APPA

2023 Milford BattleBots Season

Brandon Wang

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Acknowledgments

I would like to give a huge thank you to Milford High School, Great Oaks, Mr. Peter Leeper, and Mr. Zachary Sheppard for helping me complete this project. As my high school career comes to an end, I reflect on how much I have grown and learned about engineering. In the beginning, I knew absolutely nothing, struggling to model simple figures in CAD and not even knowing what an isometric view is. But through the years, my engineering teachers have taught me everything that I know today about engineering. Joining Battlebots was the best decision I have ever made, learning a surplus of knowledge in the field of manufacturing engineering and gaining confidence in the workshop. I was able to apply what I have learned to some of the coolest projects I have ever made.

A special thanks also go to Mr. Justin Koeth and General Tools Company for partnering with our team and offering to machine out the extremely complex parts. Without them, the team and I would not have been able to see some of our designs ever come to life. They were extremely helpful in guiding us through the process and even gave us a tour of their facility, showing us the wide variety of machines they use every day to make the products the output.

I am extremely grateful for all who have guided me through my high school career and gained a massive jump start in my engineering career. I hope to continue this passion and eventually, like my mentors, guide others to success in the field they love.

Problem Statement

The goal of this project is to design a functioning robot for the Xtreme Bots competition.

Criteria

All preparations must be completed before the April 1st, 2023 competition date. There are many objectives to satisfy to ensure a quality robot for the competition, some required and some optional.

1. Radio Connections
    a. Strong signal connections to receiver
    b. Must control all robot functions
2. Weight
    a. Can be at most 15 lbs
3. Circuits
    a. Must include a visible LED indicator for live circuit
4. Batteries
    a. Can not use LiPo
    b. Must last the full duration of match
    c. Output enough current and voltage for enough power
5. Drive
    a. Must be mobile
    b. Can be driven on either side
    c. Quick directional movement
6. Armor
    a. Material strength capable of withstanding damage
    b. Consideration of thickness, material type, and shape
7. Maintenance
    a. Easily accessibility to all parts
    b. Swappable components
8. Weapons
    a. Capable of dealing damage to opponents
9. Cost
    a. Reuse parts as much as possible and keep costs for electronics and new parts under $150

Research

Materials

Aluminum has many advantages that make it an attractive material in various applications. It is the most abundant metal in the Earth's crust, a relatively soft, durable, lightweight, ductile, and malleable metal. It acts as a good thermal and electrical conductor and is also fairly corrosion-resistant. Other advantages that aluminum brings to the table include its recyclability, its ability to take surface treatments, and its durability.

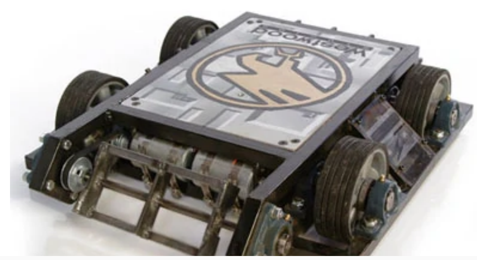
Steel is a popular metal used in manufacturing. It is an alloy of iron and carbon, and it is known for its strength, durability, and versatility. Steel is also relatively inexpensive compared to other metals such as aluminum. Some of the advantages of steel include its strength, durability, and versatility. Steel is also recyclable and can be used in a variety of applications, including construction, transportation, and manufacturing. However, steel also has some disadvantages. It is heavy and can be difficult to work with, and it is also prone to rust and corrosion.

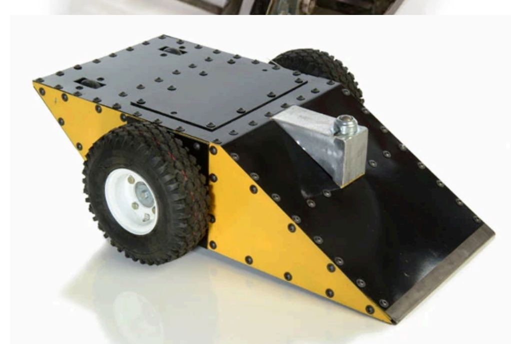
Titanium is a popular metal used in manufacturing. It is known for its strength, durability, and corrosion resistance. It is also lightweight and has a high strength-to-weight ratio. Some of the advantages of titanium include its strength, durability, and corrosion resistance. It is also biocompatible, making it ideal for use in medical implants. Titanium is also used in aerospace and military applications due to its high strength-to-weight ratio. However, titanium also has some disadvantages. It is expensive compared to other metals such as steel or aluminum, and it can be difficult to work with due to its high melting point.

Inconel is a family of nickel-chromium-based superalloys that are used in high-temperature applications. They are known for their strength, durability, and resistance to corrosion and oxidation. Some of the advantages of Inconel include its high-temperature strength and resistance to corrosion and oxidation. It is also used in aerospace and military applications due to its high strength-to-weight ratio. However, Inconel also has some disadvantages. It is expensive compared to other metals such as steel or aluminum, and it can be difficult to work with due to its high melting point.

Weapon Designs

There are many weapon designs. The most commonly used ones are drums, flippers, eggbeaters, and wedges. Drum-type robots use a heavy spinning mass in front of the robot. Due to its significant weight, there is a lot of potential in applying damage to opponents without receiving a lot of energy back. The front-heavy design does make it harder to control and depending on the design, does not have a large range of contact. Flippers use pneumatics, or other ways, to lift an arm of sorts with the intention of flipping the opponent. This is either extremely effective or a useless weapon depending on how the opponent's robot is configured. There is also the risk of the weapon arm coming off due to the constant stress at a single point. Spinners are the most common type of weapon in competitions. They can be horizontal or vertical and offer a good amount of offense and defense. However, sometimes they contain too much potential energy and when a collision does occur, the kinetic energy transfer can self-destruct the robot. Lastly, wedge robots are the simplest of weapon designs as they do not contain a spinning weapon. Using such a weapon requires a skilled driver and being able to effectively maneuver around the arena and take control of the opponents. The final decision for this season’s design is to use a beater-bar spinner weapon design. Drums, while they do have a strong appeal, would drastically increase the costs due to its complex manufacturing process. Wedges are too simple and do not give a big enough challenge for the project. With correct adjustments to the weapons mass and velocity, the amount of kinetic energy it can transfer in each collision, paired with good driving, it can be just as effective as any other weapon.



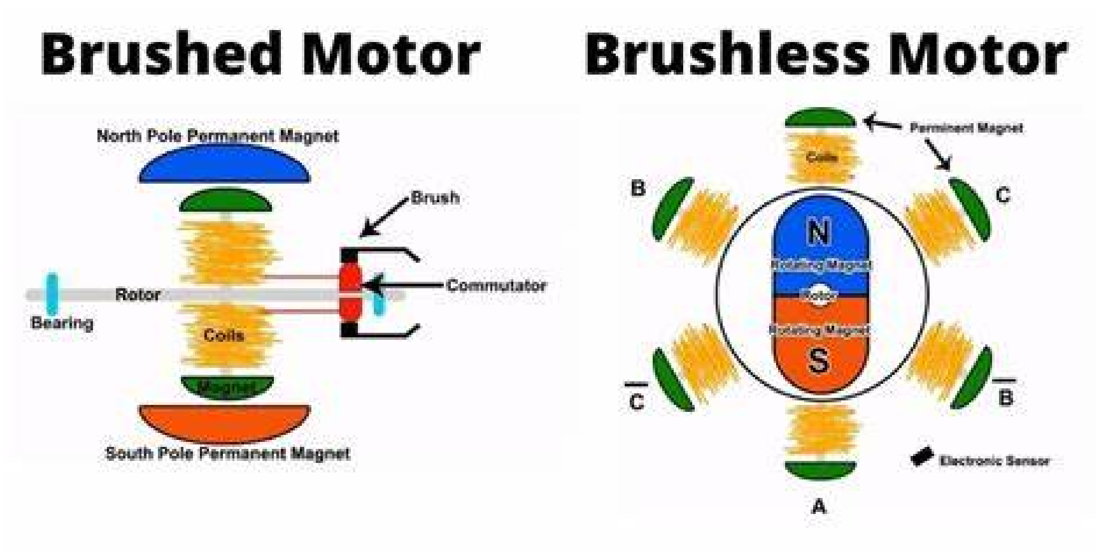


Motors

Brushed motors and brushless motors are two types of electric motors that operate differently and have different characteristics. Brushed motors have a rotor (the part that spins) with a core of metal wire (the armature) wrapped around it. The rotor also has a set of carbon brushes that make contact with a commutator (a segmented metal ring) to deliver electrical current to the armature. As the current flows through the armature, it creates a magnetic field that interacts with the magnetic field of the stationary magnets to produce torque and rotate the motor. Brushless motors, on the other hand, do not have brushes or a commutator. Instead, they have a stationary magnet in the center (the stator) and a rotor with permanent magnets on the outside. The electrical current is delivered to the stator through electronic switches that rapidly turn on and off (known as electronic commutation) to control the flow of current to the magnets and generate torque.

- Efficiency: Brushless motors are generally more efficient than brushed motors because they have less friction and heat loss due to the lack of brushes. This means that brushless motors can provide more power and longer battery life for the same size and weight.
- Durability: Brushless motors have a longer lifespan than brushed motors because they have fewer moving parts that can wear out or break. The carbon brushes in brushed motors are a common source of failure and require periodic replacement.
- Control: Brushless motors offer more precise control over speed and torque because the electronic commutation can be finely tuned. Brushed motors have a fixed commutation pattern that limits the range of speed and torque control.
- Cost: Brushed motors are generally less expensive than brushless motors because they are simpler in design and have fewer electronic components.

Overall, brushless motors are preferred for applications that require high efficiency, durability, and precise control, perfect for the use case scenario for a combat robot. For this season, the robot will be equipped with the PropDrive v2 motor for its drive system and the Power 25 motor for the weapon.



Batteries

Although there are many different types of batteries to use, due to limitations in cost and what is available to use as a high school team, the main focus will be on Lithium Phosphate batteries. Lithium phosphate batteries, also known as lithium iron phosphate (LiFePO4) batteries, are a type of rechargeable battery that uses lithium iron phosphate as the cathode material.

Advantages:

- High energy density: Lithium phosphate batteries have a high energy density, which means they can store a large amount of energy in a small space.
- Long lifespan: Lithium phosphate batteries have a longer lifespan than other types of lithium-ion batteries, which means they can last for thousands of charge and discharge cycles.
- Safety: Lithium phosphate batteries are considered to be one of the safest types of lithium-ion batteries because they are less likely to overheat or catch fire.
- Wide temperature range: Lithium phosphate batteries can operate in a wide temperature range, making them suitable for use in extreme environments.
- Environmentally friendly: Lithium phosphate batteries do not contain toxic heavy metals like cobalt, which makes them more environmentally friendly than other types of lithium-ion batteries.

Disadvantages:

- Low energy density: While lithium phosphate batteries have a higher energy density than other types of rechargeable batteries like lead-acid and nickel-metal hydride, they have a lower energy density than other types of lithium-ion batteries like lithium cobalt oxide.
- Lower voltage: Lithium phosphate batteries have a lower voltage than other types of lithium-ion batteries, which means they may not be suitable for high-power applications.
- Expensive: Lithium phosphate batteries are more expensive than other types of lithium-ion batteries, which can make them less cost-effective for some applications.
- Larger size and weight: Lithium phosphate batteries are generally larger and heavier than other types of lithium-ion batteries, which can be a disadvantage in some applications where size and weight are critical.

Overall, lithium phosphate batteries have several advantages, including high energy density, long lifespan, and safety, but they also have some disadvantages like lower energy density and higher cost. They are suitable for a wide range of applications, including electric vehicles, solar power systems, and backup power supplies.

Electronic Speed Controllers

Speed controllers are electronic devices that regulate the speed of electric motors by controlling the amount of electrical power supplied to them. They are commonly used in a variety of applications, including drones, electric vehicles, robotics, and industrial machinery. Here are the basics of how speed controllers work:

- Input: Speed controllers receive an input signal from a control device, such as a transmitter or a microcontroller. This signal typically takes the form of a pulse-width modulation (PWM) signal, which varies the width of a series of pulses to represent the desired motor speed.
- Power supply: The speed controller also receives a power supply from a battery or other power source. The voltage and current of the power supply depend on the requirements of the motor and the application.
- Transistors: Inside the speed controller, a set of transistors control the flow of current to the motor. These transistors act like switches, turning on and off rapidly to regulate the amount of power delivered to the motor. The switching frequency and duty cycle of the transistors are determined by the input signal.
- Control algorithm: The speed controller uses a control algorithm to convert the input signal into a set of commands that control the transistors. The control algorithm may include features like speed regulation, current limiting, and overheat protection to ensure safe and reliable operation of the motor.
- Feedback: Some speed controllers also include feedback mechanisms to provide information about the motor's speed and other parameters. This feedback can be used to adjust the control algorithm in real-time, improving the accuracy and stability of the motor speed control.

