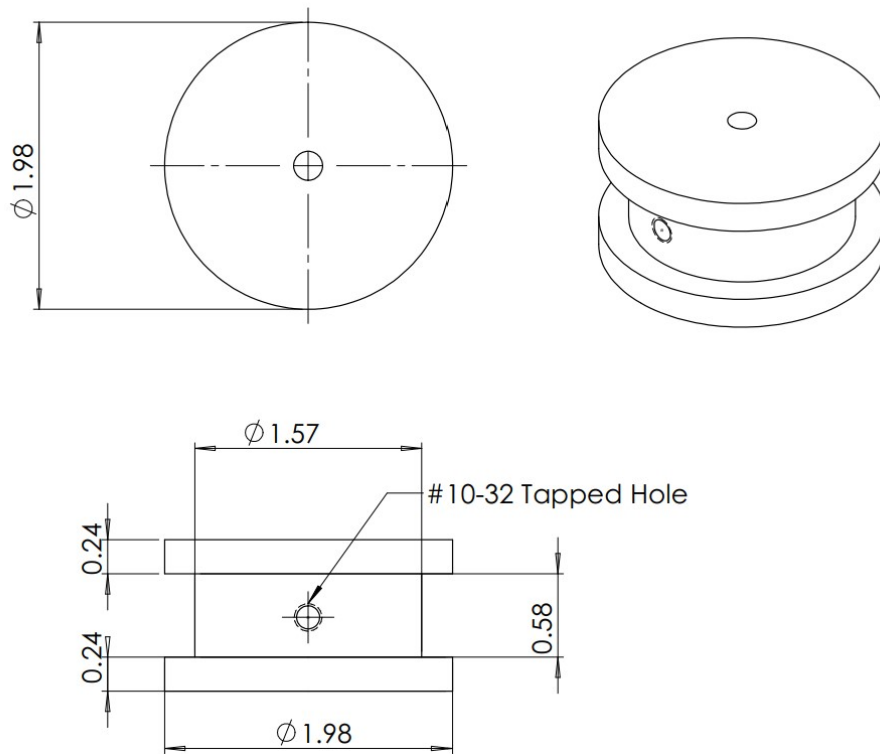


Figure 12: Aluminum motor- mounted spool blueprint

4.4 Payload

4.4.1 Triangular Payload

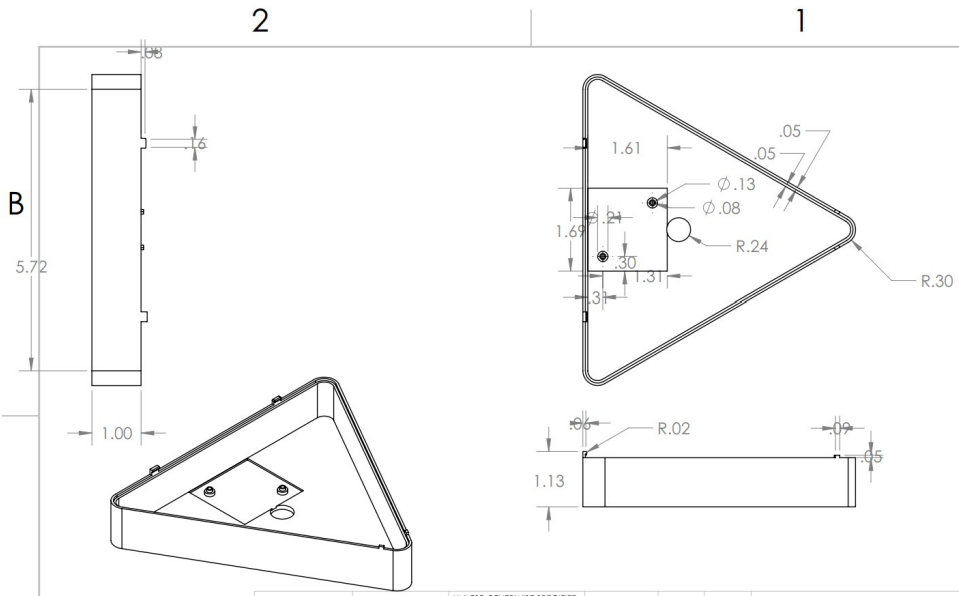


Figure 14: Triangular payload bottom part

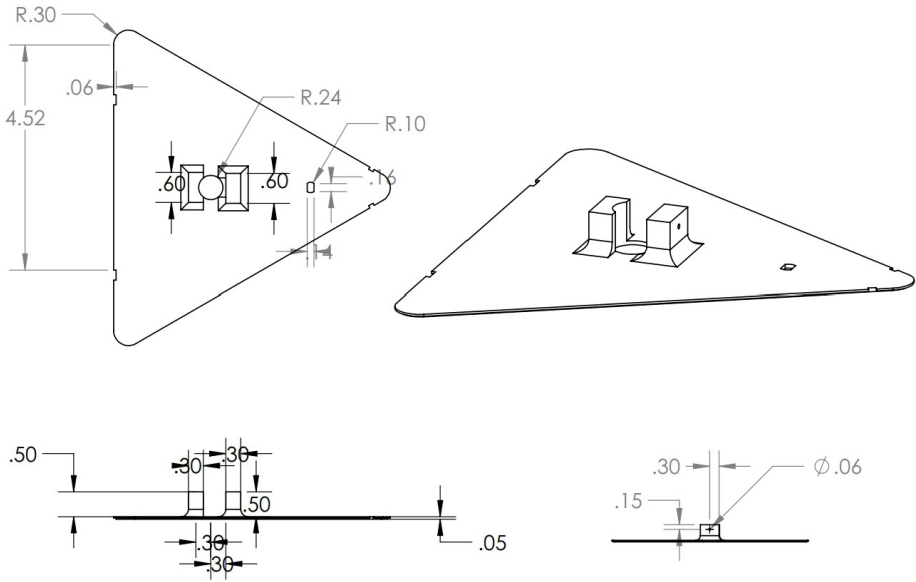


Figure 15: Triangular payload top part

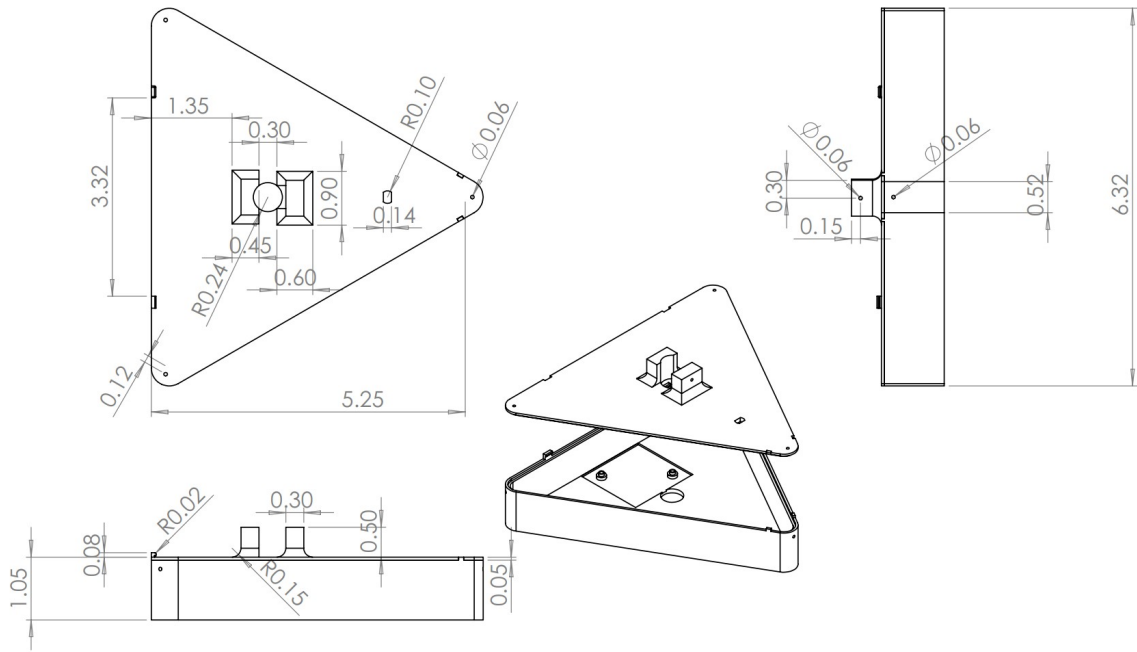


Figure 16: Triangular payload assembly- exploded view

4.4.2 Rectangular Payload

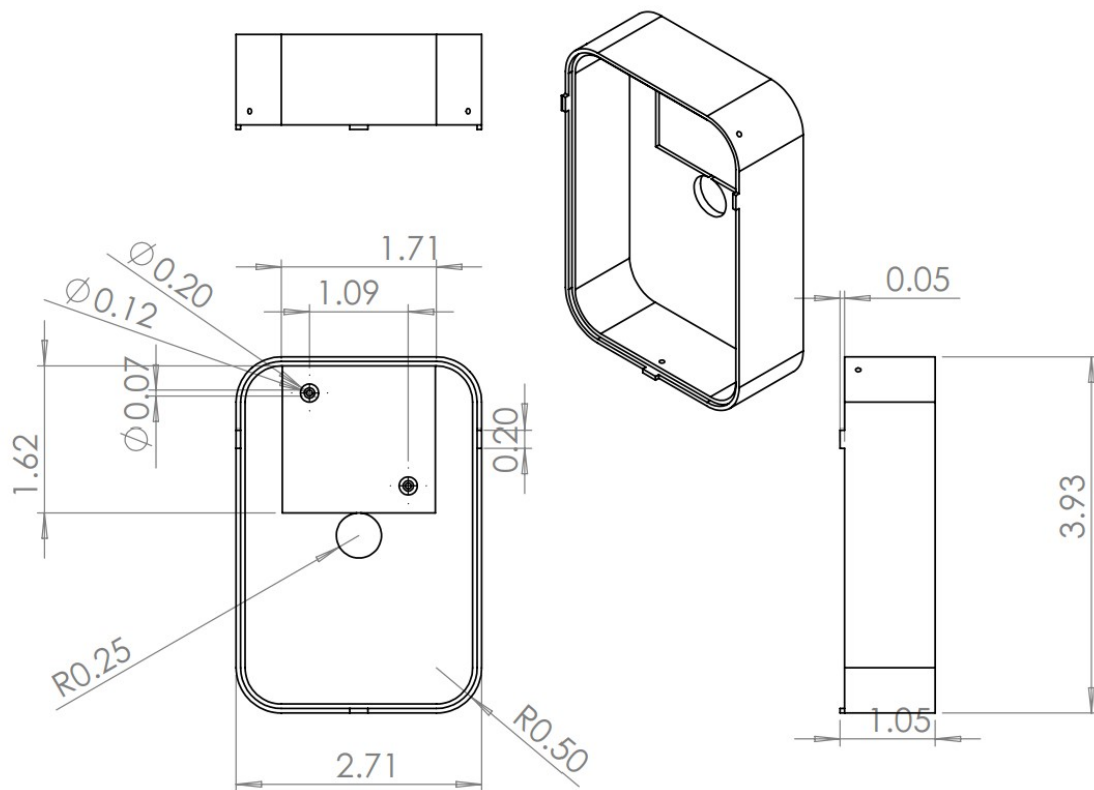


Figure 17: Rectangular payload- bottom part

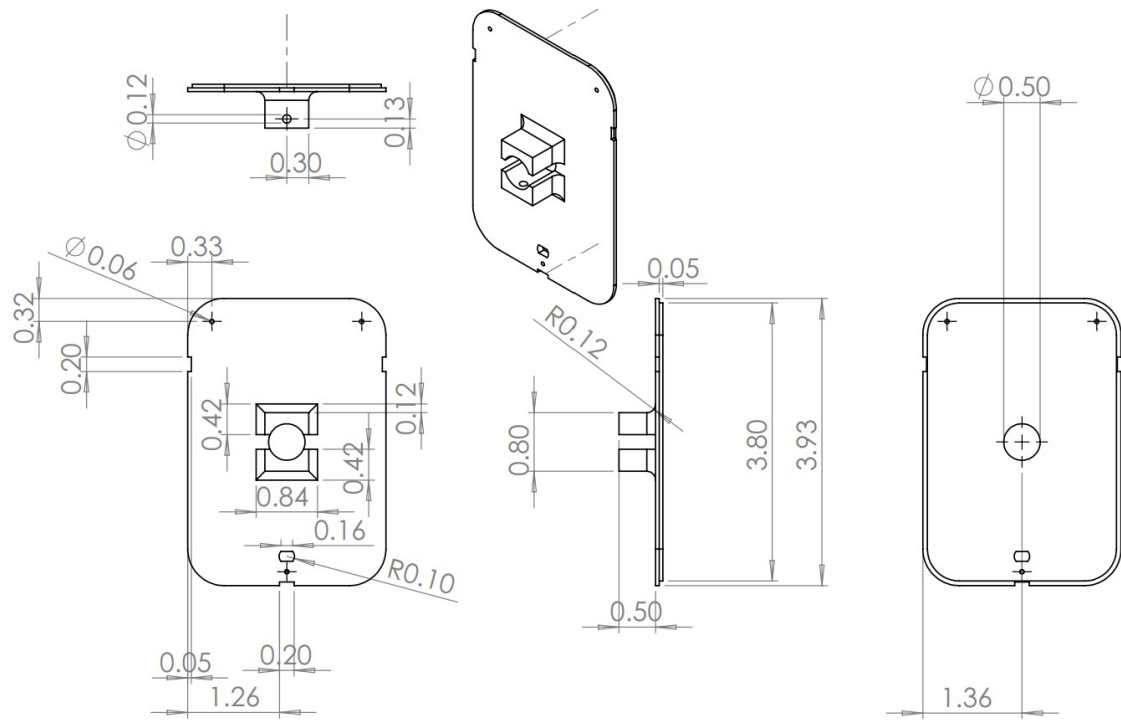


Figure 18: Rectangular payload- top part

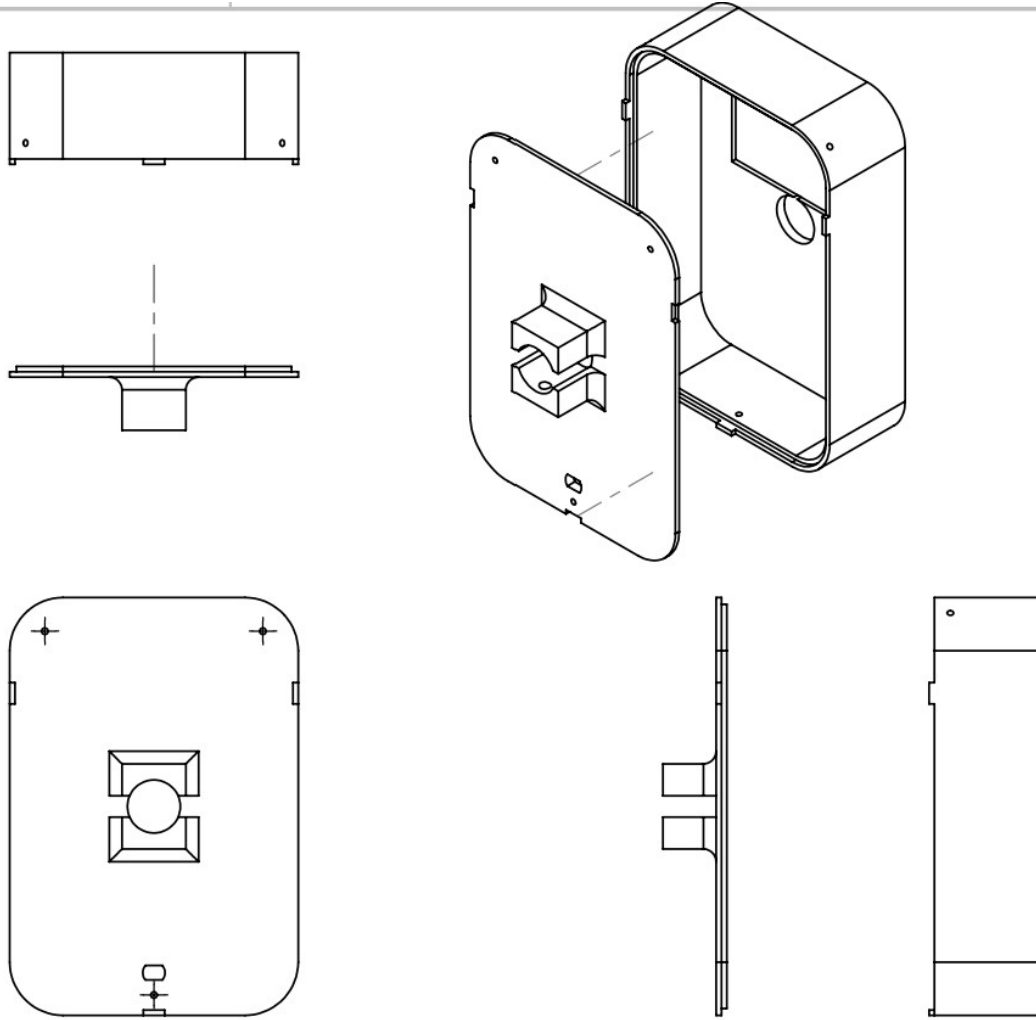


Figure 19: Rectangular payload- exploded assembly view

4.5 PCB Enclosure

The PCB enclosure was modeled using the 3D model of the PCB, such that the board would sit on supports around the mounting holes, and the top would have supports that come down to hold the board in place. four 35 mm long M3 screws hold the enclosure together. The two 40mm by 40mm by 10mm fans also mount to the top of the enclosure to provide air circulation in the top on to the motor drivers and out the side vents. there is a window in the top to make the LCD screen visible and ports in the sides for the Arduino USB, 12 volt motor power, three motor cables and the one sensor cable. Figure 20 shows the 3D model of both halves together with the model of the PCB inside of the enclosure.

Mechanical drawings for bottom and top halves of the enclosure can be found in Figures 21 and 23 respectively, followed by the models of each half in Figures 22 and 24 respectively. The final enclosure with the built PCB inside can be found in Figure 25.

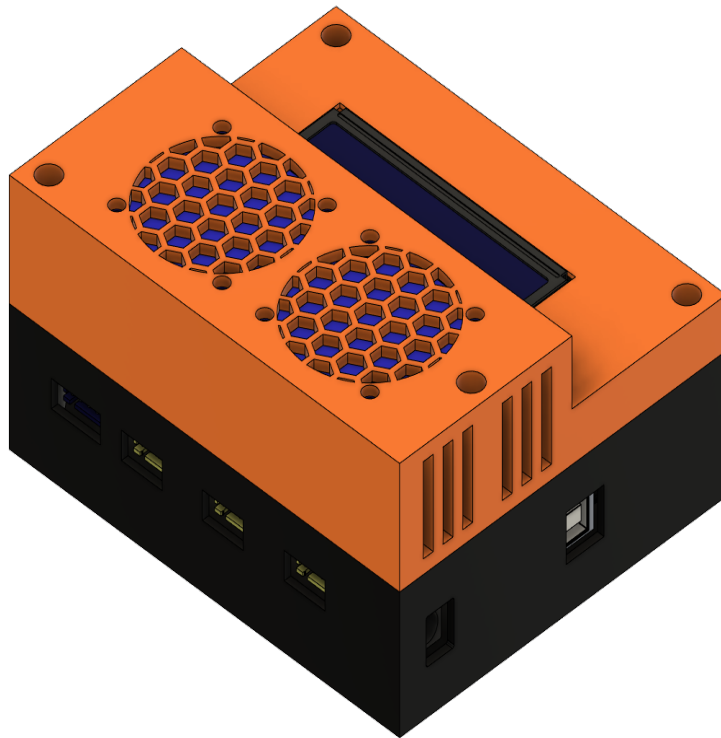


Figure 20: This is a rendering of the 3D model of what both pieces would look like together. This model has the model for the PCB inside, and has blue boxes for fans.

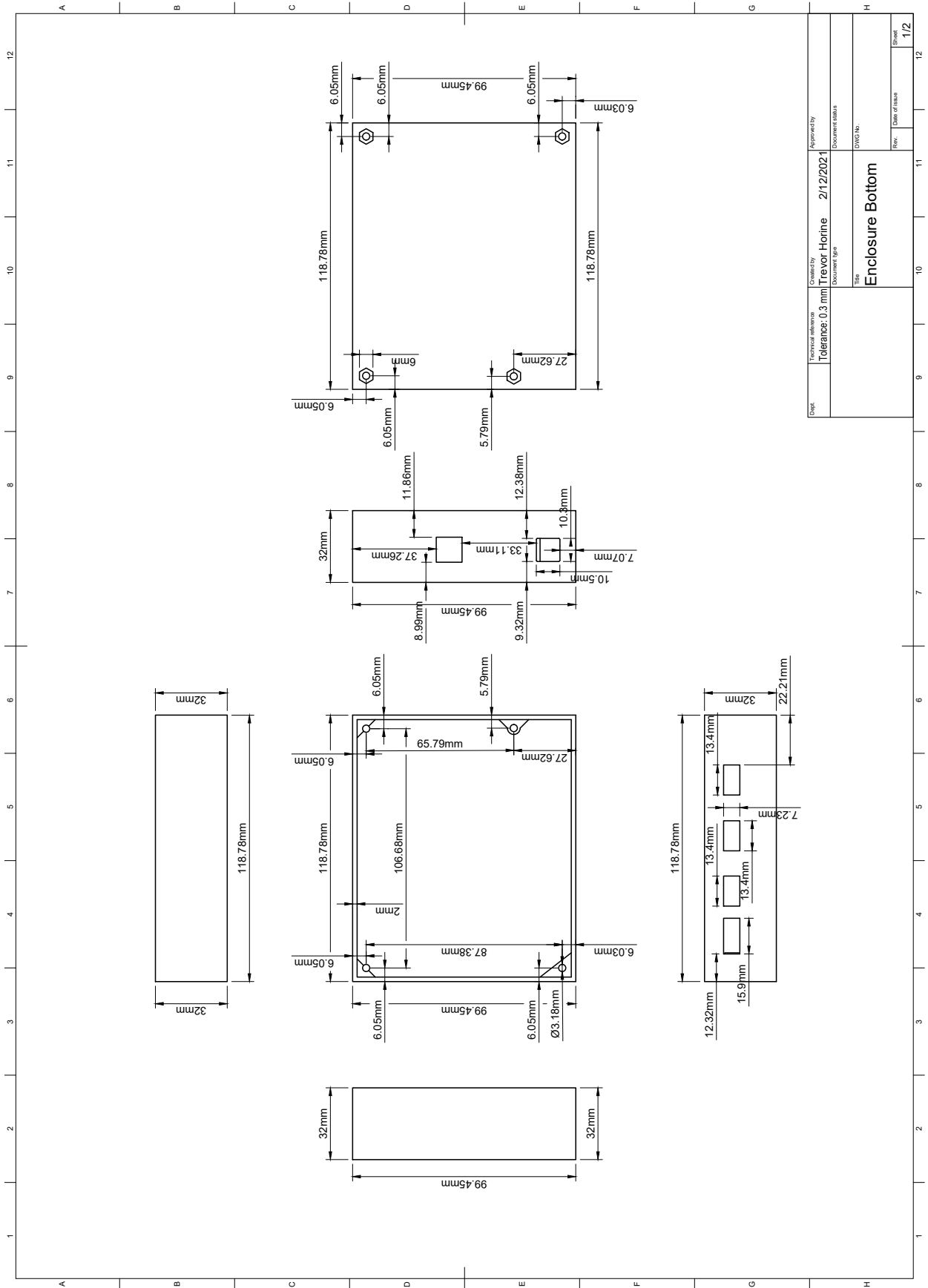


Figure 21: Mechanical drawing of the bottom half of the enclosure designed to hold the PCB.

