2021-22 UC CEAS 15lb BattleBot Team

Senior Design Proposal submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Joseph Murphy, Henry Tran, & Jacob Hoffmann

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Thesis Advisor: Dr. Janet Dong

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Problem Statement

The University of Cincinnati will once again participate in a BattleBot competition. This year, the UC Battlebot team will be competing in Xtreme Collegiate Clash. Xtreme Collegiate Clash is a combat robotics showdown for college students, hosted by Xtreme STEM, and their Non-profit parent company Ohio Robotics Inc. The competition is usually held in early April or late March. The detailed competition date is to be announced. Our team will design, build, and test a 15 lb BattleBot, and will compete at the Xtreme event in the 15 lb weight category. Our team includes Henry Tran, Joseph Murphy, and Jacob Hoffmann. Joseph Murphy is responsible for the weapon, Henry Tran is responsible for the drive train, and Jacob Hoffmann will be responsible for the armor and frame. Henry Tran is the team leader for the project.

Research

Background of the Problem

Competitive battlebots aims to "respond to the critical challenge impacting America's technical labor pool and the number of students without hands-on science, technology, engineering, and math skills used in manufacturing, industrial, and business areas" (1). Giving students the means to design and create competitive robots helps to nurture these STEM skills. Our team will create a battlebot to compete in the Xtreme Collegiate Clash. The battlebot will fall under the XtremeBOTS 15lb technical regulations guide, and the competition will regulate under the XtremeBOTS regional competition procedures. Scoring in these competitions falls into 3 categories: aggression (offensive), control (defensive), and damage (2).

Success in this competition will primarily focus on the design and maneuverability of the battlebot. During the design process, tradeoffs will occur, and our team will have to decide what to omit and what to improve on with our battlebot. Having knowledge of mechanical design and product development will help our team properly execute the phases of this project.

State of the Art

UC has participated in the battlebots Xtreme Collegiate Clash since 2017. Since then, interest in battlebots has grown each year. As of September 2021, a total of 10 senior design battlebot projects have been completed. Each of these senior design teams addressed design problems in their own unique way. By observing how previous senior design teams engineered their battlebots, and analyzing their effectiveness, our senior design team can hone in on the best possible design choices for our own battlebot project.

Weapon

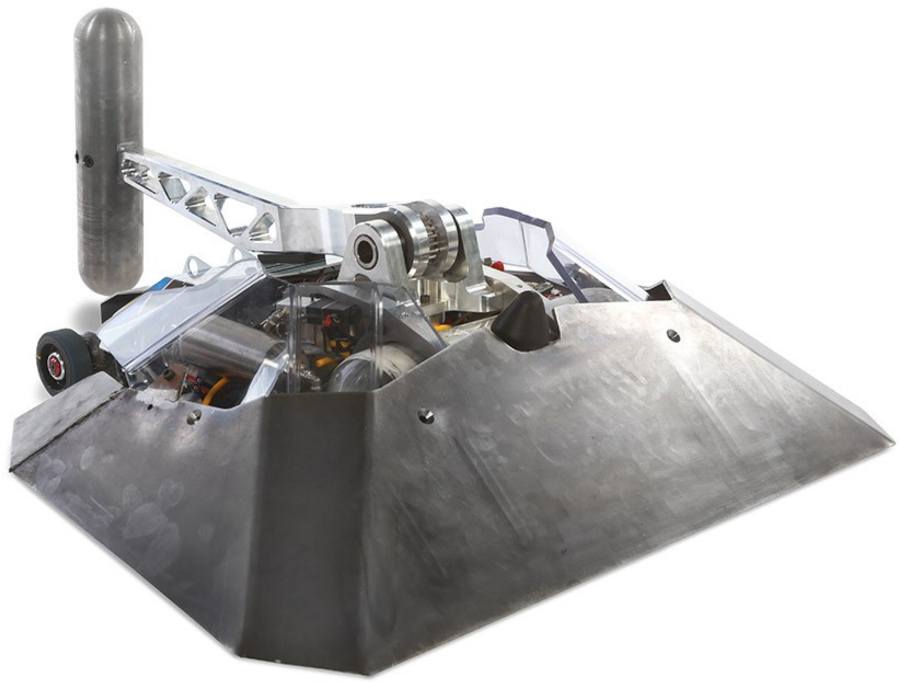
There are 4 major categories of battlebots which are defined by their weapon selection and configuration. A flipper bot aims to flip the opponent's battlebot using a ramp and/or catapult type of weapon. This is very effective against robots with no self-righting capabilities. However, flipper bots are not effective against robots that can self-right or have capabilities of driving while inverted. None of the senior design battlebot teams since 2017 have selected a flipper as their battlebot design.

Bronco (2020) BattleBots (4)

Full-body spinner bots consist of a spinner which extends to or beyond the outside of the robot's armor and wheels. This can be a long blade which spins about the robot like a helicopter's rotor, or it can be an extension of the battlebots armor. In the latter case, the battlebot's exterior armor spins around the bot, combining the armor and weapon systems into one. The earliest battlebot senior design project, completed in 2017, opted for the full-body spinner design due to its "360-degree security, deadly attack force, mechanical simplicity, attack range, and ease of driving" (5). Unfortunately, the 2017 senior design battlebots team did not compete, and the results of their design remain unknown.

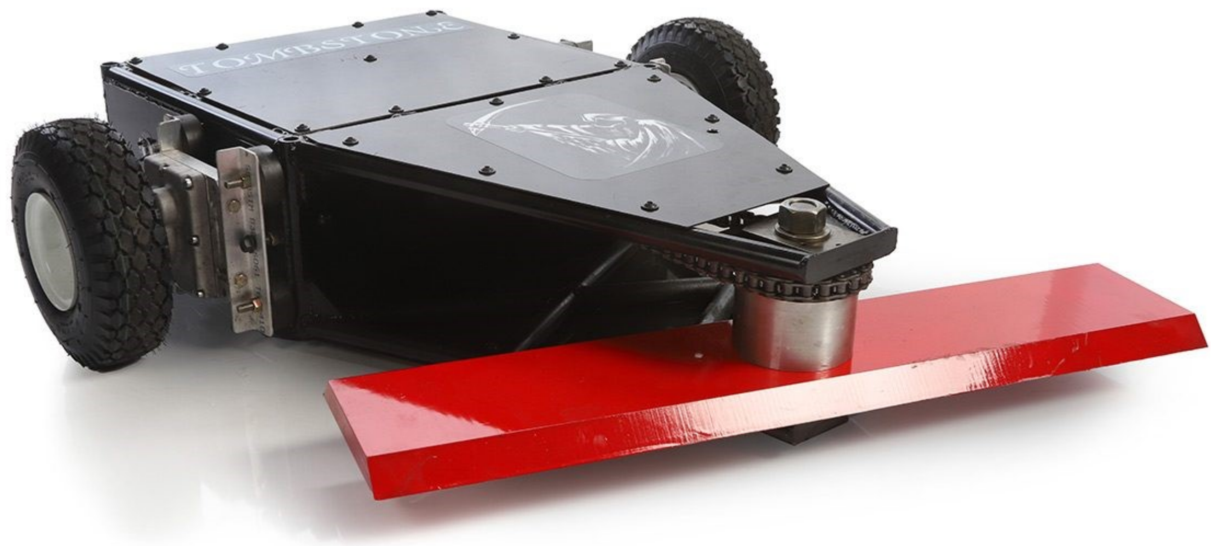
Icewave (2016) – BattleBots (4)

Dead-blow bots use a hammer-like weapon to strike blows on the opponent. This is perhaps the simplest type of battlebot to design and make, but they tend to be ineffective. Dead-blow bots have several issues to contend with. First is that after the weapon has been fired, it must be reset. Dead-blow bots are quite vulnerable while their weapons are resetting. The other big issue faced by dead-blow bots is Newton's third law of motion: "when two bodies interact, they apply forces to one another that are equal in magnitude and opposite in direction" (6). This means that every time a dead-blow bot strikes an opponent, it also deals an impact on itself. It is not uncommon to see a dead-blow bot break itself during competition just by regular use of its own weapon. No senior design battlebot teams thus far have designed a dead-blow bot.



Beta (2020) – BattleBots (4)

Inertial spinner bots use heavy spinners at high rpm to strike their opponents. They may be horizontally mounted spinners, like a lawnmower blade, or vertical spinners, like a table saw. There are pros and cons to each type of inertial spinner. Horizontally mounted inertial spinners cover a greater area, helping defend the bot while making it easy to strike the opponent. However, Newton's third law presents an issue for horizontal inertial spinners: when the spinner strikes an opponent, both bots are flung in opposite directions. In competition, horizontally mounted inertial-spinner bots tend to fling themselves all around the arena just by striking opponents with their weapon. This can damage or even break the inertial spinner bot, causing it to lose the competition. The full-body spinner from the 2017 battlebot team behaves similar to a horizontally mounted inertial-spinner, but since that team did not compete, the effectiveness of their design is unknown. 3 other battlebot senior design teams have used horizontally mounted inertial spinners since 2017. A 2018 senior design team found horizontal spinners to be highly versatile due to the fact that the blades may be changed out for different sizes depending on the opponent's design (7). This team competed post-graduation, and the success of their design is unknown. More recently, a 2021 UC senior design battlebot team designed a bot with a horizontally mounter inertial spinner. Instead of the lawnmower blade type of design the 2018 team used, the 2021 battlebot team made their spinner more round in shape. It resembles a circular saw blade but with a single tooth. The 2021 team used this spinner design due to its offensive capability, low cost, and usability (8). In competition, the weapon was successful until a pulley snapped and the weapon was rendered useless.



Tombstone (2019) – BattleBots (4)

Inertial spinner bots also use vertically mounted spinners which come with their own set of advantages and disadvantages. Vertically mounted inertial spinners can be wide, often referred to as barrel spinners, or narrow, more similar to a table saw shape. Barrel spinners are wide so they have broad offensive and defensive coverage. Barrel spinners also tend to have smaller diameters, allowing them to get up to speed very fast. However, barrel spinner battlebots experience a gyroscopic effect which can make them difficult to drive. When executing a turn, battlebots with barrel spinners tend to tilt up on their side. This can cause flipping and general loss of control. Since 2017, 5 UC senior design teams have made battlebots featuring barrel spinner designs. A 2018 senior design team selected a drum spinner because it maintains stability when striking an opponent and it allows the robot to be invertible (9). During testing and competition, this team experienced issues due to imbalances with the drum spinner. A 2019 UC senior design battlebots team designed a drum spinner weapon because it “incorporates a high contact surface with a wide face for an offensive attack” (10). This team designed their barrel spinner similar to a combine harvester, but it was made too thin and broke during competition. A UC student involved in the UC BattleBots Club has a very successful barrel spinner battlebot, dubbed Razor’s Edge, which is currently the division champion.

Minotaur (2018) – BattleBots (4)

There are some unique designs which fall outside of the primary 4 battlebot configurations discussed above (flipper, dead-blow, full-body spinner, and inertial spinner). Some teams create 2 or more smaller battlebots for competition. The combined weight of these robots must always be at or below the weight limit for the competition. This strategy has proven to be unsuccessful as the larger, full-weight battlebots have no trouble flinging the smaller ones all around the ring. Gripper bots have also been used in competition. Gripper bots are battlebots designed with large grippers which hold and sometimes even lift the opponent's battlebot into the air. Albeit rare, there have been some competitive match victories won by gripper bots. Most of the time, however, gripper bots are not capable of dealing significant damage to their opponent, making it difficult to score points in competition.

Complete Control (2016) – BattleBots (4)

Saw bots, battlebots which literally use one or more circular saws as their weapon, are somewhat common and rather effective. A 2021 UC senior design battlebots team won in the BeetleBot division with their “Slaystation” bot featuring a small, horizontally mounted circular saw. Saw bots are effective against the right opponent, but often the saws are broken during competition either by repeated use or a strike from an opponent’s weapon.

SawBlaze (2018) – BattleBots (4)

There are dozens of other novel weapon ideas seen in battlebots, ranging from rakes, drones, flamethrowers, and drones with flamethrowers. These types of weapons are exciting to see, but they are generally unsuccessful in battlebots competitions.

Drivetrain

When designing a battlebot there are typically two different wheel configurations to look at, 2 wheels and multi-wheel (anything over 3). There have many successful battlebots with all different variations of wheel configurations. Based on past results it is evident that the larger size you go the more wheels you will need. Having 4 wheels allow for the first two wheels to essentially steer the robot wile the back two pairs are powered and move the robot itself. This would provide more stability and less of an issue to try and balance the robot. A two-wheel design has also proven to be very successful in the past but the main issue comes to balancing and to help with stabilization batteries are often times mounted directly under the motor (10).

Belts have been a very common way to transmit power to a system. When compared to other forms of power transmission, belts provide a good combination of flexibility, low cost, simple installation and maintenance and minimal space requirements (11). There are two different types of belt drives that being open and crossed belt drives. An open belt is used to rotate the driven pulley in the same direction of the driving pulley. In the motion of belt drive, power transmission results make one side of the pulley more tighten compared to the other side (12). In crossed belt drives they are mainly used rotate the driven pulley in the opposite direction of the driving pulley. This produces a higher value of wrap which can

enable more power to be transmitted but the bending and wear of the belt can be a concern later down the road (12). Some common advantages of a belt driven system are that they are simple and economical, do not require parallel shafts, provide protection against factors like overload and jam, lubrication free which will lower the maintenance cost, and have an efficiency rating between 95-98% (12). Some disadvantages of this system are that the angular velocity ratio is not consistent or equal to the ratio of a pulley diameter due to slip and stretching, power is limited to 370 kilowatts, operating temperatures are limited between -35°C – 85°C, and the need for an idler pulley is needed to compensate for the stretching (12). Another major factor in determining what kind of drive system we will need is the maintenance. Although the belt does not need to be lubricated there is no easy and quick fix if the belt were to break. If we were to go with this system we would need another belt in the event that it does break because they can only be replaced.