In summary, speed controllers regulate the speed of electric motors by controlling the amount of power delivered to them. They receive an input signal from a control device, use transistors to switch the power supply on and off, and use a control algorithm to adjust the switching frequency and duty cycle of the transistors. The result is a smooth and precise control of the motor's speed, which is essential for many applications.

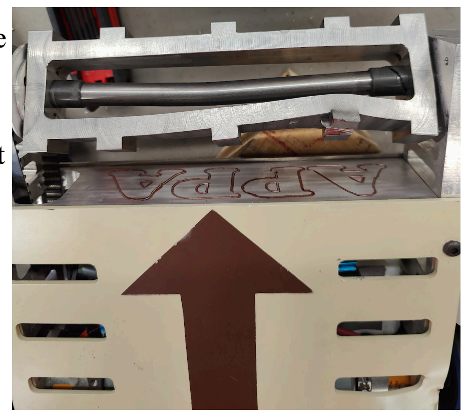
Due to the shift from brushed to brushless motors, new speed controllers were needed to be compatible with the drive motors. The only specification limitation of the motors for it to be bidirectional and support up to 50 amps. Most speed controllers for RC planes and boats will be compatible, so the ZMR 50A Bidirectional ESC was settled on. For the weapon speed controllers, the robot will be using identical speed controllers from the 2022 robot’s design.

Design

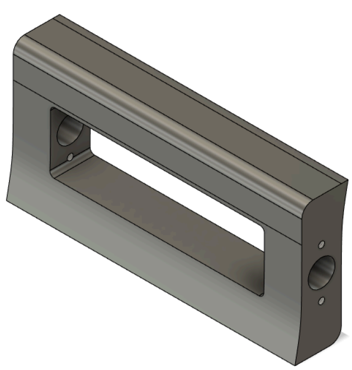
Motivation

The design for the 2022 season was extremely inviting to improve upon and I enjoyed the concept of it. So for 2023, ideas will be brought over and improved upon based on the flaws found during the season prior. Some ideas were also taken into consideration from Razors Edge from the University of Cincinnati team as both my freshmen and junior year's first match of the competition was against them. A lot of their weight went into their weapon and it appears to have worked for them, so that will be a big factor in designing this robot.

Weapon



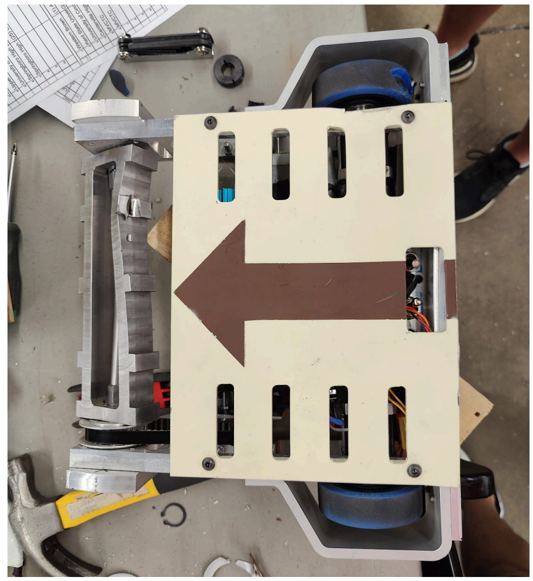
The previous season's weapon design contained a flurry of issues. Not only was there a lack of rpm, the mass and overall design of the weapon deemed it useless in the competition. During collisions between opponents, because the robot had a smaller mass and slower speed, most of the forces were transferred back to us and not the opponent. This led to a lot of damage to the robot and exposed many flaws. In fact, the weapon bent into the shaft and bent both the shaft and weapon, disallowing the rotation of the weapon. The addition of teeth with the idea of having more bite in each hit hurt the robot more than helped it as the decreased material led to a lower structural rigidity of the thinner parts of the weapon. After that point, the robot lost its damage capabilities and could not continue for the rest of the tournament.



With all the issues in mind, this season's weapon design features a beater bar design with no teeth the material of mild steel. The edges that will be in contact with opponents during a collision have a slight curve to add a bit more bite to each hit as the part that is transferring kinetic energy has less surface area. Adding the curve to the edges also allows for the chance of hooking onto an opponent and throwing them, which has the potential of creating a lot of damage. The weapon will be spinning around a dead shaft so that the motor will not have any unnecessary mass to be spinning. In addition, the shaft is locked into place with two collars This type of shaft design also adds to the frame of the robot as it is a steel rod connecting the two sides together. A 30 teeth timing belt pulley will be added via two screws to one side of the weapon which is then connected to a 24 teeth timing belt pulley inside the belt. Due to the high velocity of the motor, the weapon needed to be geared up so that there would be more torque on the weapon. Slowing down the weapon will allow for better control during the driving as there is less amount of force spinning in the front of the robot.

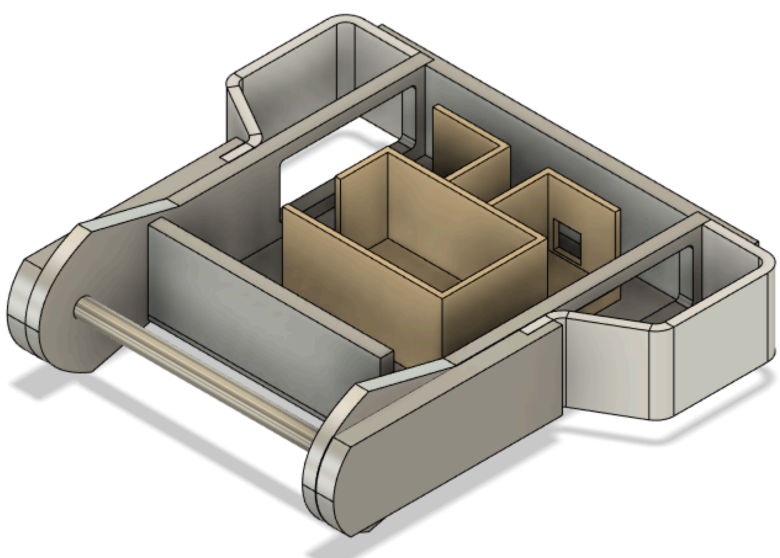
The position of the belt was also crucial. The previous season's design caused the belt to rub against the frame, so a simple fix was made so that the belt would be around the front plate rather than inside. This will make it harder to maintain but a good compromise to make.

Frame



The ½ inch walls from the previous season's design provided an extremely sturdy frame. Although the weapon suffered large amounts of damage, the frame had little to no damage to it. This is also due to the fact that the middle plate of the frame helped securely fix the two sides together. The supporting piece greatly decreased the amount of bending of the front half of the robot, where most damage will happen. However, a downside of using ½-inch thick pieces is that they will weigh a lot more. Due to so much weight being used up by the frame, less material could be added to the weapon.

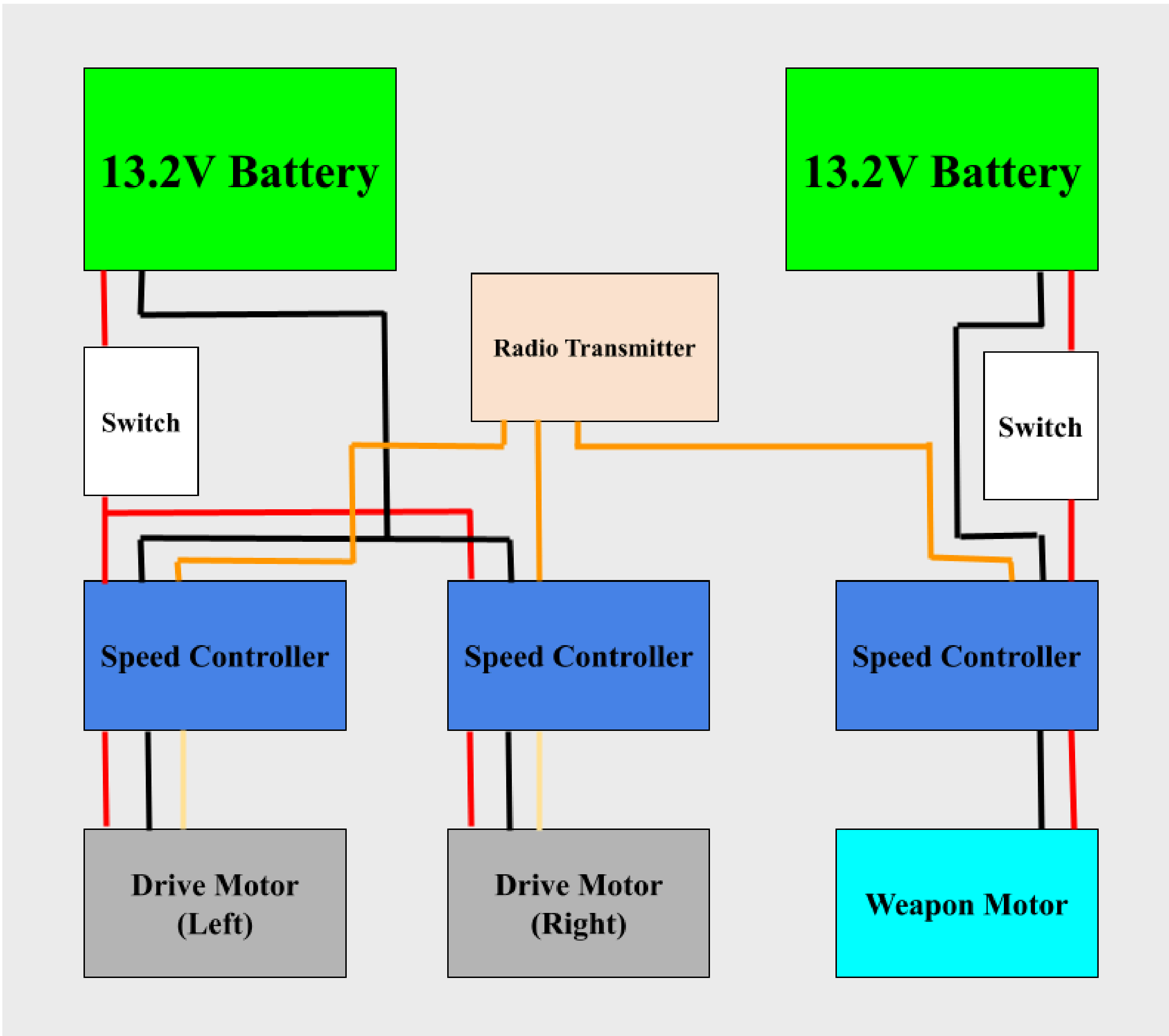
With these considerations in mind, the robot for this season will use a slightly thinner piece for its frame, ⅜ inch to be exact. The metal will still be using 6061 aluminum, as it provides a good strength-to-weight ratio while being of lower cost. However, the collar guards are the only pieces that are 1⁄2 inch in thickness. The thickness of these guards is needed as it needs to be thicker than that of the collars. Even though the collars are .341 inches thick, protecting with almost no extra material with a .375-inch piece will only add weight with no purpose. The collar guards will also be a good protector against damage to the main frame as it covers the centerpieces that are needed to lift the robot at a high enough height so that the weapon does not rub against the ground. Wheel guards used from the year prior proved very useful in protecting the wheels while also being in a very small form factor. No further revisions needed to be made to them.



The use of 3D printed parts provides a small amount of support while being extremely lightweight and without the restrictions for the manufacturing process of metals. However, for this robot, they are used solely as protection of vital electronics from the spinning shells of the outrunner motors. With the height raised almost up to the full 2.15 inches height of the frame and a 25 percent infill, it will help prevent some self-destructs due to electronics.

Electronics and Controls

Wiring Schematic



Power System

The robot will be powered using two 4-cell batteries, each powering a total of 13.2V to its respective system. These batteries have been used for prior seasons and have not brought up any issues so far. While some opponents power their robots with higher voltage systems, these batteries provide a good balance between battery life, weight, and current output.