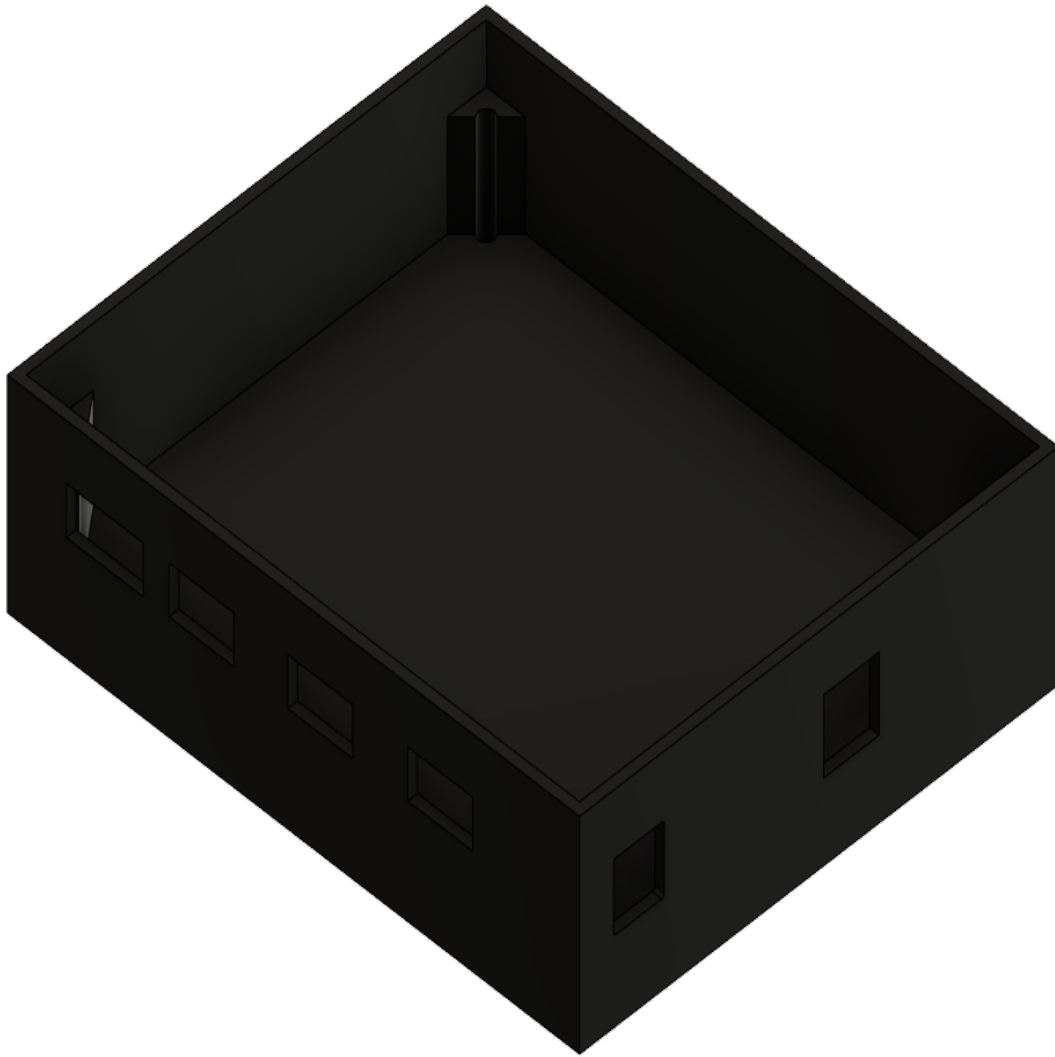


Figure 22: This is a rendering of the 3D model of the bottom half of the enclosure.

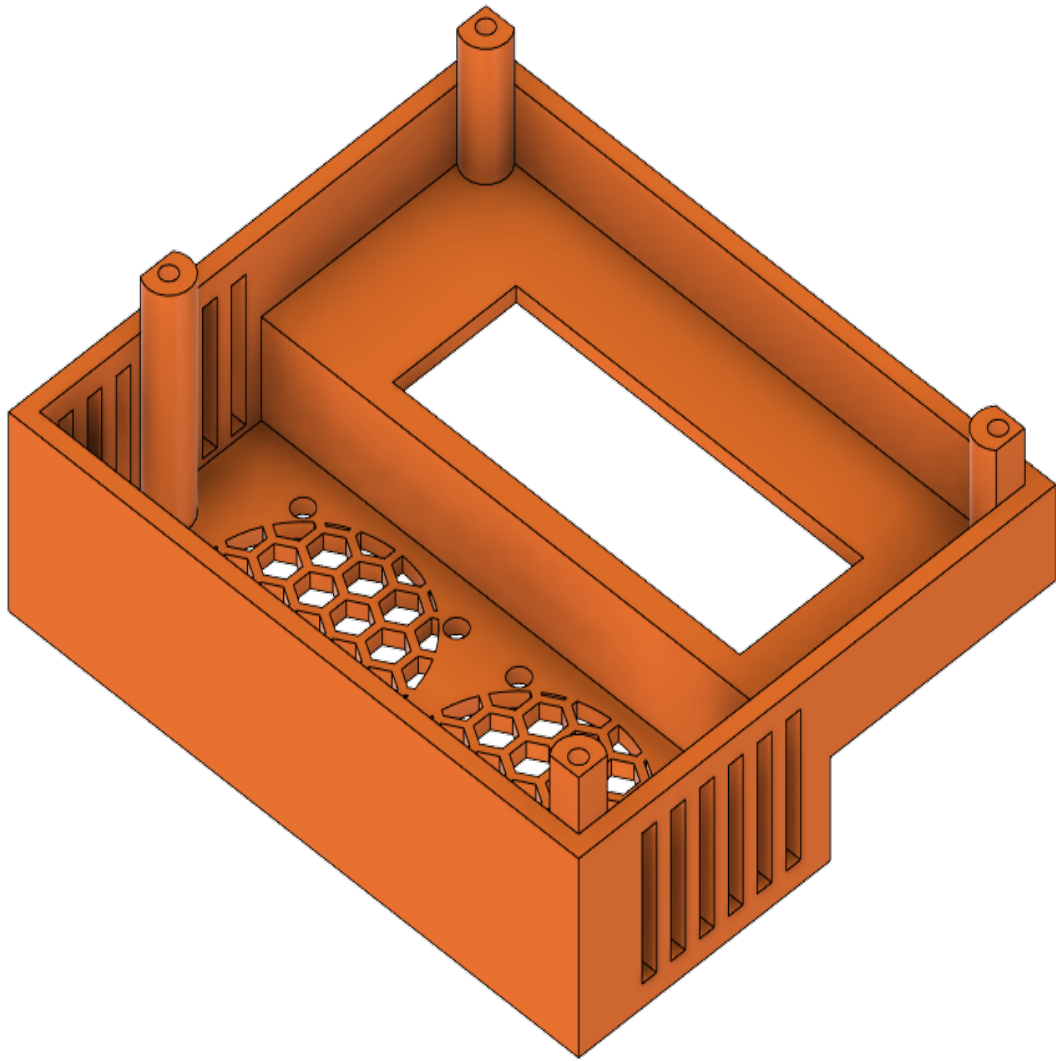


Figure 24: This is a rendering of the 3D model of the top half of the enclosure.



Figure 25: This is an image of the final enclosure with the built PCB inside.

5 PCB Information

5.1 PCB Block Diagram

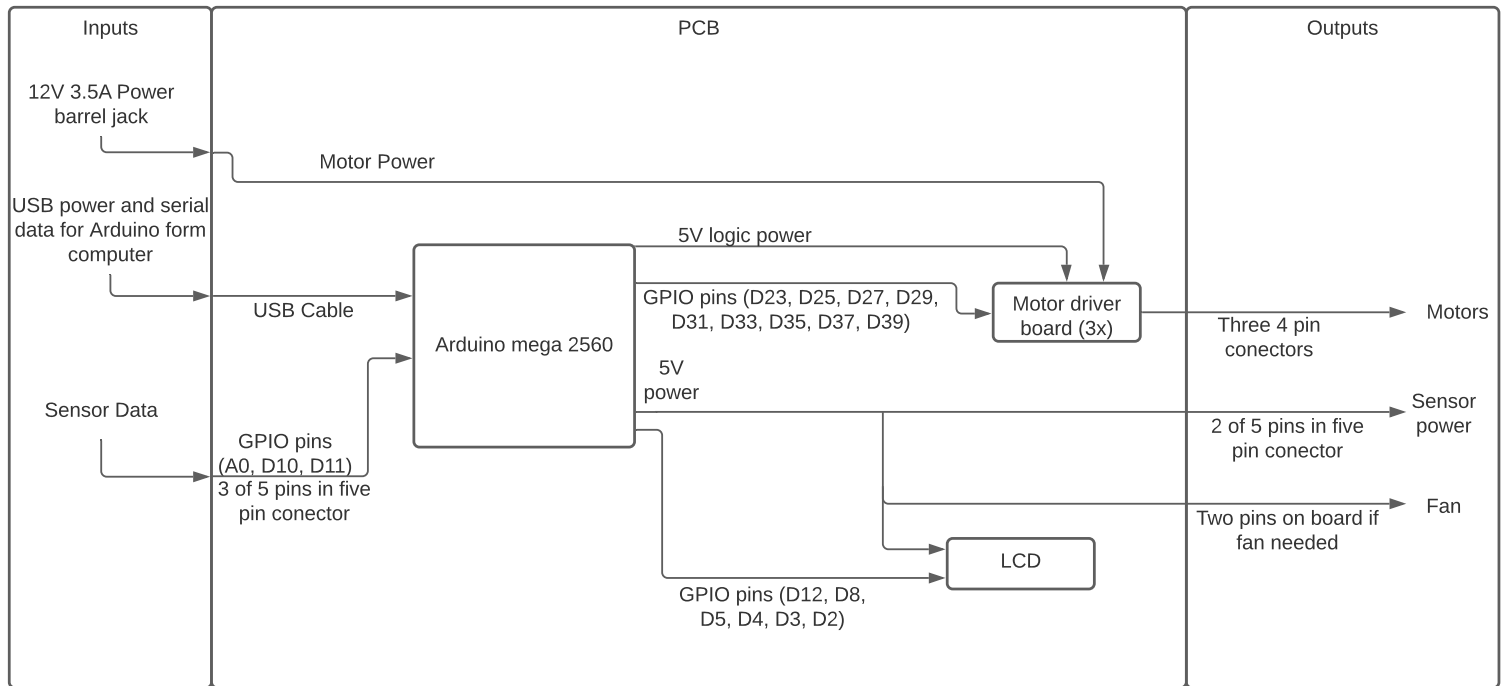


Figure 26: Block Diagram of the PCB with inputs in the inputs box on the left, outputs in the output box on the right and the blocks that make up the PCB in the middle section labeled PCB.

5.2 PCB Schematics

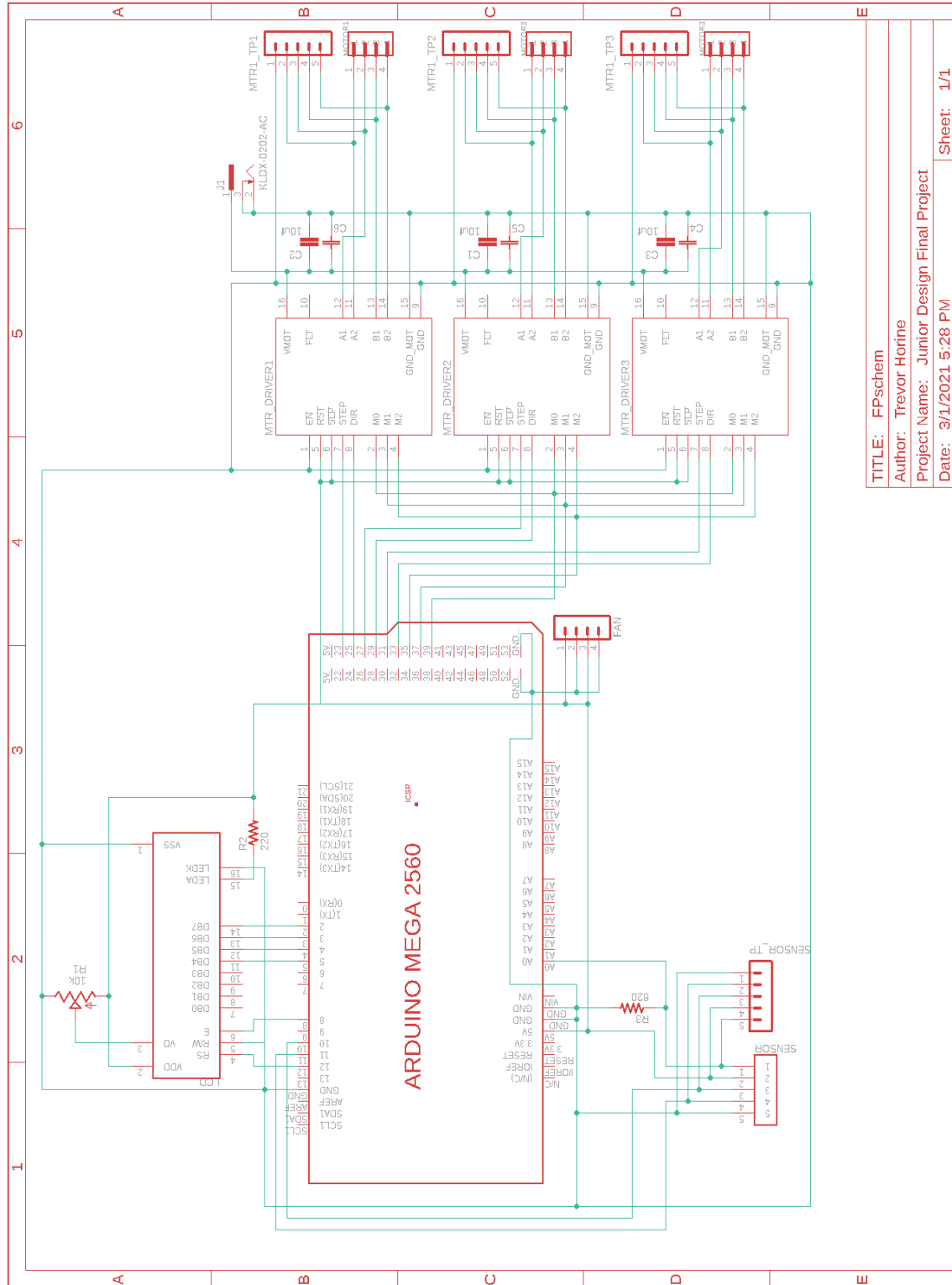


Figure 27: Detailed schematic control board, used for design layout of the PCB, which is designed as a breakout for an Arduino MEGA 2560 R3.

5.3 PCB Interface Table

Interface table	
Interface	Properties
Inputs	
USB	Supplies 5V power to Arduino. Also used a serial communication between computer and Arduino
12V Power	12V, 3.5 A power supplied to board via a barrel jack for the motor drivers.
Sensor Inputs	Three of the five pins in the 5 pin sensor connector. The light sensor goes to GPIO pin A0, and RFID goes to GPIO pins D10 and D11.
Outputs	
Motors	Three 4 pin connectors that conect the motors to the PCB. Each of these connectors is attached to a different motor controler
Fan Power	These are a few pins on the board that are connected to 5V and GND so a fan could be added to help with cooling if needed.
Sensor Power	The remaing two pins in the 5 pin sensor connector to carry 5V and ground to the sensors on the payload.
LCD	16 pin 2x16LCD attaced to GPIO pins D12, D8, D5, D4, D3, D2, 5V and GND. This will be used for debugging. (displaying corrdinates, or sensor values.)

Figure 28: list of input and outputs, as well as some of their properties or what they will be used for.

5.4 Eagle Layout and Board Dimensions

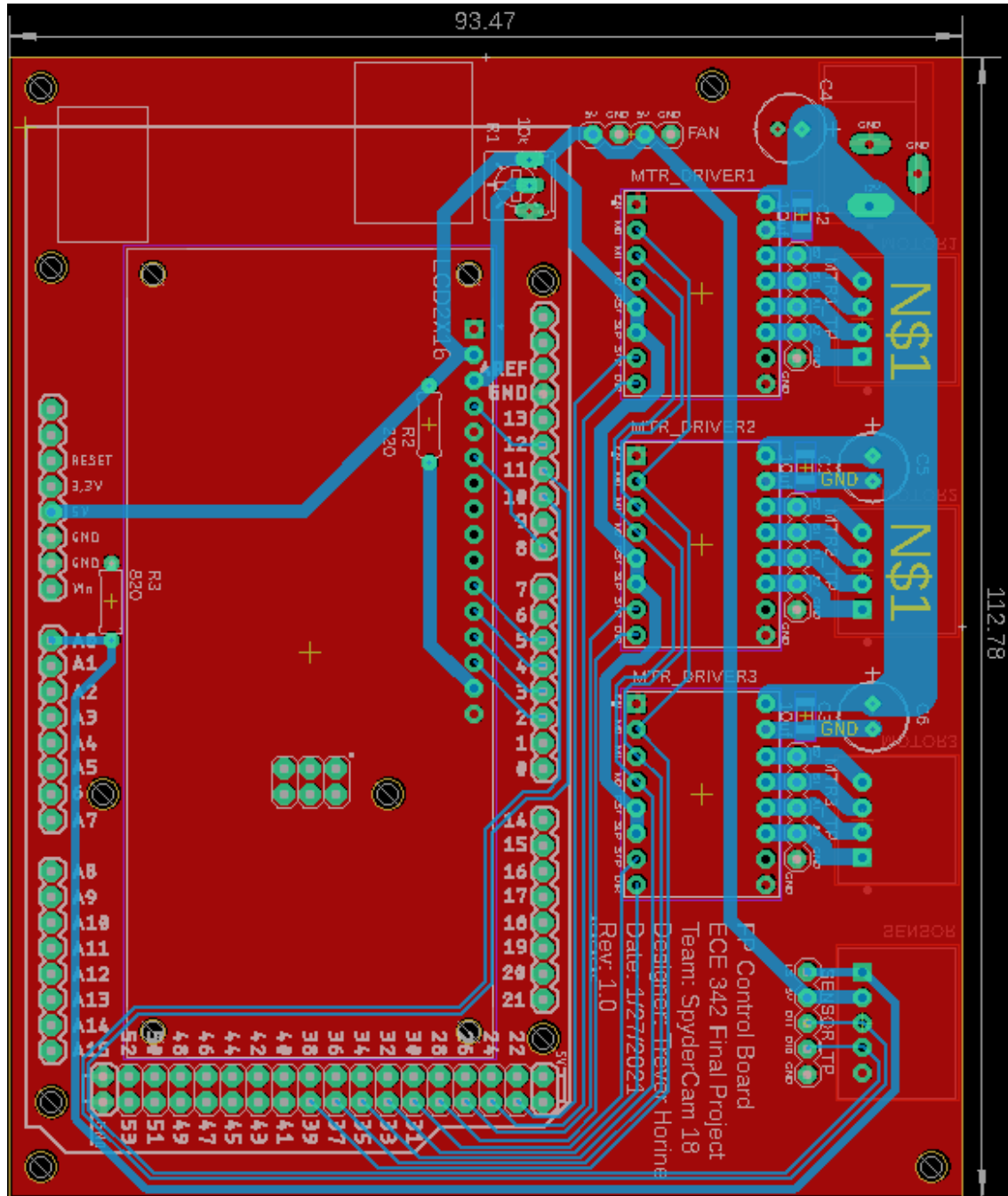


Figure 29: Layout of the PCB board built from the schematic in Figure 27, red is the bottom layer and a ground plane, blue is the top layer with traces for signals.

5.5 PCB Mechanical Drawing

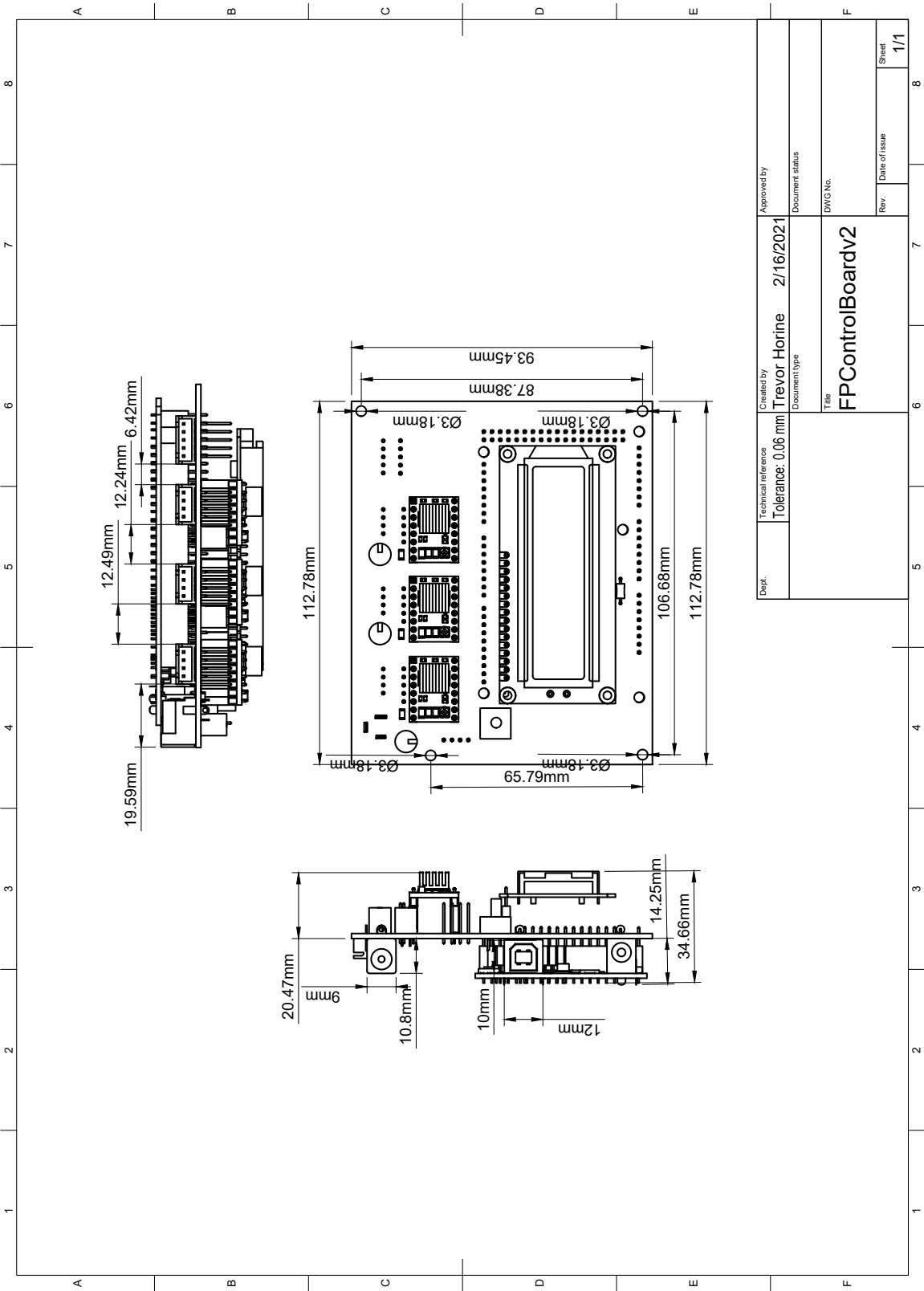


Figure 30: Mechanical drawing of PCB, with dimensions and locations of mounting holes

5.6 Board Profile

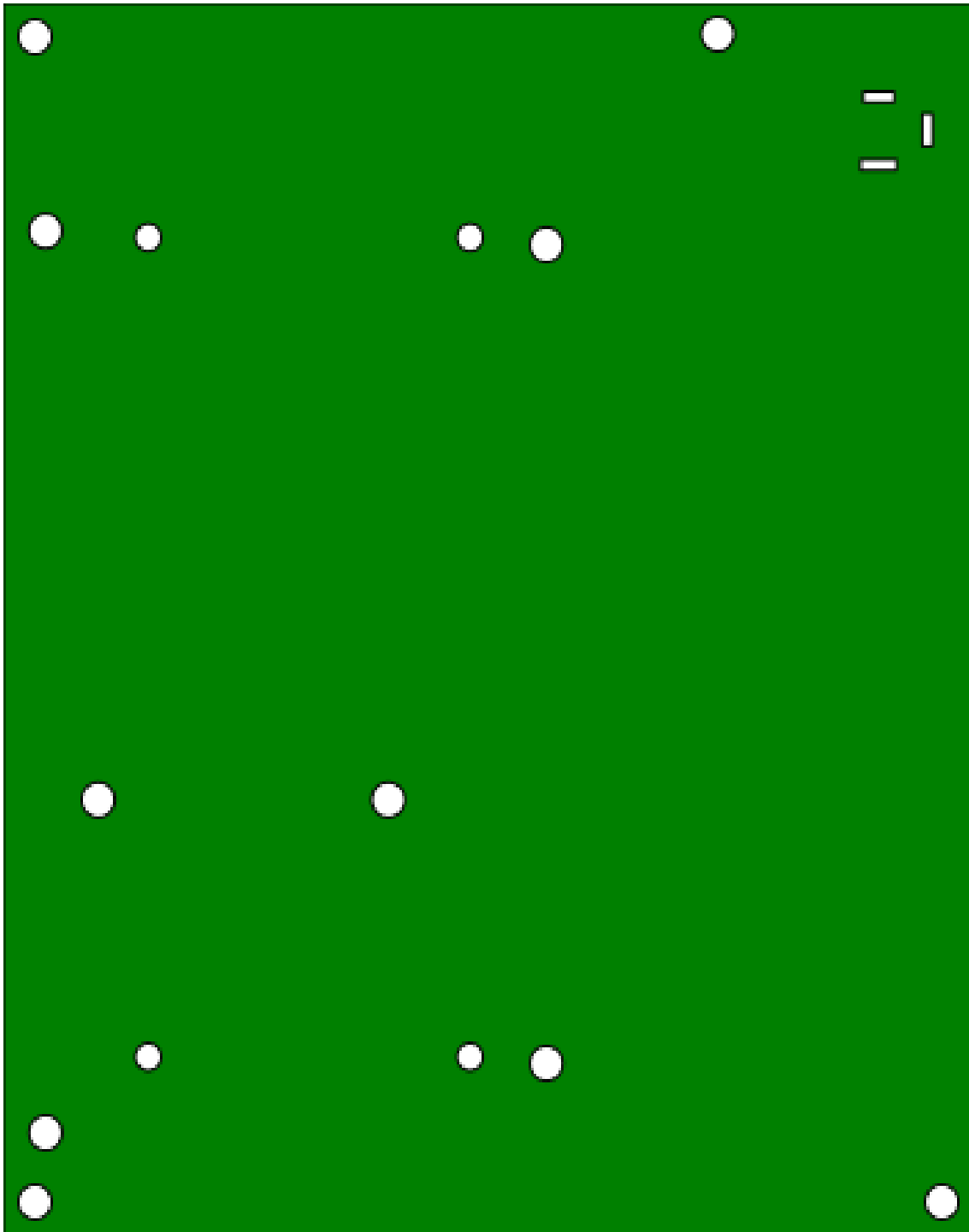


Figure 31: This is a rendering of the board profile. This image was generated from the Gerber files.