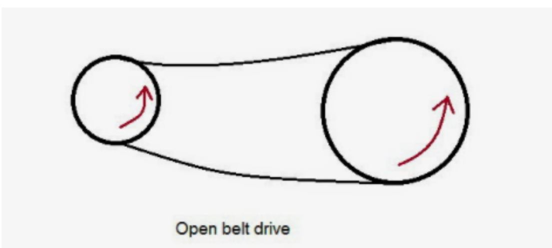


Figure 1: Open Belt Drive (12)

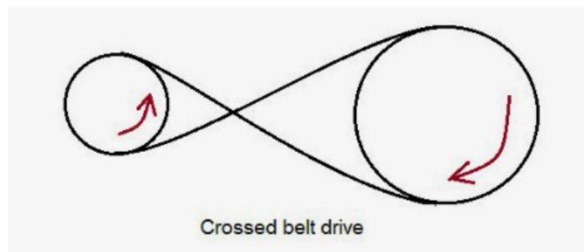


Figure 2: Crossed Belt Drive (12)

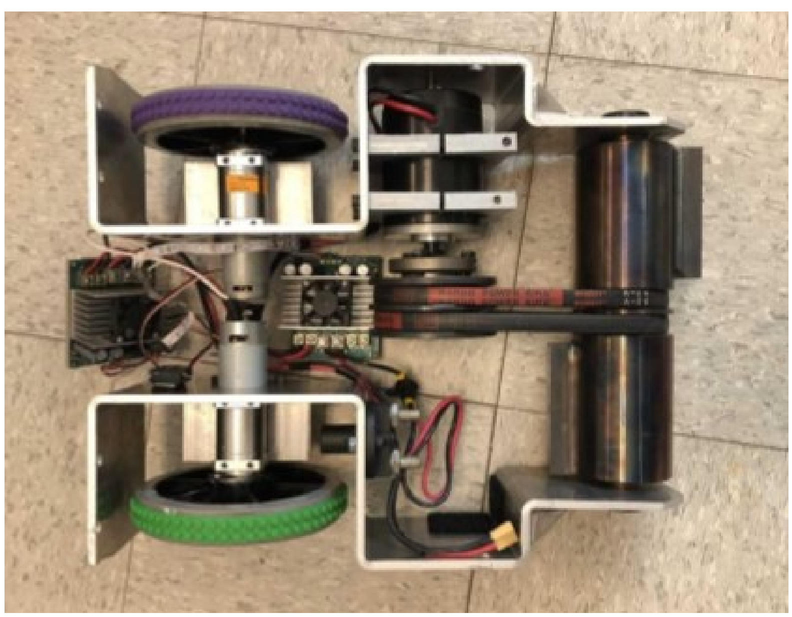


Figure 3: 2018 UC BattleBot Team 60 lb Competition (9)

The most preferred technology when you need to transmit considerable power over a short distance with a constant velocity ratio (13) is to use a gearbox/gear train. How a gear train works is that the teeth of the gears mesh with the other gears to transmit power, this is a great way to prevent against slip because one disk will mesh with the recess on another disk (13). The main advantages of a gear drive system is that there is no slip, a large and constant velocity ratio can be obtained, have a longer lifespan than the chain and belt, and are very compact (13). Some of the disadvantages of a gear drive system include the lack of flexibility, less economical compared to the other drive types, increase in weight due to the multiple gears, and require lubrication and a complicated process of applying it (13). Often the maneuverability of a system is how a battlebot match is won through. Gearboxes have been widely used in previous year designs due to the simplicity and compactness of how they work. Gearboxes are standard components and the factors to consider when ordering a gearbox would be the speed ratio and the power consumption per motor that is needed.

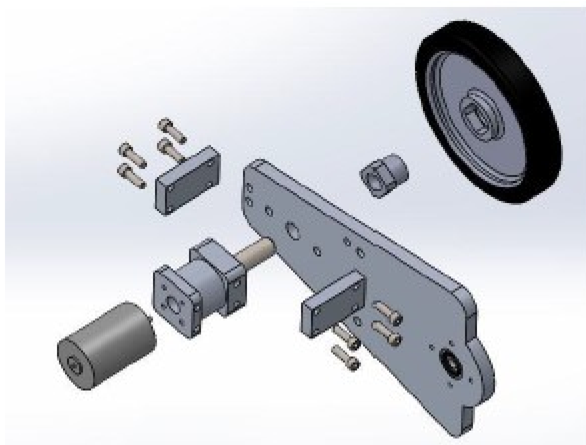


Figure 4: 2019 UC MET Battlebot Team 15lb Combat Bot Design (14)

A chain drive is a mechanically operating system where we use different types of chains to transmit power for movement (14). If we did decide to use a chain drive, we would have the chain system run over a sprocket which have multiple teeth to help move the chain and also transmit power. Some advantages of the chain and sprocket system are that chains can be smaller and transmit the same torque as a belt, sprockets wear less than gears because the loads are distributed over more teeth, chains are pretty standard components, so the selection process becomes easier, and the concern for slip is negligible (15). Some disadvantages of this is that chain drives have a high production cost and installation cost compared to belts, chain drives are noisy and can cause vibrations within the system, and they have a lower load capacity and service life compared to gear drives (13).

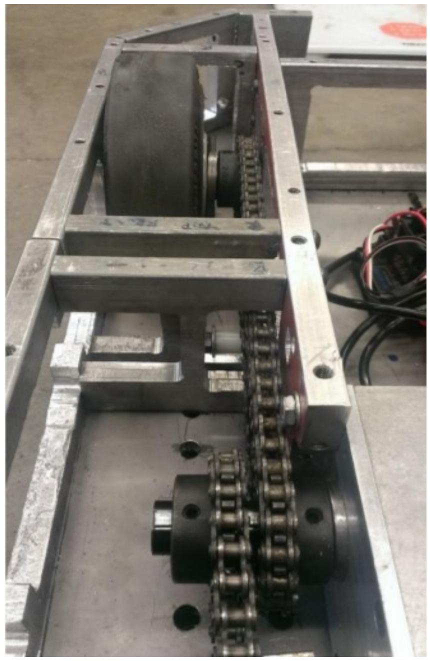


Figure 5: 2014 Battlebot Team 120lb (16)

Armor

Armor is one of the least engineered components of past robots. The previous UC 15-Pound robot (Figure 6) sported clear plastic sheet. Other robots in the league rely on metal sheet, but the geometry is simple, never vearing from a sheet of aluminum. "Push comes to shove" (Figure 7), with aluminum sheet armor. More complex armor is waterjet but complex bends are rarely attempted. The simplistic nature of former armor designs is an untapped direction for collegiate teams.

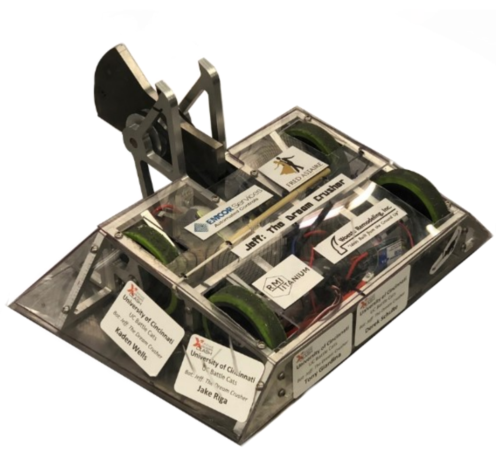


Figure 6: UC BattleBots Club's 15 Pound Robot (17)

Figure 7: Push Comes to Shove, 15 Pound Robot (18)

Understanidng the requirements for armor also requires an understanding of the stresses that battlebots undergo. The problem requires both extreme impact resistance and high rigidity of the motion system. To quantify the force undergone in competition, shear strength tests and penitration tests will need to be done on a variaty of materials. To guage the targets of these tests, our team will use the data from the 2019 XtremeBOTS champion, “Razor’s Edge” who is a part of the UC battlebots team.

Adding specific functional elements has been one of the short comings of UC’s previous battlebots. In past years, armor has been simple, relying on the aluminum frame to attach plastic sheet (17). This isn’t consistent with the pro robot above. This semester our team will focus on bringing more passive or active mechanical elements to the armor and frame, switching from plastic sheet to aluminum opens the door for hard point attachment of spikes and other geometry.

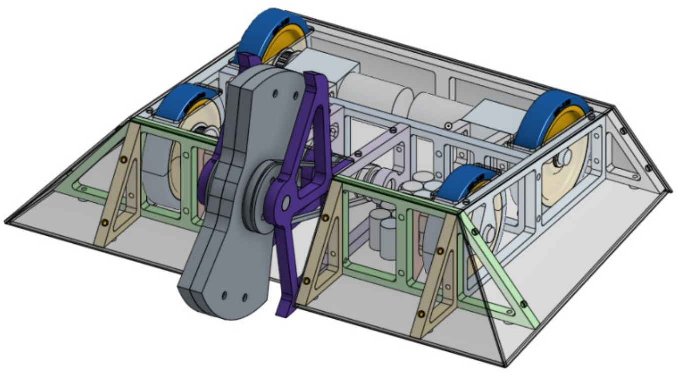


Figure 8: UC BattleBots Club’s 15 Pound Robot (17)

The primary function of armor in previous designs has been to build a buffer zone between the internal electronics and the outer skin of the robot. Using plastic sheet reenforced aluminum triangles to beef out the frame was the strategy UC’s Robotics team took in 2018 (Figure 8).

The result was a large buffer zone between the battlebots vital internals and the outside of the robot. This is a standard that the armor and frame will have to match or exceed this year.

The current 2020 national battlebots champion is EndGame; this robot relies on a single thin vertical spinner. As an additional function the robot has two scoops in the front that allow it to flip other robots. Secondary functions include a “tail” that keeps the robot upright while spikes on the top surface prevent robots from getting on top of End Game’s Chassis. The complexity of this geometry has been out of reach for former UC teams due to the manufacturing requirements and the material sciences knowledge, our team hopes to bring better expertise to the material handling and machining in order to bring our battlebot more in line with the national standards.

Figure 9: 2020 Battlebots winner, EndGame (19)

In designing our robot, our intent is to make the robot “flipable”. Meaning that in the case of the robot being turned upside down, it should still function the same. To ensure that the internals are protected no matter the orientation, the buffer zone for the electronics needs to be equal on both the top and the bottom. Frame design will come with the design of the electronics, attempting to flatten them to achieve a more compact footprint. In addition, the triangle buffer zone from previous years will not be adequate for the flipable design. Instead, our team will explore the possibility of using Reuleaux triangles, triangles of equal diameter, (5) in order to make a design that is both fliplable and has geometry that opponent tools will simply roll off of due to the nature of the shape.

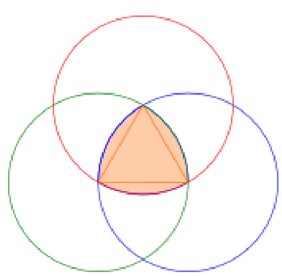


Figure 10: Reuleaux Triangle (21)

In 2021 UC’s club moved to beetle wight robots. One of the Robots utilized water jet aluminum in order to produce an armor that was highly geometrically complex, the result is a bot that though under 1.5 kg is capable of taking extreme impact (17).

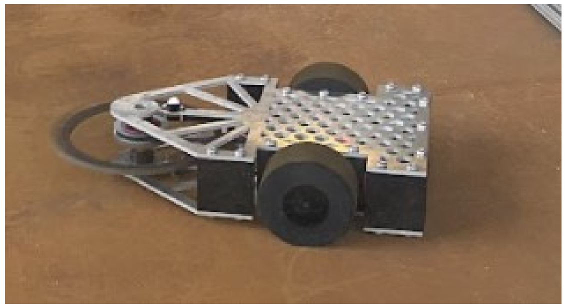


Figure 11: Beetlebot with waterjet armor (17)

In our design, weight savings should come from geometry. Saving weight means a harder material can be used for the same effect. A possible solution is to use a “kinked” metal that is as strong as a flat metal, but due to its wavy surface is more resilient to impact per mass (Figure 6). Geometric solutions will be as important to armor design as material selection.

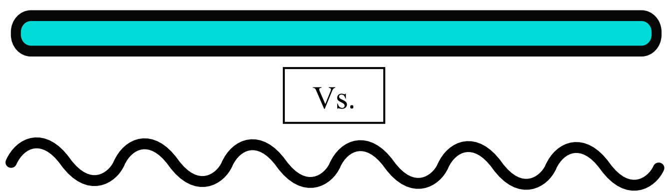


Figure 12: Potential Surface Variation to Improve Shear Strength of Sheet Material

Relevant Standards

Our battlebot must adhere to the standards and guidelines as they are written in the XtremeBOTS 15lb Technical Regulations. See appendix.

End User

Our team will design and create a 15lb battlebot for competition which will be sponsored and funded by the University of Cincinnati. The battlebot will be driven/operated by our team during the competition. Under these conditions, the end user for this project will consist of our team and, by extension, the University of Cincinnati.

Summary of Research

There are 4 primary battlebot configurations based upon the design of the weapon: flipper bots, dead-blow bots, full-body spinners, and inertial spinners. Flipper bots and dead-blow bots are uncommon to see in competition due to their general lack of effectives. No UC senior design teams have made flipper bots or dead-blow bots for competition within the past 5 years. Full-body spinner bots are similar to inertial spinner bots, but with a 360^o offensive envelope. Full-body spinner weapons can also be combined with the armor to achieve maximum offensive and defensive coverage. One UC senior design team has designed a full-body spinner battlebot since 2017. In competition, full-body spinner designs have seen some success. Inertial spinner bots are the most common types of battlebots and are generally favored for competitive effectiveness. Horizontally mounted inertial spinners cover a wide offensive area while remaining stable enough to easily maneuver. When a horizontally mounted inertial spinner strikes an opponent, both bots are flung in opposite directions. This can cause damage to the horizontal inertial spinner bot and is often the reason for losing a competition. Vertically mounted horizontal spinners may have a wide (drum) spinner or a narrow spinner. Drum spinners cover a wide offensive area and are able to strike blows without flinging themselves around the ring. However, drum spinners experience a gyroscopic effect which inhibits their maneuverability. Vertical spinners with a narrower weapon do not experience any noticeable gyroscopic effect, but their offensive area is much smaller. This makes it more difficult to easily strike the opponent. In competition, horizontally mounted inertial spinners and drum spinners see the most overall success. Both of these battlebot configurations strike devastating blows on opponents but can be difficult to control. Battlebots with narrow vertical spinners also see a lot of success in competition, but their small offensive area makes it hard to consistently strike the opponent.

The three main types of drive trains are gear drive, chain drive, and belt drive. Throughout the history of battlebots for senior design, all configurations have been used in some way. Gearboxes/gear driven systems were mainly used in lower weight class configurations due to the compactness and lightweight compared to the other systems. When battlebots were designed for higher weight classes there was a tendency to use more of a belt/chain approach due to fit their design needs. The need for a belt could be useful in the event that you would want slip or the approach for a chain may be useful in the event where you would want to do four-wheel drive to help out with maneuverability (17). Another big factor in designing drive systems is which wheeled robot configuration are we going to use. Each configuration has their own strengths and weaknesses, with the two wheeled robot being very challenging to balance but in turn would save us on weight and cost. With a four wheeled robot we could get the stability that we need to maneuver however this would drastically change our design due to the space that this would take up. Overall based off the research conducted on the drive trains there are evident reasons why each configuration should and should not be chosen for our application, and a deeper dive into the design phase will help us better select a drive train that works for our team.

The Xtreme Collegiate Clash, which is the competition our senior design team will compete in, takes place in late spring. Since this falls after the due date for senior design reports, most of the previous senior design teams have not reported on the effectiveness or overall success of their battlebot projects. To see the effectiveness of previous senior design battlebots, our team must rely on videos of the previous competitions. This is how our senior design team observes what designs are most effective in competition.

Quality Function Deployment
Customer Features

Customer features were presented on a survey to people with prior knowledge/experience in battlebots and robotics. The survey included a ranking of several characteristics on a 1-10 scale and written suggestions for more complex items. The survey was completed by 30 individuals, outliers were removed from the data, and the features were averaged and consolidated to better fit the HOQ template.