Drive System

PropDrive v2 3530 Brushless Motor	Specifications
	Purpose: Drive kV Value: 1400 kV Power Supply: 13.2V 4 Cell Battery Gearbox: BaneBots 960K Gear Ratio: 26:1 Tip Speed: 6.1mph

Weapon System

Power 25 Brushless Outrunner Motor	Specifications
	Purpose: Weapon kV Value: 1250 kV Power Supply: 13.2V 4 Cell Battery Gear Ratio: 30:24 RPM: 13200 rpm Tip Speed: 126.4 mph

Calculations

Weapon

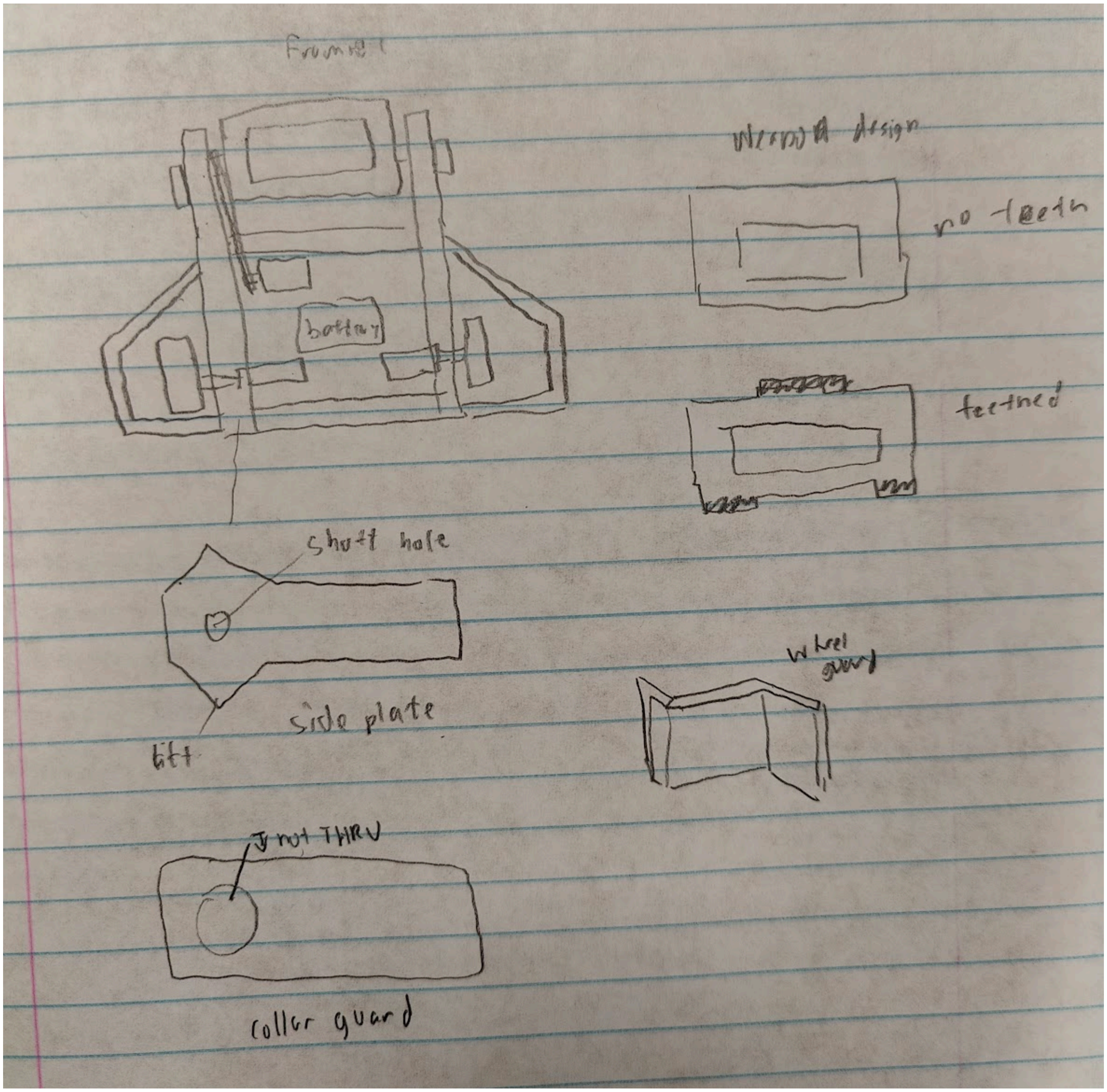
Voltage per cell = 3.3V
Motor kV = 870 rpm/V
4 cell battery → 3.3V * 4 = 13.2V = V_{Total}
rpm = kV * V_{Total} = 870 rpm/V * 13.2V = 11484 rpm
Gear ratio = G_{out} / G_{in} = 30/24
ω_{out} = rpm/Gear ratio = 11484 rpm/(30/24) = 9478 rpm

Drive

Voltage per cell = 3.3V
Motor kV = 1400 rpm/V
4 cell battery → 3.3V * 4 = 13.2V = V_{Total}
rpm = kV * V_{Total} = 1400 rpm/V * 13.2V = 18480 rpm
Gear ratio = G_{out} / G_{in} = 26/1
ω_{out} = rpm/Gear ratio = 18480 rpm/(26/1) = 711 rpm