5.7 Top Silkscreen

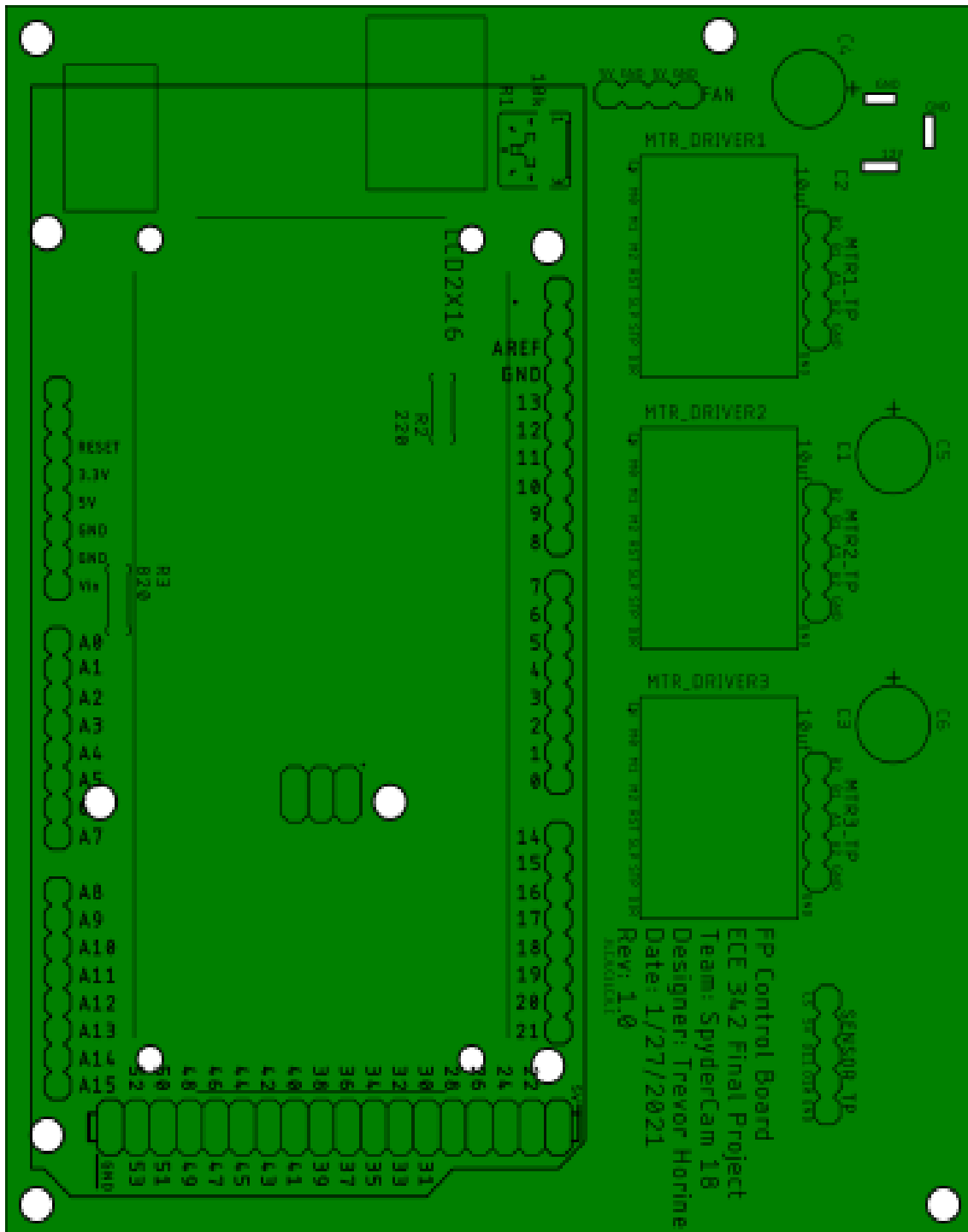


Figure 32: This is a rendering of the top silkscreen layer on top of the board profile. This image was generated from the Gerber files.

5.8 Top Copper

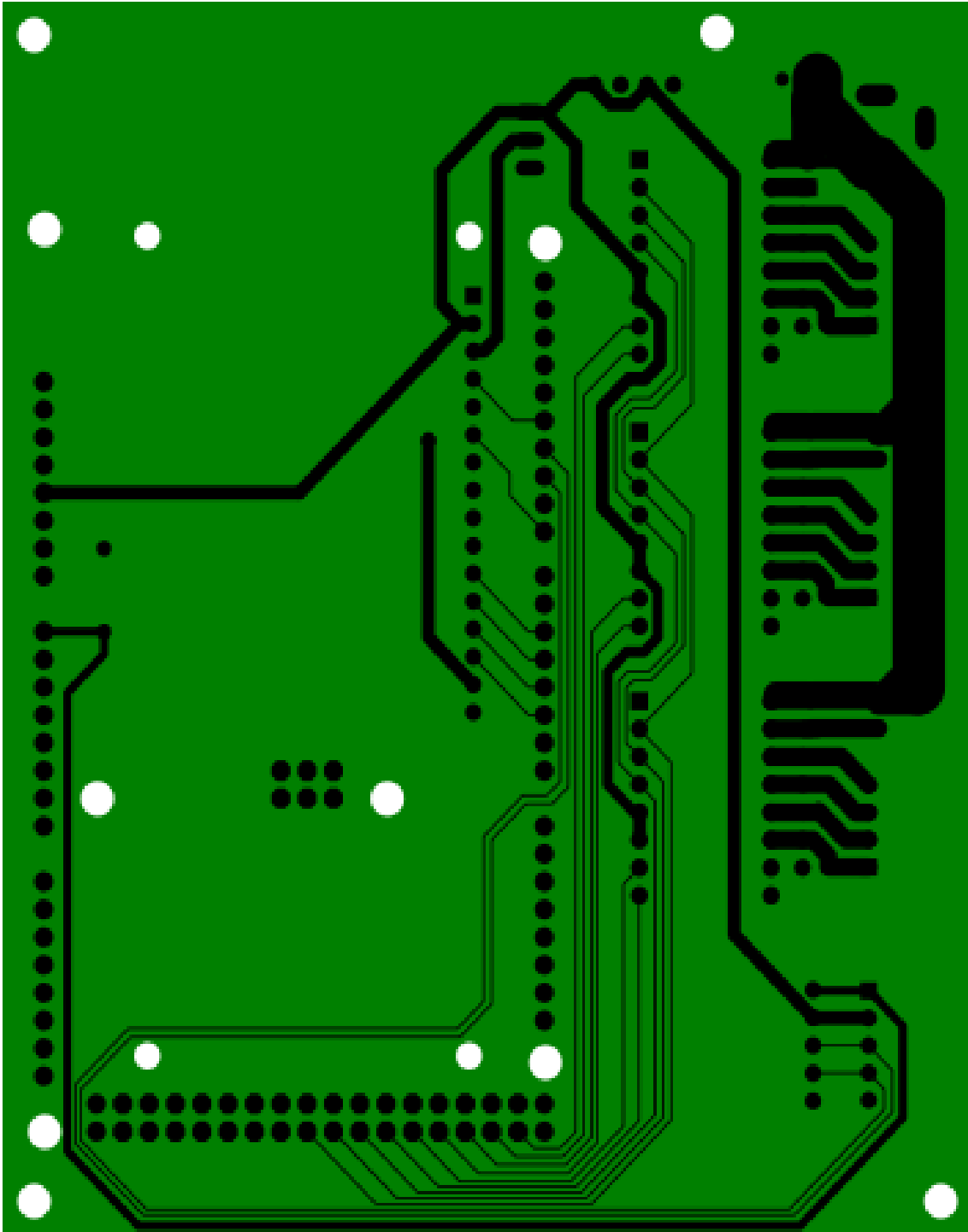


Figure 33: This is a rendering of the top copper layer on top of the board profile. This image was generated from the Gerber files.

5.9 Top Soldermask

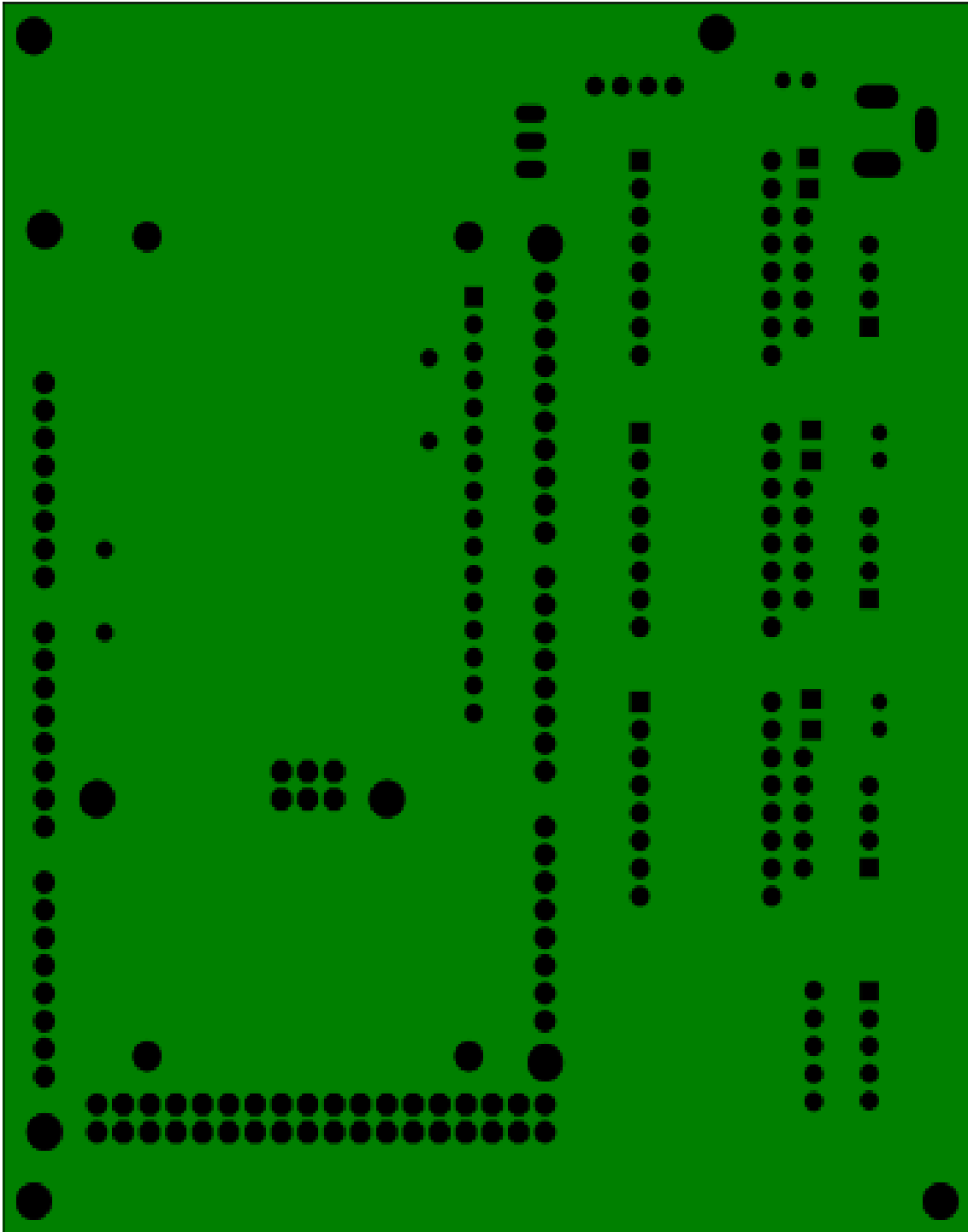


Figure 34: This is a rendering of the top soldermask layer on top of the board profile. This image was generated from the Gerber files.

5.10 Top Soldermask And Silkscreen

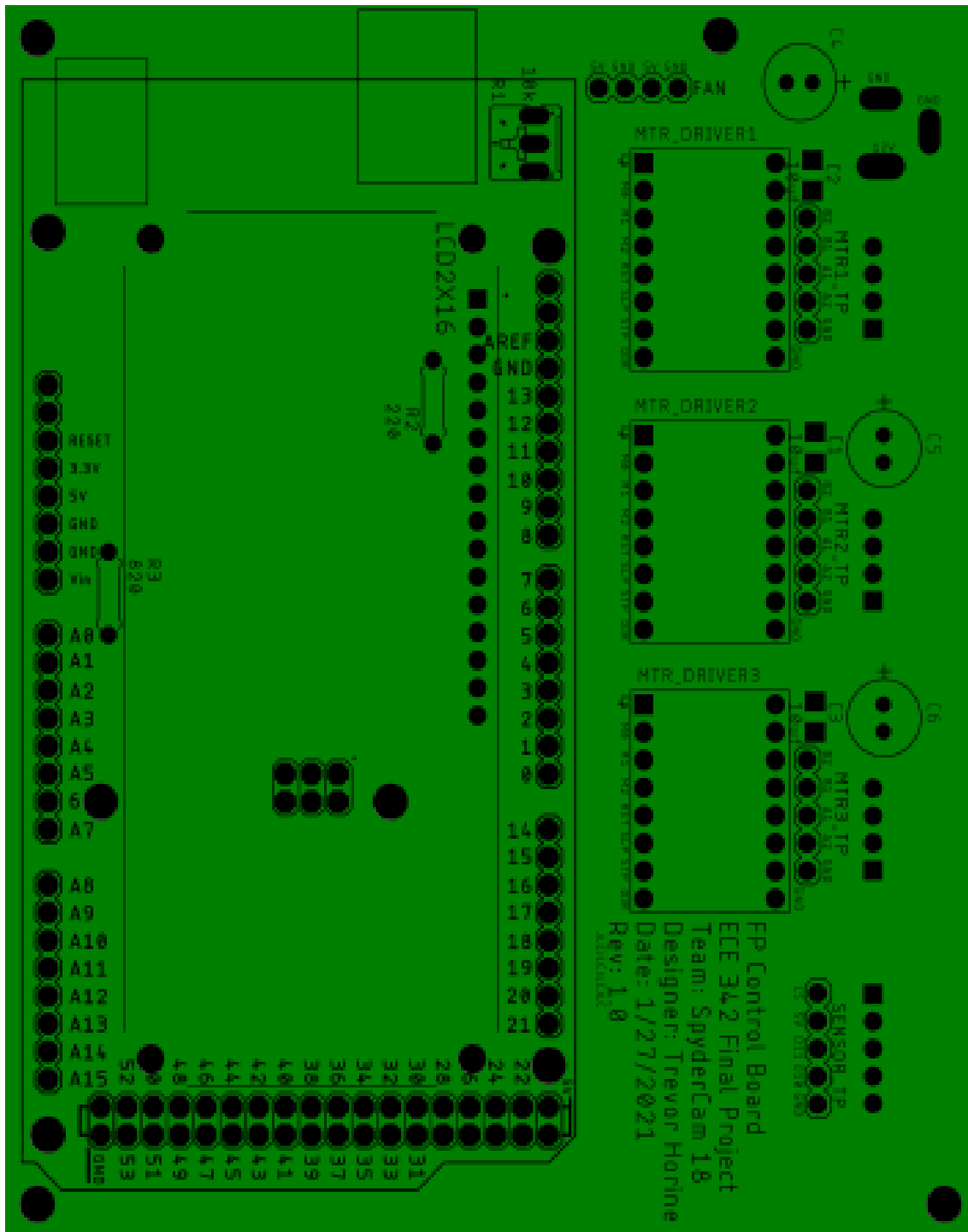


Figure 35: This is a rendering of the top soldermask layer and the top silkscreen layer on top of the board profile. This image was generated from the Gerber files.

5.11 Bottom Silkscreen

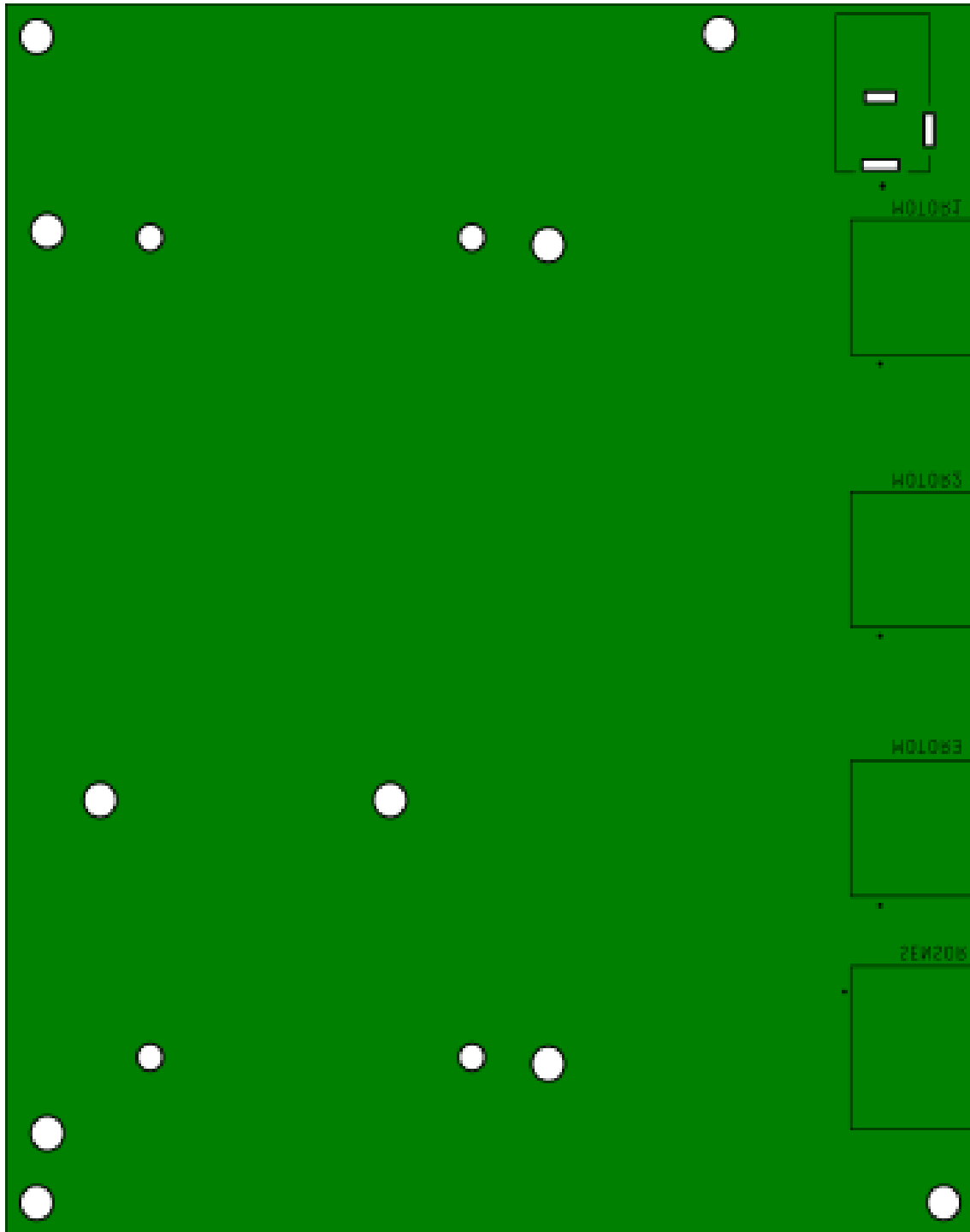


Figure 36: This is a rendering of the bottom silkscreen layer on top of the board profile. This image was generated from the Gerber files.

5.12 Bottom Copper

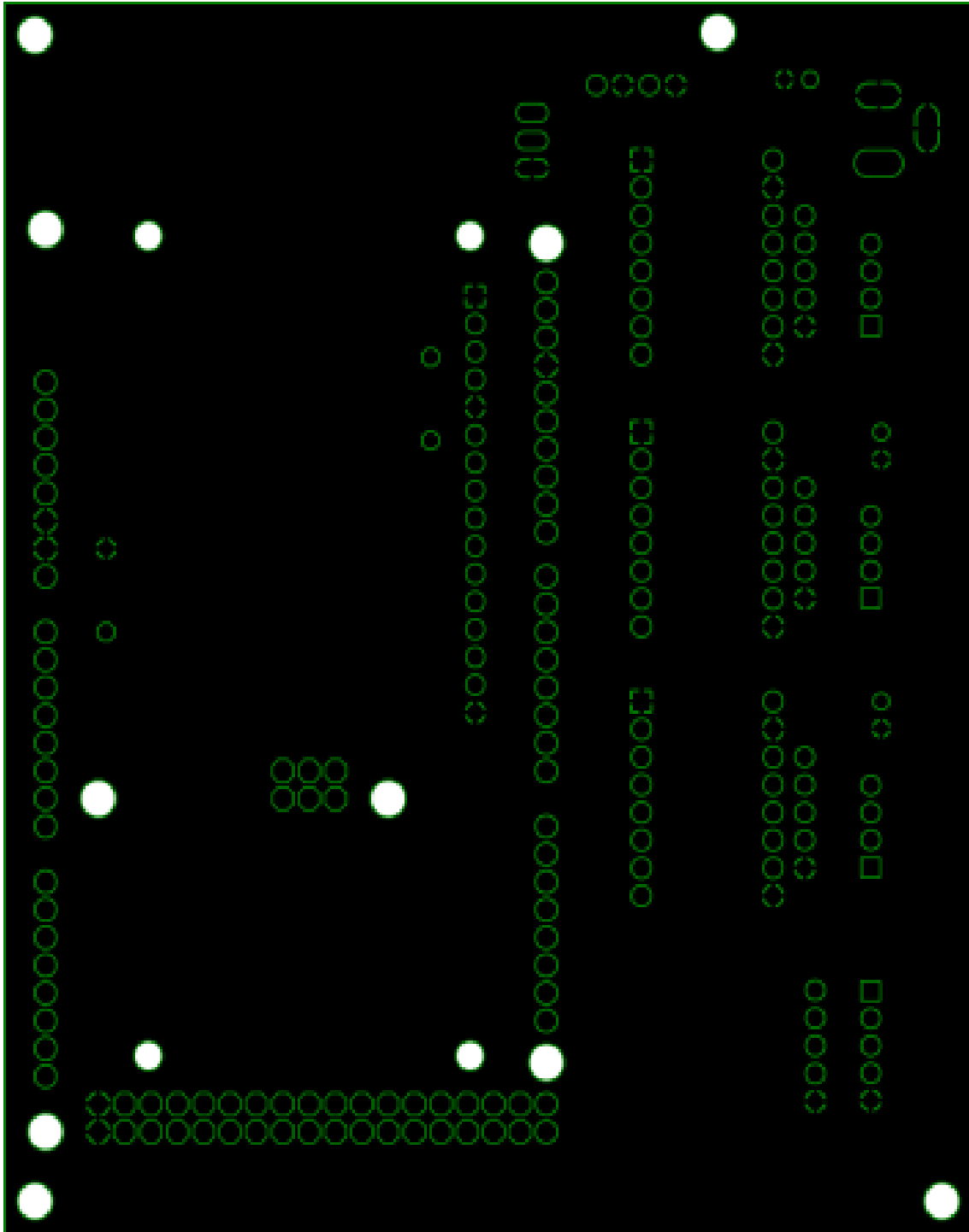


Figure 37: This is a rendering of the bottom copper layer on top of the board profile. This image was generated from the Gerber files.