- Weight
- Self-righting / Invertibility
- Traction
- Weapon Modularity
- Weapon Type
- Weapon Material
- Weapon Strength
- Armor/Frame Material
- Armor/Frame Strength
- Maneuverability
- Cost

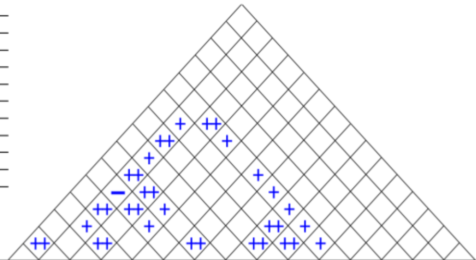
Engineering Characteristics

These engineering characteristics were developed to best measure the customer features

- BattleBot is Invertible
- Weapon is Inertial Spinner
- Armor/Frame are Aluminum
- Weight [kgs]
- Cost [USD]
- Weapon Replacement Time [s]
- Torque [N/m]
- Hardness [HB]
- Yield Strength [MPa]
- Angular Velocity [rpm]
- Angular Momentum [kg-m^2/s]
- Diameter [m]

House of Quality

Title: Senior Design BattleBots QFD
Author: Joe Murphy, Henry Tran, Jacob Hoffmann
Date: 9/24/2021
Notes:

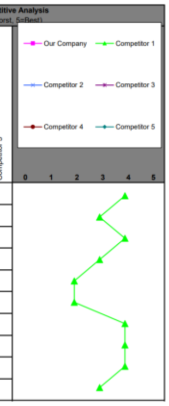


Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	x	x	x	▼	x	▲	x	x	x	x				
				Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Invertible	Weapon is inertial spinner	armor / frame is aluminum	weight (kg)	weapon replacement time (s)	hardness (HB)	yield strength (Mpa)	torque (N/m)	angular velocity (rpm)	diameter (m)	cost (USD)				
1	9	31.3	0.3	Weight			Θ	Θ											
2	9	1.0	0.0	Cost			Θ								Θ				
3	9	10.4	0.1	Self-righting / Invertibility	Θ	O													
4	9	10.4	0.1	Traction		▲	▲	Θ				Θ	O	Θ					
5	9	10.4	0.1	Maneuverability	▲	Θ		Θ				Θ	Θ	Θ					
6	9	5.2	0.1	Weapon Modularity		O			Θ										
7	9	10.4	0.1	Weapon Type	O	Θ			Θ	▲	▲				▲				
8	9	5.2	0.1	Weapon Strength		O				Θ	Θ								
9	9	5.2	0.1	Armor / Frame Material			Θ			Θ	Θ				Θ				
10	9	10.4	0.1	Armor / Frame Strength			Θ			Θ	Θ								
				Target or Limit Value	Is invertible	Is inertial spinner	Armor is aluminum	≤ 15 lbs	≤ 20 min						≤ $1,000 USD				
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	0	0	0	5	6			2	2		1				
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9				
				Weight / Importance	135.4	260.4	441.7	468.8	140.6	197.9	197.9	187.5	125.0	187.5	66.7				
				Relative Weight	5.6	10.8	18.3	19.5	5.8	8.2	8.2	7.8	5.2	7.8	2.8				

Competitive Analysis
(0=Worst, 5=Best)

Row #	Our Company	Competitor 1	Competitor 2	Competitor 3	Competitor 4	Competitor 5
1		4				
2		3				
3		4				
4		3				
5		2				
6		2				
7		4				
8		4				
9		4				
10		3				



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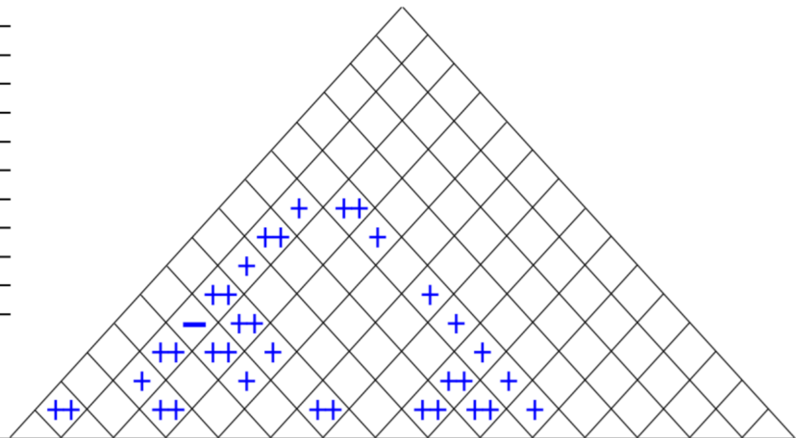
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	x	x	x	▼	x	▲	x	x	x	x				
				Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / **Quality Characteristics** (a.k.a. "Functional Requirements" or "Hows")	Invertible	Weapon is inertial spinner	armor / frame is aluminum	weight (kg)	weapon replacement time (s)	hardness (HB)	yield strength (Mpa)	torque (N/m)	angular velocity (rpm)	diameter (m)	cost (USD)				
1	9	31.3	0.3	Weight			Θ	Θ											
2	9	1.0	0.0	Cost			Θ								Θ				
3	9	10.4	0.1	Self-righting / Invertibility	Θ	O													
4	9	10.4	0.1	Traction		▲	▲	Θ				Θ	O	Θ					
5	9	10.4	0.1	Maneuverability	▲	Θ		Θ				Θ	Θ	Θ					
6	9	5.2	0.1	Weapon Modularity		O			Θ										
7	9	10.4	0.1	Weapon Type	O	Θ			Θ	▲	▲				▲				
8	9	5.2	0.1	Weapon Strength		O				Θ	Θ								
9	9	5.2	0.1	Armor / Frame Material			Θ			Θ	Θ				Θ				
10	9	10.4	0.1	Armor / Frame Strength			Θ			Θ	Θ								
				Target or Limit Value	Is invertible	Is inertial spinner	Armor is aluminum	≤ 15 lbs	≤ 20 min						≤ $1,000 USD				
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	0	0	0	5	6			2	2		1				
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9				
				Weight / Importance	135.4	260.4	441.7	468.8	140.6	197.9	197.9	187.5	125.0	187.5	66.7				
				Relative Weight	5.6	10.8	18.3	19.5	5.8	8.2	8.2	7.8	5.2	7.8	2.8				

Title: Senior Design BattleBots QFD

Author: Joe Murphy, Henry Tran, Jacob Hoffmann

Date: 9/24/2021

Notes:

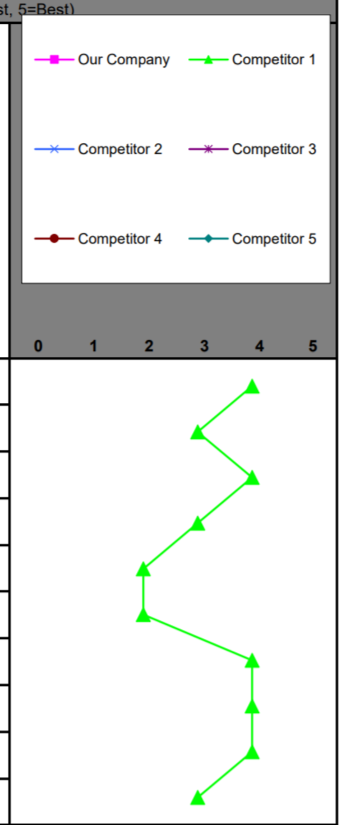


Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	X	X	X	X	▼	X	▲	X	X	X	X				
Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Invertible	Weapon is inertial spinner	armor / frame is aluminum	weight (kg)	weapon replacement time (s)	hardness (HB)	yield strength (Mpa)	torque (N/m)	angular velocity (rpm)	diameter (m)	cost (USD)				

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	**Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")

Competitive Analysis
(0=Worst, 5=Best)

Our Company	Competitor 1	Competitor 2	Competitor 3	Competitor 4	Competitor 5
	4				
	3				
	4				
	3				
	2				
	2				
	4				
	4				
	4				
	3				



Product Objectives

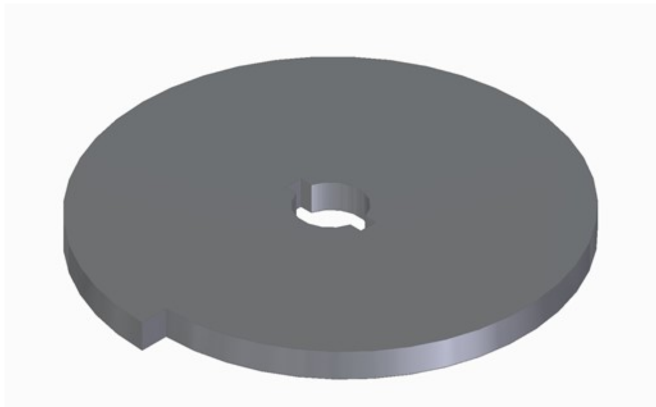
Based on the survey results and House of Quality (HOQ) for the BattleBot project, weighted importance of engineering characteristics are listed below.

1. Weight (19.5)
   - BattleBot must come in at ≤ 15lbs
2. Aluminum Armor/Frame (18.3)
3. Weapon is Inertial Spinner (10.8)
4. Hardness (8.2)
   - Want to optimize material hardness for frame, armor and weapon
5. Yield Strength (8.2)
   - Want to optimize material yield strength for frame, armor and weapon
6. Torque (7.8)
   - Sufficient torque to push the opponent
   - Optimize torque for inertial spinner
7. Diameter (7.8)
   - Wheel diameters
   - Inertial spinner weapon diameter
   - Shaft and axle diameters
8. Weapon Replacement Time (5.8)
   - Modularity allows for BattleBot repair between matches
9. Invertible (5.6)
   - Invertibility allows BattleBot to drive on both sides
10. Angular Velocity (5.2)
    - Optimize angular velocity of inertial spinner weapon
    - Optimize angular velocity of drive systems for maneuverability
11. Cost (2.8)
    - Stay within budget allotted by UC BattleBots Club (~$1,200)

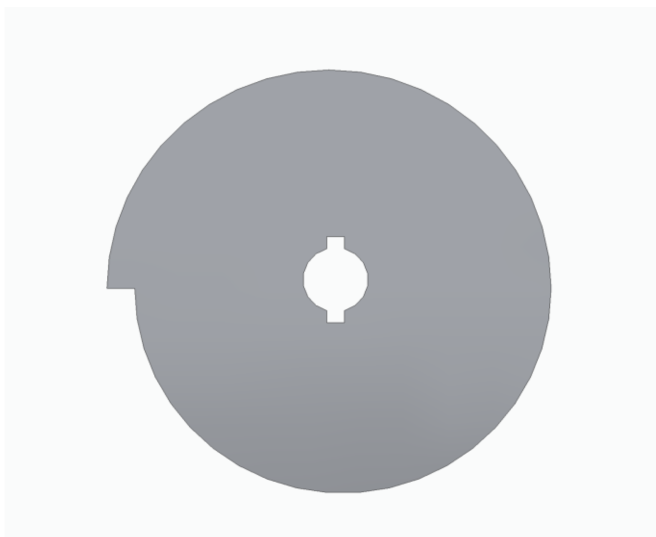
Concept Drawings

Weapon Concepts

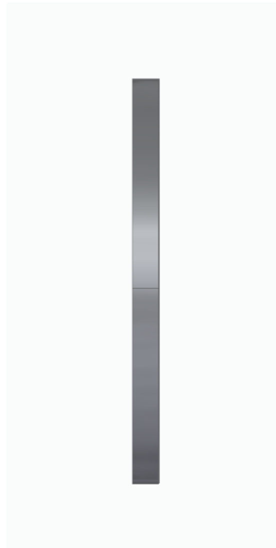
Concept 1: Circular Spinner



Circular spinner – isometric view



Circular spinner – top view

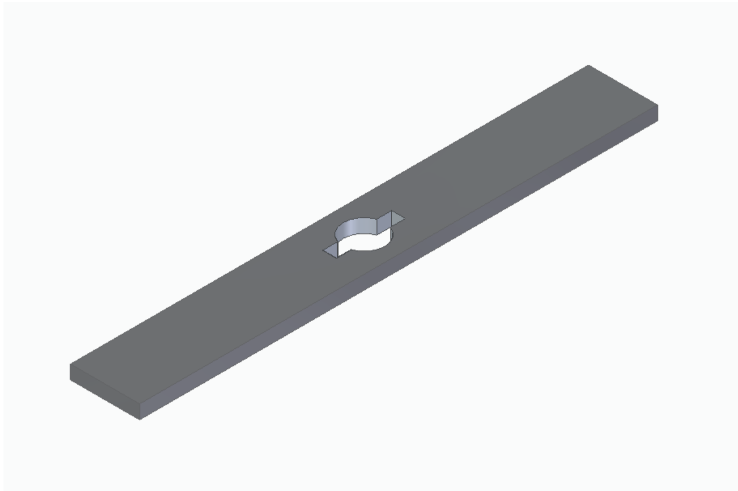


Circular spinner – side view

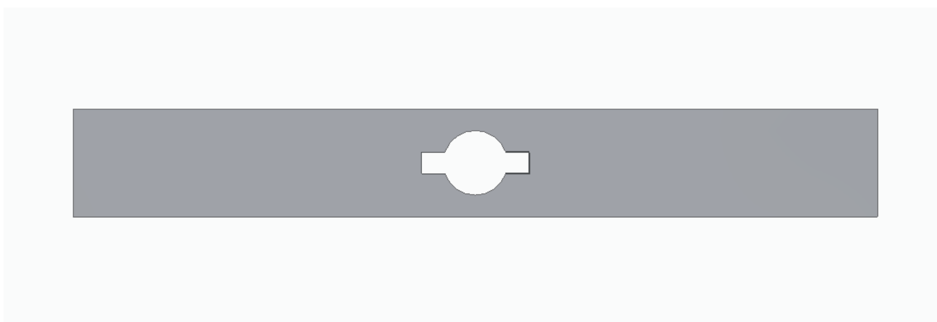
This design is based on a similar design made by a 2020 senior design battlebots team. The idea is that by having only one biting edge, the spinner can spin a full 360º before striking again. This gives the spinner the opportunity to get up to speed resulting in more forceful hits. The added material required for the weapon's circular design also creates more weight, adding to its inertia, which also helps to deliver more forceful hits.

The largest issue with this design is identifying the center of gravity and manufacturing the profile of the spinner around that center of gravity. If this spinner is not precisely manufactured around its center of gravity, it will produce vibrations when it gets up to speed. Vibrations make it difficult to drive and/or control one's battlebot and can also result in significant damage to the internal and external components of the bot. The 2020 senior design battlebots team that used this type of design was unable to machine it precisely around its center of gravity and this ultimately caused their bot to fail during competition.

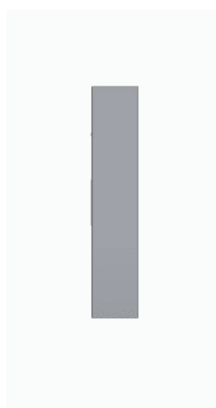
Concept 2: Bar Spinner



Bar spinner – isometric view



Bar spinner – top view

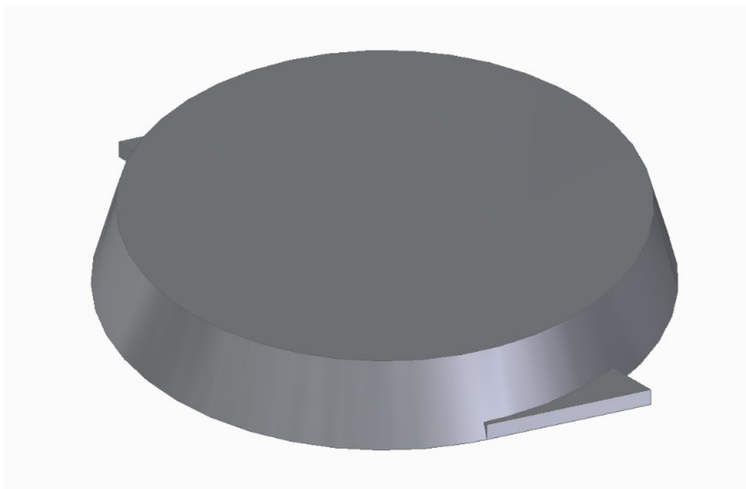


Bar spinner – side view

This is a tried-and-true design which has been demonstrated for years by BattleBots legend Tombstone. With this type of weapon equipped, Tombstone has won several BattleBot championship titles and is a name recognized even by those outside of the battlebots hobby. The idea of this weapon design is to spin a heavy, rectangular bar at high speed and deliver devastating blows upon contact with opponents. Because this type of design is very easy to design and manufacture, our team could save on manufacturing/machining costs and use those savings to stock up on spare blades and/or select better materials for the weapon. The general simplicity and effectiveness of this design makes it ideal for a team like ours with rudimentary manufacturing experience in no prior experience in battlebots.