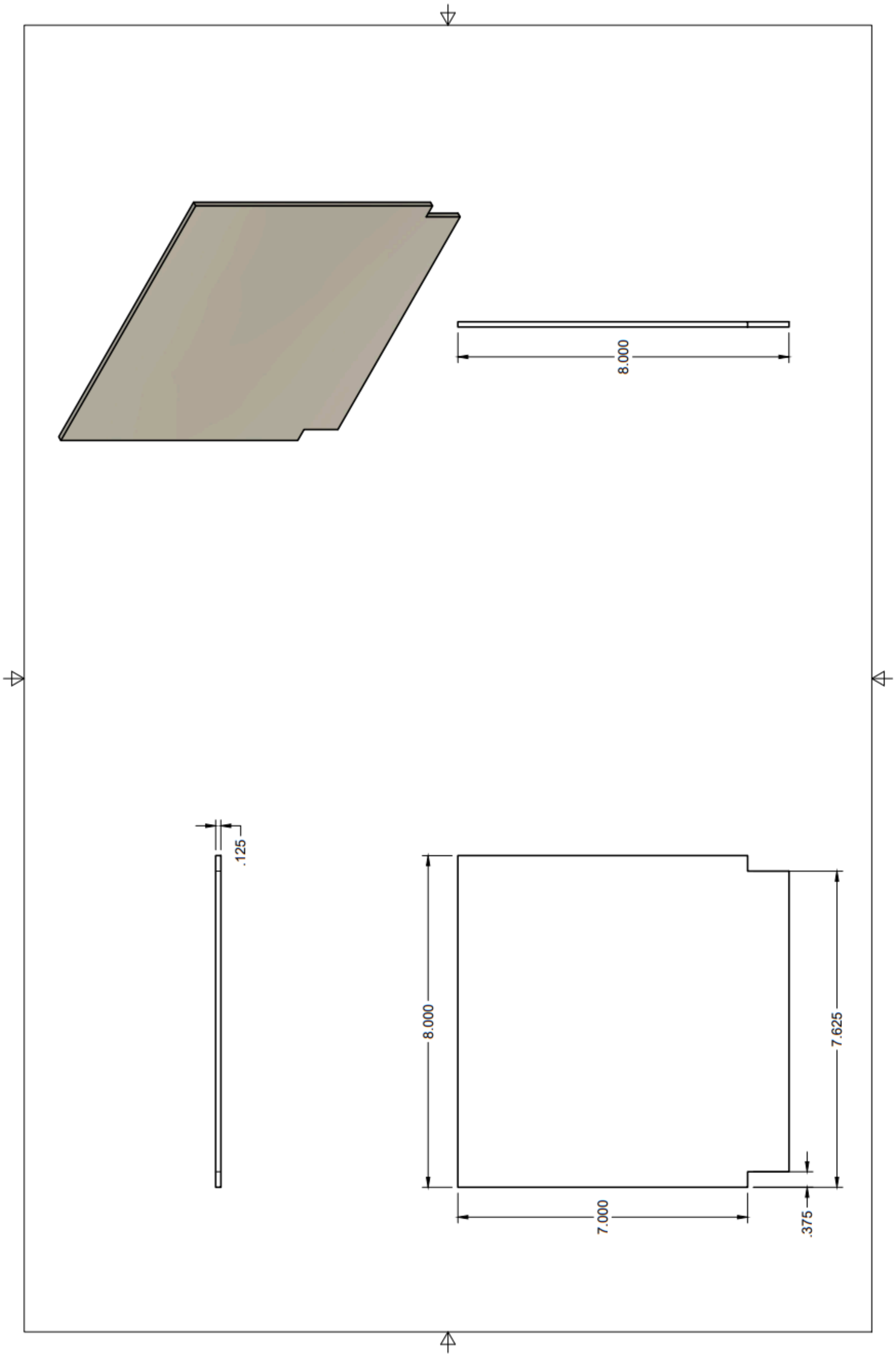
CAD

Conceptual Sketches

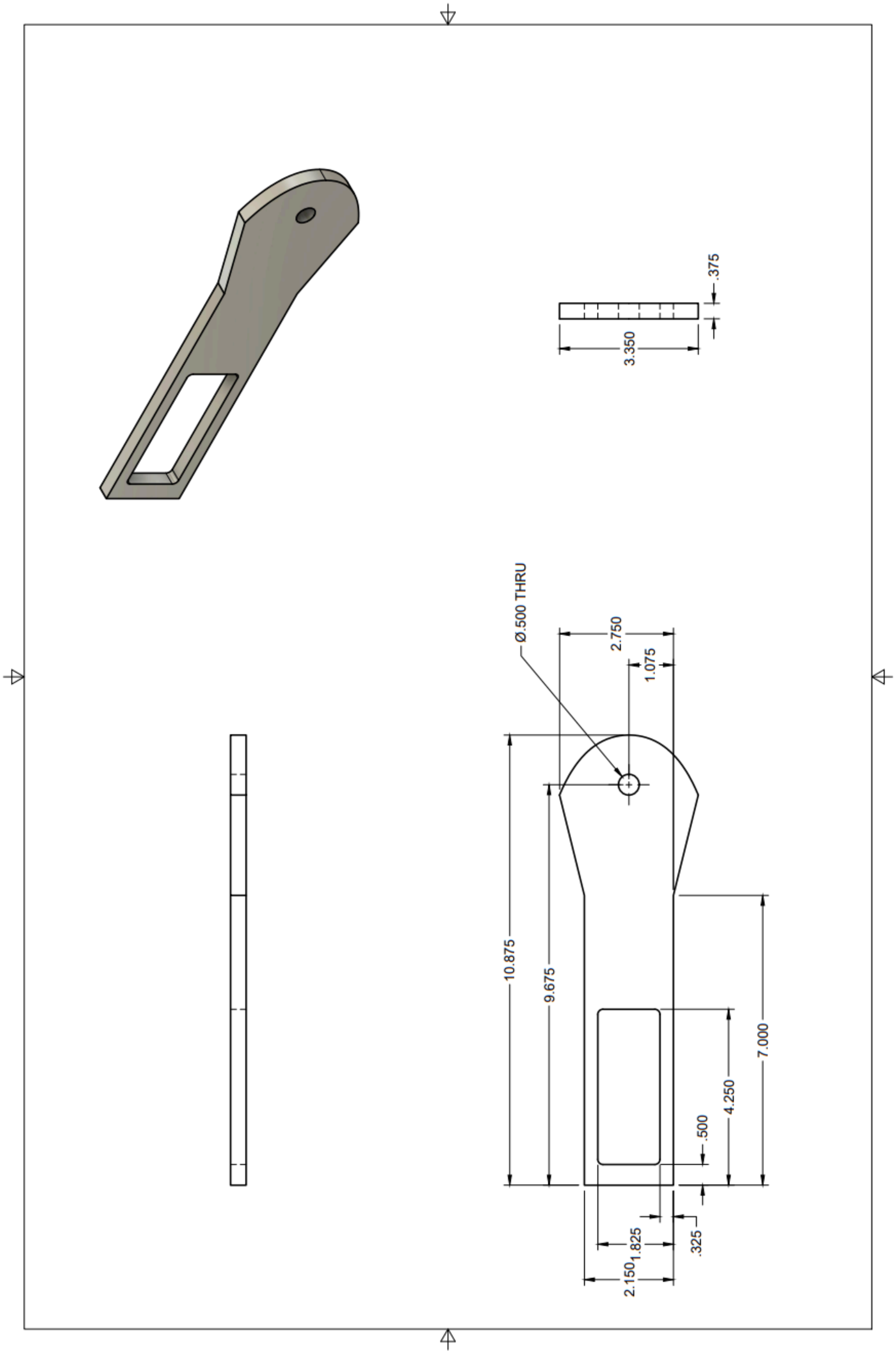


Drawings

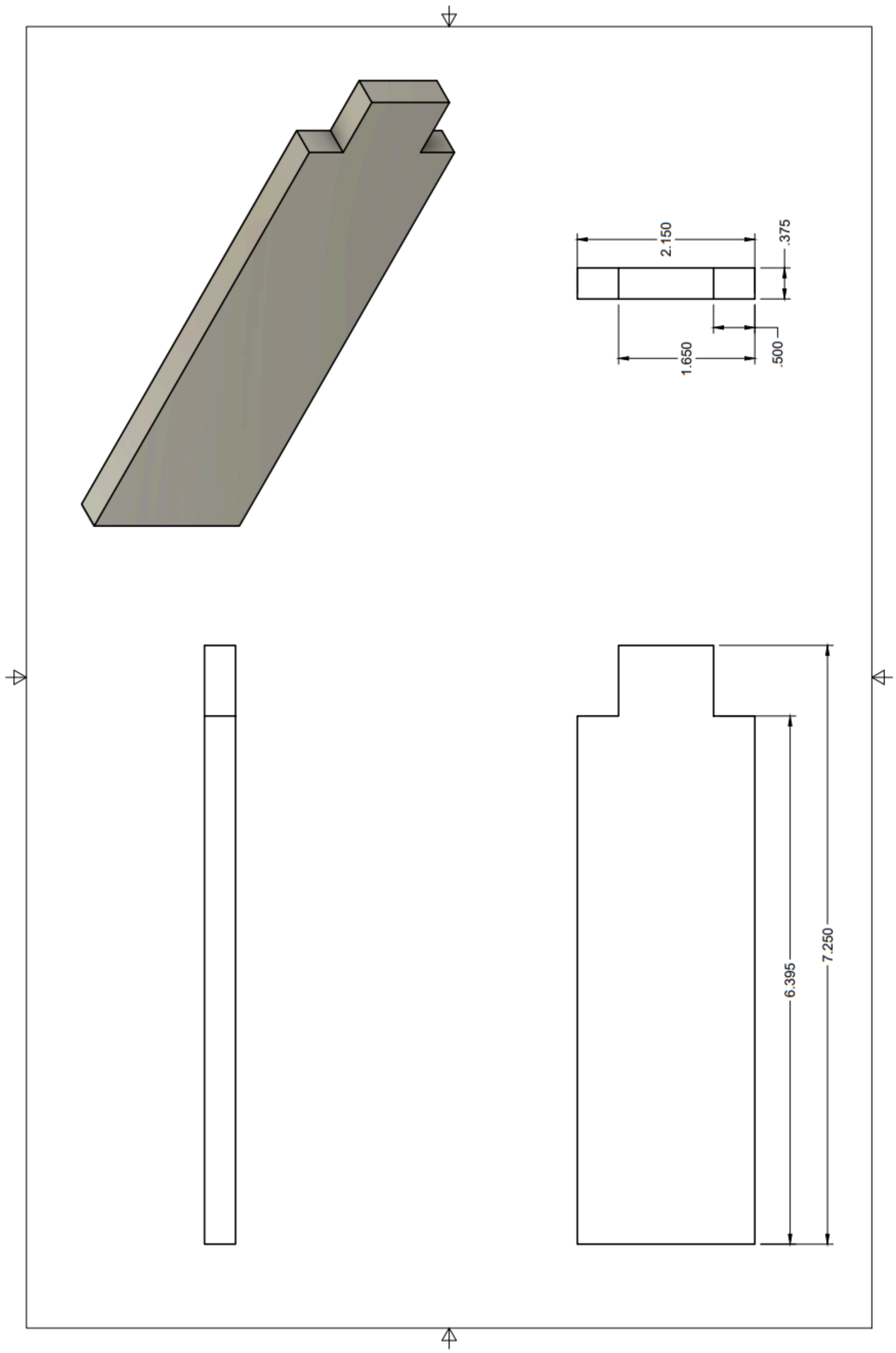
Top Plate



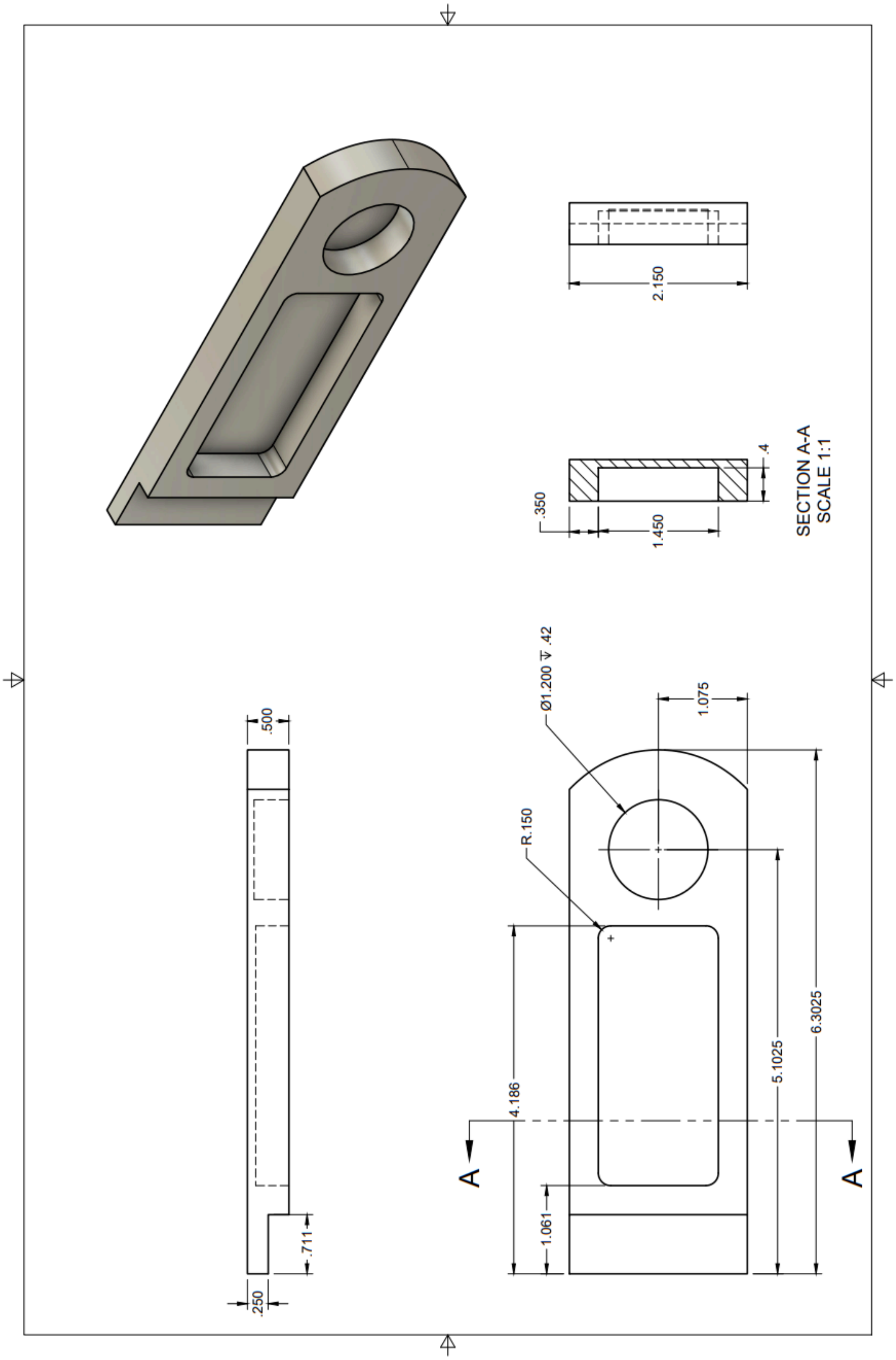
Side Plate


.375
3.350
Ø.500 THRU
2.750
1.075
10.875
9.675
7.000
4.250
.500
.325
1.825
2.150

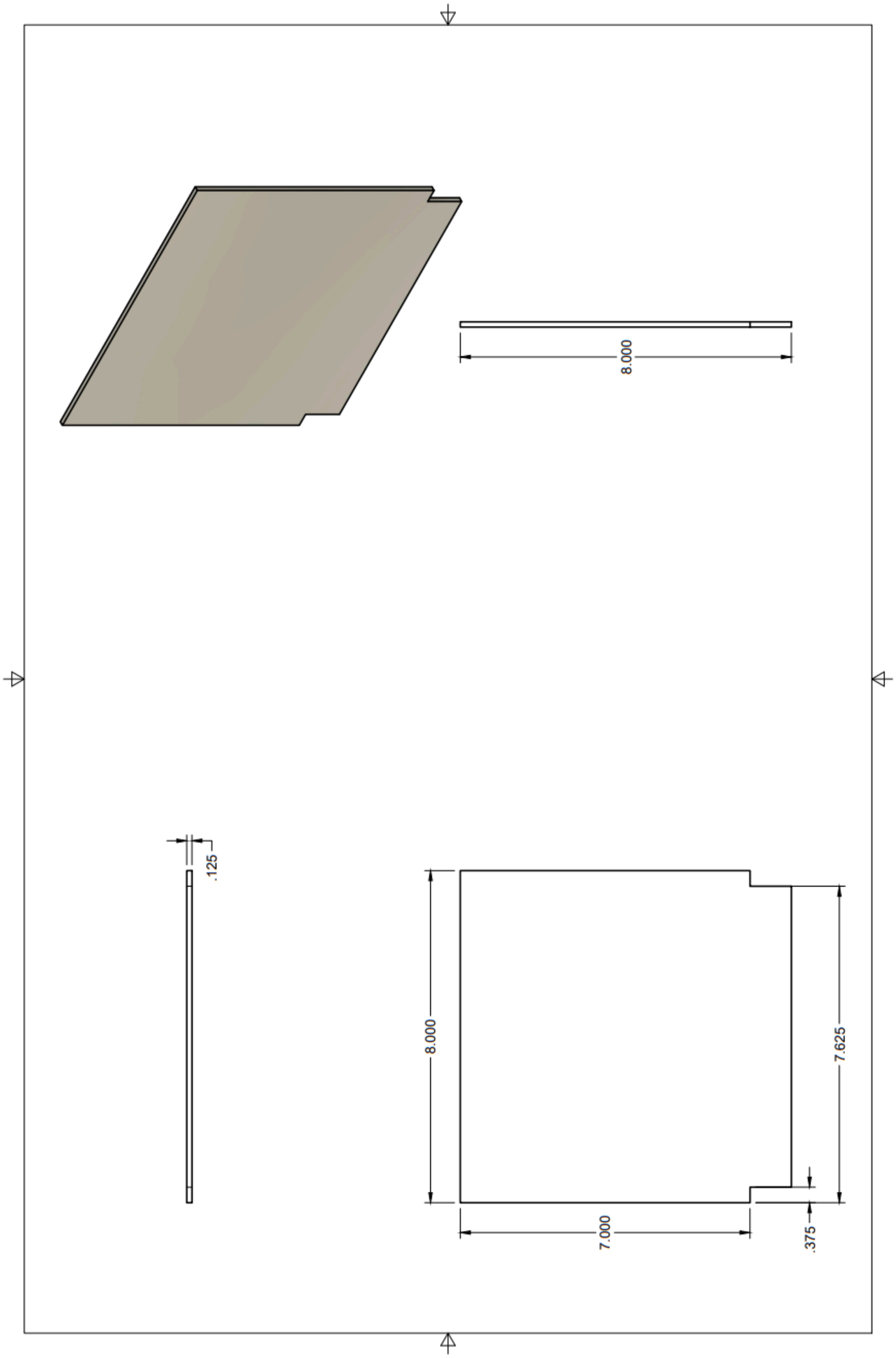
Front Plate



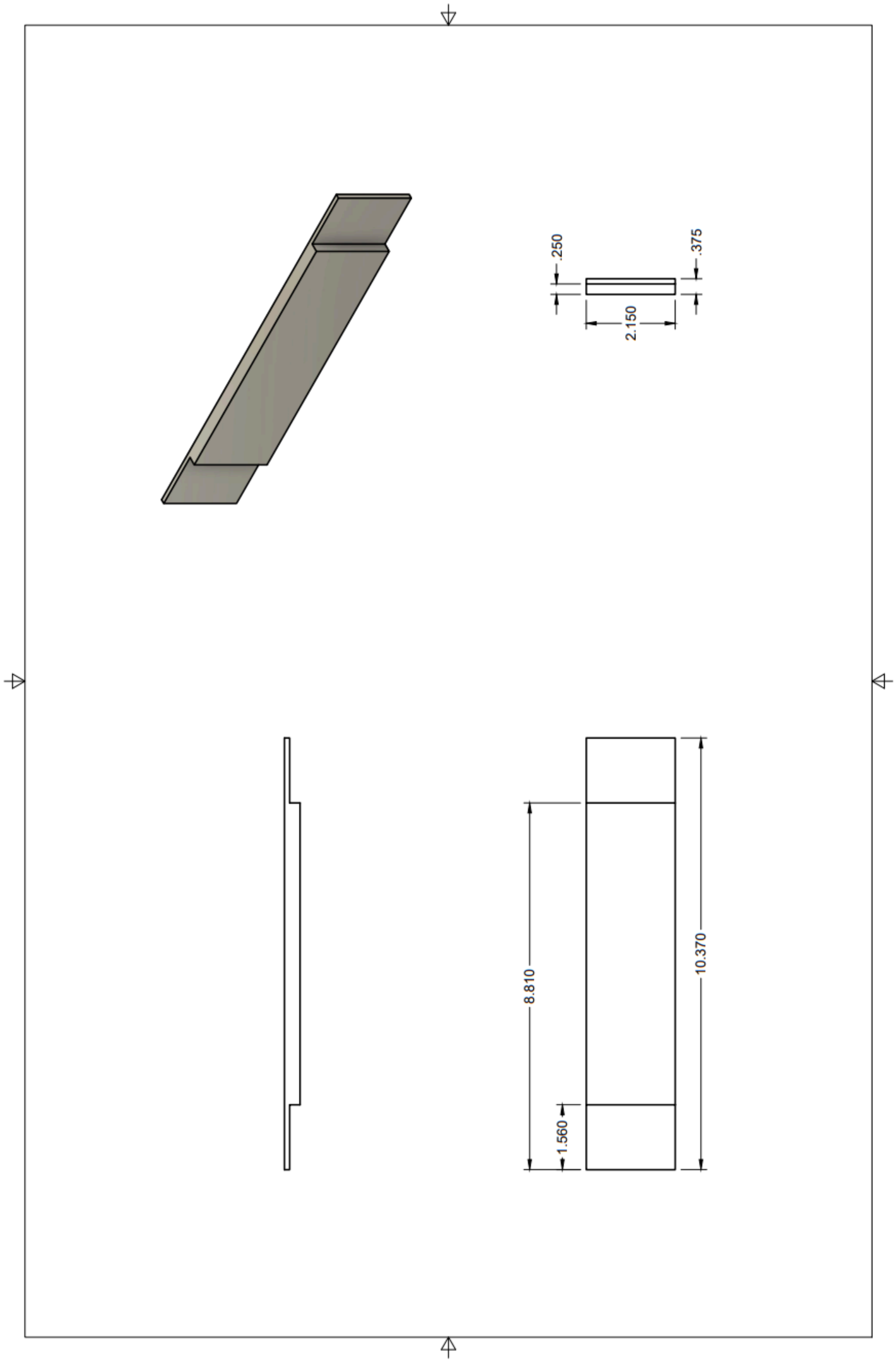
Collar Guard



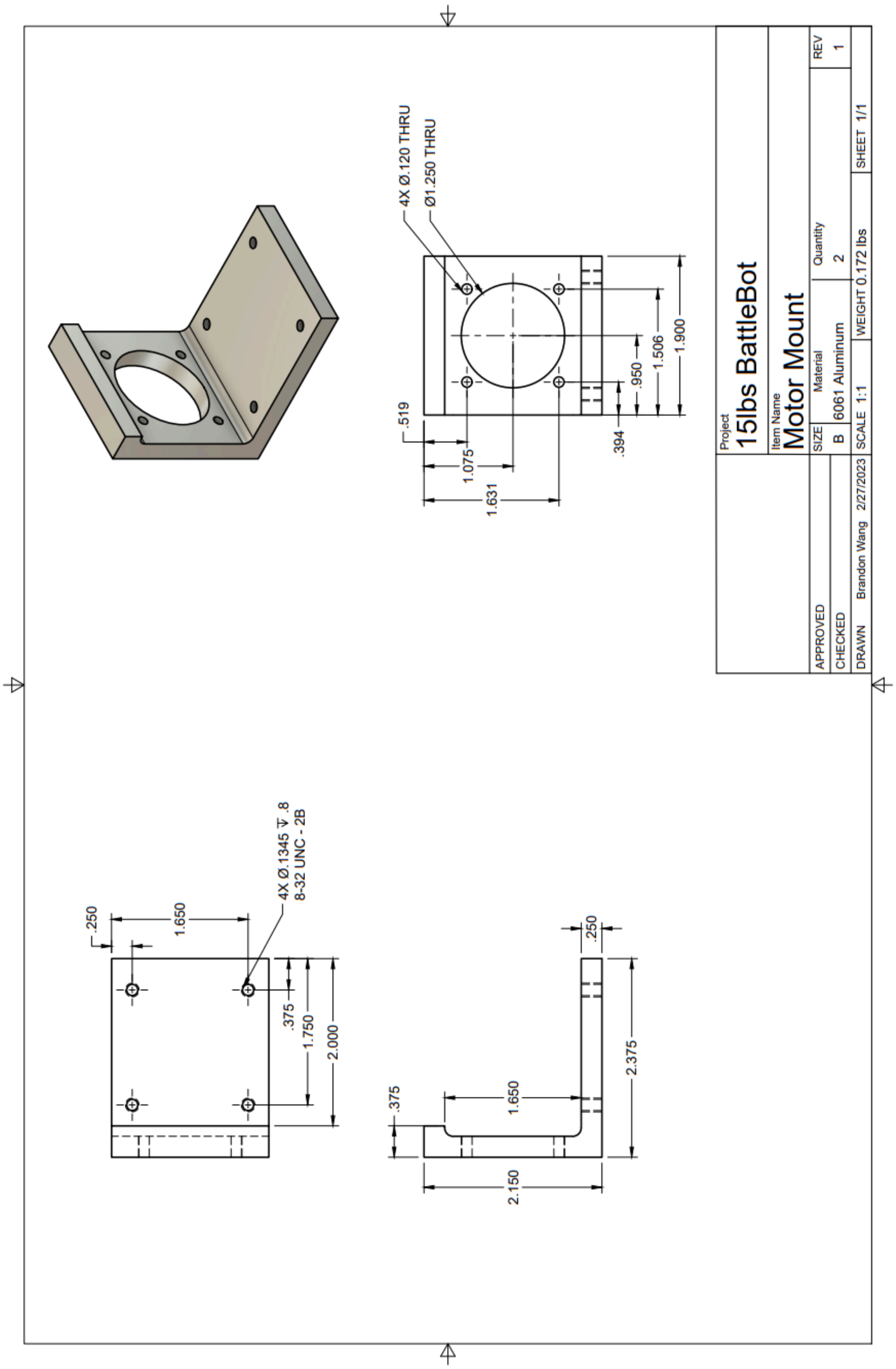
Bottom Plate



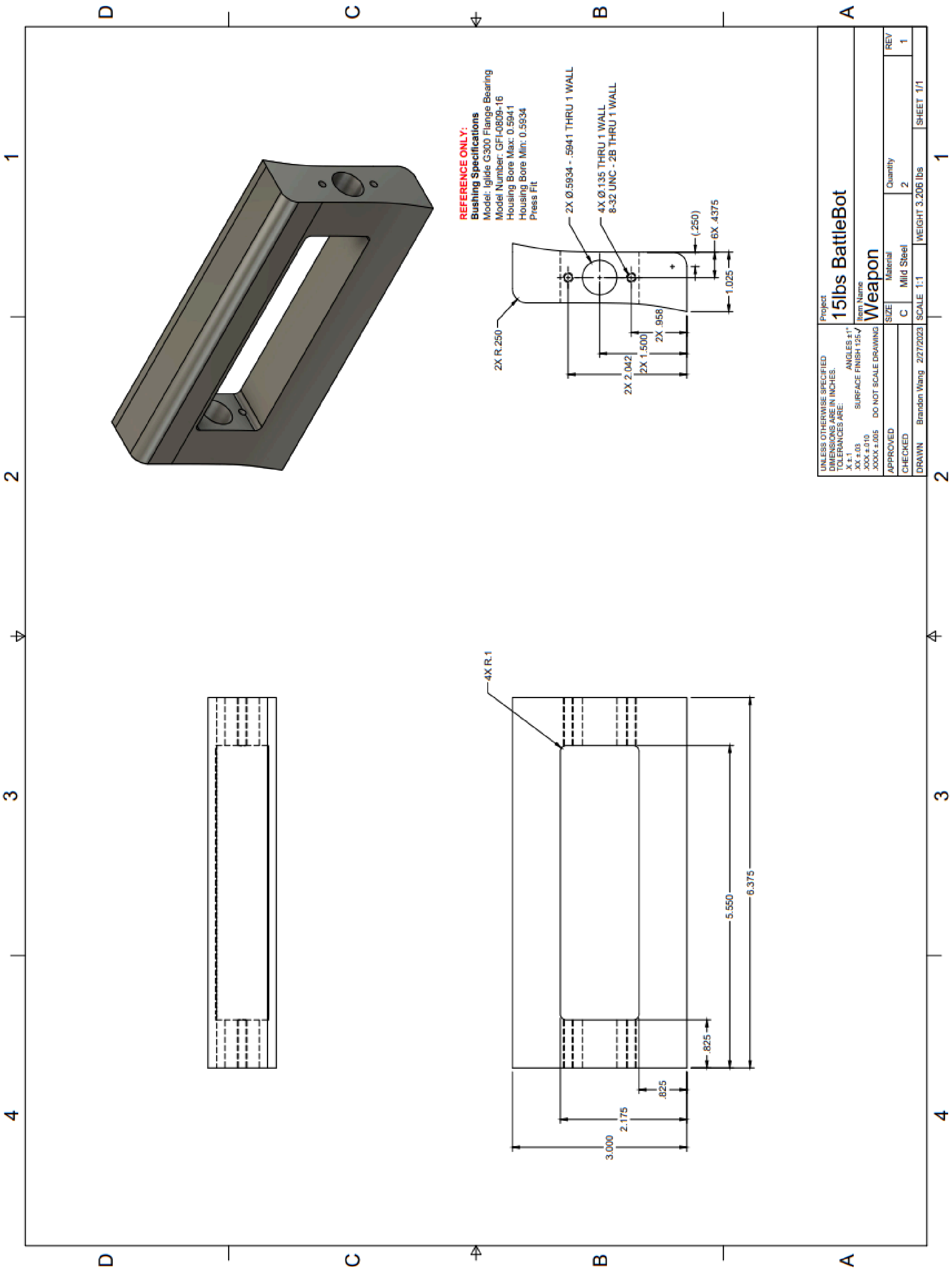
Back Plate



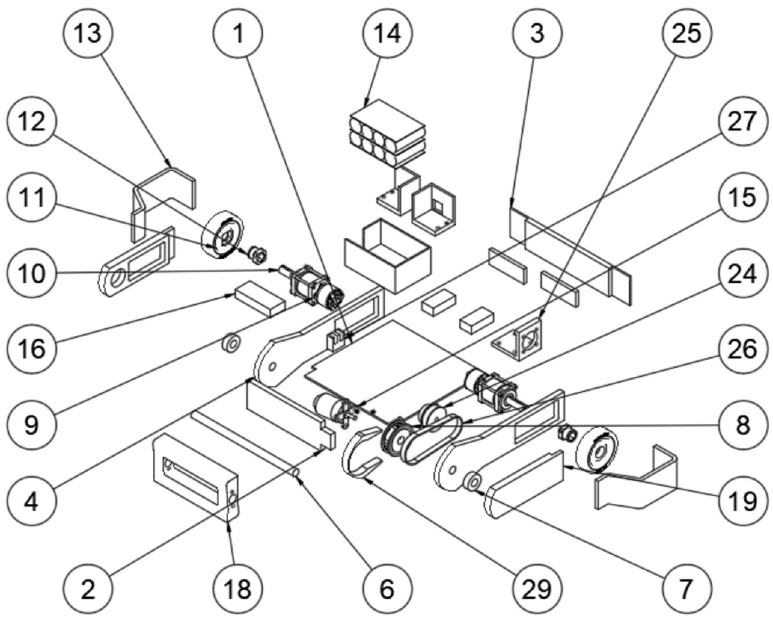
Collar Guard



Weapon

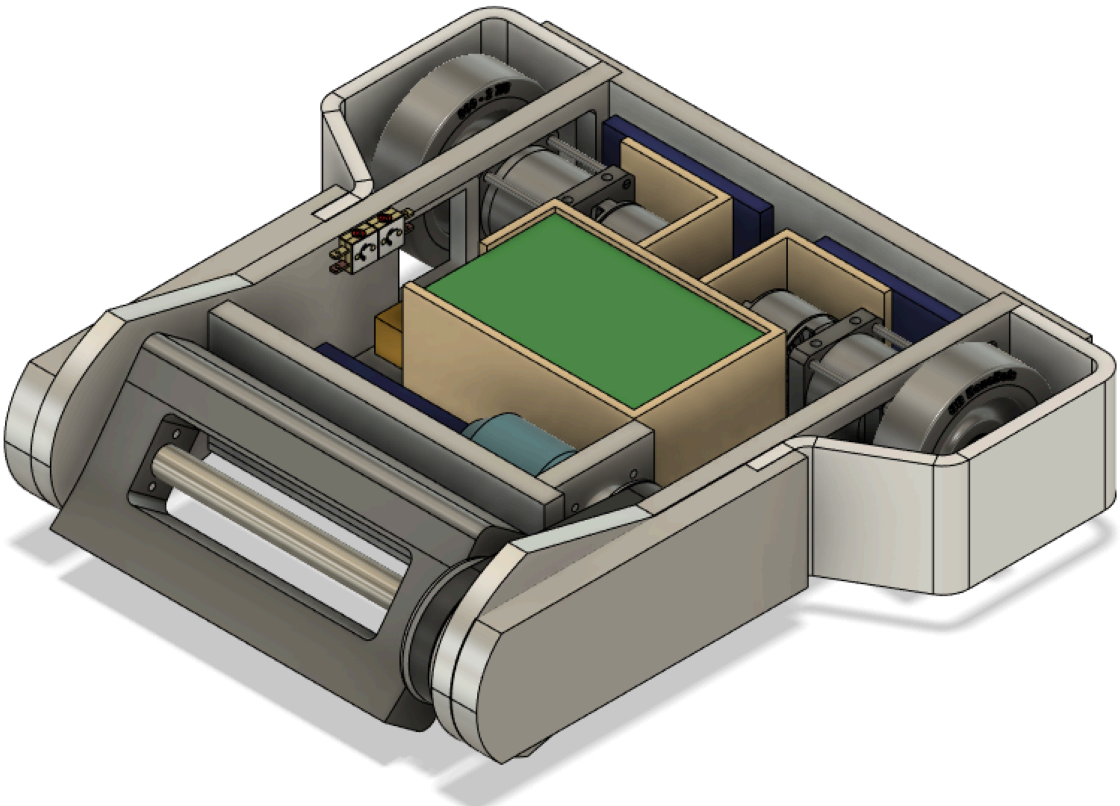

REFERENCE ONLY:
Bushing Specifications
Model: Iglide G300 Flange Bearing
Model Number: GFI-0809-16
Housing Bore Max: 0.5941
Housing Bore Min: 0.5934
Press Fit
2X Ø.5934 - .5941 THRU 1 WALL
4X Ø.135 THRU 1 WALL
8-32 UNC - 2B THRU 1 WALL
2X R.250
(.250)
6X .4375
1.025
2X .958
2X 1.500
2X 2.042
4X R.1
5.550
6.375
.825
.825
2.175
3.000
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ARE:
X ±.1
XX ±.03
XXX ±.010
XXXX ±.005
ANGLES ±1°
SURFACE FINISH 125
DO NOT SCALE DRAWING
APPROVED
CHECKED
DRAWN Brandon Wang 2/27/2023
Project
15lbs BattleBot
Item Name
Weapon
SIZE C
Material Mild Steel
Quantity 2
REV 1
SCALE 1:1
WEIGHT 3.206 lbs
SHEET 1/1

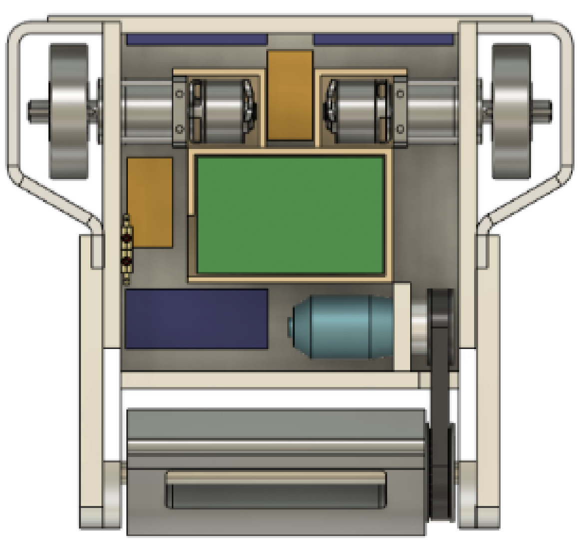
Exploded View

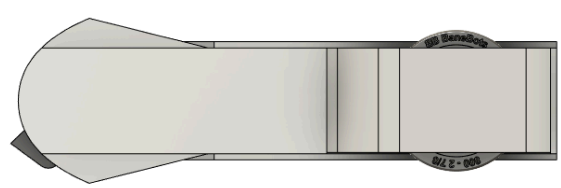


PARTS LIST				
ITEM	QTY	PART NUMBER	DESCRIPTION	MATERIAL
1	1	BOTTOM PLATE		ALUMINUM 6061
2	1	FRONT PLATE		ALUMINUM 6061
3	1	BACK PLATE		ALUMINUM 6061
4	2	SIDE PLATE		ALUMINUM 6061
5	1	TOP PLATE		ALUMINUM 6061
6	1	WEAPON SHAFT		INCONEL 718 PLUS
7	2	COLLAR		ALUMINUM 6061
8	1	PULLEY 30 TEETH		
9	2	DRIVE MOTOR		STEEL
10	2	GEARBOX		STEEL
11	2	2 7/8 WHEEL		STEEL