5.13 Bottom Soldermask

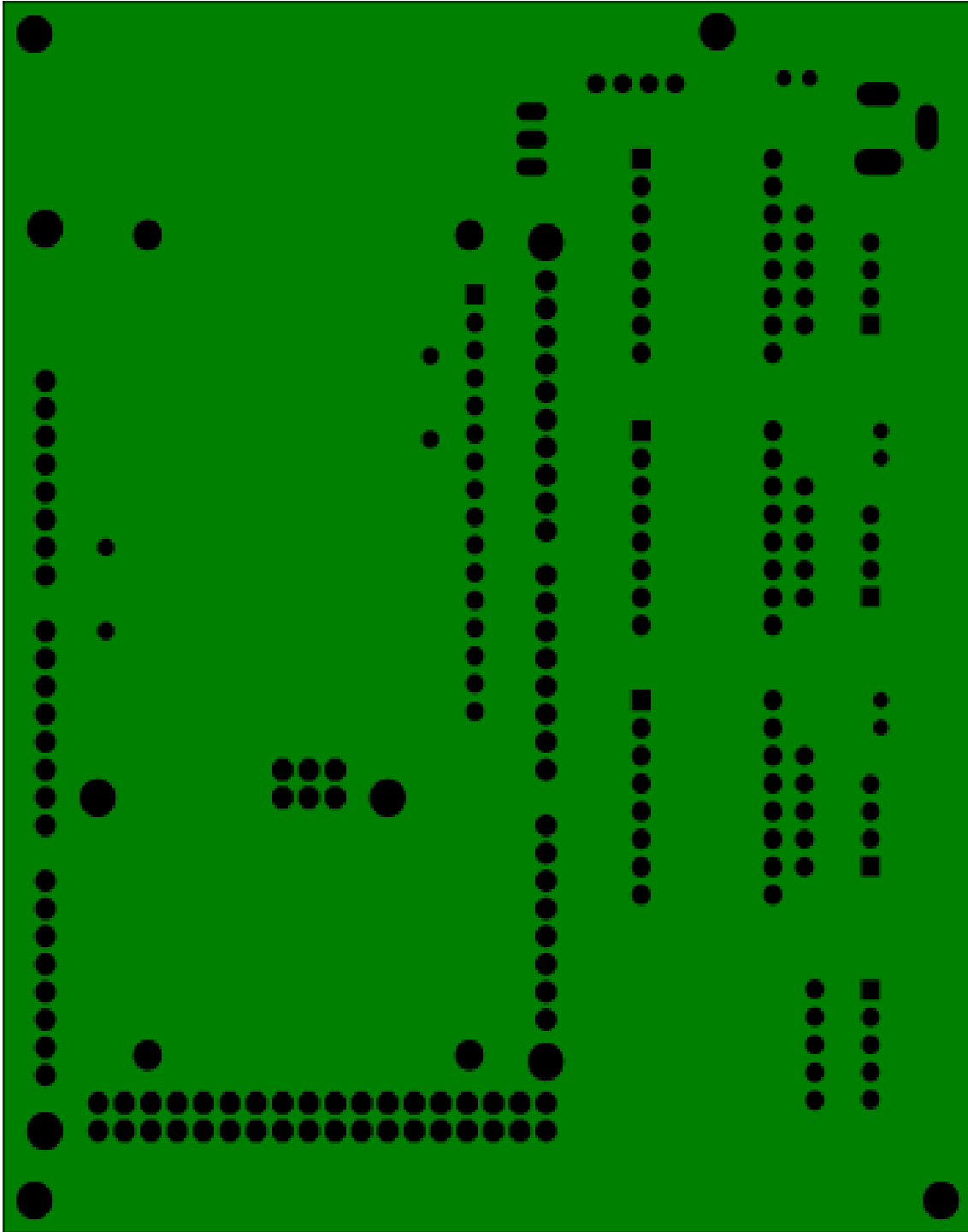


Figure 38: This is a rendering of the bottom soldermask layer on top of the board profile. This image was generated from the Gerber files.

5.14 Bottom Soldermask and Silkscreen

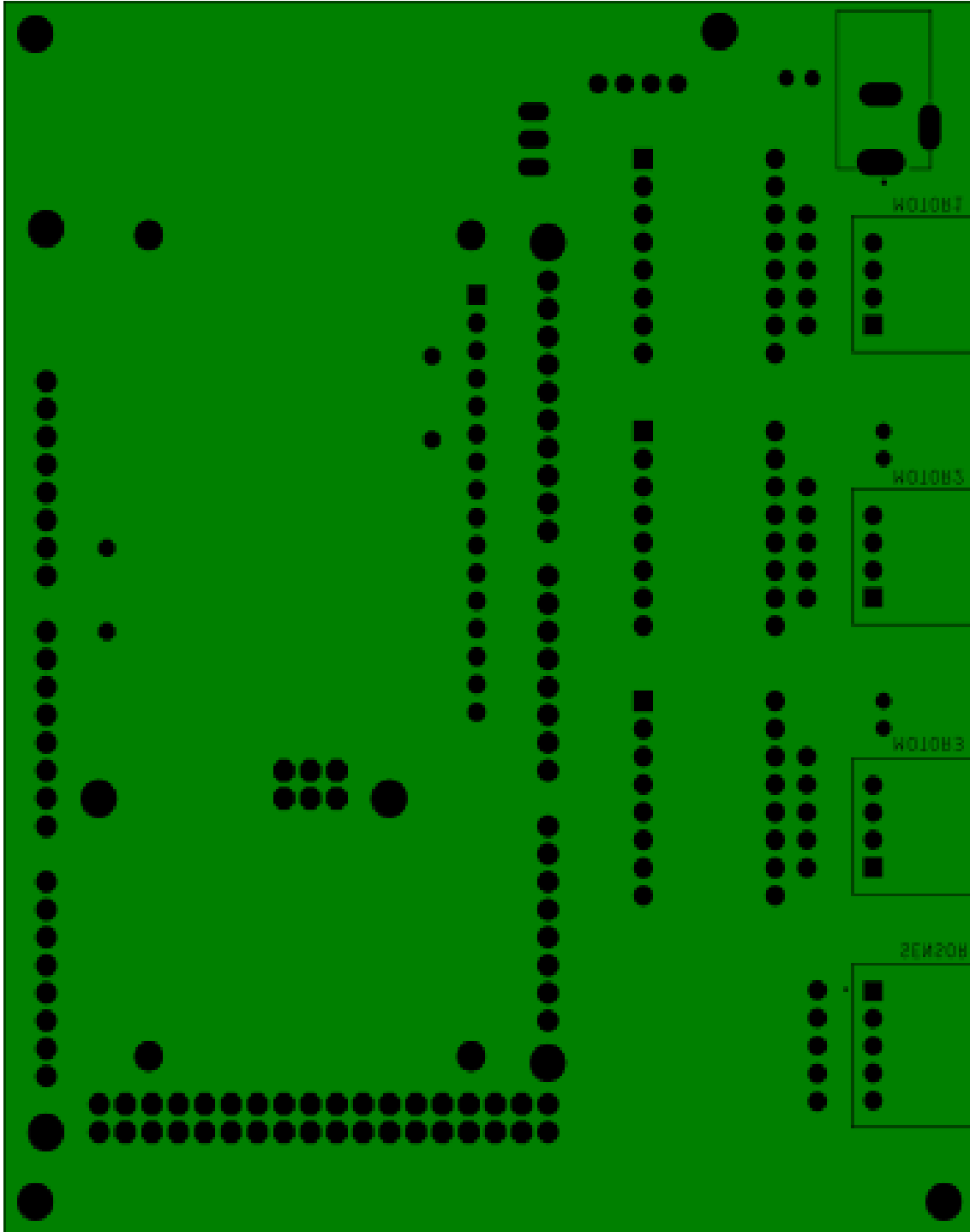


Figure 39: This is a rendering of the bottom soldermask and silkscreen layers on top of the board profile. This image was generated from the Gerber files.

5.15 Top Gerbers

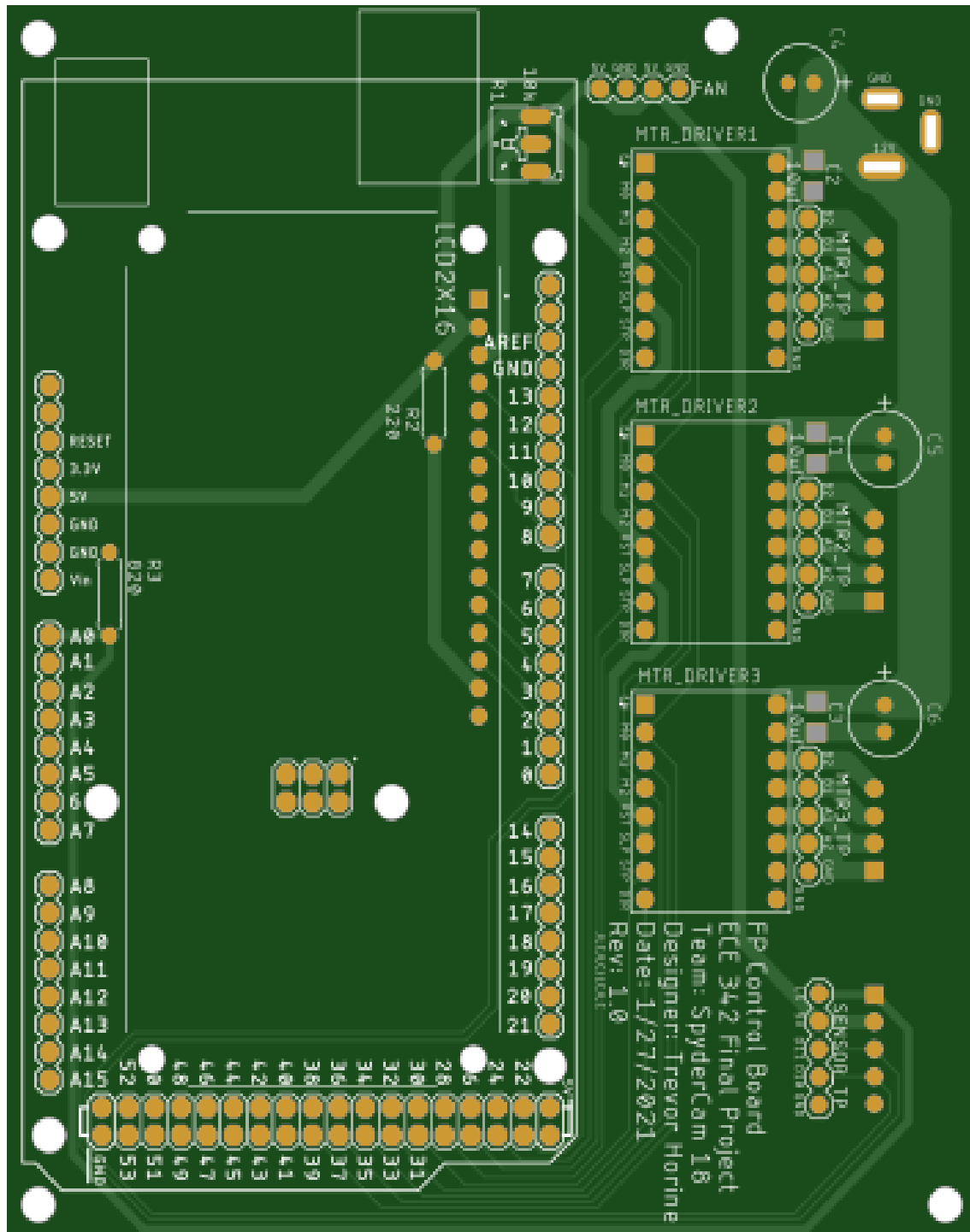


Figure 40: This is a rendering of the top layer Gerber files placed on top of each other. The white is the text and lines are the silkscreen, the gold is the soldermask, light green is the copper traces, and gray is the solderpaste. All of this is on top of the profile of the board or the darker green area, the black holes are holes in the board.

5.16 Bottom Gerbers

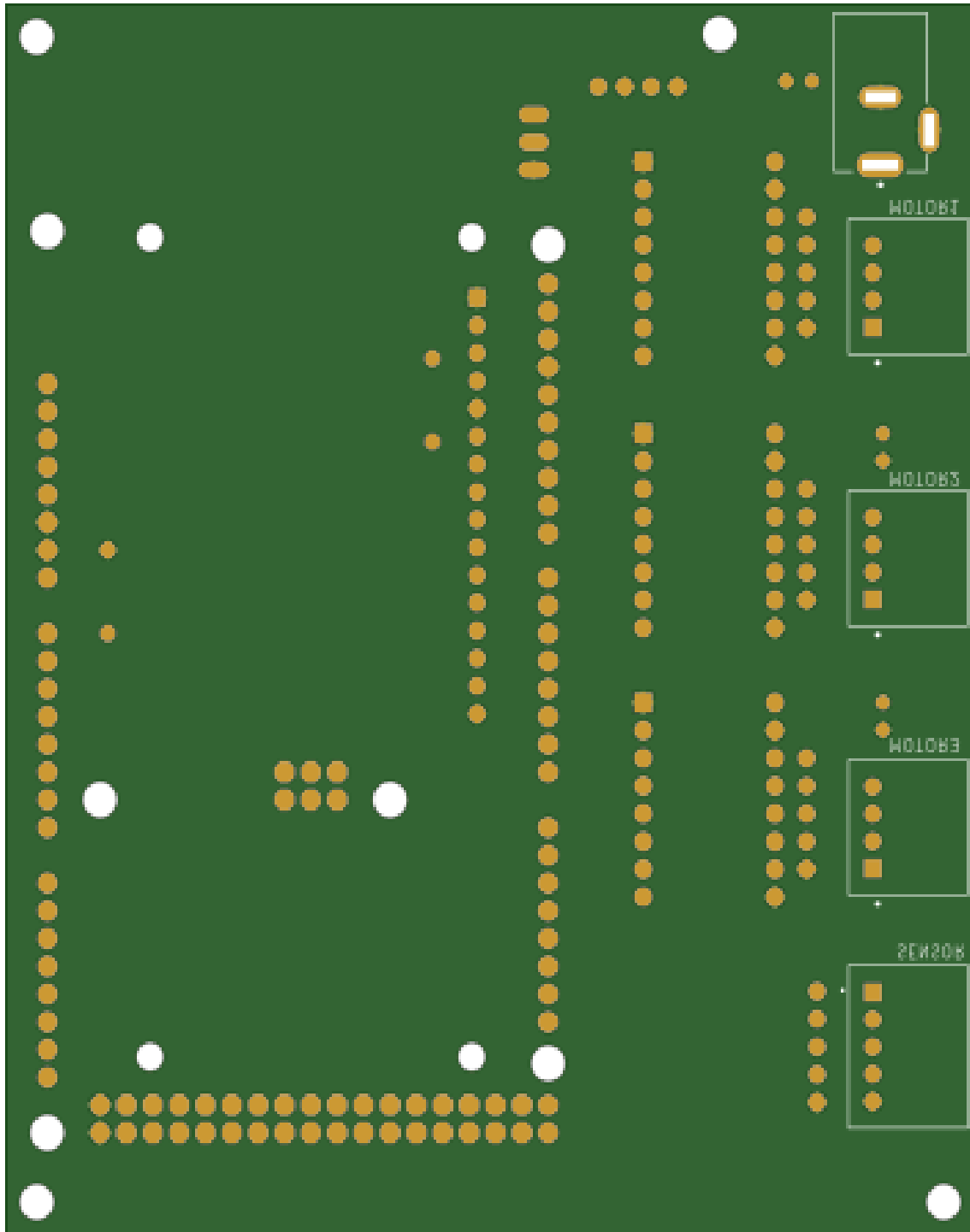


Figure 41: This is a rendering of the bottom layer Gerber files placed on top of each other. This layer has no white silkscreen, the gold is the soldermask, light green is the copper traces, and there is no gray solderpaste on this layer. All of this is placed on the profile of the board or the darker green area, the black holes are holes in the board. It may be hard to tell but there is only a little dark green around the soldermask and the edges of the board and holes because the bottom of this board is a copper ground plane.

5.17 3D Model

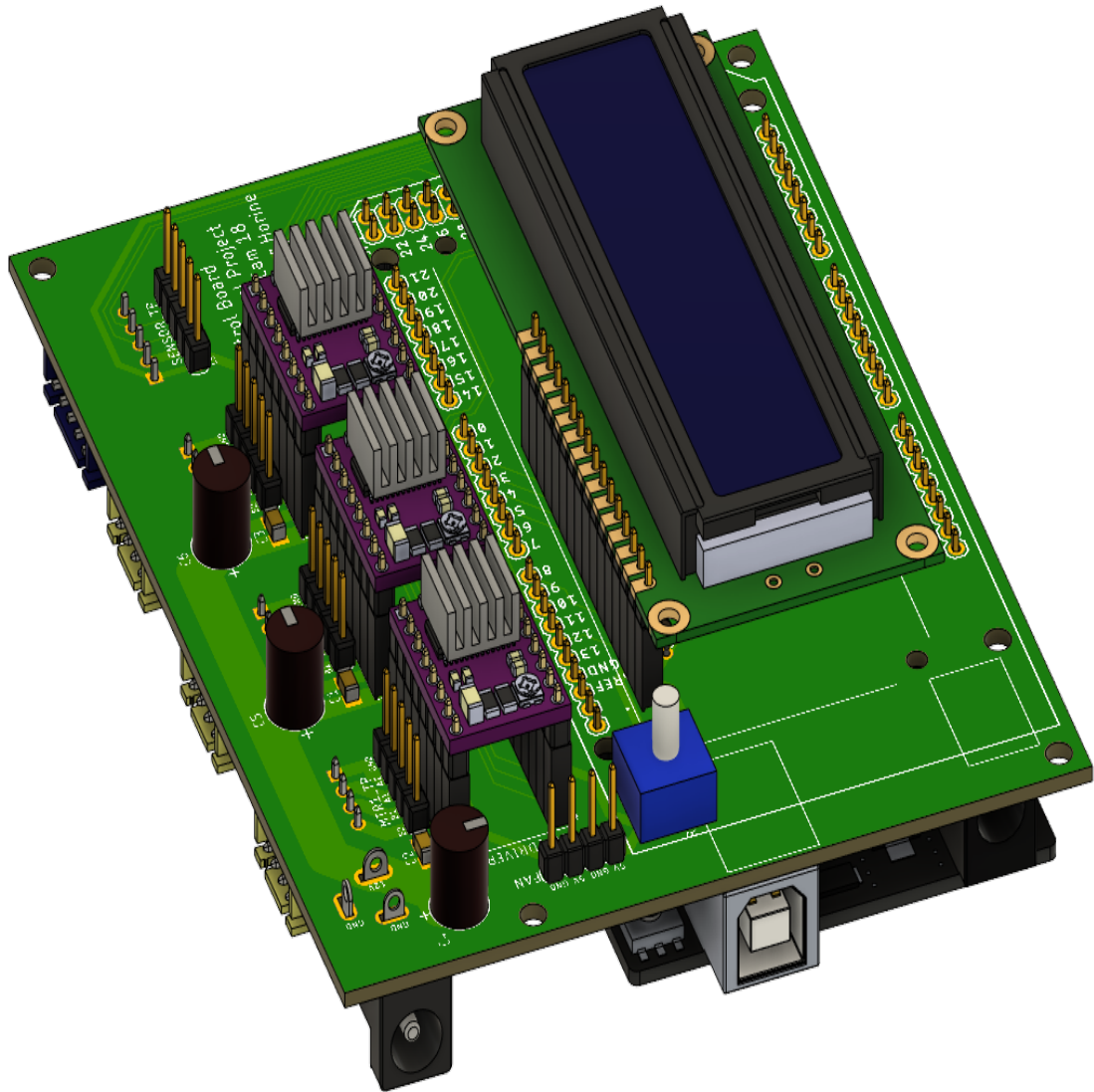


Figure 42: This is a rendering of the 3D model produced from the board designed with components added to give an idea of what the board will look like assembled. It will also be used to design the enclosure.

5.18 Assembled Board

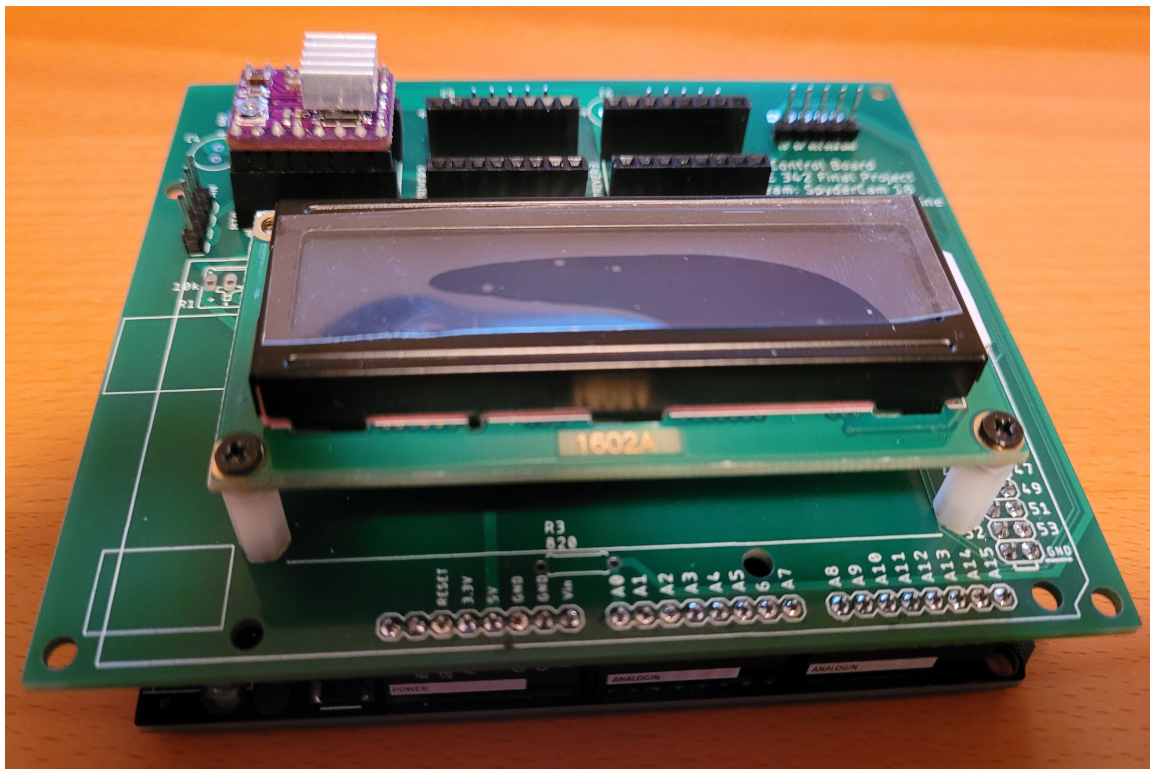


Figure 43: This is the board with some of the components added to it.