Unlike the circular spinner concept, this design is only able to spin 180º between consecutive blows. This small angular distance may not be enough to allow the spinner to get back to speed, decreasing the force delivered by each blow. The lack of material around the axle raises concern for stress concentrations and possible weak points which may need to be addressed. The possibility of one or both of the spinner's arms snapping is also a point of concern with this design.

Concept 3: Full-Body Spinner



Full-body spinner – isometric view

Full-body spinner – top view

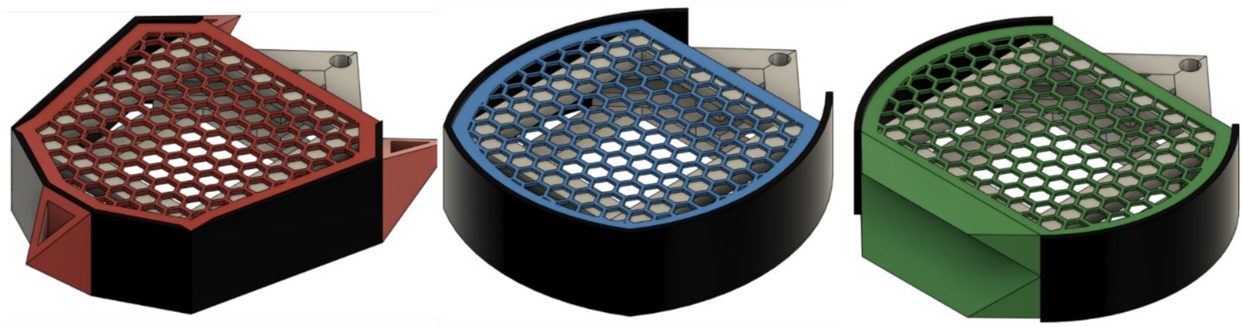
Full-body spinner – side view

This full-body spinner design is based on the Gigabyte design seen on Discovery’s BattleBots TV show. The idea of such a design is to fuse the armor and weapon into one allowing for 360º offensive and defensive capabilities at all times. Being fully symmetric with a spinning weapon/armor combo, this 360º design offers no weak points to be exploited by an opponent.

This type of battlebot design is not often seen in compeition, especially in the 15lb devision, because it is inherently complex. Manufacturing a weapon/armor combo is not a simple task. Desinging and manufacturing a system to spin the weapon/armor combo around the inner electronics and drivetrain adds even more complexity to this design. Self-rignting, or invertibility, to protect against being flipped over is another very tricky part about desinging full-body spinner battlebots. Driving full-body spinner battlebots is a challenge in and of itself because there is no front or rear to help indicate which way is forwards ot backwards. While full-body spinners are very good in theory, many would argue that the challenges and complexities of actually making such a design outweight all of the potential advantages.

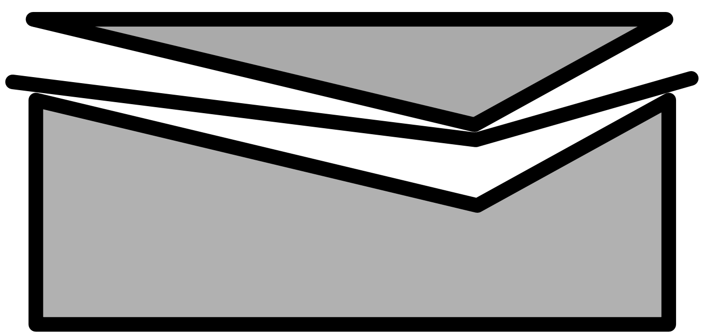
Armor Concepts

The driving focus of all three of the following concepts is to build armor that is rugged enough to survive direct hits while light enough to be maneuverable. Offensive capabilities as well as defensive capabilities are a focus of each design. The following concepts have each been mounted to the same frame, and sport 5mm thick outer sheet metal (black) and a 3mm hex plate for the top and bottom (various colors). These ideas are expected to evolve to meet the demands of the weapon and drive train.



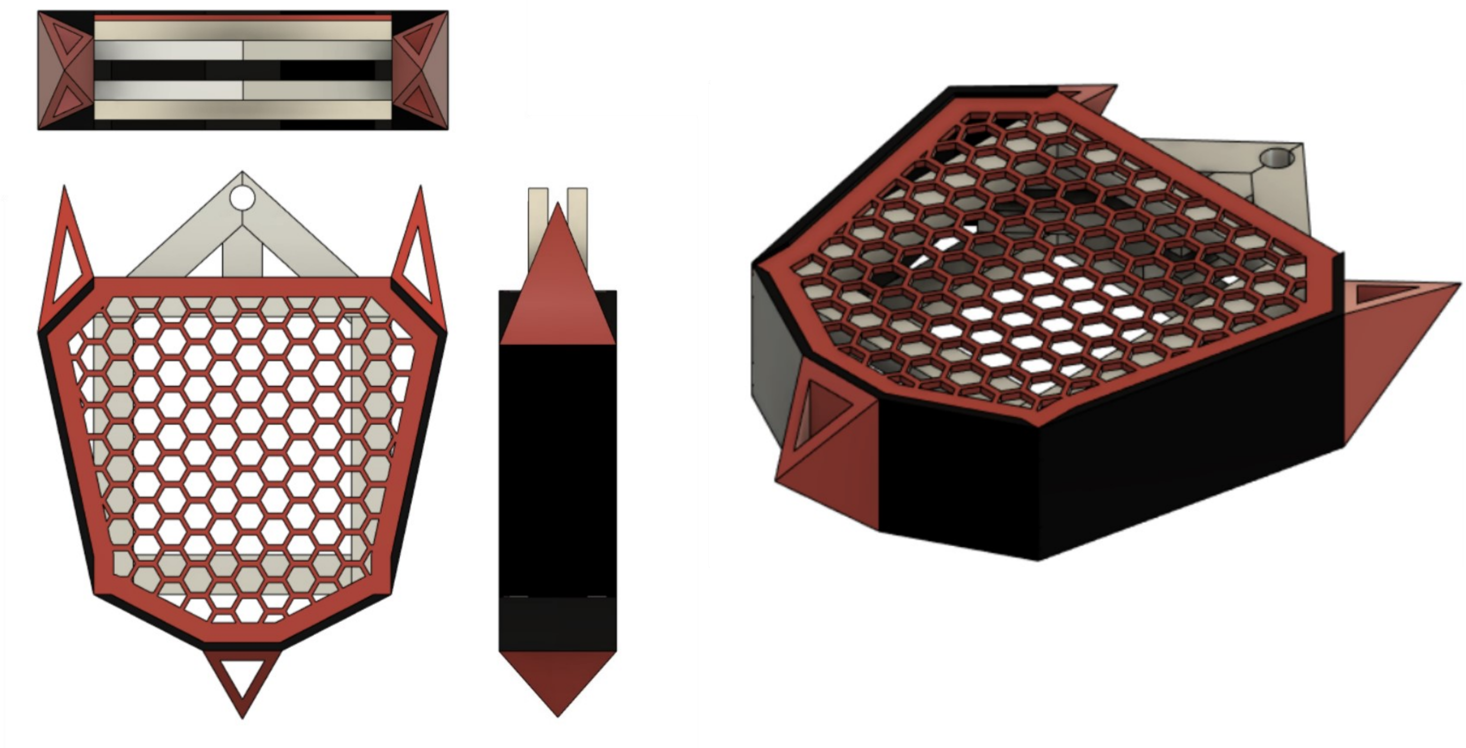
Red, Blue and Green Concepts

The top hex plate will be water jet aluminum, or laser cut high impact polycarbonate/ABS blend. The water jet and laser process will yield a high accuracy two-dimensional sheet, with digital files that can be modified quickly for multiple iterations. For the manufacturing of the outside skin, a high impact steel or aluminum will be chosen based on shear and impact strength characteristics. To create complex geometry in the sheet metal, wood or metal dies will be made in order to stamp a precise cross section. Using a hydraulic press, the process will allow us to make many backup components and iterate different geometries. The attachment to the frame will be accessible enough for these plates to be essentially modular. By establishing these universal concepts early in the design process, a driving consistency between ideas will allow us to iterate within a flexible platform.



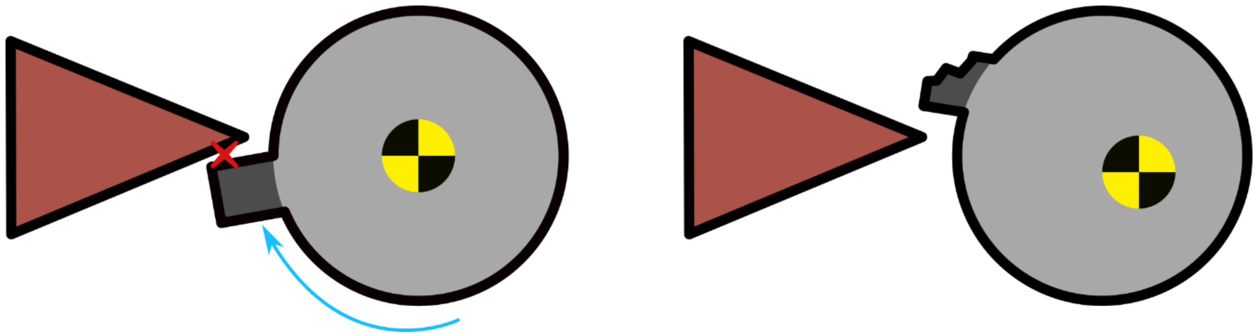
Manufacturing of precise complex geometry is possible using a stamping process in a hydraulic press

Concept 1: Red Concept



The Red Concept: An Offensive Focus

The idea driving the red concept is armor that brings extreme offensive capability to the table. The intention driving the distinct spikes that are attached to the armor are to be made of a hardened steel. The intention is specifically to take out other vertical or horizontal rotating blades, which are a major threat in the 15-pound weight class. Red Concept's spikes take advantage of one of the weak points of a spinning blade design: precise center of mass must be maintained. If the center of mass varies even a few millimeters, the spinner will aggressively wobble, making steering difficult and consecutive strikes challenging. Using this effect against our opponent in our design is the best way for us to out a spinner without putting our moving components at risk.

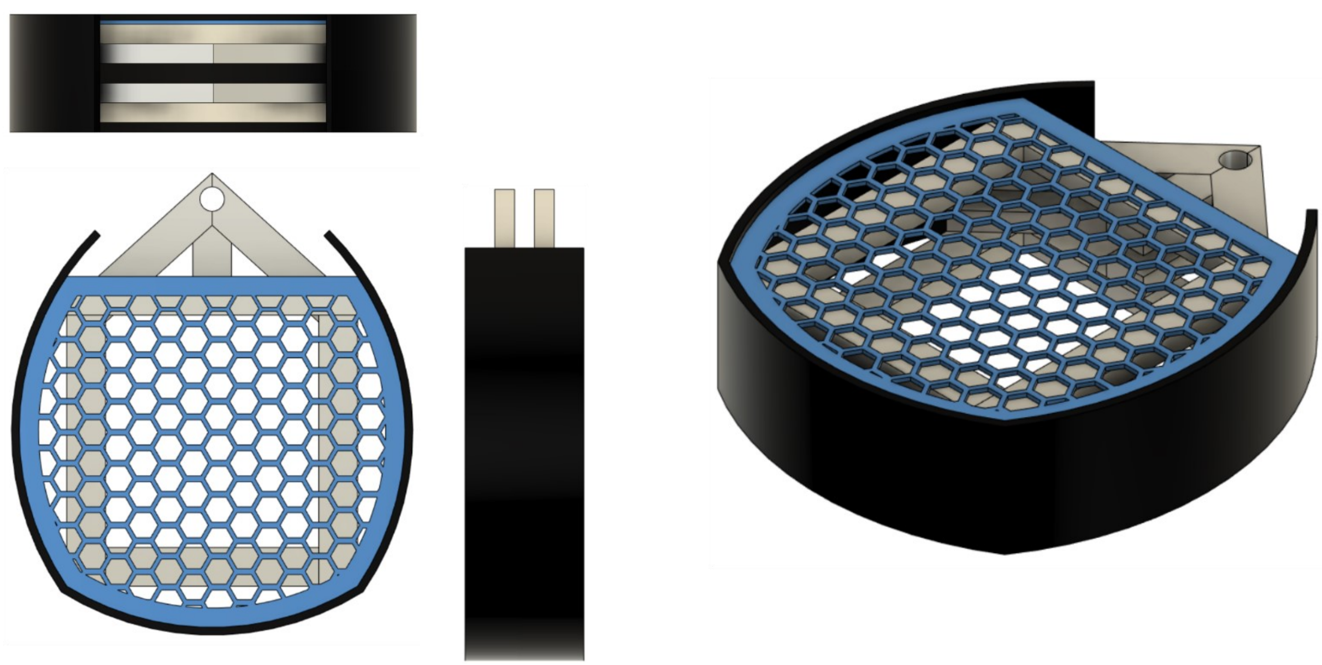


The concept driving the Red Concept's Spike defense. Grey wheel represents an opponent spinner, yellow and black represents an opponent spinner's enter of mass

The hardened steel spikes must be harder than the opponent's spinner to have a great enough impact. This means that they will most likely be very brittle. After the round is over, it is expected that there will be significant damage to the surface of the spike, potentially lessening their effectiveness. The spikes will be attached with two screws into a blind whole from behind, making them quickly replaceable. This modularity will ensure that we have a robot at peak effectiveness for the entire competition.

A drawback to this design is the frame will have to be designed to absorb the serious impact delt to these spikes. A direct hit from a spinner moving ~300 MPH (tip speed) will transfer immense energy into the frame of the robot, if it is not designed to absorb this impact the wheels and motion system may become misaligned.