12	2	T81 WHEEL HUB		STEEL
13	2	WHEEL GUARD		ALUMINUM 6061
14	2	BATTERY		STEEL
15	1	WEAPON MOTOR		GENERIC
16	1	WEAPON ESC		ALUMINUM 6061
17	2	BRUSHLESS DRIVE ESC		ALUMINUM 6061
18	1	WEAPON		STEEL
19	2	COLLAR GUARD		ALUMINUM 6061
20	1	BATTERY CASE		ABS PLASTIC
21	2	RECIEVER		ABS PLASTIC
22	1	DRIVE MOTOR GUARD (LEFT)		ABS PLASTIC
23	1	DRIVE MOTOR GUARD (RIGHT)		ABS PLASTIC
24	1	PULLEY 24 TEETH CLAMPING		ALUMINUM 6061
25	1	MOTOR MOUNT		ALUMINUM 6061
26	1	BELT		NYLON 12 (WITH FORMLABS FUSE 1 3D PRINTER)
27	1	SWITCH HOLDER		ALUMINUM 6061
28	2	SWITCH		
29	1	BELT GUARD		ALUMINUM 6061

3D Model





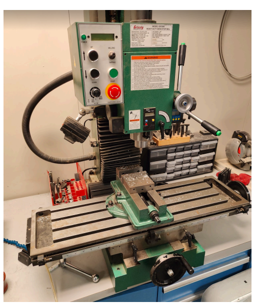


Fabrication

Manufacturing

The weapon and the weapon mount are the only two parts that will require a manufacturing company to do for us. With the help of Mr. Leeper connecting with General Tool, a meeting was able to take place in late February where the robot's design, weapon, and mount specifically, was pitched to Justin Koeth, a manufacturing engineer at the company. From there, they agreed to help manufacture the products through whichever process they deemed fit at their location. Everything else was able to be done at the school's workshop.

The CNC mill was responsible for cutting out all of the robot's aluminum pieces. After cutting the first couple of pieces out, there came the issue where the router began sparking. Troubleshooting revealed that the brushes were worn down inside the router, however, after replacing them, they still continued to spark. There were not any more apparent problems and it was decided to purchase a new router as the issues from the old one were most likely due to years of use with poor maintenance. Parts cut out from the router include the top plate, bottom plate, front plate, back plate, side plates, and collar guards.