6 Parts Information and Bill of Material

Part	Value and units	Quantity	Price	Notes
PCBs				
				Boards have to be ordered in increments of 5.
Stepper drivers		5	9.99	Datasheet was found for a board that appears to be same as there was not a datasheet on the amazon page. DRV8825 Chip data sheet
Pin Headers		150	0	Will use pin headers from previous classes 64 female, 86 male
Barrel Jack		1	0.53	Used to connect wall wart to board
LCD		1	3.25	Used for debug and display
S5B-XH(LF)(SN)	Conector	1	0.31	Conector to attach light sensor and RFID 5 pin right angle conector
S4B-XH-A(LF)(SN)	Conector	3	0.81	Conectors to attach motors to board each one is a 4 pin right angle conector
Arduino Mega 2560	Arduino	1	16.99	Arduino, this is the brain
POTENTIOMETER	10k	1	2.9	Used for contrast on LCD
Resistor	220	1	0	Resistor for LCD
Resistor	10K	1	0	Resistor for voltage divider with photocell to measure light level
Capacitor	100μ	3	0.69	Used on the 12 volt power source before the motor drivers to help with current draw
Capacitor	10μ	3	0.66	Used on the 12 volt power source before the motor drivers to help with current draw. These may not be needed but pads were added so they could be added later if needed.
Fan	Fan	2	6	40mmx40mmx10mm fan should it be needed to keep motor drivers from heating up to much.
Boards		5	10	Minimum order quantity is 5 boards.
PCB Enclosure		1	5	3D printed enclosure for the PCB
M3, 35mm screws		4	2.48	Screws used to hold PCB in place and the enclosure closed.
PAYLOAD				
Photocell		1	0.89	photocell to be used in voltage divider for measuring light level
RFID breakout		1	10	
Female Cable Connector Housing		1	0.12	
Ribbon Cable	3 ft, 6 wire 24awg	1	5.05	
#2 screw- RFID board mount		2	0.14	Used to mount board to payload
#6-32 1/2" set screw		1	0.19	Used to secure writing utensil
Payload Enclosure- Top		1	5.44	3D printed enclosure for the payload sensors and writing implement through Corvallis3d.
Payload Enclosure- Bottom		1	14.98	3D printed enclosure for the payload sensors and writing implement through Corvallis3d.
Mechanical				
Stepper motors		3	24.99	Datasheet info on the amazon page
Stepper Motor Brackets		5	13.99	
2" Aluminum Round Stock		1 ft	0	Used scrap aluminum
Aluminum Tube Stock 1/8" wall, 1" nominal (ID)		3.375 ft	0	Used scrap aluminum
15/32" Plywood sheet		3.5' x 3.5'	0	Used scrap wood
1/4"-20 x 1.25" Socket Head Cap Screw		9	1.71	Pylon attachment hardware
1/4" Washer		9	0.63	Pylon attachment hardware
1/4"-20 Nut		9	0.81	Pylon attachment hardware
Fishing line			0	Monofilament 9lb test fishing line was used as a strong light weight string to connect the payload to the motors.
			Total Cost	
			138.55	

Figure 44: This is the bill of materials for the system. The bill of materials also lists component's values, name on board, quantities and costs.

7 Time Report

7.1 Time sheet

Name	Date	Time spent (Hours rounded to nearest .5)	What did you work on
All	1/8/2021	4	Team Meeting
All	1/10/2021	4	Team Meeting
All	1/11/2021	4	Meet with mentor an debrief
All	1/13/2021	2	Recitation work time
Trevor	1/13/2021	1	CAD Drawings
All	1/14/2021	8	Team Meeting
Ben	1/14/2021	2	Hardware Research and order
Miles	1/12/2021	3	MATLAB Code
Trevor	1/15/2021	4	Schematics, Sensor payload, and PCB
Trevor	1/16/2021	6	Schematics, Sensor payload, and PCB
Trevor	1/17/2021	5	Schematics and PCB
Ben	1/17/2021	6	Mechanical Component Design & Fabrication
Ben	1/20/2021	2	Mechanical Component Design & Fabrication
All	1/24/2021	12	Team meeting and block checkoff prep
Miles	1/26/2021	8	MATLAB GUI
Ben	1/26/2021	3	Mechanical assembly testing
Trevor	1/26/2021	5	PCB finishing touches and ordering
Trevor	2/5/2021	3	Putting the PCBs together
Ben	2/6/2021	6	Payload Design
Trevor	2/1-9/2021	18	Enclosure design
Ben	2/8/2021	3	Payload Redesign for 3d printing
Trevor	2/11-2/13	3	Enclosure mechanical drawings
Ben	2/13/2021	4	Payload implementation and testing
Trevor	2/15/2021	1	Enclosure
Miles	2/15/2021	4	MATLAB Arduino Serial Comm
Miles	2/17/2021	4	MATLAB Arduino Serial Comm
Ben	2/18/2021	2	Hardware integration testing
Felipe	1/17/2021	12	Arduino Control Software Design/Implementation
Felipe	2/7/2021	8	Arduino Motor Control Firmware Design/Implementation
Felipe	2/14/2021	9	Testing Arduino Software
All	2/20/2021	12	Putting together the final hardware and troubleshooting
Miles	2/20/2021	3	Finishing serial interface and reading Arduino code
Ben	2/21/2021	3	Testing Hardware/software integration
Trevor	2/26/2021	2	CAD Drawings
All	2/27/2021	4	Debug and testing
Ben	2/28/2021	6	MATLAB testing, arduino testing, redesigning payload for backup
Miles	2/28/2021	2	MATLAB debugging
All	2/28/2021	8	System debugging and testing
Trevor	3/1/2021	3	Documentation
Ben	3/1/2021	1	Documentation
Trevor	3/3/2021	2	Documentation
Total Manhours			
Percentage per Person			202
Trevor	33.42	67.5	
Ben	25.99	52.5	
Miles	19.06	38.5	
Felipe	21.53	43.5	

Figure 45: This is the time sheet used to track hours on this project.

7.2 Percentage By Person

Percentage and Hours by Person

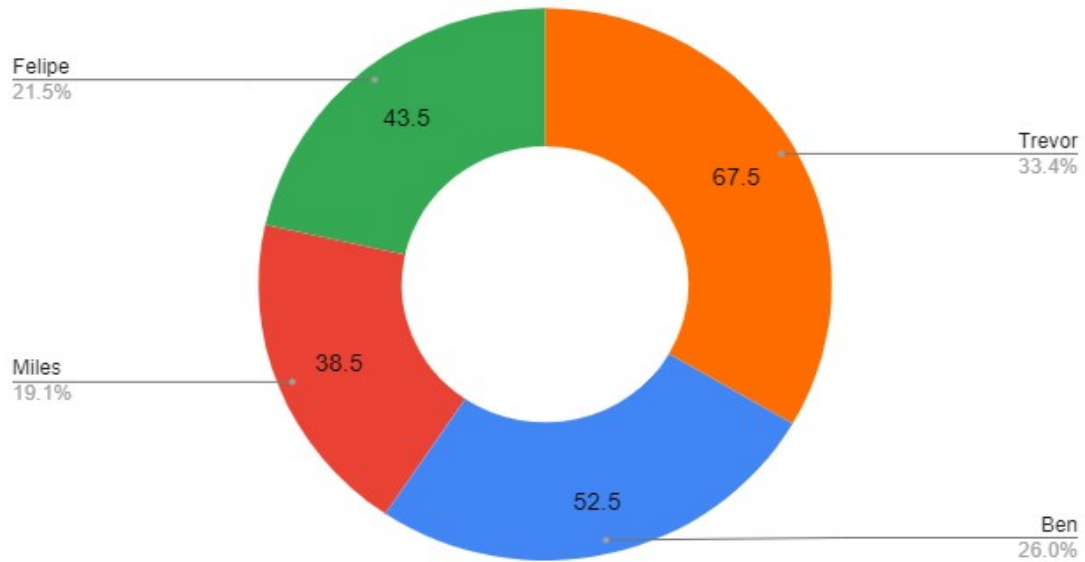


Figure 46: This graph plots the hours spent on the project by person.

7.3 What We Worked On

Hours Per Part of Project

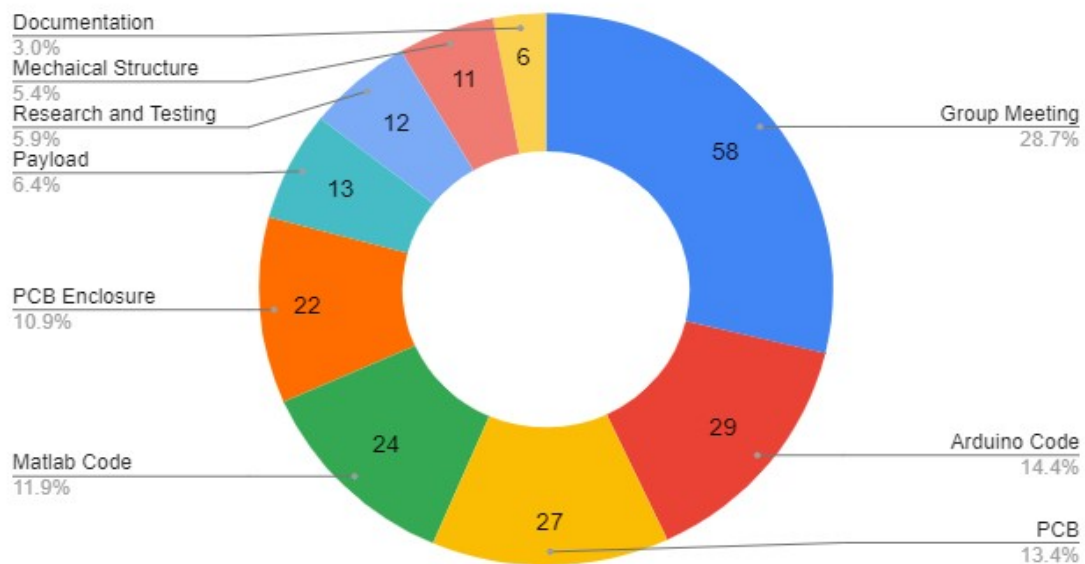


Figure 47: This graph plots the hours spent on each part of the project.

8 Appendix

8.1 Arduino Code

```
1  /*
2   Arduino Control Software Block & Motor Control Firmware
3   Author: Felipe Orrico Scognamiglio
4   For: Oregon State University - Junior Design - Final Project
5   Spydercam18
6   Date: 03/01/2021
7   Version: BETA 1.25 - FINAL
8   */
9  /*
10  Known Problems:
11    - After M2 command, Incremental Coordinate mode will not work
12      properly
13      and C1 will not be able to report correct coordinates
14    - Inputting M2 and M6 right after the other has undefined
15      behaviour
16    - Current X, Y, Z positions are not available after receiving
17      M2/M6, only
18      after another G0 or G1 is executed. This happens because it is
19      hard to extrapolate
20      the current position only based on current thread lengths.
21      Instead, the program will
22      update after another G0 or G1 command.
23  */
24
25  //////////////////////////////////LCD SETUP////////////////////////////////////
26  #include <LiquidCrystal.h>
27  const int rs = 12, en = 8, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
28  LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
29  //////////////////////////////////LCD SETUP////////////////////////////////////
30
31  //////////////////////////////////Sensor SETUP////////////////////////////////////
32  #include <SoftwareSerial.h>
33  #include "PN532_SWHSU.h"
34  #include "PN532.h"
35
36  SoftwareSerial SWSerial( 10, 11 ); // RX, TX
37  PN532_SWHSU pn532swhsu( SWSerial );
38  PN532 nfc( pn532swhsu );
39
40  const int sensor = A0;
41
42  float sensorVal = 0;
43  float voltage = 0;
44  float lightLevel = 0;
45
46  //////////////////////////////////Sensor SETUP////////////////////////////////////
47
48  //////////////////////////////////CONSTANTS////////////////////////////////////
49
50  //ALL PHYSICAL VALUES ARE REPORTED IN INCHES
51  const double A_PAPER_DISTANCE = 11.583;
```

```

49 const double B_PAPER_DISTANCE = 7.2;
50 const double C_PAPER_DISTANCE = 7.2;
51
52 const double HEIGHT_PYLON_A = 11.8;
53 const double HEIGHT_PYLON_B = 11.8;
54 const double HEIGHT_PYLON_C = 11.8;
55
56 const double PAYLOAD_CENTER_THREAD_DISTANCE_A_x = 3.6;
57 const double PAYLOAD_CENTER_THREAD_DISTANCE_C_x = 1.85;
58 const double PAYLOAD_CENTER_THREAD_DISTANCE_C_y = 3.15;
59 const double PAYLOAD_CENTER_THREAD_DISTANCE_B_x = 1.85;
60 const double PAYLOAD_CENTER_THREAD_DISTANCE_B_y = 3.15;
61
62 const double PAPER_HEIGHT = 11.00;
63 const double PAPER_WIDTH = 8.50;
64
65 const double PAPER_DISTANCE_LOW_EDGE = 1.856;
66
67 const double HOME_X = 0;
68 const double HOME_Y = 0;
69 const double HOME_Z = 6;
70
71 const double INCHES_PER_STEP = 0.024662;
72 const double MAX_STEPS_PER_SEC = 182;
73
74 //////////////////////////////////////////////////CONSTANTS////////////////////////////////////
75
76 //////////////////////////////////////////////////VARIABLES////////////////////////////////////
77
78 double CURRENT_PAYLOAD_HEIGHT = 0;
79 double CURRENT_THREAD_LEN_A = 0;
80 double CURRENT_THREAD_LEN_B = 0;
81 double CURRENT_THREAD_LEN_C = 0;
82 double CURRENT_X = 0;
83 double CURRENT_Y = 0;
84
85 //values that are updated when there is movement
86 int OPCODE = -1;
87 double X_ADDRESS_TARGET = -1;
88 double Y_ADDRESS_TARGET = -1;
89 double Z_ADDRESS_TARGET = -1;
90 int F_PERCENT_SPEED = 100;
91
92 ///M6///
93 double M6_SAVE_LEN_A = 0;
94 double M6_SAVE_LEN_B = 0;
95 double M6_SAVE_LEN_C = 0;
96 double M6_SAVE_X = -1;
97 double M6_SAVE_Y = -1;
98 double M6_SAVE_Z = -1;
99 double M6_SAVE_Speed = 0;
100 bool M6_EN = false;
101
102 //////////////////////////////////////////////////VARIABLES////////////////////////////////////
103
104 //////////////////////////////////////////////////FLAGS////////////////////////////////////
105
106 bool UNIT_MODE = true; //true = inches, false = mm;

```

```

107 bool ABSOLUTE_COORDINATES = true; //true = absolute, false =
    incremental
108 bool ON_MOVE = false;
109 bool M2_EN = false;
110
111 ///////////////////////////////////////////////////FLAGS//////////////////////////////////////
112
113 ///////////////////////////////////////////////////STEPPER//////////////////////////////////////
114
115 #include "AccelStepper.h"
116 #include "MultiStepper.h"
117
118 //change pins here to reflect correct pins
119 #define dirPinA 25
120 #define stepPinA 23
121 #define dirPinB 29
122 #define stepPinB 27
123 #define dirPinC 33
124 #define stepPinC 31
125
126 #define motorInterfaceType 1
127
128 AccelStepper stepperA; // = AccelStepper(motorInterfaceType,
    stepPinA, dirPinA);
129 AccelStepper stepperB; // = AccelStepper(motorInterfaceType,
    stepPinB, dirPinB);
130 AccelStepper stepperC; // = AccelStepper(motorInterfaceType,
    stepPinC, dirPinC);
131
132 MultiStepper steppers = MultiStepper();
133
134 ///////////////////////////////////////////////////STEPPER//////////////////////////////////////
135
136 ///////////////////////////////////////////////////G-CODE LIB SETUP//////////////////////////////////////
137 #include "gcode.h"
138 #include "Arduino_Firmware_ALPHA.h"
139 #define NumberOfCommands 10
140 //you can add more more commands here if needed and create a
    function under G-Code to execute.
141 struct commandscallback commands[NumberOfCommands] = {{"G0",G0_cmd
    },{"G1",G1_cmd},{"G20",G20_cmd},{"G21",G21_cmd},{"G90",G90_cmd
    },{"G91",G91_cmd},{"M2",M2_cmd},{"M6",M6_cmd},{"C1",C1_cmd},{"C2
    ",C2_cmd}};
142 gcode Commands(NumberOfCommands, commands);
143 ///////////////////////////////////////////////////G-CODE LIB SETUP//////////////////////////////////////
144
145 ///////////////////////////////////////////////////G-Code//////////////////////////////////////
146
147 void G0_cmd(){
148
149     if (ON_MOVE || M6_EN) {
150         //Serial.println("ON_MOVE");
151         return;
152     }
153
154
155     double x_coord = CURRENT_X;
156     double y_coord = CURRENT_Y;

```

```

157     double z_coord = CURRENT_PAYLOAD_HEIGHT;
158
159     if(Commands.availableValue('X')){
160         x_coord = Commands.GetValue('X');
161     }
162     if(Commands.availableValue('Y')){
163         y_coord = Commands.GetValue('Y');
164     }
165     if(Commands.availableValue('Z')){
166         z_coord = Commands.GetValue('Z');
167     }
168
169     int f_speed = 100; //maximum speed
170
171     if (!UNIT_MODE){ //translate mm to in
172         x_coord = mm_to_in(x_coord);
173         y_coord = mm_to_in(y_coord);
174         z_coord = mm_to_in(z_coord);
175     }
176
177     if (!ABSOLUTE_COORDINATES){ //incremental mode
178         x_coord += CURRENT_X;
179         y_coord += CURRENT_Y;
180         z_coord += CURRENT_PAYLOAD_HEIGHT;
181     }
182
183     //checking for boundaries
184     if (x_coord > 8.5)
185         x_coord = 8.5;
186     if (y_coord > 11)
187         x_coord = 11;
188     if (z_coord > 11)
189         z_coord = 11;
190
191     //update global values
192     Y_ADDRESS_TARGET = y_coord;
193     X_ADDRESS_TARGET = x_coord;
194     Z_ADDRESS_TARGET = z_coord;
195     F_PERCENT_SPEED = f_speed;
196
197     update_lcd(0);
198
199     go(x_coord,y_coord,z_coord, f_speed);
200 }
201
202 void G1_cmd(){
203
204     if (ON_MOVE || M6_EN) return;
205
206     double x_coord = CURRENT_X;
207     double y_coord = CURRENT_Y;
208     double z_coord = CURRENT_PAYLOAD_HEIGHT;
209     double f_speed_in = 4.5;
210     int f_speed = 100; //maximum speed
211
212     if(Commands.availableValue('X')){
213         x_coord = Commands.GetValue('X');
214     }

```

```

215     if(Commands.availableValue('Y')){
216         y_coord = Commands.GetValue('Y');
217     }
218     if(Commands.availableValue('Z')){
219         z_coord = Commands.GetValue('Z');
220     }
221     if(Commands.availableValue('F')){
222         f_speed_in = Commands.GetValue('F');
223     }
224
225     if (!UNIT_MODE){ //translate mm to in
226         x_coord = mm_to_in(x_coord);
227         y_coord = mm_to_in(y_coord);
228         z_coord = mm_to_in(z_coord);
229         f_speed_in = mm_to_in(f_speed_in);
230     }
231
232     if (!ABSOLUTE_COORDINATES){//incremental mode
233         x_coord += CURRENT_X;
234         y_coord += CURRENT_Y;
235         z_coord += CURRENT_PAYLOAD_HEIGHT;
236     }
237
238     //checking for boundaries
239     if (x_coord > 8.5)
240         x_coord = 8.5;
241     if (y_coord > 11)
242         x_coord = 11;
243     if (z_coord > 11)
244         z_coord = 11;
245
246     f_speed_in = (f_speed_in/4.5)*100;
247
248     if (f_speed_in > 100)
249         f_speed = 100;
250     else if (f_speed_in <= 1)
251         f_speed = 1;
252     else
253         f_speed = int(f_speed_in);
254
255     //update global values
256     Y_ADDRESS_TARGET = y_coord;
257     X_ADDRESS_TARGET = x_coord;
258     Z_ADDRESS_TARGET = z_coord;
259     F_PERCENT_SPEED = f_speed;
260
261     update_lcd(1);
262
263     go(x_coord, y_coord, z_coord, f_speed);
264 }
265
266 void G20_cmd(){
267
268     if (ON_MOVE || M6_EN) return;
269
270     UNIT_MODE = true;
271     update_lcd(20);
272 }

```

```

273
274 void G21_cmd(){
275
276     if (ON_MOVE || M6_EN) return;
277
278     UNIT_MODE = false;
279     update_lcd(21);
280 }
281
282 void G90_cmd(){
283
284     if (ON_MOVE || M6_EN) return;
285
286     ABSOLUTE_COORDINATES = true;
287     update_lcd(90);
288 }
289
290 void G91_cmd(){
291
292     if (ON_MOVE || M6_EN) return;
293
294     ABSOLUTE_COORDINATES = false;
295     update_lcd(91);
296 }
297
298 void M2_cmd(){
299     update_lcd(2);
300     if (ON_MOVE){
301         stepperA.stop();
302         stepperB.stop();
303         stepperC.stop();
304
305         ON_MOVE = false;
306         ABSOLUTE_COORDINATES = true;
307         M2_EN = true;
308         M6_EN = false;
309     }
310 }
311
312 void M6_cmd(){
313     update_lcd(6);
314     if (!M6_EN){ //m6 first time
315         //stop
316
317         //if (ON_MOVE){
318             stepperA.stop();
319             stepperB.stop();
320             stepperC.stop();
321
322             ON_MOVE = false;
323             ABSOLUTE_COORDINATES = true;
324             M6_EN = true;
325
326             double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
327             double actual_b = -(stepperB.currentPosition() *
INCHES_PER_STEP);
328             double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
329

```

```

330     CURRENT_THREAD_LEN_A += actual_a;
331     CURRENT_THREAD_LEN_B += actual_b;
332     CURRENT_THREAD_LEN_C += actual_c;
333
334     M6_SAVE_LEN_A = CURRENT_THREAD_LEN_A;
335     M6_SAVE_LEN_B = CURRENT_THREAD_LEN_B;
336     M6_SAVE_LEN_C = CURRENT_THREAD_LEN_C;
337     M6_SAVE_X = X_ADDRESS_TARGET;
338     M6_SAVE_Y = Y_ADDRESS_TARGET;
339     M6_SAVE_Z = Z_ADDRESS_TARGET;
340
341     if (M6_SAVE_X == -1 || M6_SAVE_Y == -1 || M6_SAVE_Z == -1){
342         M6_SAVE_X = CURRENT_X;
343         M6_SAVE_Y = CURRENT_Y;
344         M6_SAVE_Z = CURRENT_PAYLOAD_HEIGHT;
345     }
346     if (M6_SAVE_X == 0 && M6_SAVE_Y == 0 && M6_SAVE_Z == 0){
347         M6_SAVE_X = CURRENT_X;
348         M6_SAVE_Y = CURRENT_Y;
349         M6_SAVE_Z = CURRENT_PAYLOAD_HEIGHT;
350     }
351     M6_SAVE_Speed = F_PERCENT_SPEED;
352
353     go_block(HOME_X,HOME_Y,HOME_Z, 100);
354 }
355 else {
356
357     go_len_block(M6_SAVE_LEN_A,M6_SAVE_LEN_B,M6_SAVE_LEN_C, 100);
358
359     M6_EN = false;
360
361     //go(M6_SAVE_X,M6_SAVE_Y,M6_SAVE_Z,M6_SAVE_Speed);
362
363     /*M6_SAVE_LEN_A = 0;
364     M6_SAVE_LEN_B = 0;
365     M6_SAVE_LEN_C = 0;
366     M6_SAVE_X = -1;
367     M6_SAVE_Y = -1;
368     M6_SAVE_Z = -1;
369     M6_SAVE_Speed = 0;*/
370 }
371 }
372
373 void C1_cmd(){ //Write value of X,Y,Z to the Serial Connection
374
375     //if (ON_MOVE || M6_EN) return;
376
377     Serial.write("X");
378     Serial.print(CURRENT_X);
379     Serial.write("Y");
380     Serial.print(CURRENT_Y);
381     Serial.write("Z");
382     Serial.print(CURRENT_PAYLOAD_HEIGHT);
383     Serial.write("#");
384     update_lcd(57);
385     delay(500);
386 }
387