Concept 2: Blue Concept



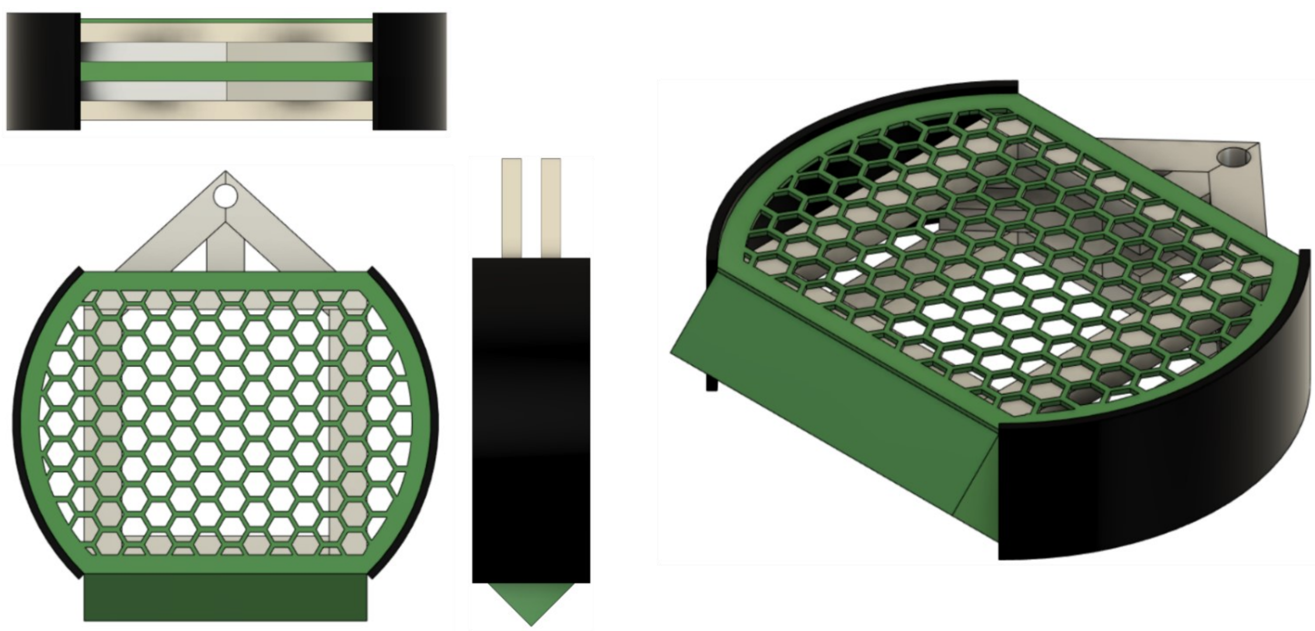
The Blue Concept: A Defensive Focus

While the Red Concept provides targeted areas for contact with opponent robots in an attempt to deal damage, the Blue Concept aims to deflect all damage. By using an extremely smooth skin, the intention is to eliminate any opportunity for enemy robots to inflict damage. In addition, the skin extends nearly to the ground to prevent opponent spinners from getting a grip on the outside of the robot.

The gap between the floor and the outside of the armor (black) is at a minimum. The bottom of the wheel (grey) determines the position of the floor

The positives to this design is that the frame can be lighter weight. Assuming the armor is good at deflecting shots, the frame does not have to be prepared for significant impact. This means more weight can be distributed to weapons and movement systems. However, the purely defensive focus has potential drawbacks; the main drawback that, should the spinner fail, the robot has no passive recourse. While the red concept can use its spikes in the event of a weapon failure, the blue concept is left with no options.

Concept 3: Green Concept

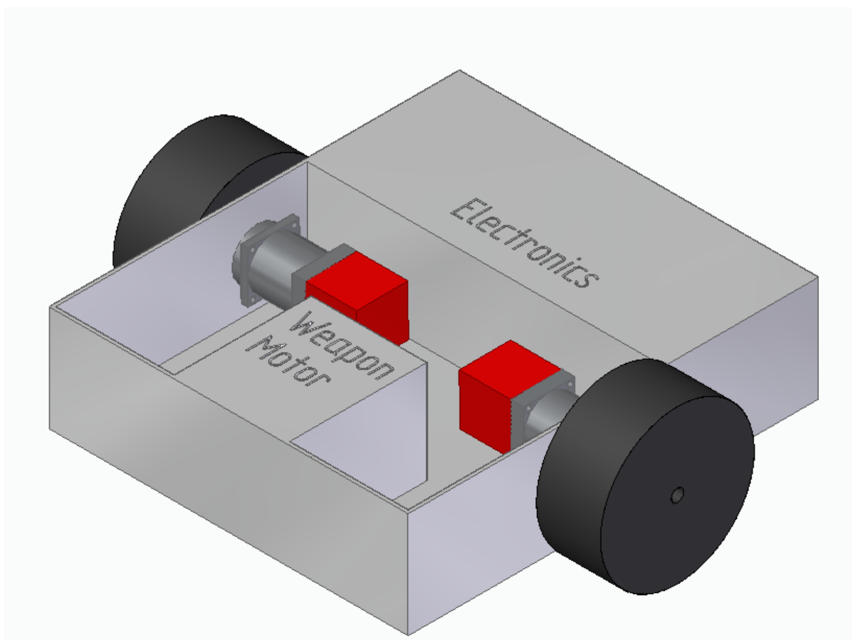


The Green Concept: A Balanced Focus

To conclude the three concepts, the Green Concept. While the failing of the blue concept is its lack of passive offensive features, and the failing of the red concept is its possible attack zones, the green concept combines both ideas into a single system. Its curved edges prevent attack to the flank while the hardened steel back bar provides a targeted hit zone for doing damage to spinning attack systems. The rear attack bar can be changed out for different shapes, if a longer spike is desired or if multiple spikes are desired, the platform allows for quick reconfiguration. The example system is a long bar, the idea is that there is a minimal amount of surface for an enemy spinner to grab onto in the horizontal direction, but plenty of surface area to distribute a direct hit. Though the Green Concept offers both offensive and defensive capabilities, the effectiveness of both these features is not in the intensity of the Red or Blue concepts. Though the Green concept is balanced, it might not be defensively or offensively great enough to be viable. If our team moves in this direction we will have to continue to balance these two variables.

Drivetrain Concepts

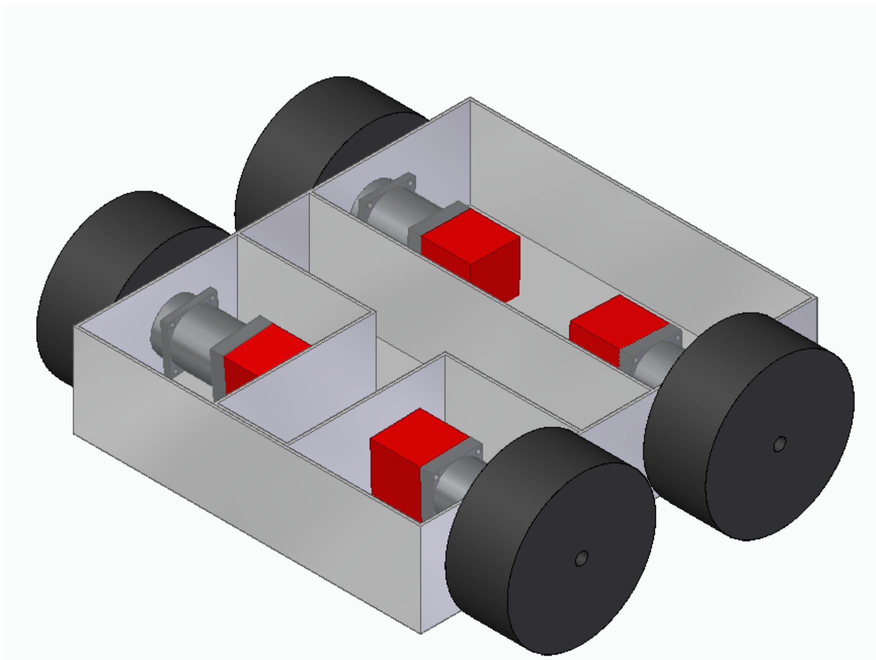
Concept 1: Two-Wheel Exposed



Two-Wheel Exposed

This two-wheel exposed design allows for more space on the inside to pack away electronics and provides more space for the weapon motor. As illustrated, there is a planetary gearbox that is attached to each wheel and a red housing for the brushless motor to be enclosed. This design incorporates the usage of electric motors to power the wheels. Having two wheels cuts down on weight and saves space compared to a 4- or 6-wheel design. Having two wheels also cuts down on cost compared to having more wheels. The downside to this design of having the wheels exposed is that are wheels are going to be a weak point if struck and the potential to jam is much higher. This design is also flawed in there is less power behind a two-wheel drive system compared to a four-wheel drive system.

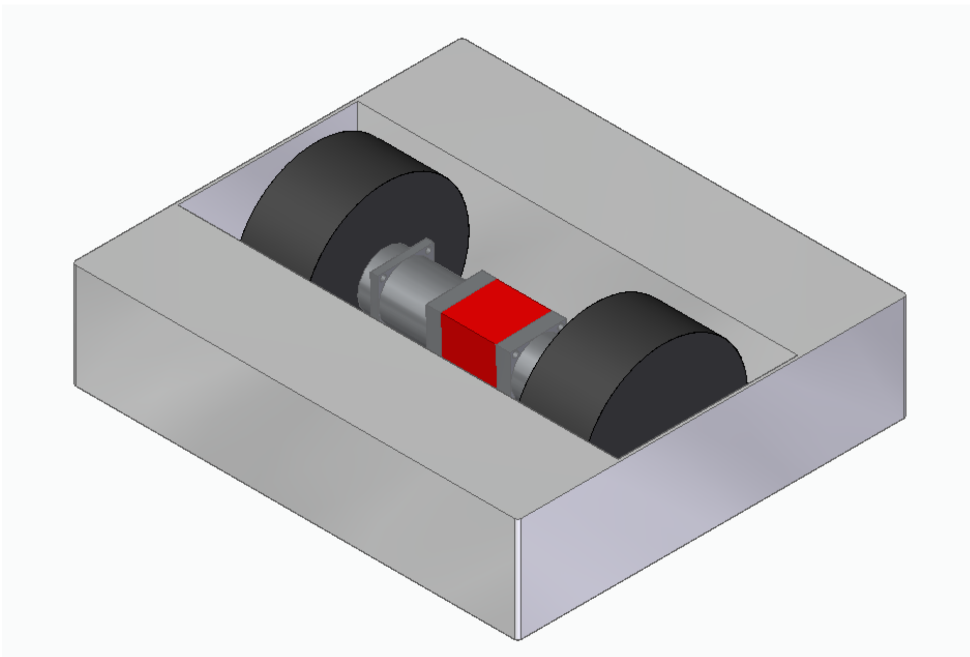
Concept 2: Four-Wheel Design



Four-Wheel Design

Concept 2 is a four-wheel design and incorporates a motor for each wheel to obtain more power. As illustrated, there is a planetary gearbox that is attached to each wheel and a red housing for the brushless motor to be enclosed. This design reduces the amount of space that we will be able to have inside the frame for features such as weapon motors and electronics. The flaws with this design are also like concept 1 and the wheels are the weak points and could cause potential movement stoppage and the potential to have the wheels knock off or jam up. Overall, this concept would cost more due to the increase in wheels and motors, The weight would be increased also and would be a challenge to limit under the 15 lb. requirement.

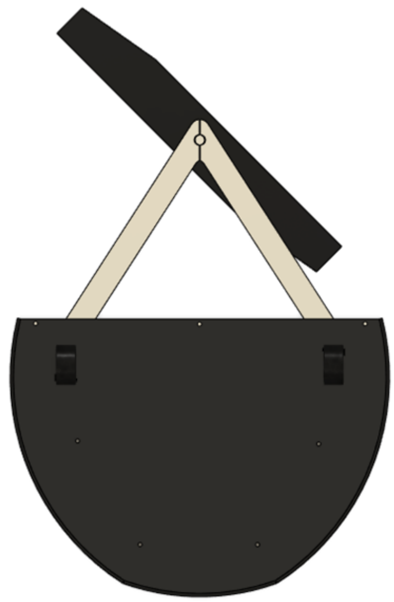
Concept 3: Two-Wheel Inside

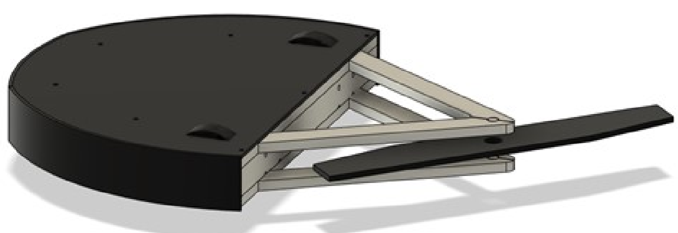


Two-Wheel Inside

Concept 3 is a two-wheel design but differs from concept 1 because the wheels are inside the unit and not exposed. As illustrated, there is a planetary gearbox that is attached to each wheel and a red housing for the brushless motor to be enclosed. This reduces the problem of having the wheel break off or jam due to impact during combat. The downside to this design is that the space reduction for the weapon motor and other electronics due to the wheels being inside the frame. This would overall be the best design though because the chances of our movement being stopped through combat decreases, and we would maintain a low cost and weight due to the reduction of motors and wheels compared to a four-wheel design.

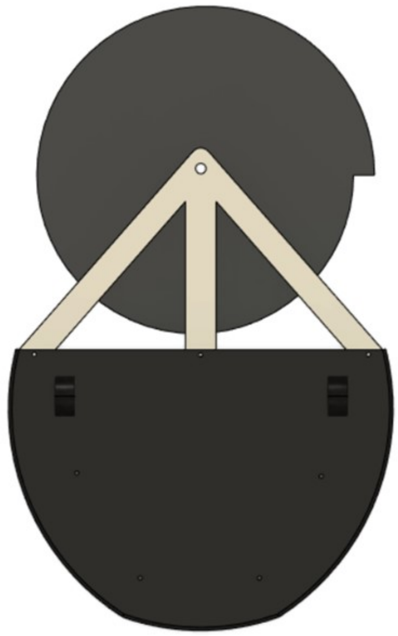
Final Design Concepts
Concept 1: Lawnmower Blade

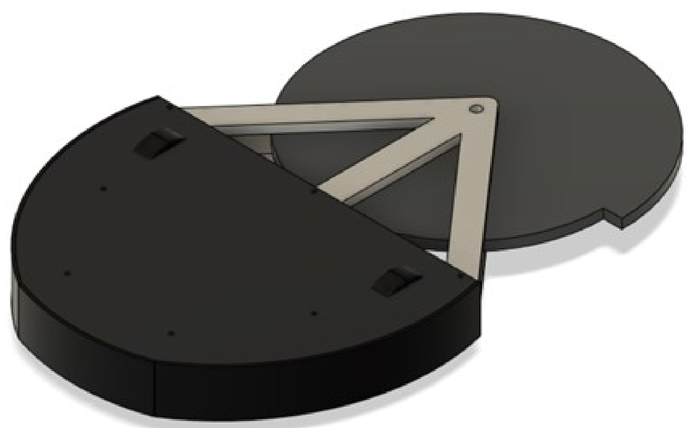




The lawnmower blade design combines a two-wheel drive system with a plug-and-play lawnmower blade as its weapon. Using a lawnmower blade allows for a cheaper overall design by eliminating the weapon fabrication and also promotes modularity since mower blades are designed to be swapped out. A lawnmower blade also has inherent material characteristics and heat treating which make it an ideal weapon choice. The frame/armor design aims to be more defensive than offensive while maintaining the thinnest possible profile to help achieve invertibility. The mower blade used in this design could bend upwards or downwards during a match which could potentially cut the belt that drives it, rendering our battlebot useless. Another issue with this concept is that the lawnmower blade is very hard to modify. Due to its hardness, it would be extremely difficult to drill and/or machine the mower blade if we needed to.

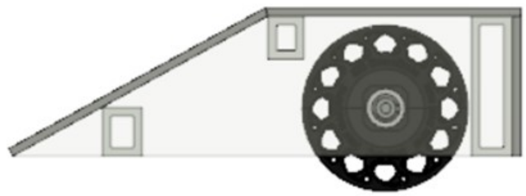
Concept 2: Circular Spinner

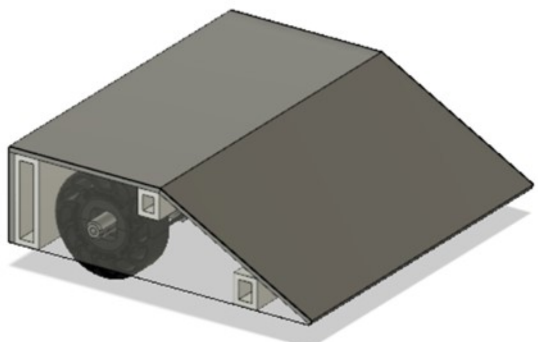




The circular spinner design uses the frame as the lawnmower blade concept to achieve a thin, defensive build which allows for invertibility. The weapon used in this concept would be of a circular disc shape with a single cutting edge. The weapon in this case would be heavier, adding more inertia to strike harder blows. Having only one cutting edge helps give the weapon time to spin up for nearly full 360° without any impedances which. This would help guarantee that all blows are struck with the maximum possible spinner speed and with the maximum amount of inertia behind each hit. Due to its lack of symmetry, the circular spinner is very hard to manufacture. It is difficult to identify the weapon's center of gravity and machine the spinner to be perfectly balanced about that center of gravity. Because this weapon is heavier than the lawnmower blade, this design would have a longer weapon spin up time and stopping time.