The mill was also used to clean up certain areas where tolerances were tighter. For example, certain pieces needed to contain a close-to-perfect 90-degree cut for the pieces to line up with each other. By milling out certain areas manually, there was no worry about the filets that a CNC mill will typically create. Parts that used the mill include the pulley, back plate, and collar guards.

The band saw was used to cut pieces of metal that did not need any precise milling. For example, the shaft was simply cut from a large rod. The saw was also used on the metal pieces after cutting them out because the tabs holding the part onto the stock piece needed to be removed. A major component that needed to use the band saw was the motor mount as the imperfect hole alignments of the motors caused it to not fit in its intended position. The saw was used to trim down one of the edges by roughly .1 of an inch to account for the misalignment.

A belt sander was also needed post-manufacturing to help smooth out rough edges and created small filets on the edges of each part to make them safer to handle and assemble. It was also beneficial when shortening screws to the correct length as it provided a quick and convenient process to do so. All parts had some form of manufacturing done on the belt sander.

An arbor press was used to press fit the bushings into the weapon.

Tools

The following tools were used during the manufacturing process:

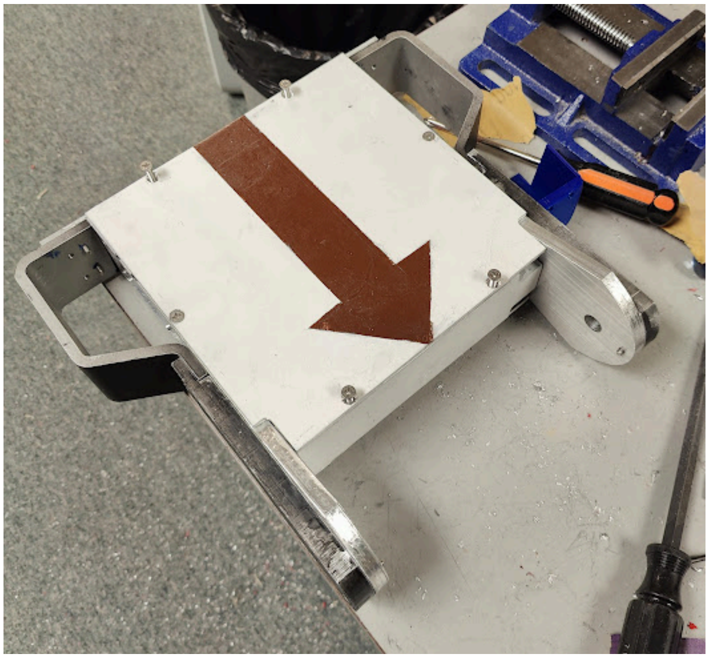
- Hammer
- Manual punch
- Spring loaded punch
- Mill
- CNC Mill
- Manual tap
- Band saw
- Drill press
- Vise
- File/sandpaper
- Belt sander
- Power drill