```

```

388 void C2_cmd() { //Write thread lengths to Serial
389 //if (ON_MOVE || M6_EN) return;
390
391 Serial.write("A");
392 Serial.print(CURRENT_THREAD_LEN_A);
393 Serial.write("B");
394 Serial.print(CURRENT_THREAD_LEN_B);
395 Serial.write("C");
396 Serial.print(CURRENT_THREAD_LEN_C);
397 Serial.write("#");
398 update_lcd(58);
399 delay(500);
400 }
401
402 //////////////////////////////////////////////////G-Code////////////////////////////////////
403
404
405 //////////////////////////////////THREAD CALCULATIONS////////////////////////////////////
406 double calculate_thread_height_var(double z){
407     return HEIGHT_PYLON_A - z;
408 }
409
410 double calculate_thread_length_A_h(double x, double y, double z) {
411     double height_created_triangle = A_PAPER_DISTANCE + 8.5 - x -
        PAYLOAD_CENTER_THREAD_DISTANCE_A_x;
412     double side_created_triangle;
413     if ((y - 5.5) < 0)
414         side_created_triangle = 5.5 - y;
415     else
416         side_created_triangle = y - 5.5;
417
418     double trace_length = sqrt(pow(height_created_triangle, 2) + pow(
        side_created_triangle, 2));
419
420     double thread_length = sqrt(pow(trace_length,2) + pow(
        calculate_thread_height_var(z),2));
421
422     return thread_length;
423 }
424
425 double calculate_thread_length_B_h(double x, double y, double z) {
426     double height_created_triangle = PAPER_HEIGHT + B_PAPER_DISTANCE
        - y - PAYLOAD_CENTER_THREAD_DISTANCE_B_y;
427     double side_created_triangle = PAPER_DISTANCE_LOW_EDGE + x -
        PAYLOAD_CENTER_THREAD_DISTANCE_B_x;
428
429     double trace_length = sqrt(pow(height_created_triangle,2) + pow(
        side_created_triangle,2));
430
431     //double trace_length = PAPER_DISTANCE_1 - y -
        PAYLOAD_CENTER_THREAD_DISTANCE_B_y;
432
433     double thread_length = sqrt(pow(trace_length,2) + pow(
        calculate_thread_height_var(z),2));
434
435     return thread_length;
436 }
437

```

```

438 double calculate_thread_length_C_h(double x, double y, double z) {
439     double height_created_triangle = C_PAPER_DISTANCE + y -
        PAYLOAD_CENTER_THREAD_DISTANCE_B_y;
440     double side_created_triangle = PAPER_DISTANCE_LOW_EDGE + x -
        PAYLOAD_CENTER_THREAD_DISTANCE_C_x;
441
442     double trace_length = sqrt(pow(height_created_triangle,2) + pow(
        side_created_triangle,2));
443
444     double thread_length = sqrt(pow(trace_length,2) + pow(
        calculate_thread_height_var(z),2));
445
446     return thread_length;
447 }
448
449 //////////////////////////////////////////////////THREAD CALCULATIONS////////////////////////////////////
450
451 //////////////////////////////////////////////////UNIT CONVERSION////////////////////////////////////
452 double mm_to_in(double mm){
453     return (mm/(25.4));
454 }
455
456 double in_to_mm(double in){
457     return (in *(25.4));
458 }
459 //////////////////////////////////////////////////UNIT CONVERSION////////////////////////////////////
460
461 void update_lcd(int opcode){
462     lcd.clear();
463     if (opcode == 0 || opcode == 1){ //G0 or G1 (displays as integer
        for size)
464         lcd.setCursor(0, 0); //1st line 1st char
465         lcd.print("OPCODE: G");
466         lcd.print(opcode);
467         lcd.print(" F:");
468         lcd.print(F_PERCENT_SPEED);
469         lcd.setCursor(0, 1); //2nd Line 1st char
470         double x = X_ADDRESS_TARGET;
471         double y = Y_ADDRESS_TARGET;
472         if (!UNIT_MODE){ //translate mm to in
473             x = in_to_mm(X_ADDRESS_TARGET);
474             y = in_to_mm(Y_ADDRESS_TARGET);
475         }
476         lcd.print("X: ");
477         lcd.print(x);
478         lcd.setCursor(8, 1); //2nd Line 9th char
479         lcd.print("Y: ");
480         lcd.print(y);
481     }
482     else if (opcode == 20){
483         lcd.setCursor(0, 0); //1st line 1st char
484         lcd.print("OPCODE: G");
485         lcd.print(opcode);
486         lcd.setCursor(0, 1); //2nd Line 1st char
487         lcd.print("Input Mode > IN");
488     }
489     else if (opcode == 21){
490         lcd.setCursor(0, 0); //1st line 1st char

```

```

491     lcd.print("OPCODE: G");
492     lcd.print(opcode);
493     lcd.setCursor(0, 1); //2nd Line 1st char
494     lcd.print("Input Mode > MM");
495 }
496 else if (opcode == 90){
497     lcd.setCursor(0, 0); //1st line 1st char
498     lcd.print("OPCODE: G");
499     lcd.print(opcode);
500     lcd.setCursor(0, 1); //2nd Line 1st char
501     lcd.print("Coord Mode > ABS");
502 }
503 else if (opcode == 91){
504     lcd.setCursor(0, 0); //1st line 1st char
505     lcd.print("OPCODE: G");
506     lcd.print(opcode);
507     lcd.setCursor(0, 1); //2nd Line 1st char
508     lcd.print("Coord Mode > INC");
509 }
510 else if (opcode == 2){
511     lcd.setCursor(0, 0); //1st line 1st char
512     lcd.print("OPCODE: M");
513     lcd.print(opcode);
514     lcd.setCursor(0, 1); //2nd Line 1st char
515     lcd.print("END PROGRAM");
516 }
517 else if (opcode == 6){
518     lcd.setCursor(0, 0); //1st line 1st char
519     lcd.print("OPCODE: G");
520     lcd.print(opcode);
521     lcd.setCursor(0, 1); //2nd Line 1st char
522     lcd.print("TOOL CHANGE");
523 }
524 else if (opcode == 57){
525     lcd.setCursor(0, 0); //1st line 1st char
526     lcd.print("Sending Location");
527     lcd.setCursor(0, 1); //2nd Line 1st char
528     lcd.print("<<<<<<<>>>>>>");
529 }
530 else if (opcode == 58){
531     lcd.setCursor(0, 0); //1st line 1st char
532     lcd.print("Sending Threads");
533     lcd.setCursor(0, 1); //2nd Line 1st char
534     lcd.print("<<<<<<<>>>>>>");
535 }
536 else {
537     lcd.setCursor(0, 0); //1st line 1st char
538     lcd.print("ERROR: ");
539     lcd.print(opcode);
540     lcd.setCursor(0, 1); //2nd Line 1st char
541     lcd.print("OPCODE NOT FOUND");
542 }
543 }
544
545 //Calculates the number of steps to move from current_ to new_
    length of thread.
546 //If the output is negative, then the motor must reduce the size of
    the thread instead of increasing it

```

```

547
548 ///////////////////////////////////////////////////CALCULATIONS FOR MOVEMENT
549 ///////////////////////////////////////////////////
550 int calculate_number_steps(double current_, double new_){
551     int num_steps = int((new_ - current_)/INCHES_PER_STEP);
552     return num_steps;
553 }
554
555 int go_block(double x, double y, double z, int f_speed) {
556     X_ADDRESS_TARGET = x;
557     Y_ADDRESS_TARGET = y;
558     Z_ADDRESS_TARGET = z;
559     F_PERCENT_SPEED = f_speed;
560
561     //calculate new necessary thread lengths
562     double new_len_a = calculate_thread_length_A_h(x,y,z);
563     double new_len_b = calculate_thread_length_B_h(x,y,z);
564     double new_len_c = calculate_thread_length_C_h(x,y,z);
565
566     //calculate number of steps and direction of movement to move
567     //from current pos to new pos.
568     int steps_A = calculate_number_steps(CURRENT_THREAD_LEN_A,
569     new_len_a);
570     int steps_B = calculate_number_steps(CURRENT_THREAD_LEN_B,
571     new_len_b);
572     int steps_C = calculate_number_steps(CURRENT_THREAD_LEN_C,
573     new_len_c);
574
575     //Setting important info in stepper classes
576     stepperA.setCurrentPosition(0);
577     stepperB.setCurrentPosition(0);
578     stepperC.setCurrentPosition(0);
579     int max_speed = int((MAX_STEPS_PER_SEC/100)*f_speed);
580     stepperA.setMaxSpeed(max_speed);
581     stepperB.setMaxSpeed(max_speed);
582     stepperC.setMaxSpeed(max_speed);
583     //move the payload to location
584     long steps[] = {steps_A, -steps_B, steps_C};
585
586     lcd.clear();
587     lcd.print("Moving to >>>>");
588     lcd.setCursor(0, 1);
589     lcd.print(x);
590     lcd.print(" ");
591     lcd.print(y);
592     lcd.print(" ");
593     lcd.print(z);
594
595     steppers.moveTo(steps);
596
597     //move_to(steps_A, steps_B, steps_C);
598
599     //blocks until steppers finish moving
600     while(steppers.run()){
601     }
602
603     //find actual displacement

```

```

600 double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
601 double actual_b = -(stepperB.currentPosition() * INCHES_PER_STEP)
602 ;
603 double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
604
605 //after done, update current values
606 CURRENT_X = x;
607 CURRENT_Y = y;
608 CURRENT_PAYLOAD_HEIGHT = z;
609 CURRENT_THREAD_LEN_A += actual_a;
610 CURRENT_THREAD_LEN_B += actual_b;
611 CURRENT_THREAD_LEN_C += actual_c;
612
613 return 0;
614 }
615
616 int go_len_block(double a, double b, double c, int f_speed) {
617
618     //calculate number of steps and direction of movement to move
619     //from current pos to new pos.
620     int steps_A = calculate_number_steps(CURRENT_THREAD_LEN_A, a);
621     int steps_B = calculate_number_steps(CURRENT_THREAD_LEN_B, b);
622     int steps_C = calculate_number_steps(CURRENT_THREAD_LEN_C, c);
623
624     //Setting important info in stepper classes
625     stepperA.setCurrentPosition(0);
626     stepperB.setCurrentPosition(0);
627     stepperC.setCurrentPosition(0);
628     int max_speed = int((MAX_STEPS_PER_SEC/100)*f_speed);
629     stepperA.setMaxSpeed(max_speed);
630     stepperB.setMaxSpeed(max_speed);
631     stepperC.setMaxSpeed(max_speed);
632     //move the payload to location
633     long steps[] = {steps_A, -steps_B, steps_C};
634
635     steppers.moveTo(steps);
636
637     //blocks until steppers finish moving
638     while(steppers.run()){
639     }
640
641     //find actual displacement
642     double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
643     double actual_b = -(stepperB.currentPosition() * INCHES_PER_STEP)
644     ;
645     double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
646
647     //after done, update current values
648     CURRENT_THREAD_LEN_A += actual_a;
649     CURRENT_THREAD_LEN_B += actual_b;
650     CURRENT_THREAD_LEN_C += actual_c;
651
652     X_ADDRESS_TARGET = 0;
653     Y_ADDRESS_TARGET = 0;
654     Z_ADDRESS_TARGET = 0;
655
656     return 0;

```

```

655 }
656
657
658 int go(double x, double y, double z, int f_speed) {
659     X_ADDRESS_TARGET = x;
660     Y_ADDRESS_TARGET = y;
661     Z_ADDRESS_TARGET = z;
662     F_PERCENT_SPEED = f_speed;
663
664     //calculate new necessary thread lengths
665     double new_len_a = calculate_thread_length_A_h(x,y,z);
666     double new_len_b = calculate_thread_length_B_h(x,y,z);
667     double new_len_c = calculate_thread_length_C_h(x,y,z);
668
669     /*Serial.println("");
670     Serial.print("New Length A: ");
671     Serial.println(new_len_a);
672     Serial.print("New Length B: ");
673     Serial.println(new_len_b);
674     Serial.print("New Length C: ");
675     Serial.println(new_len_c);
676
677     Serial.println("");
678     Serial.print("CurrentLength A: ");
679     Serial.println(CURRENT_THREAD_LEN_A);
680     Serial.print("CurrentLength B: ");
681     Serial.println(CURRENT_THREAD_LEN_B);
682     Serial.print("CurrentLength C: ");
683     Serial.println(CURRENT_THREAD_LEN_C);*/
684
685     //calculate number of steps and direction of movement to move
        from current pos to new pos.
686     int steps_A = calculate_number_steps(CURRENT_THREAD_LEN_A,
        new_len_a);
687     int steps_B = calculate_number_steps(CURRENT_THREAD_LEN_B,
        new_len_b);
688     int steps_C = calculate_number_steps(CURRENT_THREAD_LEN_C,
        new_len_c);
689
690
691     //Setting important info in stepper classes
692     stepperA.setCurrentPosition(0);
693     stepperB.setCurrentPosition(0);
694     stepperC.setCurrentPosition(0);
695     int max_speed = int((MAX_STEPS_PER_SEC/100)*f_speed);
696     stepperA.setMaxSpeed(max_speed);
697     stepperB.setMaxSpeed(max_speed);
698     stepperC.setMaxSpeed(max_speed);
699     //stepperA.setAcceleration(max_speed/5);
700     //stepperB.setAcceleration(max_speed/5);
701     //stepperC.setAcceleration(max_speed/5);
702     //move the payload to location
703     long steps[] = {steps_A, -steps_B, steps_C};
704
705     lcd.clear();
706     lcd.print("Moving to: F");
707     lcd.setCursor(0, 1);
708     lcd.print(x);

```

```

709 lcd.print(" ");
710 lcd.print(y);
711 lcd.print(" ");
712 lcd.print(z);
713
714 steppers.moveTo(steps);
715
716 //move_to(steps_A, steps_B, steps_C);
717
718 ON_MOVE = true;
719
720 //blocks until steppers finish moving
721 while(steppers.run() && ON_MOVE){
722     Commands.available();
723 }
724
725 //find actual displacement
726 double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
727 double actual_b = -(stepperB.currentPosition() * INCHES_PER_STEP)
728 ;
729 double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
730
731 /*Serial.println("");
732 Serial.print("DELTA A:");
733 Serial.println(actual_a);
734 Serial.print("DELTA B:");
735 Serial.println(actual_b);
736 Serial.print("DELTA C:");
737 Serial.println(actual_c);
738
739 Serial.println("\nFinal Stepper Pos:");
740 Serial.print("Stepper A: ");
741 Serial.println(stepperA.currentPosition());
742 Serial.print("Stepper B: ");
743 Serial.println(-stepperB.currentPosition());
744 Serial.print("Stepper C: ");
745 Serial.println(stepperC.currentPosition());*/
746
747 ON_MOVE = false;
748
749 //after done, update current values
750 if (!M2_EN && !M6_EN){
751     CURRENT_X = x;
752     CURRENT_Y = y;
753     CURRENT_PAYLOAD_HEIGHT = z;
754 }
755 if (!M6_EN){
756     CURRENT_THREAD_LEN_A += actual_a;
757     CURRENT_THREAD_LEN_B += actual_b;
758     CURRENT_THREAD_LEN_C += actual_c;
759 }
760 M2_EN = false;
761
762 X_ADDRESS_TARGET = 0;
763 Y_ADDRESS_TARGET = 0;
764 Z_ADDRESS_TARGET = 0;
765
766 /*Serial.println("");

```

```

766 Serial.print("Final Length A: ");
767 Serial.println(CURRENT_THREAD_LEN_A);
768 Serial.print("Final Length B: ");
769 Serial.println(CURRENT_THREAD_LEN_B);
770 Serial.print("Final Length C: ");
771 Serial.println(CURRENT_THREAD_LEN_C);*/
772
773 return 0;
774 }
775
776 ///////////////////////////////////////////////////CALCULATIONS FOR MOVEMENT
777 ///////////////////////////////////////////////////
778 void init_values(){ //expects in not mm
779   lcd.clear();
780   lcd.print("Location:");
781   lcd.setCursor(0, 1);
782   lcd.print("Z, X, Y");
783   while(Serial.available() <= 0){
784   }
785   double h = Serial.parseFloat();
786   double x = Serial.parseFloat();
787   double y = Serial.parseFloat();
788
789   CURRENT_PAYLOAD_HEIGHT = h;
790
791   double La = calculate_thread_length_A_h(x,y,h);
792   double Lb = calculate_thread_length_B_h(x,y,h);
793   double Lc = calculate_thread_length_C_h(x,y,h);
794
795   CURRENT_THREAD_LEN_A = La;
796   CURRENT_THREAD_LEN_B = Lb;
797   CURRENT_THREAD_LEN_C = Lc;
798   CURRENT_X = x;
799   CURRENT_Y = y;
800
801   lcd.clear();
802   lcd.print("Z: ");
803   lcd.print(CURRENT_PAYLOAD_HEIGHT);
804   lcd.setCursor(0, 1); //2nd Line 1st char
805   lcd.print("X: ");
806   lcd.print(CURRENT_X);
807   lcd.setCursor(8, 1); //2nd Line 9th char
808   lcd.print("Y: ");
809   lcd.print(CURRENT_Y);
810
811 }
812
813 void ready_command_lcd(){
814   lcd.clear();
815   lcd.setCursor(0, 0); //2nd Line 1st char
816   lcd.print("    <READY>    ");
817   lcd.setCursor(0, 1); //2nd Line 1st char
818   lcd.print("    Listening    ");
819 }
820
821 void send_sensor(){
822

```

```

823
824 sensorVal = analogRead(sensor);
825 lightLevel = (sensorVal/1023)*10;
826 Serial.write("L");
827 Serial.print(lightLevel);
828
829 boolean success = false;
830 uint8_t uid[] = { 0, 0, 0, 0, 0, 0, 0, 0 }; // Buffer to store the
      returned UID
831 uint8_t uidLength; // Length of the UID (4
      or 7 bytes depending on ISO14443A card type)
832 success = nfc.readPassiveTargetID(PN532_MIFARE_ISO14443A, &uid
      [0], &uidLength);
833 long test = 0;
834 if (success){
835     for (uint8_t i=0; i < uidLength; i++)
836     {
837         //Serial.print(" 0x");Serial.print(uid[i], HEX);
838         test = test + uid[i];
839         if(i<3){
840             test = test * 256;
841         }
842     }
843     Serial.write("R");
844     Serial.write(test);
845 } else {
846     Serial.write("R0");
847 }
848 }
849
850 void task_done(){
851     X_ADDRESS_TARGET = 0;
852     Y_ADDRESS_TARGET = 0;
853     Z_ADDRESS_TARGET = 0;
854     F_PERCENT_SPEED = 100;
855     OPCODE = 1000; //change OPCODE to 1000 when task is done
856     //delay(2000);
857     ready_command_lcd();
858
859     Serial.write("X");
860     Serial.print(CURRENT_X);
861     Serial.write("Y");
862     Serial.print(CURRENT_Y);
863     Serial.write("Z");
864     Serial.print(CURRENT_PAYLOAD_HEIGHT);
865     Serial.write("A");
866     Serial.print(CURRENT_THREAD_LEN_A);
867     Serial.write("B");
868     Serial.print(CURRENT_THREAD_LEN_B);
869     Serial.write("C");
870     Serial.print(CURRENT_THREAD_LEN_C);
871
872     send_sensor();
873
874     delay(1000);
875
876     Serial.write("G"); //let matlab know when it is good to send
      another command.

```

```

877 }
878 }
879
880 void set_pins(){
881     //LCD
882     pinMode(2, OUTPUT);
883     pinMode(3, OUTPUT);
884     pinMode(4, OUTPUT);
885     pinMode(5, OUTPUT);
886     pinMode(8, OUTPUT);
887
888     //STEPPERS
889     pinMode(25, OUTPUT);
890     pinMode(23, OUTPUT);
891     pinMode(29, OUTPUT);
892     pinMode(27, OUTPUT);
893     pinMode(33, OUTPUT);
894     pinMode(31, OUTPUT);
895
896     pinMode(35, OUTPUT);
897     pinMode(37, OUTPUT);
898     pinMode(39, OUTPUT);
899
900 }
901
902 void setup() {
903     Commands.begin();
904     lcd.begin(16, 2);
905     lcd.print("      <FP>      ");
906     lcd.setCursor(2, 1);
907     lcd.print("Spydercam 18");
908     delay(2000);
909     lcd.clear();
910     lcd.print("      BETA      ");
911     lcd.setCursor(0, 1);
912     lcd.print("Arduino Firmware");
913     delay(2000);
914     init_values();
915     delay(2000);
916     set_pins();
917     stepperA = AccelStepper(motorInterfaceType, stepPinA, dirPinA);
918     stepperB = AccelStepper(motorInterfaceType, stepPinB, dirPinB);
919     stepperC = AccelStepper(motorInterfaceType, stepPinC, dirPinC);
920
921     digitalWrite(35, LOW);
922     digitalWrite(37, LOW);
923     digitalWrite(39, LOW);
924
925     steppers.addStepper(stepperA);
926     steppers.addStepper(stepperB);
927     steppers.addStepper(stepperC);
928
929
930     //sensor setup
931     nfc.begin();
932     lcd.clear();
933     lcd.print("  Enabling NFC  ");
934     lcd.setCursor(0, 1);

```

```

935 lcd.print(" In Progress... ");
936 uint32_t versiondata = nfc.getFirmwareVersion();
937 if (! versiondata) {
938     lcd.clear();
939     lcd.print("      ERROR      ");
940     lcd.setCursor(0, 1);
941     lcd.print("    NFC Failed    ");
942     while (1); // Halt
943 }
944
945 delay(1000);
946 nfc.SAMConfig();
947 ready_command_lcd();
948
949 //Serial.write("G");
950 }
951
952 void loop() {
953     if (Commands.available()) {
954         task_done();
955     }
956 }