Concept 3: Wedge Bot





The wedge bot design is very simplistic as it simply consists of a ramp with wheels. This concept would be best for racking up points by tanking hits with minimal damage. This design also has the ability to flip opponents, which is very effective against battlebots with no form of self-righting. The wedge bot design would be the cheapest concept to produce. It can be difficult to design a wedge bot with self-righting capabilities. Also, without the ability to actually “strike blows” against opponents, this design has very limited offensive capabilities. It is extremely uncommon for wedge bots to make it very far in competitions.

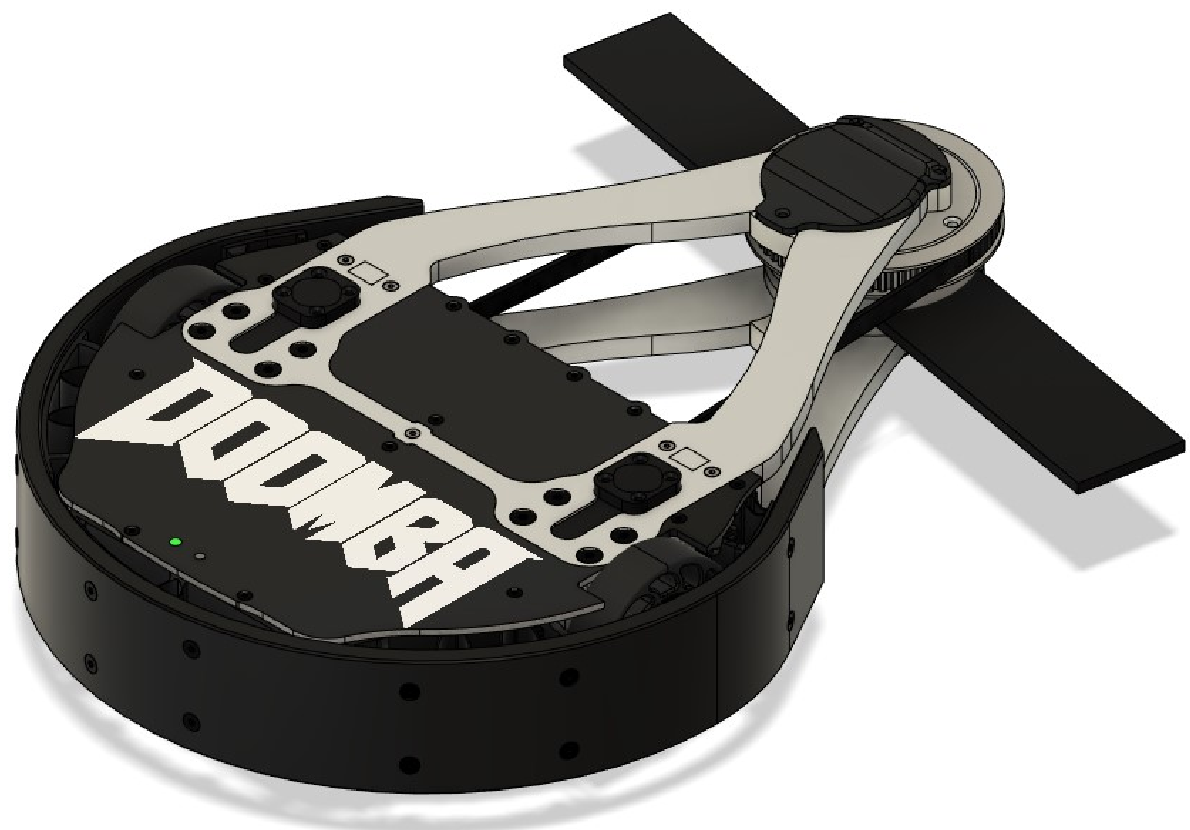
Final Concept Weighted Matrix

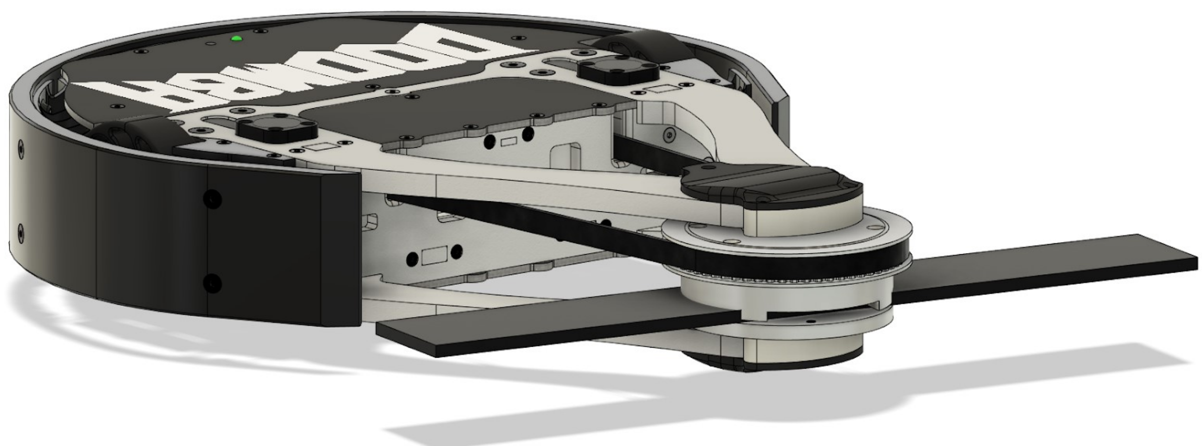
BattleBot Concept Selection							
TABLE-Weighted Rating Method							
				BattleBot Concepts			
		Lawnmower Blade		Circular Spinner		Wedge	
Criteria	Importance Weight (%)	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Weight	25	3	0.75	2	0.5	4	1
Manufacturability	10	4	0.4	2	0.2	4	0.4
Invertibility	20	4	0.8	4	0.8	0	0
Weapon Modularity	10	4	0.4	3	0.3	4	0.4
Maneuverability	5	3	0.15	3	0.15	4	0.2
Offensive Capabilities	10	4	0.4	4	0.4	1	0.1
Defensive Capabilities	10	3	0.3	3	0.3	4	0.4
Cost	10	3	0.3	2	0.2	4	0.4
	100	NA	3.5	NA	2.85	NA	2.9
Rating					Value		
Unsatisfactory					0		
Just tolerable					1		
Adequate					2		
Good					3		
Very Good					4		

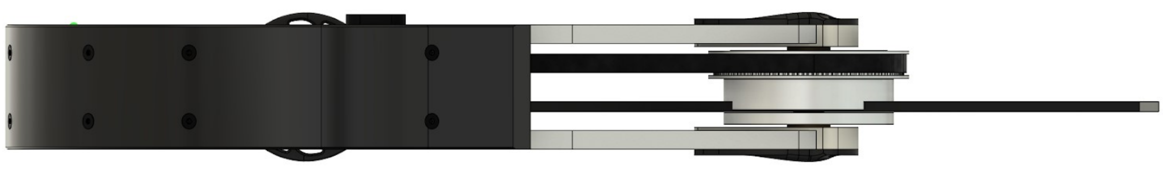
Based off our survey results in Senior Design I, we were able to determine customer features that needed to be met in our design process. Maintaining the 6.8 kg weight limit was the most important factor so, our team provided that with the highest importance weight. Similar results were observed when comparing the lawnmower blade to the circular spinner. The lawnmower blade was found to be the best design alternative because it would be more lightweight, cost effective, and allows for modularity in our design

Final Design

DOOMBA



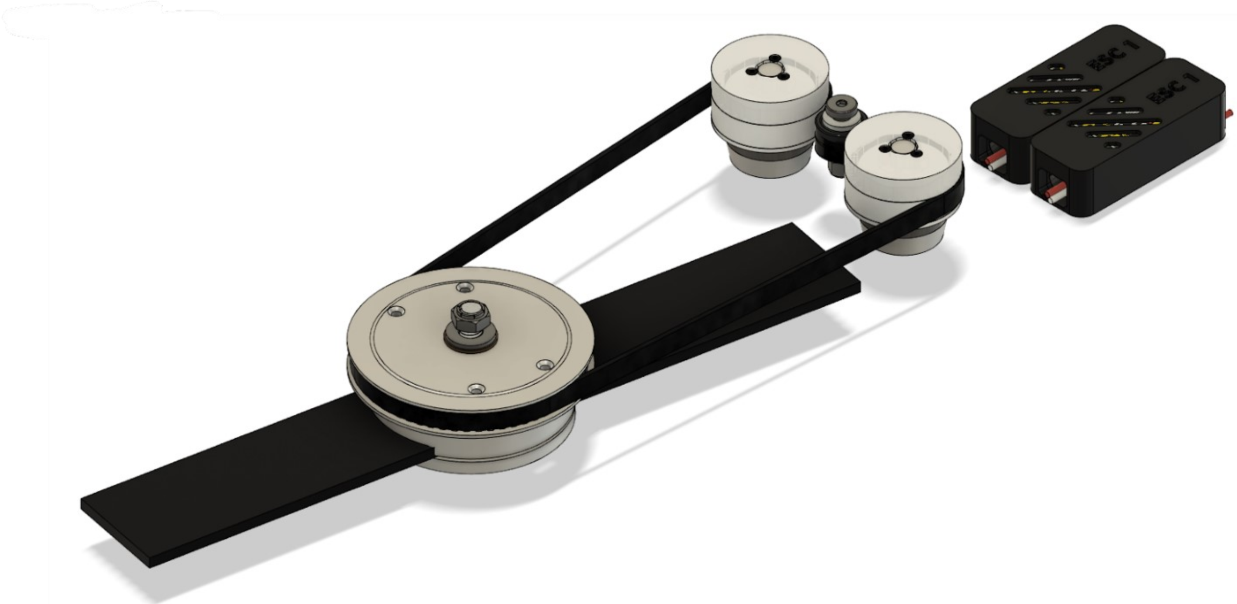




Component Selection

Weapon

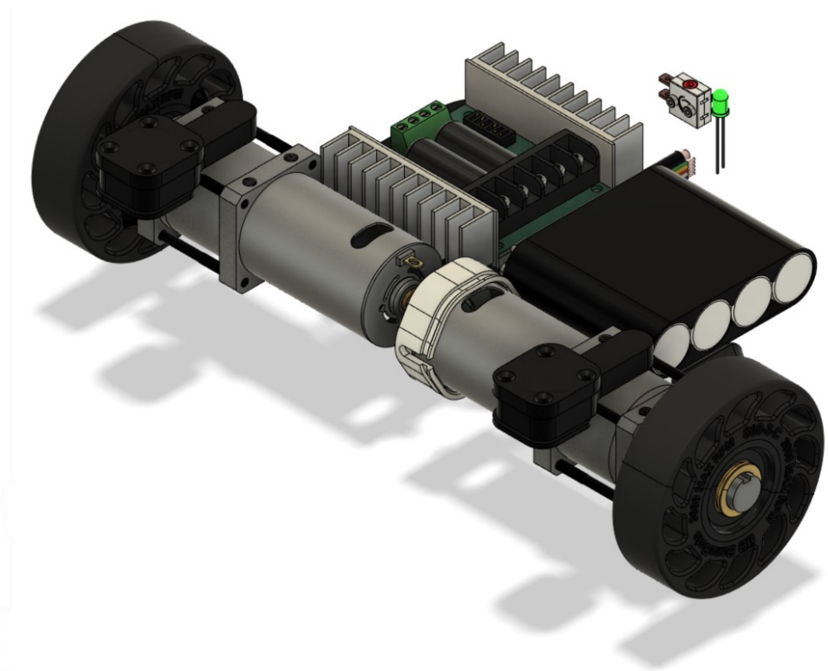
Our team will use an off-the-shelf 13-7/8” Oregon lawnmower blade as our weapon. This will allow for modularity in our design while ensuring a durable weapon which can strike devastating blows to our opponents. The mower blade will be driven by two brushless motors and an XL timing belt. At 14.8V, our 1000kv brushless weapon motors will run at 14,800rpm. This is rpm is too high for our lawnmower blade, so the motors will be fitted with 28-tooth sprockets and the mower blade assembly will be equipped with a 60-tooth sprocket, which will create a gear reduction of 0.466. At this reduction, our lawnmower blade will spin at 6,907rpm with a tip speed of 285mph. Motor sprockets will be 3D printed using nylon, and the weapon assembly sprocket will be an off the shelf part.



Weapon System

Drive Train

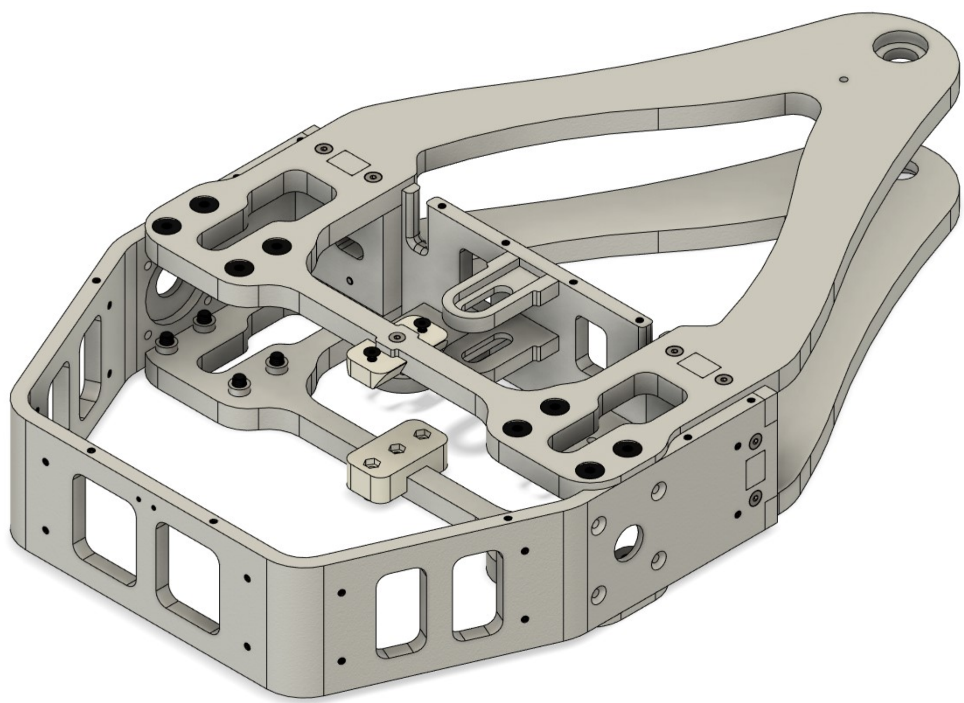
Our design will utilize a two-wheel drive system featuring 2 drive motors each equipped with a 26:1 gearbox. Using a two-wheel drive system allows us to cut down on weight and stick to a more compact design. For a 3rd point of contact, nylon riders will be attached to both ends of the weapon shaft assembly. This is the same type of configuration that is seen on the infamous Tombstone as seen on Discovery's BattleBots.