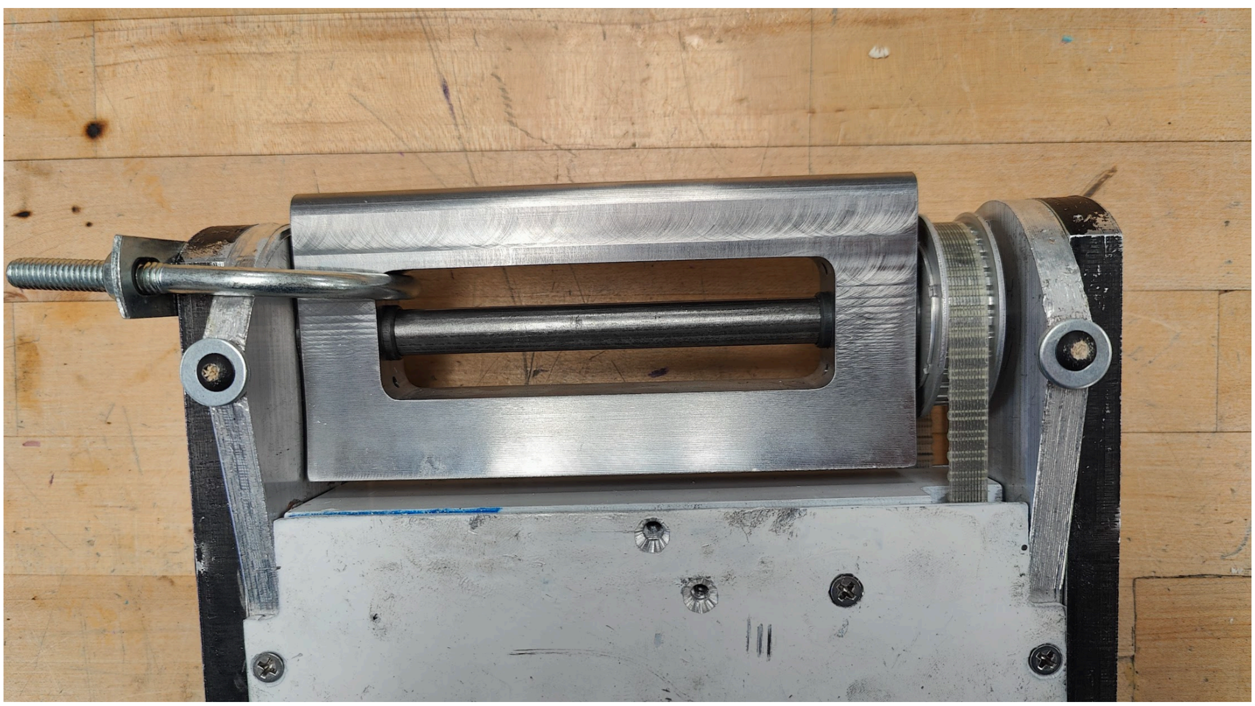
The following tools were used during the assembly process:

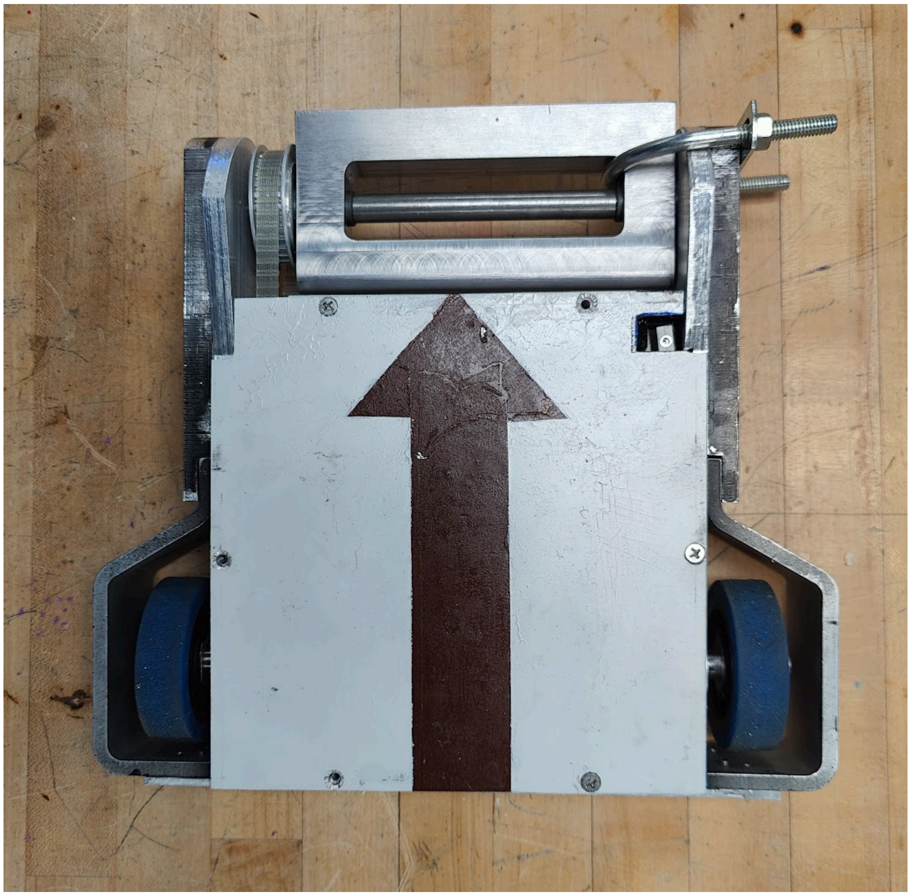
- Callipers
- Clamps
- Flathead screwdriver
- Snap ring pliers
- Allen wrench
- Phillips screwdriver

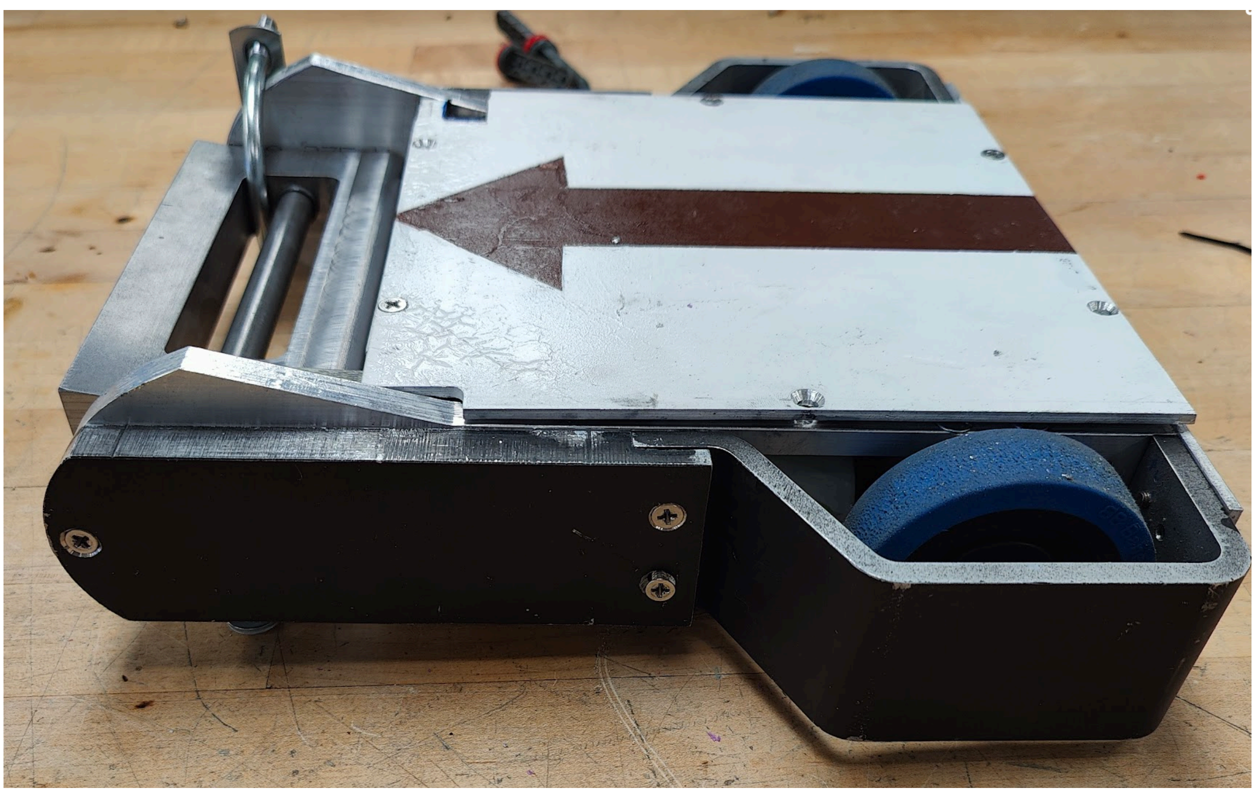
Assembly

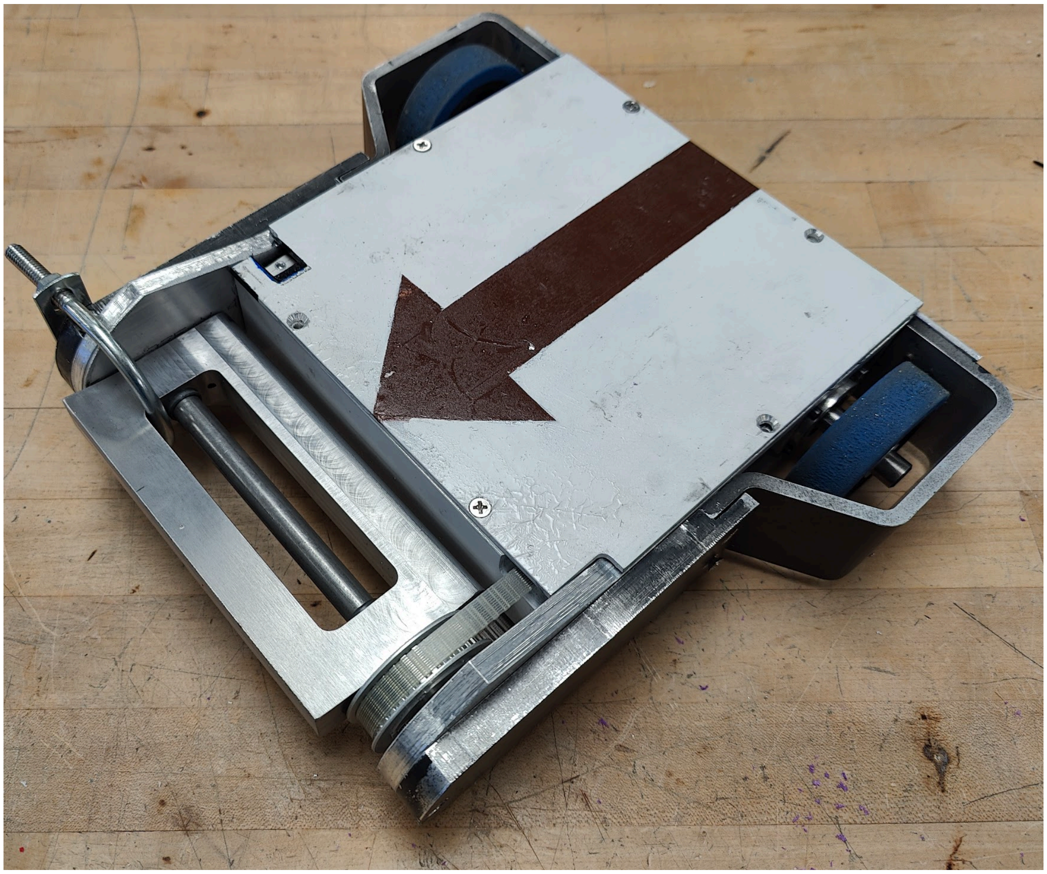
There were no major issues during the assembly process that needed a part to be remade. Since the CAD models did not contain holes for where each screw will be placed, each hole needed to be individually measured, drilled, tapped, and countersinked (when needed). That process can be tedious and prone to mistakes, which occurred in some areas of the robot. However, this does allow for an open plan on where exactly to place screws when needed. The most difficult part of the process was aligning the holes for the drive motors as there were no edge or wall guidelines to base off of. Such an issue was solved by attaching the drive motor to the side plate first and then marking perpendicular lines with a caliper to determine the drill point. After the frame was completed, the parts for the weapon were added. No issues occurred when aligning the weapon with the shaft into the frame. Some areas for improvement for future designers is to have the CNC mill drill out holes to help guide where each screw should be to prevent the time-consuming process of measuring and drilling. This method will also quicken the process of making replacement parts.