```

8.2 MATLAB Code

```
1 % ===== %
2 % === MATLAB GUI FOR SPYDERCAM TEAM 18 === %
3 % ===== %
4
5 % === Main Program === %
6 clear;
7
8 % --- Variables --- %
9 global drawing_input; %Cell array holding sets of user drawn lines
10 drawing_input = cell(1);
11
12 global num_sets; %Number of user entered sets of lines. (Sets are
    connected lines
13 num_sets = 0;
14
15 global home; %Home Location for Payload
16 home = [0 0 3];
17
18 global draw_height; %Height (Z Pos) for Drawing with Pen attachment
19 draw_height = 3.6;
20
21 global non_draw_height; %Height (Z Pos) for NOT Drawing with pen
22 non_draw_height = 4.6;
23
24 global gcode_buffer; %Buffer for holding G-Code to be sent to
    Arduino
25 gcode_buffer = [];
26
27 global sensor_data; %Incoming sensor data from the Arduino is
    stored here
28 sensor_data = zeros(0,5);
29
30 global serial_on; %Turn on or off incoming serial (1 = on, 0 =
    off)
31 serial_on = 1;
32
33 global prgm_end; %Set to 0 if the current Gcode sequence is over
34 prgm_end = 1;
35
36 % --- Serial --- %
37 global s; %Serial port. Open it up. Throw an error and quit if it
    wont open
38 try s = serialport("COM3",9600);
39 catch
40     disp("Serial device not connected. Reconnect and restart");
41     return;
42 end
43 configureCallback(s,"byte",1,@readSerialData) %Callback function
    for serial. Executes if there is 1 byte available
44
45 % --- GUI Figure --- %
46 global gui; %GUI uifigure and overarching labels
47 gui = uifigure(1,'Position', [250, 70, 1100, 700], 'Name', 'SpyderCam
    Team 18 MATLAB GUI');
48
49 % Main area labels
```

```

50 drw_lbl = uilabel(gui,'Text', 'Drawing Input', 'Position',[45 660
    200 40], 'FontSize',24);
51 gcode_lbl = uilabel(gui,'Text', 'G-Code Input', 'Position',[400 660
    200 40], 'FontSize',24);
52 ea_lbl = uilabel(gui,'Text', 'Execution Area', 'Position',[740 660
    200 40], 'FontSize',24);
53
54 % Child figures
55 global sensorViewFig; %Figure that shows sensor data
56 global bufferfig; %Figure that shows Gcode buffer
57
58 % --- User Drawing Input Area --- %
59 draw_area = uiaxes(gui,'Position', [20, 227, 340, 440], '
    ButtonDownFcn',@axesCallback); %Create Axes
60 draw_area.XLim = [0 8.5]; %Set axes limits
61 draw_area.YLim = [0 11];
62 draw_area.PickableParts = 'all'; %Make axes clickable
63 draw_area.HitTest = 'off'; %Make axes not clickable
64 draw_area.NextPlot = 'replacechildren'; %Each plot replaces the
    last, but axes settings stay the same
65
66 % Buttons for adding a new line set or clearing the drawing
67 draw_line = uibutton(gui,'state','Text','Draw Line','Position',[30,
    197, 100, 22], 'ValueChangedFcn',{@drawBtnCallback,draw_area});
    %State button: pushed in is drawing mode, pushed out = finished
    drawing line set
68 clear_drawing = uibutton(gui,'push','Text','Clear Drawing','
    Position',[140, 197, 100, 22], 'ButtonPushedFcn',{
    @clearBtnCallback,draw_area}); %Push button: clears everything
    in drawing window
69 slbl = uilabel(gui,'Text','Speed (IPM)','Position',[25, 167, 70,
    25]); %Label for Speed Slider
70 speed = uislider(gui,'Position',[110, 180, 230, 3], 'Limits',[0.1
    4.5]); %Speed Slider
71 convert_to_gcode = uibutton(gui,'push','Text','Convert to G-Code ->
    ', 'Position',[250, 197, 110, 22]); %Convert to G-Code Button
72
73
74 % --- GCODE Input Area --- %
75 gcode_area = uitextarea(gui,'Position',[400, 270, 300, 390]); %Text
    box for inputting GCODE
76 gcode_area.Value = sprintf(";"); %Initialize gcode text input area
77 gcode_dropdown = uidropdown(gui,'Items',{'G00','G01','G04','G20','
    G21','G28','G90','G91','M00','M02','M06','M30','M72'}, 'Position'
    ,[400,230,100,22], 'ValueChangedFcn',@GdownCallback); %Dropdown
    for choosing G-code
78 arg_boxes(); %Set up boxes for inputting arguments
79 disp_args('G00','000'); %Initialize argument boxes with the ones
    for G00
80 global currentgcode; %Current G-Code being formulated with dropdown
    and argument input boxes
81 enter_gcode = uibutton(gui,'push','Text','Enter G-Code','Position'
    ,[400, 190, 100, 22], 'ButtonPushedFcn',{@enterCallback,
    gcode_area}); %Send current G-Code into the G-Code text area
82 line_break = uibutton(gui,'push','Text','Line Break','Position'
    ,[520, 190, 100, 22], 'ButtonPushedFcn',{@linebreakCallback,
    gcode_area}); %Add a line break (;)
83 delete_line = uibutton(gui,'push','Text','Delete Line','Position'

```

```

    ,[400, 150, 100, 22], 'ButtonPushedFcn',{@deleteLineCallback,
    gcode_area});%Delete 1 line from the G-Code text area
84 clear_gcode = uibutton(gui,'push','Text','Clear G-Code','Position'
    ,[520, 150, 100, 22], 'ButtonPushedFcn',{@clearGcodeCallback,
    gcode_area}); %Clear all G-Code from text area
85
86 convert_to_gcode.ButtonPushedFcn = {@convertCallback, gcode_area,
    speed}; %Set callback for convert_to_gcode button. Down here so
    it can reference speed
87
88
89 % --- Execution Area --- %
90 incr_distance = uieditfield(gui,'Position',[800, 270, 50, 20]); %
    Incremental movement distance
91 incr_dlbl = uilabel(gui,'Text','Distance','Position',[750, 270, 60,
    25]); %label for ^
92 incr_speed = uieditfield(gui,'Position',[940, 270, 50,20]); %
    Incremental movement speed
93 incr_slbl = uilabel(gui,'Text','Speed (IPM)','Position',[865, 270,
    70,25]); %Label for ^
94
95 % X, Y, and Z incremental movement buttons
96 yplus_btn = uibutton(gui,'push','Text','Y+', 'Position',[850, 530,
    100, 100], 'ButtonPushedFcn',{@directionBtnCallback,"Y+",
    incr_distance,incr_speed});
97 xminus_btn = uibutton(gui,'push','Text','X-', 'Position',[740, 420,
    100, 100], 'ButtonPushedFcn',{@directionBtnCallback,"X-",
    incr_distance,incr_speed});
98 xplus_btn = uibutton(gui,'push','Text','X+', 'Position',[960, 420,
    100, 100], 'ButtonPushedFcn',{@directionBtnCallback,"X+",
    incr_distance,incr_speed});
99 yminus_btn = uibutton(gui,'push','Text','Y-', 'Position',[850, 310,
    100, 100], 'ButtonPushedFcn',{@directionBtnCallback,"Y-",
    incr_distance,incr_speed});
100 zplus_btn = uibutton(gui,'push','Text','Z+', 'Position',[960, 530,
    50, 50], 'ButtonPushedFcn',{@directionBtnCallback,"Z+",
    incr_distance,incr_speed});
101 zminus_btn = uibutton(gui,'push','Text','Z-', 'Position',[790, 360,
    50, 50], 'ButtonPushedFcn',{@directionBtnCallback,"Z-",
    incr_distance,incr_speed});
102 home_btn = uibutton(gui,'push','Text','Home', 'Position',[850, 420,
    100, 100], 'ButtonPushedFcn',{@directionBtnCallback,"home",
    incr_distance,incr_speed}); %Button for sending the payload to
    the home locations
103
104 % Buffer and sensor data control buttons
105 send_btn = uibutton(gui,'push','Text','Send G-Code to Buffer (From
    Text Area)', 'Position',[740, 150, 270, 50], 'ButtonPushedFcn',{
    @send2bufferCallback,gcode_area}); %Sends G-Code from text area
    to buffer
106 run_btn = uibutton(gui,'state','Text','Run', 'Position',[1020, 150,
    40, 50], 'ValueChangedFcn',@runCallback,'Tag','RUN'); %Start the
    gcode sequence
107 sensor_data_btn = uibutton(gui,'push','Text','Sensor Data', '
    Position',[740, 210, 100, 20], 'ButtonPushedFcn',
    @sensorViewCallback); %Show the sensor data window
108 buffer_btn = uibutton(gui,'push','Text','G-Code Buffer', 'Position',
    ,[845, 210, 100, 20], 'ButtonPushedFcn',@bufferCallback); %

```

```

109     Displays the contents of the buffer in a new window
clear_buffer_btn = uibutton(gui,'push','Text','Clear Buffer (0)',,
    'Position',[950, 210, 110, 20], 'Tag','C', 'ButtonPushedFcn',
    @bufferClearCallback); %Clears the contents of the buffer (if
    they haven't been sent to the Arduino)
110
111 % Direct Serial Area
112 ds_lbl = uilabel(gui,'Text','Direct Serial Comm','Position',[40,
    100, 300, 40], 'FontSize',24); % Label for direct serial area
113 ser_get = uitextarea(gui,'Position',[30 50 950, 50], 'Tag','SER',,
    'ValueChangedFcn',@serGetCallback); % Box for receiving serial
114 dir_ser = uitextarea(gui,'Position',[30 20 950, 20]); % Box for
    sending serial
115 dir_send = uibutton(gui,'push','Text','Send','Position',[990 20 70,
    80], 'ButtonPushedFcn',{@dirSendCallback,dir_ser,ser_get}); %
    Button that sends serial
116
117 % === UTILITY FUNCTIONS === %
118 function plot_input(obj,new_point)
119     % This is the plotting function. It takes in the axes object
    and a new
120     % point. It adds the point to drawing input, then plots all of
    drawing
121     % input. Inputting [-1 -1] clears the plot
122
123     global drawing_input;
124     global num_sets;
125
126     if new_point ~= [-1 -1] %Only plot if the new point is not [-1
    -1];
127         drawing_input{num_sets+1} = [drawing_input{num_sets+1};
    new_point]; %Add new point to drawing input
128
129         inplot = cell(num_sets+1); %Input plot
130         obj.NextPlot = 'add'; % Change plot settings so that plots
    get added to existing plots
131         for i = 1:num_sets+1 % Draw each cell (1 cell = 1 line
    set) of drawing input. Make them not clickable.
132             inplot{i} = plot(obj,drawing_input{i}(:,1),
    drawing_input{i}(:,2),'r-o');
133             inplot{i}.HitTest = 'off';
134         end
135         obj.NextPlot = 'replacechildren'; %Change plot back to
    replaceable
136     else %If new_point is [-1 -1]
137         plot(obj,-1,-1); %Just plot 1 garbage point off the axes
138     end
139 end
140
141 function disp_args(code,prevcode)
142     % This is the display arguments function. This function turns
    on or off
143     % the visibility of each argument editfield depending on which
    G-Code
144     % has been chosen in the dropdown menu. code and prevcode refer
    to the
145     % new and old values of the dropdown, respectively.
146

```

```

147 global gui;
148 global currentgcode;
149 children = get(gui, 'Children');
150
151 % If dropdown changed from G00
152 if sum(prevcode == 'G00') == 3
153     %Find the editfields/labels with the G00 tag and make them
invisible.
154     for i = 1:1:length(children)
155         if ~isempty(children(i).Tag) && (children(i).Tag == "
G00")
156             children(i).Visible = 'off';
157             %Find the editfield and set its value to empty
158             if length(children(i).Type) == 11
159                 children(i).Value = '';
160             end
161         end
162     end
163     %Find the editfields/labels with the G01 or G00 tag and make
them
164     %invisible. (G00 and G01 both have XYZ, G01 just also has F)
165     elseif sum(prevcode == 'G01') == 3
166         for i = 1:1:length(children)
167             if ~isempty(children(i).Tag) && ((children(i).Tag == "
G00") || (children(i).Tag == "G01"))
168                 children(i).Visible = 'off';
169                 %Find the editfield and set its value to empty
170                 if length(children(i).Type) == 11
171                     children(i).Value = '';
172                 end
173             end
174         end
175     %Find the editfields/labels with the G04 tag and make them
invisible
176     elseif sum(prevcode == 'G04') == 3
177         for i = 1:1:length(children)
178             if ~isempty(children(i).Tag) && (children(i).Tag == "
G04")
179                 children(i).Visible = 'off';
180                 %Find the editfield and set its value to empty
181                 if length(children(i).Type) == 11
182                     children(i).Value = '';
183                 end
184             end
185         end
186     else
187
188     end
189
190     %If the new code is G00, turn editfields/labels tagged G00
visible
191     if sum(code == 'G00') == 3
192         for i = 1:1:length(children)
193             if ~isempty(children(i).Tag) && (children(i).Tag == "
G00")
194                 children(i).Visible = 'on';
195             end
196         end

```

```

197         %Set the current G-Code to be filled with arguments
198         currentgcode = ["G00" "" "" "" ""];
199         %If the new code is G01, turn editfields/labels tagged G00 or
200         G01 visible
201         elseif sum(code == 'G01') == 3
202             for i = 1:1:length(children)
203                 if ~isempty(children(i).Tag) && ((children(i).Tag == "
204                 G00") || (children(i).Tag == "G01"))
205                     children(i).Visible = 'on';
206             end
207         end
208         %Set the current G-Code to be filled with arguments
209         currentgcode = ["G01" "" "" "" "" ""];
210         %If the new code is G04, turn editfields/labels tagged G04
211         visible
212         elseif sum(code == 'G04') == 3
213             for i = 1:1:length(children)
214                 if ~isempty(children(i).Tag) && (children(i).Tag == "
215                 G04")
216                     children(i).Visible = 'on';
217             end
218         end
219         %Set the current G-Code to be filled with arguments
220         currentgcode = ["G04" ""];
221     else
222         %Set the current G-Code (no arguments)
223         currentgcode = [convertCharsToStrings(code)];
224     end
225 end
226
227 function arg_boxes()
228     % This function sets up the editfields and labels for argument
229     input on
230     % the G-Code Input. It puts all of the items in position, then
231     makes
232     % them all invisible
233
234     global gui;
235
236     % XYZ labels/editfields
237     xl = uilabel(gui,'Text', 'X','Position',[520 230 10 20],'Tag',"
238     G00");
239     xe = uieditfield(gui,'Position',[535 230 30 20],'Tag',"G00",'
240     ValueChangedFcn',{@fieldChange,'X','0'});
241     yl = uilabel(gui,'Text', 'Y','Position',[580 230 10 20],'Tag',"
242     G00");
243     ye = uieditfield(gui,'Position',[595 230 30 20],'Tag',"G00",'
244     ValueChangedFcn',{@fieldChange,'Y','0'});
245     zl = uilabel(gui,'Text', 'Z','Position',[640 230 10 20],'Tag',"
246     G00");
247     ze = uieditfield(gui,'Position',[655 230 30 20],'Tag',"G00",'
248     ValueChangedFcn',{@fieldChange,'Z','0'});
249
250     % F label/editfield
251     fl = uilabel(gui,'Text', 'F','Position',[640 190 10 20],'Tag',"
252     G01");
253     fe = uieditfield(gui,'Position',[655 190 30 20],'Tag',"G01",'
254     ValueChangedFcn',{@fieldChange,'F','0'});

```

```

241
242 % PX dropdown/editfield
243 pxdd = uiddropdown(gui,'Items',{'P','X'},'Position',[520 230 40
244 20],'Tag',"G04");
245 pxe = uieditfield(gui,'Position',[565 230 30 20],'Tag',"G04",'
246 ValueChangedFcn',{@fieldChange,'P',pxdd});
247 pxdd.ValueChangedFcn = {@pxChange,pxe};
248
249 % Turn all of the elements created in this function invisible
250 xl.Visible = 'off';
251 xe.Visible = 'off';
252 yl.Visible = 'off';
253 ye.Visible = 'off';
254 zl.Visible = 'off';
255 ze.Visible = 'off';
256 fl.Visible = 'off';
257 fe.Visible = 'off';
258 pxdd.Visible = 'off';
259 pxe.Visible = 'off';
260
261 end
262
263 function [gcode] = drawing2gcode(speed)
264 % This function turns data from the user inputted drawing and
265 % turns it
266 % into G-Code. It takes in a constant speed for the whole
267 % operation. It
268 % orders the drawing lines by proximity and then turns that
269 % path into
270 % G-Code
271
272 %Setup
273 F = speed;
274 global home;
275 global drawing_input;
276 sets = length(drawing_input);
277 if length(drawing_input{sets}) < 1
278     sets = sets-1;
279 end
280 indexes = [];
281
282 %Find the line set that starts closest to the origin
283 lowest_dist = 100;
284 for i = 1:1:sets
285     temp = sqrt(sum((home(1:2) - drawing_input{i}(1,:)).^2));
286     if temp < lowest_dist
287         lowest_dist = temp;
288         indexes(1) = i;
289     end
290 end
291
292 %Add line set that starts closest to the origin to a new
293 %ordered array
294 new_order{1} = drawing_input{indexes(1)};
295
296 % Order the rest of of the line sets, next closest starting
297 % point after
298 % current set endpoint.

```

```

292     while length(new_order) < sets
293         lowest_dist = 100;
294         for i = 1:1:sets
295             if ~ismember(i,indexes)
296                 temp = sqrt(sum((new_order{end}(end,:) -
drawing_input{i}(1,:)).^2));
297                 if temp < lowest_dist
298                     lowest_dist = temp;
299                     indexes(length(indexes)+1) = i;
300                     new_order{length(new_order)+1} = drawing_input{
i};
301                 end
302             end
303         end
304     end
305
306     %Initialize gcode
307     gcode = {};
308     gcode{1} = sprintf(';');
309
310     % Turn each set into a set of G-Code Commands
311     for i = 1:1:sets
312         %Go to location of first point and lower down into pen
height
313         gcode{length(gcode)+1} = ['G00' ' X' num2str(new_order{i}
(1,1)) ' Y' num2str(new_order{i}(1,2)) ' Z3;'];
314         gcode{length(gcode)+1} = ['G01' ' Z2' ' F' num2str(F) ';''];
315         %Stay in pen heigh and go through the points in the set (
draw the
316         %line)
317         for j = 2:1:length(new_order{i})
318             gcode{length(gcode)+1} = ['G01' ' X' num2str(new_order{
i}(j,1)) ' Y' num2str(new_order{i}(j,2)) ' F' num2str(F) ';''];
319         end
320         %Lift up out of pen height
321         gcode{length(gcode)+1} = ['G01' ' Z3' ' F' num2str(F) ';''];
322     end
323
324 end
325 % ===== %
326
327
328
329 % === GUI ELEMENT CALLBACK FUNCTIONS === %
330 function axesCallback(obj,~)
331     % This is the callback function for clicking on the Drawing
Axes.
332     % It gets the mouse click location and sends it to the plotting
333     % function.
334
335     mouse_loc = obj.CurrentPoint;
336     plot_input(obj,mouse_loc(1,1:2));
337 end
338
339 function drawBtnCallback(obj,~,obj2)
340     % This is the callback function for clicking the "Draw Line"
Button.
341     % It turns on the ability to draw on the axes.

```

```

342
343     global drawing_input;
344     global num_sets;
345
346     if obj.Value == 1                                % If button is pressed
347         obj2.HitTest = 'on';                          % Turn axis clicking on
348         obj.Text = 'End Line';
349     else                                              % If button is not pressed
350         (un-pressed? pulled?)
351         obj2.HitTest = 'off';                          % Turn axis clicking
352         off
353         obj.Text = 'Draw Line';
354         if ~isempty(drawing_input{num_sets+1}) % If something has
355             been drawn in this set
356                 num_sets = num_sets + 1;                % Add 1 to num_sets
357                 drawing_input{num_sets+1} = [];          % Add another
358             cell to user input
359         end
360     end
361 end
362
363 function clearBtnCallback(~,~,obj2)
364     % This is the callback function for the "Clear Drawing" button.
365     % It just resets the user input/number of sets then plots an
366     empty
367     % graph.
368
369     global drawing_input;
370     global num_sets;
371
372     num_sets = 0;
373     drawing_input = cell(1);
374
375     plot_input(obj2,[-1 -1]);
376
377 end
378
379 function GdownCallback(obj,event)
380     %This is the callback function for the G-Code dropdown menu. It
381     grabs
382     %the current and previous values, then sends them to the
383     disp_args
384     %function
385
386     val = obj.Value;
387     prevVal = event.PreviousValue;
388     disp_args(val,prevVal);
389
390 end
391
392 function enterCallback(~,~,text_area)
393     %This is the callback function for the send gcode button. It
394     adds the
395     %G-Code formed by the dropdown and argument inputs to the text
396     area.
397
398     global currentgcode;
399     index = length(text_area.Value)+1;

```

```

391     text_area.Value{index} = sprintf('');
392     for i = 1:1:length(currentgcode)
393         charcode = convertStringsToChars(currentgcode(i));
394         if ~isempty(charcode)
395             text_area.Value{index} = [text_area.Value{index}
sprintf(charcode) sprintf(' ')];
396         end
397     end
398     text_area.Value{index} = text_area.Value{index}(1:end-1);
399     text_area.Value{index} = [text_area.Value{index} sprintf(';')];
400
401 end
402
403 function fieldChange(obj,~,lbl,obj2)
404     %This is the callback function for when the argument fields are
405     %updated. This function runs every time those are changed
406     values.
407
408     global currentgcode;
409
410     %Depending on the argument label, add argument to current g
411     code
412     if lbl == 'X'
413         currentgcode(2) = convertCharsToStrings([lbl obj.Value]);
414     elseif lbl == 'Y'
415         currentgcode(3) = convertCharsToStrings([lbl obj.Value]);
416     elseif lbl == 'Z'
417         currentgcode(4) = convertCharsToStrings([lbl obj.Value]);
418     elseif lbl == 'F'
419         currentgcode(5) = convertCharsToStrings([lbl obj.Value]);
420     elseif lbl == 'P'
421         currentgcode(2) = convertCharsToStrings([obj2.Value obj.
422         Value]);
423     else
424     end
425
426 end
427
428 function convertCallback(~,~,text_area,speed)
429     % This is the callback function for the convert to G-Code
430     button. It
431     % calls the drawing2gcode function on the drawing_input, then
432     puts the
433     % results in the text area.
434
435     global drawing_input;
436     if length(drawing_input{1}) > 0
437         gcode = drawing2gcode(speed.Value);
438         text_area.Value = gcode;
439     end
440
441 end
442
443 function linebreakCallback(~,~,text_area)
444     %This is the callback function for the line break button. It
445     just
446     %prints a ';' on the next line.