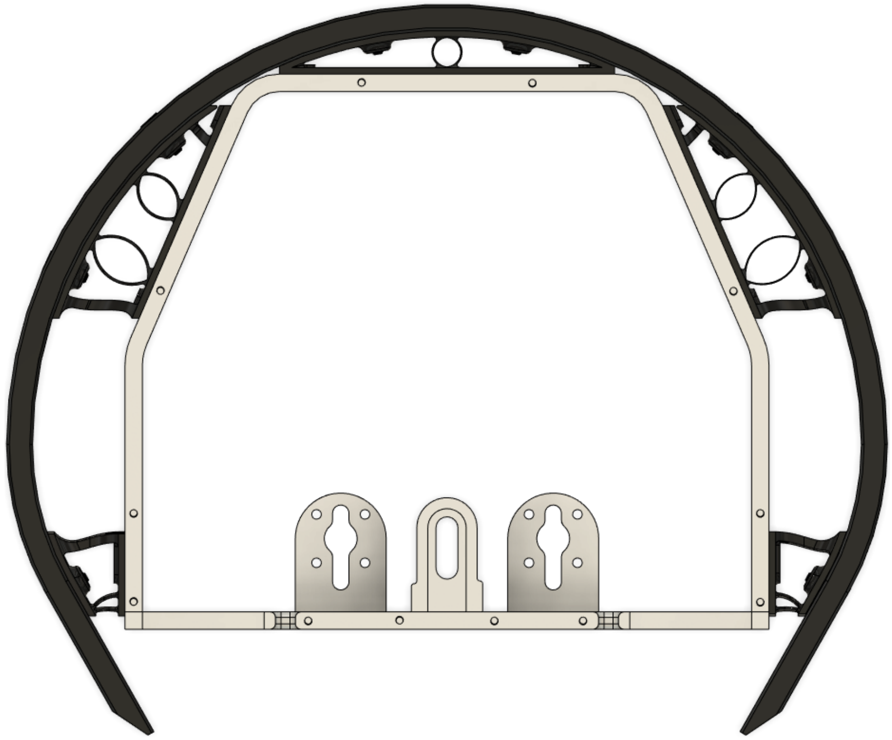
Drive Train

Frame/Armor

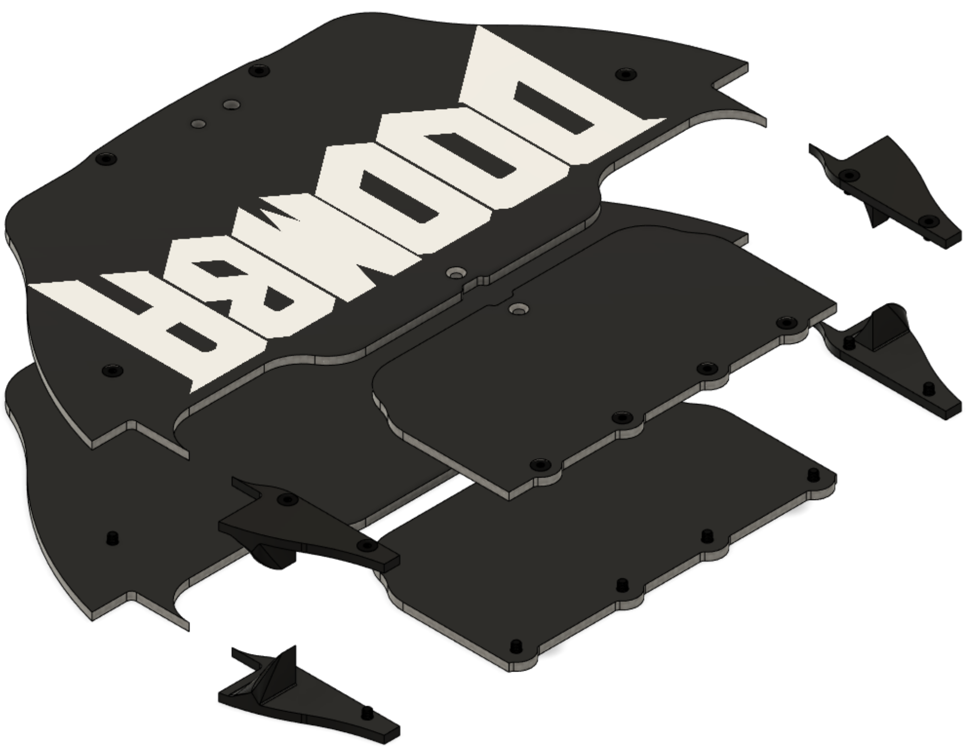
The frame of our battlebot will be comprised of 1/4" thick aluminum for the inner frame and 3/8" thick aluminum for the weapon support bars. 3D printed shocks will be mounted around the perimeter of the 1/4" aluminum frame to absorb impacts from opposing bots. A 3/8" thick UHMW band will be wrapped around the 3D printed shock absorbers and frame to create a sturdy, hard layer of defense. This UHMW hard layer combined with a 3D printed shock layer will protect the frame and inner components of the battlebot.



BattleBot Frame



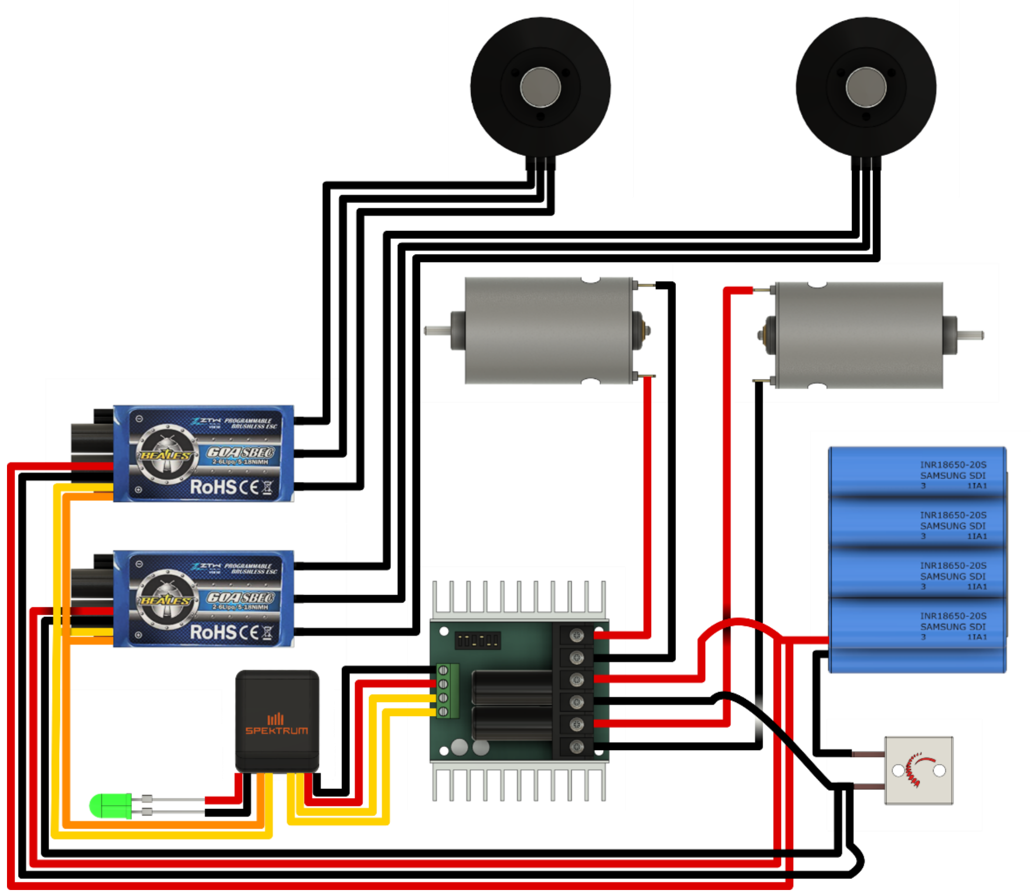
Rear Frame with Attached Armor



Garolite Top and Bottom Covers

Electronics

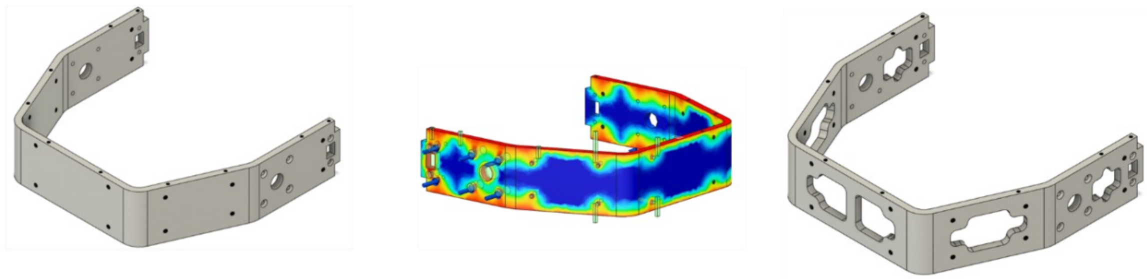
The weapon system for our battlebot will consist of 2 brushless weapon motors each equipped with its own ESC. Our battlebot's drive train system will consist of two drive motors which both plug into a single ESC. Aside from the weapon and drive train systems, our battlebot will also include a receiver, a battery pack, and a power switch and an LED light per XtremeBOTS rules and regulations.



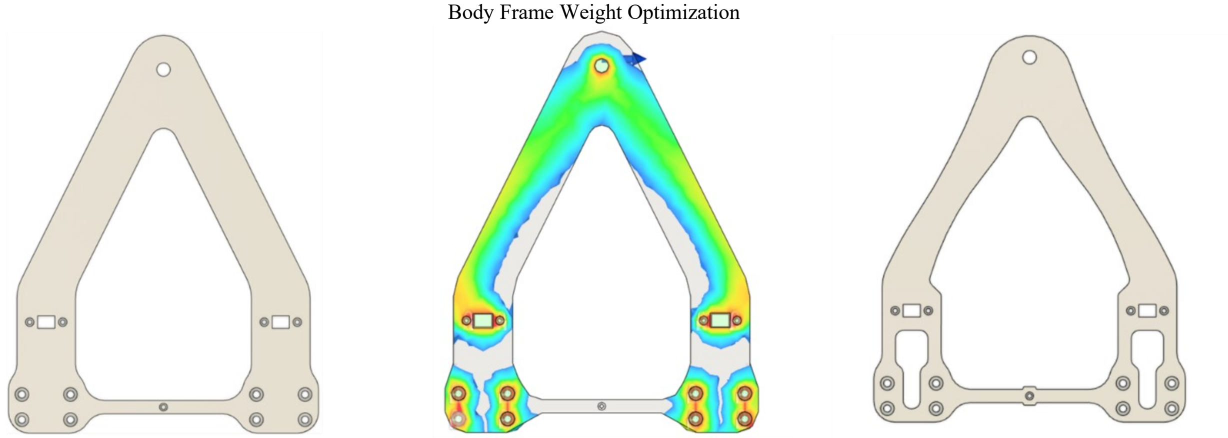
Wire Schematic

Weight Optimization

The first iteration of our battlebot design was found to be over the 15lb limit. To address this, an optimization study was ran on our aluminum frame components to see where material could be removed. Specifically, the optimization study simulated a force applied to our frame component and then identified high and low stress areas. This allowed our team to remove material from the low stress areas for weight reduction. Additionally, material was removed from the aluminum weapon shaft to help bring down the overall weight of the bot. After weight optimization, our team was able to bring the weight of our build down from 17.16lbs to 14.41lbs, a total improvement of 19.1%.



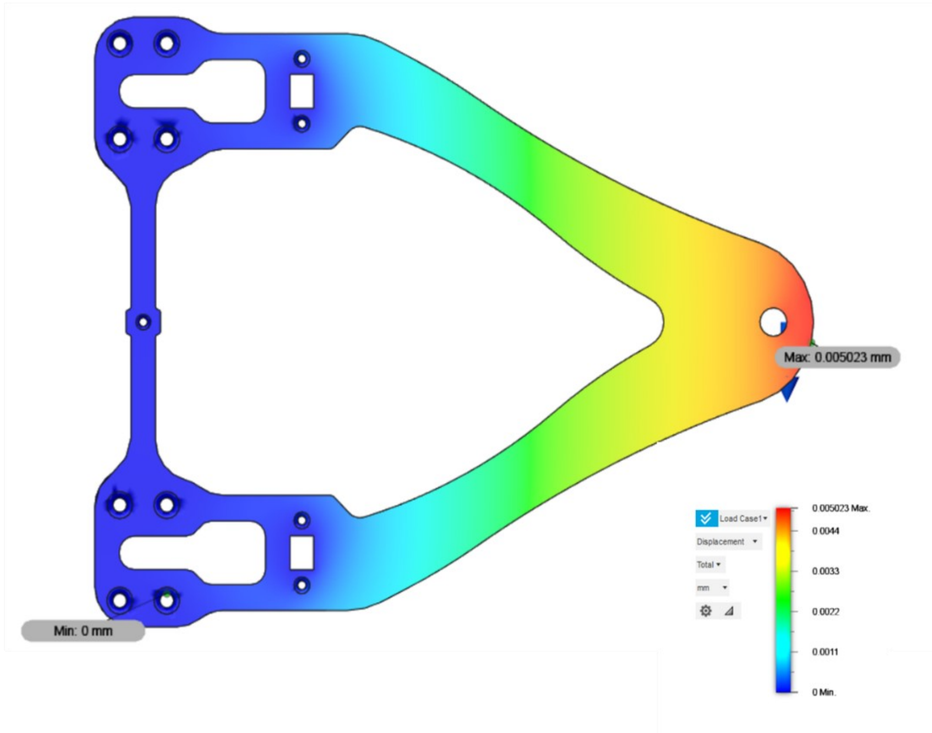
Body Frame Weight Optimization



Weapon Bar Weight Optimization

Stress Analysis and Safety Factor

An area of concern in our battlebot design is deformation in the aluminum weapon bar. Due to its long, cantilever design, it may bend or deform under heavy loads. Because it is made of 3/8” thick aluminum, the weapon bar is unlikely to yield or break during competition, but deformation for any amount of time could cause our weapon shaft to temporarily or permanently seize. To identify the risk of having our weapon seize, our team conducted a load study in Fusion 360. Functional failure via weapon seizing would occur at 1mm of deformation. Our team found that under a 900N load, maximum deformation would be 0.0052mm. This gives us a factor of safety >190 for weapon seizing functional failure.