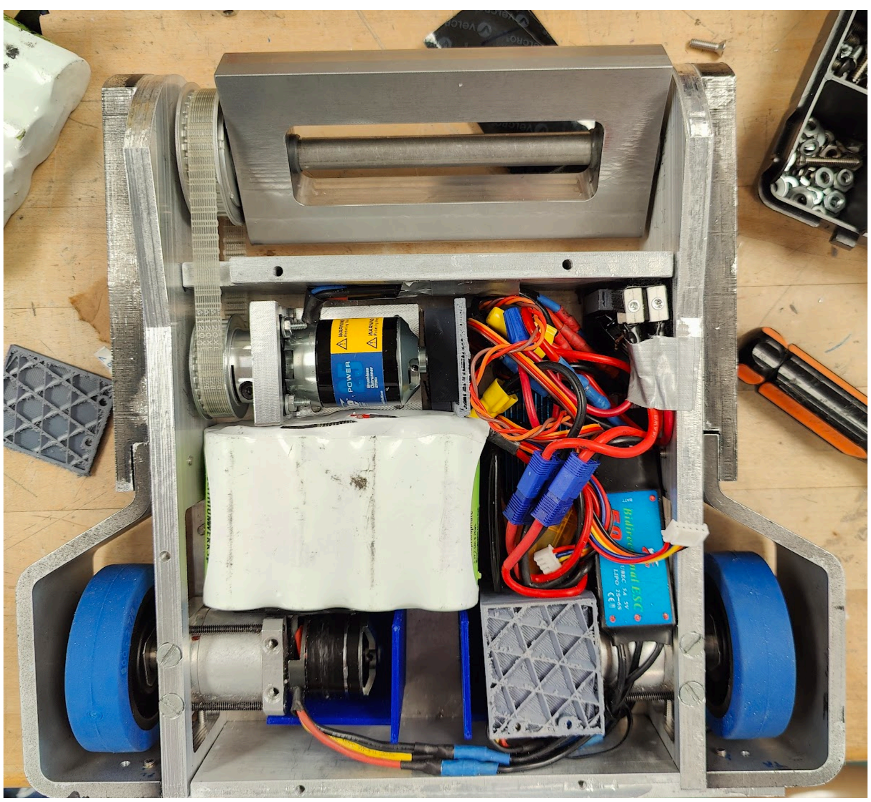












Testing and Refinement

After fully assembling the robot and going through a few test runs, some issues came up.

- Weapon: When attaching the pulley to the weapon with two screws, tightening them all the way in would lock up the movement of the weapon on the shaft. With a brief look at the angling of the pulley, one of the countersink holes was slightly deeper than the other. This caused one end to be lower, and thus lower than the other side. Although the shaft could easily move through both the holes of the weapon and pulley, the slight offset caused the pulley to make contact with the shaft and restrict any rotational movement. To combat this problem, the first idea was to put washers on the screw holes of the weapon to even the spacing between the pulley, bushing, and weapon. However, due to the screw holes being so close to the weapon, it was extremely difficult to fit any form of the washer where it would not interfere with the bushing. So the solution was created that the easiest way to fix this issue was to increase the pulley hole diameter from ½ inch to ⅝ inch. On the drill press, the large bit when drilling consistently vibrated almost uncontrollably while drilling slowly. Although it could be finished with patience, the job was finished at the mill instead. This would mean that the hole will not be a perfect circle, but that would not be a huge issue because the only purpose of that part is to transfer the motor's rotation into the weapon through a timing belt.
- Switches: Another minor issue encountered during testing involved the robot randomly switching off at random times. Checking for continuity in the circuits was inconclusive. After checking each of the electronic parts individually, it was determined that the Fingertech switches were faulty. Because the screw was stripped, it could not be screwed in all the way, creating a poor connection between the two terminals that would eventually loosen itself. Two options were available, either replace the switch entirely or replace just the screw. To keep the robot in completely new condition, new switches were used, but replacement screws and switches will be brought to the competition as a safety measure.
- Drive: The arrangement of the electronics and weight distribution overall was as centered as possible. However, due to the weight of the weapon, the robot was very front-heavy, causing some resistance when trying to drive. As seen in many other examples from other teams and online forums, drum spinners and other designs where a lot of weight goes into the weapon cause a gyroscopic effect when driving. This causes the robot to occasionally spin around and lose control of the drive. There is not a lot that can be done to alleviate this issue aside from slowing down the weapon when this does occur. By doing so, it leaves the robot vulnerable for a brief period of time but with further practice with driving, difficulties with drive can be dealt with to some extent.
- Drive Part 2: The robot was not able to drive completely straight. This could have been caused by many different reasons such as the angling of the robot, traction from the wheel, power output of the motor, etc. Luckily, the controller allows us to mix the channels of the transmitter and can set limits to how high the potentiometers of the

joystick can go. This allows us to “power down” the motor that was more dominant in an attempt to drive more straight. After further testing after this fix, it seemed to alleviate the issue.

- Motors: The configuration of the brushless outrunner motors powering the weapon after the first test run exposed a slight flaw. The slight movement of the motor shaft caused the shell to move backward, causing friction between the pulley and the motor mount. After analyzing the situation, the issue was due to the shaft collar being on the wrong side of the motor. This was a simple fix as it only required the collar to be taken out and attached to the other end after using an arbor press to push the shaft about ¼ inch to the other side.
- Side Plate: After test driving for a short period of time, the weapon began scraping the surface of the ground. The angled part of the side plate lifts the front body and gets sanded down to a flat edge due to friction. This is a huge design flaw and the only way to counteract this is to screw in a round-head stainless screw with some washers into the flat edge. In theory, however, this solution makes the bot better as it reinforces one of the critical points of the robot.

Other issues, especially the unpredictable ones during a match, will appear during the competition. As of now before the competition date, everything is in working condition and working as intended.

Weight Chart

Item	Quantity	Item Weight (lbs)	Net Weight (lbs)
Weapon	1	3.241	3.241
Weapon Shaft	1	0.535	0.535
Pulley 30 Teeth	1	0.165	0.165
Pulley 24 Teeth	1	0.144	0.144
Belt	1	-	-
Weapon Motor	1	0.413	0.413
Weapon ESC	1	0.144	0.144
Weapon Collar	2	0.035	0.07
Drive ESC	2	0.088	0.175
Drive Motor	2	0.275	0.550
Drive Gearbox	2	0.488	0.975
Wheel	2	0.131	0.263
Wheel Guard	2	0.410	0.820
Top Plate	1	0.771	0.771
Bottom Plate	1	0.771	0.771
Side Plate	2	0.709	1.418
Back Plate	1	0.652	0.652
Front Plate	1	0.539	0.539
Vertical Support	0	0.154	0.000
Horizontal Support	0	0.260	0.000
Motor Mount	1	0.172	0.172
Collar Guards	2	0.386	0.772
Battery	2	0.900	1.800
Receiver	2	0.030	0.060
Wiring	1	0.500	0.500

Total weight: 14.948lbs

Bill of Materials

Purchased Items

Part	Part Number	Quantity	Manufacturer	Price
30T Pulley	U-ATP30XL037-A-P0.5	1	Misumi	$27.85
24T Pulley	n/a	2	Ebay	$17.18
Timing Belt	TUN120XL037	2	Misumi	$17.64
8-32 Stainless Steel Flat Head Screws	403206802707	1	Everbilt	$10.00
50A Bidirectional Brushless ESC 2-6S UBEC 5A 5V Electric Speed Controller	B08C9XHMBX	4	Ready To Sky	$45.98
E-flite 60-Amp Pro SB Brushless ESC (V2)	EFLA1060B	1	E Flite	$0
Power 25 Brushless Outrunner Motor 870kv	EFLM4025A	1	E Flite	$0
13.2V 4S Lithium Nanophosphate Battery	ANR26650M1B	2	A123 Systems	$0
PropDrive v2 3530 Brushless Motor	9192000334-0	2	PropDrive	$0

Manufactured Items

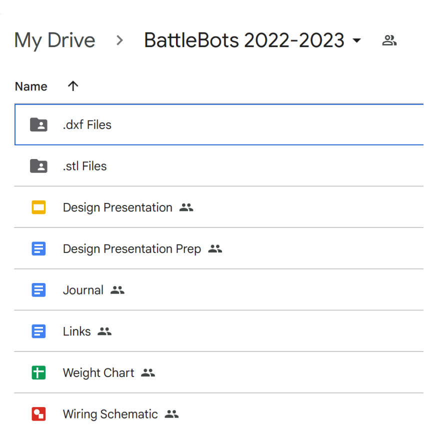
Part	Part Number	Quantity	Manufacturer	Price
Weapon	n/a	2	General Tools Company	Donated
Collar Guards	n/a	2	General Tools Company	Donated
6061 Aluminum	n/a	n/a	General Tools Company	Donated
Mild Steel	n/a	n/a	General Tools Company	Donated
Top Plate	n/a	1	Milford High School	$0
Bottom Plate	n/a	1	Milford High School	$0
Side Plate	n/a	2	Milford High School	$0
Front Plate	n/a	1	Milford High School	$0
Mild Steel Shaft	n/a	2	Milford High School	$0

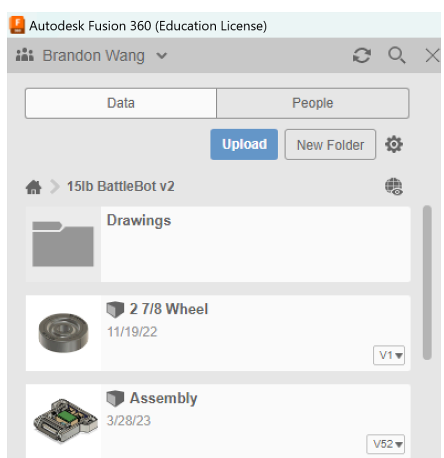
Total cost of materials: $118.65

Organization and Management

Time Management: The 2023 season began in the middle of September. Meetings are held every Tuesday from 2:30 PM to 4:00 PM. Sketches were drawn to give a direction to what is exactly being designed and what should be researched. When October came around, I began researching electronics and began organizing which items needed to be purchased. This was also the time when my sports season started, causing me to not be able to attend the usual meetings. However, most of the things could be done at home as once all specifications were listed, it was rather easy to find online. The design for the 2023 season was finalized at the end of December, but due to delays in receiving metal and getting in contact with General Tools Company, the manufacturing process did not begin until the start of March. From there, I stayed after school every day to manufacture every part. The weapon and collar guard did not arrive until the week of 3/27, which aligned perfectly with when the frame was fully assembled. The robot was fully completed 2 days before the competition, allowing for a few days to practice driving and strategy.

Data Management: Keeping organized and knowing where everything is is extremely important to have things running smoothly. Any documents (ie. journals, spreadsheets, etc.) were kept in a google drive folder that was constantly updated whenever a change was made. The google drive folder also contained separate subfolders where special file types including .dxf and .dwg were kept for easy access. In Fusion 360, the CAD software used for this project, the 2022 season's design and the 2023 season's design were kept in two different project files. In the current season's project file, two folders were created, one for dimensioned drawings and one for the parts of the robot.





Strategy

Offensive: Because I know my driving skills are not the best and my opponents will most likely have the advantage over me in that aspect, I will focus on control and make sure I do not be over-aggressive and only hit the opponents when there is a clear and obvious chance. Slow and controlled to ensure optimal hits are the way to go and will be the main focus in winning the competition.

Defensive: To be better able to dodge, I slowed down how fast the robot can drive for me to better be able to drive around during the match. During the match, the focus is to keep the weapon facing the opponent no matter where in the arena to prevent any hits to the side or front, which are areas with less mass. As long as I play it safe and keep control of the robot, the best defense will become the best offense.

Winning: Having a good balance between offense and defense is the key to victory. The key to victory is to stay calm and collected and drive smart. If I follow my plan for offense and defense, it will give me a higher chance at victory.

Robot Project Composition

The battle bot created for the 2023 season is a very compact design with a heavy and fast-spinning weapon in the front. The weapon weighs a little over 3 lbs and spins at almost 10000 rpm. Packing a lot of kinetic energy, this year’s design was essentially everything that went wrong last year but greatly improved. Throughout the design and manufacturing process, the main focus was on the weapon, collar guards, and side plates. These are crucial components to ensure the bot functions as intended. The weapon is the main damage-capable part of the robot. The collar guards not only protect the collars but also lock the shaft in place and protect the side plate from any damage. The side plate needs to be protected because it is responsible for lifting the robot’s front half to allow for the rotation of the weapon.

However, a weakness of this design is that the side plate’s angled area gets sanded down after continued friction at that point. After a while, it will get to a point where the weapon will begin scraping the ground and prevent the full rotation of the weapon. This issue was counteracted with the addition of found head screws, but it is not guaranteed to work for the full duration of the match. The pulley can also be hit if an unlucky collision occurs. Hopefully, if the weapon is constantly spinning at the desired RPM, such a case will not happen. Aside from these two, there are no other weaknesses that I see with this design.

In contrast, the strength of the robot is definitely in the weapons and the frame. The armor package of this design makes the bot extremely sturdy in the front where most collisions will occur. The weapon is also ⅕ of the robot's weight and spins up to a considerable amount of speed. This combination creates a lot of kinetic energy and as many may know, more kinetic energy equals higher capability to knockout capable hits due to the amount of energy transfer involved.

Being the only member in this project, all of the work was done by me. I researched different parts of the robot, created the drawings, modeled the CAD files, manufactured the parts, journaled, etc. It was extremely challenging doing what would be a 3 group project as a single-person team. Time management was crucial and every meeting required me to be focused on the task at hand and not get distracted.