```

```

442
443     index = length(text_area.Value)+1;
444     text_area.Value{index} = sprintf(';');
445
446 end
447
448 function deleteLineCallback(~,~,text_area)
449     %This is the callback function for the delete line button. It
450     just
451     %deletes the last line in the G-Code text box
452
453     temp = {};
454     if length(text_area.Value) > 1
455         for i = 1:(length(text_area.Value)-1)
456             temp{i} = text_area.Value{i};
457         end
458         text_area.Value = temp;
459     end
460 end
461
462 function pxChange(obj,~,ef)
463     % This is the callback for the P and X dropdown on the G04
464     argument
465     % inputs. It updates the currentgcode value and also deletes
466     the
467     % editfield value if the drop down changes value
468
469     global gui;
470     global currentgcode;
471     children = get(gui,'Children');
472
473     for i = 1:length(children)
474         if length(children(i).Type) == 11
475             children(i).Value = '';
476         end
477     end
478     currentgcode(2) = convertCharsToStrings([obj.Value ef.Value]);
479 end
480
481 function clearGcodeCallback(~,~,text_area)
482     % This is the callback function for the clear gcode button. It
483     just
484     % sets the text_area to be equal ';'
485
486     text_area.Value = sprintf(';');
487 end
488
489 function send2bufferCallback(~,~,text_area)
490     % This function is the callback for the send to buffer button.
491     It adds
492     % the lines from the text area to the buffer, then deletes the
493     text
494     % area.
495
496     global gcode_buffer;

```

```

494     for i = 1:1:length(text_area.Value)
495         gcode_buffer = [{text_area.Value{i}}; gcode_buffer];
496     end
497     text_area.Value = {' '};
498     update_clear_btn();
499     update_bufferfig();
500
501 end
502
503 function directionBtnCallback(~,~,dir,dist,speed)
504     % This is the callback function for the directional buttons. It
505     % takes a
506     % direction, distance, and speed, and then ti moves at that
507     % speed for
508     % that dist in that direction.
509
510     global gcode_buffer;
511
512     %If user didn't set distance or speed, give them some default
513     % values
514     if isempty(dist.Value)
515         dist.Value = '1';
516     end
517     if isempty(speed.Value)
518         speed.Value = '100';
519     end
520
521     % If direction = Y+,Y-,X+,X-,Z+,Z-
522     % add 'G91' to buffer (Set incremental movement)
523     % add 'G01' to buffer with distance and speed (Move in the
524     % specified
525     % direction
526     % add 'G90' to buffer (Set absolute movement)
527     if dir == "Y+"
528         gcode_buffer = [{'G91;'}; gcode_buffer ];
529         gcode_buffer = [{['G01 Y' dist.Value ' F' speed.Value '
530         ']]; gcode_buffer ];
531         gcode_buffer = [{'G90;'}; gcode_buffer ];
532     elseif dir == "X-"
533         gcode_buffer = [{'G91;'}; gcode_buffer ];
534         gcode_buffer = [{['G01 X-' dist.Value ' F' speed.Value '
535         ']]; gcode_buffer ];
536         gcode_buffer = [{'G90;'}; gcode_buffer ];
537     elseif dir == "X+"
538         gcode_buffer = [{'G91;'}; gcode_buffer ];
539         gcode_buffer = [{['G01 X' dist.Value ' F' speed.Value '
540         ']]; gcode_buffer ];
541         gcode_buffer = [{'G90;'}; gcode_buffer ];
542     elseif dir == "Y-"
543         gcode_buffer = [{'G91;'}; gcode_buffer ];
544         gcode_buffer = [{['G01 Y-' dist.Value ' F' speed.Value '
545         ']]; gcode_buffer ];
546         gcode_buffer = [{'G90;'}; gcode_buffer ];
547     elseif dir == "Z+"
548         gcode_buffer = [{'G91;'}; gcode_buffer ];
549         gcode_buffer = [{['G01 Z' dist.Value ' F' speed.Value '
550         ']]; gcode_buffer ];
551         gcode_buffer = [{'G90;'}; gcode_buffer ];

```

```

543 elseif dir == "Z-"
544     gcode_buffer = [{'G91;'}]; gcode_buffer ];
545     gcode_buffer = [{'G01 Z-' dist.Value ' F' speed.Value '
546     ;'}]; gcode_buffer ];
547     gcode_buffer = [{'G90;'}]; gcode_buffer ];
548 elseif dir == "home"
549     gcode_buffer = [{'G28;'}]; gcode_buffer ];
550 else
551 end
552
553 %Update the clear button because values have been added to the
554 buffer
555 update_clear_btn();
556 update_bufferfig();
557 end
558
559 function bufferCallback(~,~)
560     %This is the view gcode buffer button callback. It shows a
561     figure which
562     %contains a text area which contains the contents of the G-Code
563     Buffer
564     global bufferfig;
565     global gcode_buffer;
566     bufferfig = uitextarea('Position',[50 20 460, 380]);
567     bufferfig.Parent.Name = 'G-Code Buffer';
568
569     bufferfig.Value = flip(gcode_buffer);
570 end
571
572 function bufferClearCallback(~,~)
573     %This function is the buffer clear button callback. It clears
574     the
575     %buffer and updates the number on itself.
576
577     global gcode_buffer;
578     gcode_buffer = [];
579     update_clear_btn();
580     update_bufferfig();
581 end
582
583 function sensorViewCallback(~,~)
584     %This is the callback function for the button that opens the
585     sensor
586     %data view window. It opens the sensor data view window.
587
588     global sensorViewFig;
589
590     %Make the figure and the headings
591     sensorViewFig = uifigure('Position',[200 100 600 500],'Tag','
592     svf');
593     axes_label = uilabel(sensorViewFig,'Text', 'Data Points', '
594     Position',[45 460 200 40],'FontSize',24);
595     info_label = uilabel(sensorViewFig,'Text', 'Sensor Data', '
596     Position',[390 460 200 40],'FontSize',24);

```

```

592
593 %Label and values for coordinates (data from Arduino)
594 coord_label = uilabel(sensorViewFig,'Text', 'Coordinates (
Inches):', 'Position',[390 430 200 25],'FontSize',16);
595 coord_val = uilabel(sensorViewFig,'Text', ' ', 'Position',[390
410 200 25],'Tag','COORD');
596
597 %Label and value for light sensor (data from Arduino)
598 lsv_label = uilabel(sensorViewFig,'Text', 'Light Sensor Value:',
, 'Position',[390 360 200 25],'FontSize',16);
599 lsv_val = uilabel(sensorViewFig,'Text', ' ', 'Position',[390
340 200 25],'Tag','LSV');
600
601 %Label and value for RFID (data from Arduino)
602 RFID_label = uilabel(sensorViewFig,'Text', 'RFID Value:', '
Position',[390 290 200 25],'FontSize',16);
603 RFID_val = uilabel(sensorViewFig,'Text', ' ', 'Position',[390
270 200 25],'Tag','RFID');
604
605 %Axes that will show data points
606 dataAxes = uiaxes(sensorViewFig,'Position', [20, 20, 340,
440], 'ButtonDownFcn',@dataAxesCallback); %Create Axes
607 dataAxes.XLim = [0 8.5]; %Set axes limits
608 dataAxes.YLim = [0 11];
609 dataAxes.PickableParts = 'all'; %Make axes clickable
610 dataAxes.HitTest = 'on'; %Make axes clickable
611 dataAxes.NextPlot = 'replacechildren';
612
613 %Scroll buttons and data point number. Scrolling increases/
decreases
614 %data point number.
615 scroll_left = uibutton(sensorViewFig,'push','Text','<<','
Position',[390, 50, 90, 22],'ButtonPushedFcn',{
@leftScrollCallback,dataAxes});
616 scroll_right = uibutton(sensorViewFig,'push','Text','>>','
Position',[490, 50, 90, 22],'ButtonPushedFcn',{
@rightScrollCallback,dataAxes});
617 dpn_val = uilabel(sensorViewFig,'Text', 'Data Point Number: ',
'Position',[390 75 200 25],'Tag','DPN');
618
619 %Plot the sensor data on the axes
620 update_sensor_data(dataAxes);
621
622 end
623
624 function runCallback(obj,~)
625 %This is the callback function for the run button. It starts
running
626 %whatever Gcode sequence is currently in the buffer by sending
a start
627 %signal to the Arduino. The Arduino responds with some initial
location
628 %and sensor data, then MATLAB knows that it can send the first
gcode
629 %command
630
631 global gcode_buffer;
632 global s;

```

```

633     global serial_on;
634     global prgm_end;
635
636     %Program end set to 0 means the program is starting.
637     prgm_end = 0;
638     serial_on = 1;
639
640     %If theres stuff in the buffer and run has been turned on, send
        the
641     %start signal
642     if length(gcode_buffer) > 0 && obj.Value == 1
643         %serial_on = 0;
644         t = timer('TimerFcn',@timer_trash,'StopFcn',{@send_gcode,s
        },'StartDelay',0.05);
645         start(t);
646     %Otherwise, turn the button back off
647     else
648         obj.Value = 0;
649     end
650
651     %If the button has been unpressed, press it again
652     if obj.Value == 0
653         obj.Value = 1;
654     end
655
656     %If there's nothing in the buffer, the program can be ended by
        %unpressing manually
657     if length(gcode_buffer) == 0 && obj.Value == 1
658         obj.Value = 0;
659     end
660
661 end
662
663
664 function leftScrollCallback(~,~,dataAxes)
665     %This is the callback function for the left scroll button in
        the sensor
666     %view window. This decreases the datapoint number so that you
        can look
667     %at the next data point on the list
668
669     global sensor_data;
670     sds = size(sensor_data);
671
672     %Find the data point colored blue
673     last = findobj(dataAxes.Children,'Color',[0 0 1]);
674     if size(last) > 0
675         %get the data point number from the tags
676         id = last.Tag;
677         newid = str2num(id)-1; %decrease data point number (go to
        next point)
678         %If the data point number is 0, go to the highest one
679         if newid == 0
680             newid = sds(1);
681         end
682         %Update the sensor view with the new selected data point
        update_sensor_view(num2str(newid),dataAxes);
683     else
684         %If none had been selected previously, just select the

```

```

first one
686     update_sensor_view('1',dataAxes);
687     end
688 end
689
690 function rightScrollCallback(~,~,dataAxes)
691     %This is the callback function for the right scroll button in
        the sensor
692     %view window. This increases the datapoint number so that you
        can look
693     %at the next data point on the list
694
695     global sensor_data;
696     sds = size(sensor_data);
697
698     %Find the data point colored blue
699     last = findobj(dataAxes.Children,'Color',[0 0 1]);
700     if size(last) > 0
701         %Grab the data point number and increase it by one
702         id = last.Tag;
703         newid = str2num(id)+1;
704         %If the new data point number is too large, go back to the
        first
705         %one
706         if newid == sds(1)+1
707             newid = 1;
708         end
709         %Update the sensor view with the new selected data point
710         update_sensor_view(num2str(newid),dataAxes);
711     else
712         %If no point had been selected previously, just select
        number 1
713         update_sensor_view('1',dataAxes);
714     end
715 end
716
717 function dataPointCallback(self,~,dataAxes)
718     %This is the callback function for clicking on a data point. It
        simply
719     %grabs the tag from itself and then passes it on to the
720     %update_sensor_view function so that it can select this new
        point.
721
722     id = self.Tag;
723
724     update_sensor_view(id,dataAxes);
725
726 end
727
728 function dirSendCallback(~,~,dir_ser,ser_get)
729     % Callback function for the send button in the direct serial
        comm
730     % section.
731
732     global s;
733
734     % For every item in the serial send bar, send it on serial and
        delete

```

```

735 % the line from the text area.
736 for idx = 1:1:length(dir_ser.Value)
737     disp(dir_ser.Value{idx});
738     ser_get.Value{end+1} = '';
739     ser_get.Value{end+1} = sprintf('Outgoing Serial');
740     ser_get.Value{end+1} = sprintf(dir_ser.Value{idx});
741     scroll(ser_get,'bottom');
742
743     % Only send if its not an empty line.
744     if ~isempty(dir_ser.Value{idx})
745         writeline(s,dir_ser.Value{idx});
746         dir_ser.Value{idx} = '';
747     end
748 end
749 end
750
751 function serGetCallback(self,~)
752     %Scroll the serial monitor to the bottom
753
754     scroll(self,'bottom');
755 end
756
757 function dataAxesCallback(~,~)
758     %This callback function does nothing
759 end
760 % ===== %
761
762
763 % === UPDATE FUNCTIONS === %
764 function update_clear_btn()
765     % This function updates the display on the buffer clear button
766     % that
767     % tells you how many lines are in the buffer
768
769     global gui;
770     global gcode_buffer;
771     children = get(gui,'Children');
772     % Find the button by Tag and then set the number in the text to
773     % include
774     % new size of gcode_buffer
775     for i = 1:1:length(children)
776         if children(i).Tag == 'C'
777             children(i).Text = ['Clear Buffer (' int2str(length(
778                 gcode_buffer)) ')'];
779         end
780     end
781
782     if length(gcode_buffer) == 0
783         run_btn = findobj(gui.Children,'Tag','RUN');
784         run_btn.Value = 0;
785     end
786 end
787
788 function update_bufferfig()
789     %This function updates the contents of the text box in the
790     %external
791     %figure which shows the GCode buffer.

```

```

789
790     global bufferfig;
791     global gcode_buffer;
792
793     %If the gcode buffer has stuff in it and the figure exists, set
794     %the new
795     %value of the text box
796     if length(gcode_buffer) > 0 && sum(size(findobj('Value',
797         bufferfig))) > 0
798         bufferfig.Value = flip(gcode_buffer);
799     end
800 end
801
802 function update_sensor_data(dataAxes)
803     %This function updates the plot in the sensor view window. It
804     %plots all
805     %of the newest sensor data on the axes.
806
807     global sensor_data;
808
809     %Set the axes to replace old plots with new ones, then plot a
810     %garbage
811     %point
812     dataAxes.NextPlot = 'replacechildren';
813     plot(dataAxes,-1,-1,'ro');
814
815     %Set axes to ADD all new plots
816     dataAxes.NextPlot = 'add';
817
818     sd = size(sensor_data);
819
820     %Plot all of the points
821     for i = 1:1:sd(1)
822         plot(dataAxes,sensor_data(i,1),sensor_data(i,2),'ro','Tag',
823             num2str(i),'ButtonDownFcn',{@dataPointCallback,dataAxes});
824     end
825 end
826
827 function update_sensor_view(id,dataAxes)
828     %This function updates the sensor view window given a newly
829     %selected
830     %data point. The data point with data point number 'id' is
831     %turned blue
832     %and its data is shown on the right hand side of the window.
833
834     global sensorViewFig;
835     global sensor_data;
836
837     %Find the point that's colored blue
838     last = findobj(dataAxes.Children,'Color',[0 0 1]);
839
840     %If there was a blue point, turn it back to red
841     if size(last) > 0
842         last.Color = [1 0 0];
843         last.MarkerSize = 6;
844     end
845 end

```

```

840
841 %Get the point with data point number id and turn it blue
842 curr = findobj(dataAxes.Children,'Tag',id);
843 curr.Color = [0 0 1];
844 curr.MarkerSize = 10;
845
846 nid = str2num(id);
847
848 %Grab all of the data display labels
849 coord_lbl = findobj(sensorViewFig.Children,'Tag','COORD');
850 lsv_lbl = findobj(sensorViewFig.Children,'Tag','LSV');
851 rfid_lbl = findobj(sensorViewFig.Children,'Tag','RFID');
852 dpn_lbl = findobj(sensorViewFig.Children,'Tag','DPN');
853
854 %get all of the values to display from the sensor data (depends
on id)
855 x = num2str(sensor_data(nid,1));
856 y = num2str(sensor_data(nid,2));
857 z = num2str(sensor_data(nid,3));
858 lsv = num2str(sensor_data(nid,7));
859 rfid = num2str(sensor_data(nid,8));
860
861 %Change the text of the labels to match the data gathered from
862 %sensor_data
863 coord_lbl.Text = ['X: ' x ' Y: ' y ' Z: ' z];
864 lsv_lbl.Text = lsv;
865 rfid_lbl.Text = rfid;
866 dpn_lbl.Text = ['Data Point Number: ' id];
867
868 end
869 % ===== %
870
871
872 % === SERIAL FUNCTIONS === %
873 function readSerialData(src,~)
874 %This is the callback function for the serial device. This is
called
875 %when there are bytes available.
876
877 global sensor_data;
878 global gui;
879 global sensorViewFig;
880 global serial_on;
881 values = zeros(1,8);
882
883 %If there are bytes available and serial is enabled, grab all
of the
884 %new data.
885 serial_on = 1;
886 if src.NumBytesAvailable > 0 && serial_on == 1
887     values = getSerial(src);
888     sensor_data = [sensor_data; values];
889
890 %If the sensor view window is open, update the axes.
891 if size(findobj(sensorViewFig,'Type','figure')) > 0
892     dataAxes = findobj(sensorViewFig.Children,'Type','axes'
);
893     if size(dataAxes) > 0

```

```

894         update_sensor_data(dataAxes);
895     end
896 end
897 end
898
899 end
900
901 function [values] = getSerial(src)
902     %This function actually accesses the serial data and parses it
903     %into the
904     %sensor data matrix
905
906     global gcode_buffer;
907     global gui;
908
909     character = ' ';
910     data = '';
911     current = '';
912     j = -1;
913     lastj = -1;
914     values = zeros(1,8);
915
916     %Keep getting data until it hits a G (end of code) or a # (end
917     %of transmission);
918     while character ~= 'G' && character ~= '#'
919         character = read(src,1,"char");
920         data = [data character];
921     end
922
923     %Parse data and place into sensor_data depending on the letter
924     %preceding it.
925     for i = 1:length(data)
926         if data(i) == 'X' %X location
927             j = 1;
928         elseif data(i) == 'Y' %Y location
929             j = 2;
930         elseif data(i) == 'Z' %Z location
931             j = 3;
932         elseif data(i) == 'A' %X location
933             j = 4;
934         elseif data(i) == 'B' %Y location
935             j = 5;
936         elseif data(i) == 'C' %Z location
937             j = 6;
938         elseif data(i) == 'L' %Light sensor value
939             j = 7;
940         elseif data(i) == 'R' %RFID value
941             j = 8;
942         elseif data(i) == 'G' %Send another Gcode command
943             j = -1;
944             %For some reason, the serial write command cannot be
945             %used
946             %within the serial read callback, so short timers have
947             %to be
948             %used.
949             if ~isempty(gcode_buffer)
950                 t = timer('TimerFcn',@timer_trash,'StopFcn',{
951                     @send_gcode,src},'StartDelay',0.1);

```

```

947         start(t);
948     end
949     elseif data(i) == '#'
950         while character ~= 'G'
951             character = read(src,1,"char");
952         end
953         character = read(src,1,"char");
954         j=-1;
955     end
956
957     %If theres a new letter, put all of the previous numbers
into the
958     %sensor values
959     if j ~= lastj && lastj ~= -1
960         values(1,lastj) = str2double(current(2:end));
961         current = '';
962     end
963
964     %If j is unchanged (same letter), keep adding the
information
965     if j ~= -1
966         current = [current data(i)];
967     end
968
969     lastj = j;
970 end
971
972 ser_get = findobj(gui,'Tag','SER');
973
974 if sum(values(1:3)) ~= 0
975     disp("Incoming Location Data:");
976     disp(values(1:3));
977     ser_get.Value{end+1} = sprintf('Incoming Location Data:');
978     ser_get.Value{end+1} = sprintf(['X: ' num2str(values(1)) '
Y: ' num2str(values(2)) ' Z: ' num2str(values(3))]);
979     scroll(ser_get,'bottom');
980 end
981
982 if sum(values(4:6)) ~= 0
983     disp("Incoming Thread Length Data:");
984     disp(values(4:6));
985     ser_get.Value{end+1} = sprintf('Incoming Thread Length Data
:');
986     ser_get.Value{end+1} = sprintf(['A: ' num2str(values(4)) '
B: ' num2str(values(5)) ' C: ' num2str(values(6))]);
987     scroll(ser_get,'bottom');
988 end
989
990 end
991
992 function send_gcode(~,~,src)
993     %This function sends 1 line of gcode through serial to the
Arduino.
994     %Because of the nature of the serial read callback, this
function has
995     %to be set up as a callback function for a timer.
996
997     global gcode_buffer;

```

```

998     global serial_on;
999     global gui;
1000     global prgm_end;
1001
1002     % Grab the serial monitor
1003     ser_get = findobj(gui,'Tag','SER');
1004
1005     serial_on = 0;
1006
1007     %If the gcode buffer has stuff in it and theres nothing more to
1008     %read,
1009     %send the stuff.
1010     if length(gcode_buffer) > 0 && src.NumBytesAvailable == 0
1011         %get rid of all of the empty lines or line breaks
1012         while (sum(gcode_buffer{end} == ';'') == 1 && length(
1013             gcode_buffer{end}) == 1) || length(gcode_buffer{end}) == 0
1014             gcode_buffer(end) = [];
1015         end
1016         writeline(src,gcode_buffer{end});
1017         disp("Outgoing GCode:");
1018         disp(gcode_buffer{end});
1019         % Print gcode to serial monitor
1020         ser_get.Value{end+1} = '';
1021         ser_get.Value{end+1} = sprintf('Outgoing Gcode');
1022         ser_get.Value{end+1} = sprintf(gcode_buffer{end});
1023         scroll(ser_get,'bottom');
1024         gcode_buffer(end) = [];
1025         update_clear_btn();
1026     end
1027
1028     %Only turn the serial back on if the program is not ended
1029     if prgm_end == 0
1030         serial_on = 1;
1031     end
1032
1033     update_bufferfig();
1034
1035 end
1036
1037 % === PROGRAM FLOW FUNCTIONS === %
1038 function timer_trash(~,~)
1039     %Timers have to have a function to be executed when they start.
1040     %Nothing
1041     %needed to happen at the start of the timers in this program,
1042     %so this
1043     %function is empty.
1044 end
1045
1046 function end_program(~,~)
1047     %This function is run when the current gcode sequence has run
1048     %its
1049     %course. It deactivates serial, deactivates the run button, and
1050     %sets
1051     %the program end flag to true.
1052
1053     global gui;
1054     global serial_on;

```

```
1050     global prgm_end;
1051
1052     run_btn = findobj(gui.Children,'Tag','RUN');
1053     run_btn.Value = 0;
1054     serial_on = 0;
1055     prgm_end = 1;
1056
1057 end
```

8.3 Calculating Thread Lengths in Arduino

Current and target thread lengths are calculated using Pythagorean's theorem within the Arduino. First we must find the length of the projection of the thread connected to the payload. With that length, it is possible to calculate the necessary thread length by using the height of the triangle that is created between the thread, projection and the pylon.

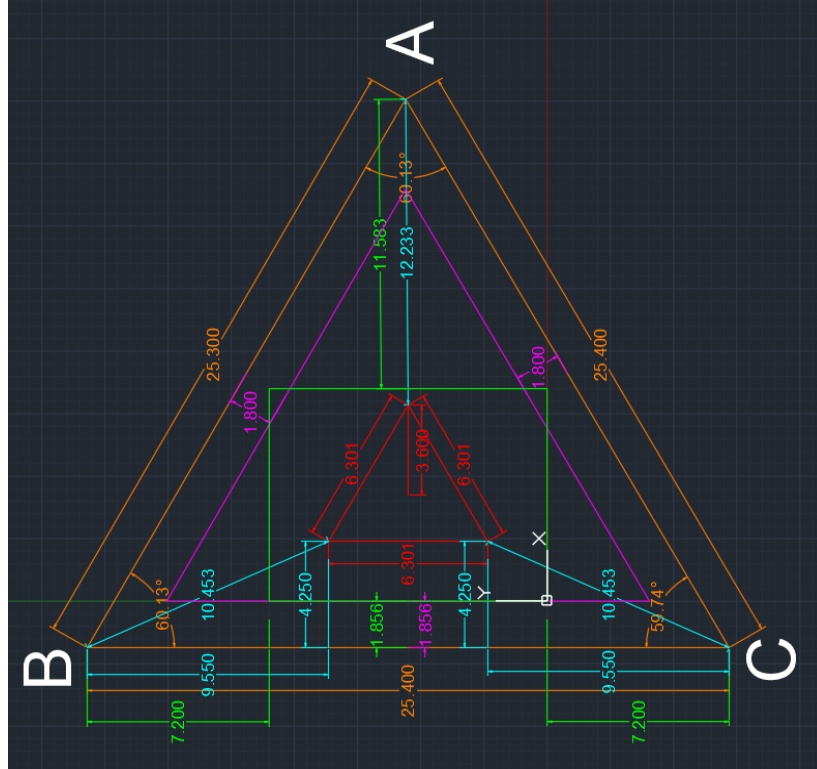


Figure 48: Calculating projection of thread length based on known values.

After the projections in light blue in Figure 48 are calculated, the actual thread length can be calculated by using the Pythagorean's theorem with the difference in height from the top of the pylon to the payload and the projection length. This is very evident when you look at Figure 49.

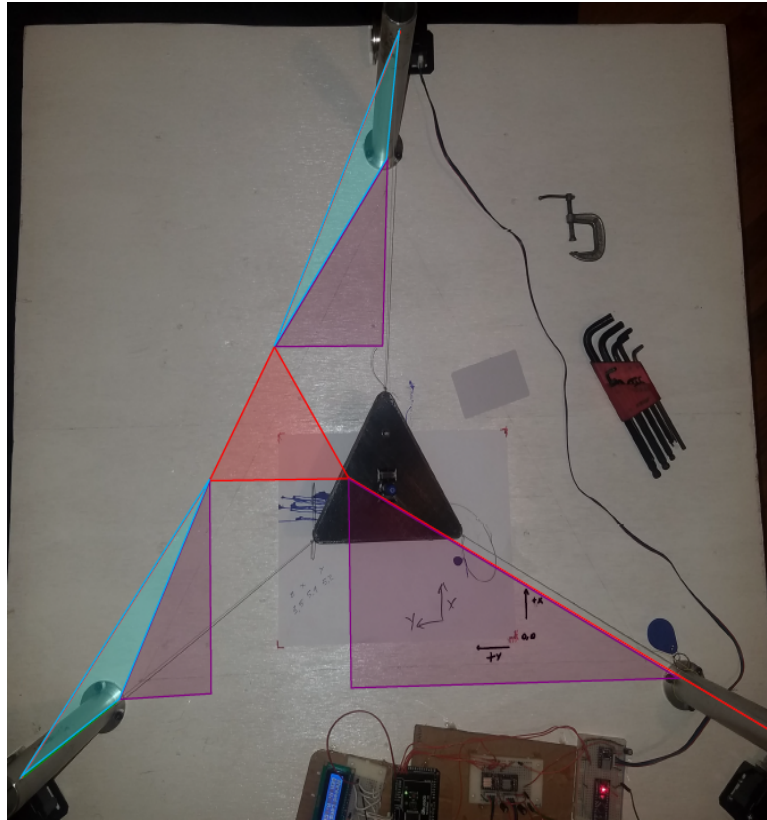


Figure 49: Calculating thread length based on projection of thread and height of the blue triangle.