Weapon Bar Deformation of 0.0052mm under 900N Load

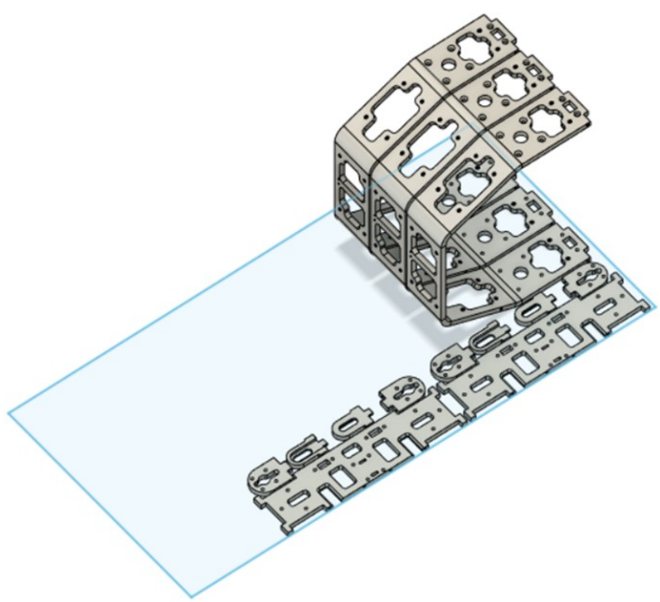
The primary area of concern for our battlebot design in terms of functional failure is lawnmower blade deflection causing our belt to snap. If our lawnmower blade experiences a force in an upward direction, it may deflect enough to run into and snap the belt which drives the weapon. This would render our weapon entirely useless and we would likely have to forfeit the match or watch our bot be destroyed by the opponent. In our case, functional failure via belt snapping would occur at 12mm of vertical blade deflection. Using a load study on the lawnmower blade, our team found a maximum deflection of 5.66mm under a 450N load. This corresponds to a safety factor of 2.12 for functional failure due to belt snapping by the lawnmower blade. Because 2.12 is not a very high safety factor, our team is going to look into moving the mower blade further from the belt and/or adding armor around the belt.

Lawnmower Blade Deflection of 5.66mm under 450N Load

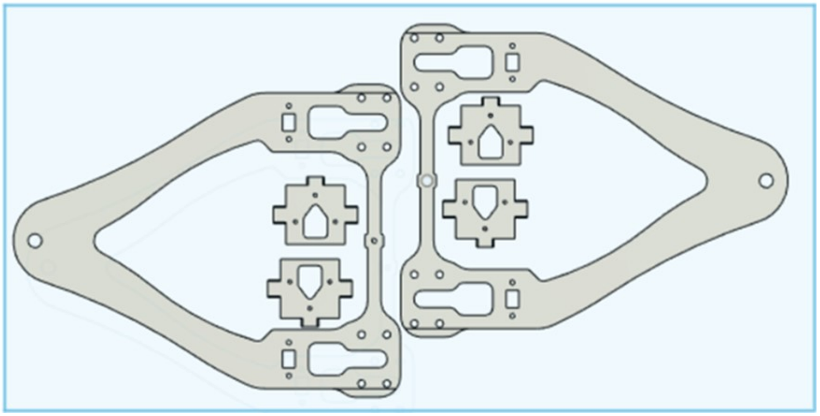
Fabrication

Planning

The aluminum frame components of our battlebot design consist of complex geometries due to material savings through weight optimization. Because of this, our aluminum components will need to be waterjet cut. Post machining will take place to add the necessary threads, countersinks, slots, and edge breaks. The UHMW band will be received as a 3'x2" sheet and bent to shape using a mold and an oven.



Aluminum Frame Layout for Waterjet Cutting



Aluminum Weapon Bar Layout for Waterjet Cutting

The weapon shaft consists of a lawnmower blade sandwiched between two halves of a thick aluminum billet. The aluminum billet will be turned on a lathe to the required 3" outer diameter and drilled and reamed using the tailstock to add the 5/8" thru hole for the bushing. A mill will be used to cut holes for fasteners.

Our team created a fabrication schedule/plan which lists each task along with the estimated time required to compete said task. Based on the experiences of past battlebot teams, we budgeted a very generous amount of time for each task. Each of our team members will be responsible for several of the required fabrication tasks with the expectation that we will each be working on different tasks simultaneously. A color code will be used to show whether tasks are in progress, completed, or not started. In the case of tasks not started, color will be used to denote what section of the battlebot the task is related to. The color coding should help the team identify tasks which should be done in sequence with each other, or tasks which can be completed at the same time. The fabrication schedule/plan is designed to help our team stay as efficient and focused as possible during the fabrication process.

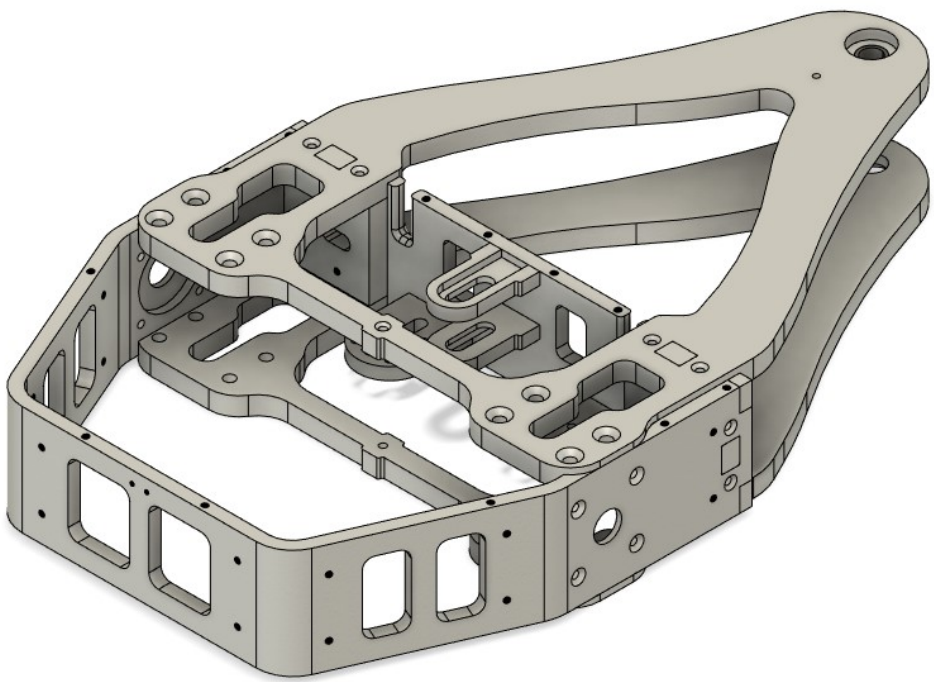
		Worker														
		1					2					3				
		Process	Component	Tools	Page	Est. Time	Process	Component	Tools	Page	Est. Time	Process	Component	Tools	Page	Est. Time
stage	1	Drill/Tap	Rear Bar	M3 tap, 2.5mm bit; M2 Tap, 1.6mm Bit	3	2 hours	Mill Slot	Top Slider/ Bottom Slider	CNC Mill	5	1 Hour	Chamfer	Front Bar	90°	4	1 hour
	2	Chamfer; Pocket	Rear Bar	CNC mill; 90°; 82°	3	2 hours	Cutting/Drilling	Armor Panel	4.3mm Bit	9	3 hour	Drill/Tap	Block	M3 tap, 2.5mm bit	7	2 hours
	3	Drill/Tap	Weapon Motor Mount	M3 tap, 2.5mm bit	6	1 hour	Chamfer	Top/Bottom Sheet	90°	none	1 hour	Pocket/ Recess mill	Weapon Bar	CNC Mill	8	1 hours
	4	Bend	Rear Bar	bending tooling	1	1 hour	Drill/Tap	Top Slider/ Bottom Slider	M3 tap, 2.5mm bit	5	1 hour	Chamfer	Weapon Bar	90°	8	1 hours
	5	Drill/Tap	Rear Bar/ Front Bar	M3 tap, 2.5mm bit	2,4	1 hour	Chamfer	Armor Panel	90°	9	2 hours	Machine	Weapon Shaft	CNC Mill	none	2 hours

Preliminary Fabrication Schedule/Plan

To go along with the fabrication schedule/plan, our team also created the "Doomba Guide" which serves as an instruction manual of how to machine/manufacture individual components. The Doomba Guide includes CAD drawings of all of the frame, armor, and weapon components. The Doomba Guide, along with a larger image of the fabrication schedule/plan, can be found in the appendix section of this report.

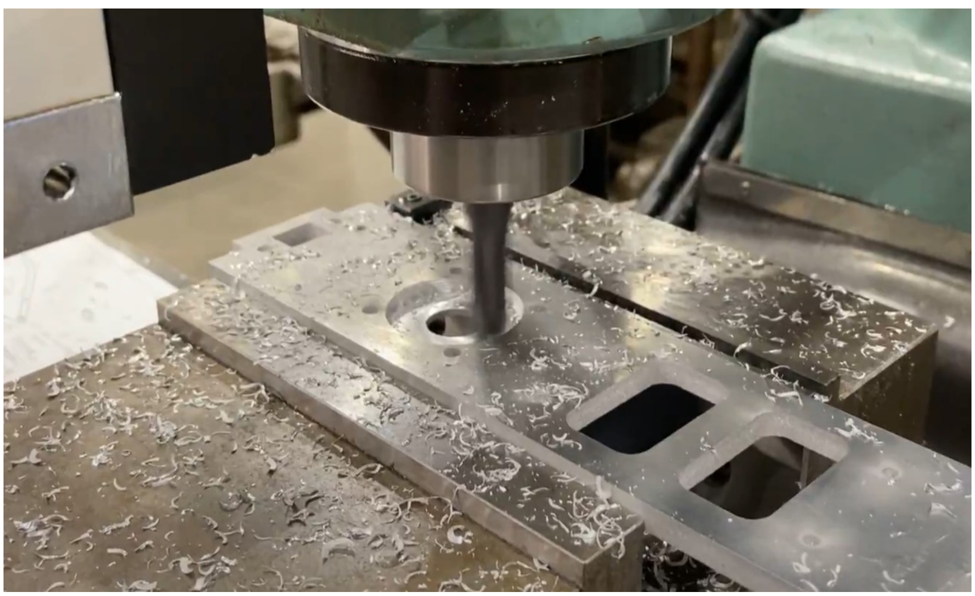
Frame

As soon as waterjet cut parts were received, our team began the fabrication process using our preliminary fabrication schedule/plan and the Doomba Guide. We started work on the frame because it is quite literally the backbone of our battlebot. Fabrication on the frame included milling pockets, milling slots, chamfering holes, threading holes, breaking edges, and bending the rear bar into shape. Most of this was accomplished using the regular lathes, mills, and drill presses found at UC's Victory Parkway campus. The only challenging and/or unusual fabrication step with regards to the frame was bending the rear bar into shape. To do this, we made tooling to bend the aluminum bar around our desired radii. The tooling allowed us to essentially press a cylindrical shape into our aluminum bar, supported on the outer edges by a vise, such that the aluminum bar wraps around the tool as it is pressed. During the process, the aluminum was bent to the specific radii and angles specified in the Doomba Guide.



3D Model of Battlebot Frame

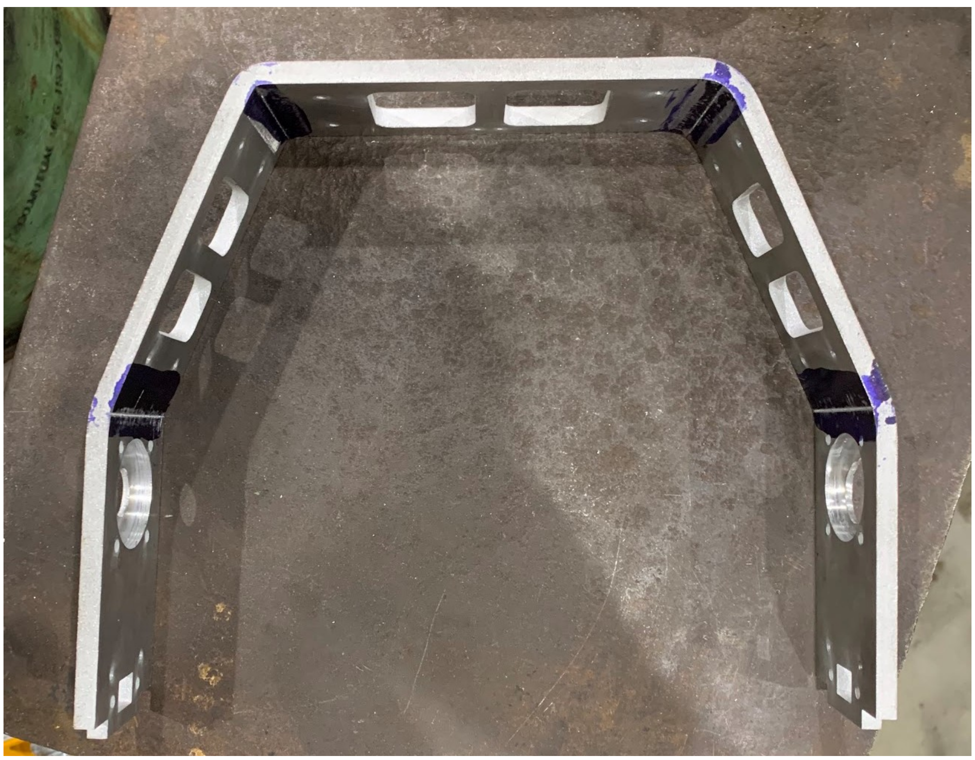
Frame and Tensioner Components Received After Being Waterjet Cut


Milling a Pocket to House the Drive Train Gearbox in the Rear Bar of the Battlebot Frame

Tapping Threads in the Rear Bar of the Battlebot Frame

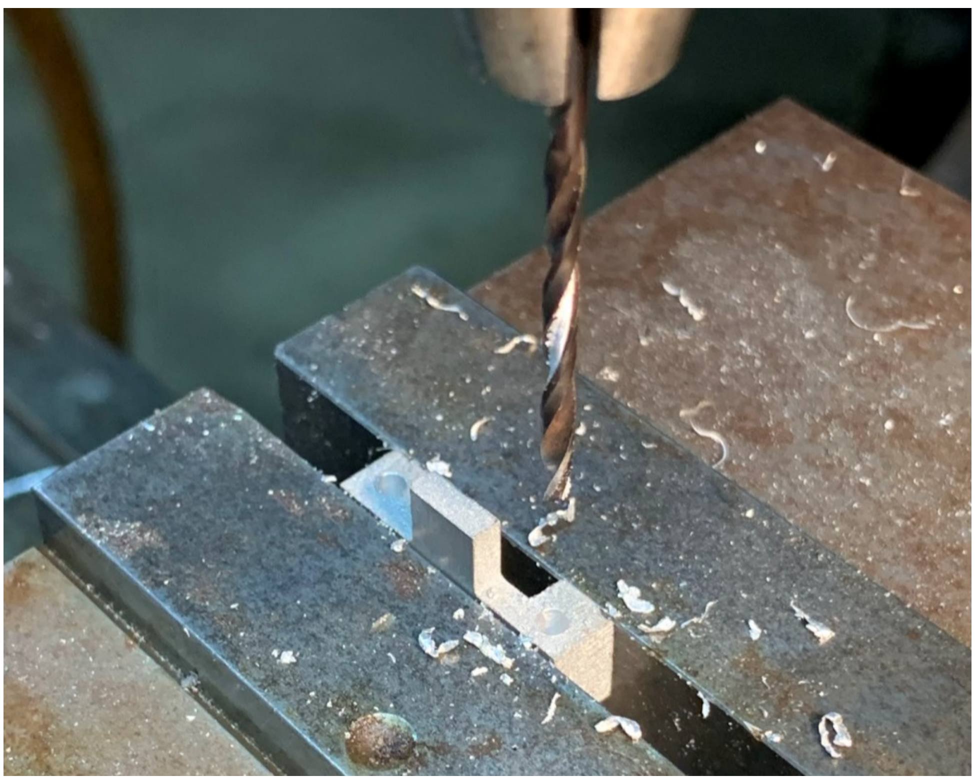

Using Our Custom-Made Tooling on an Arbor Press to Bend the Battlebot Frame into Shape

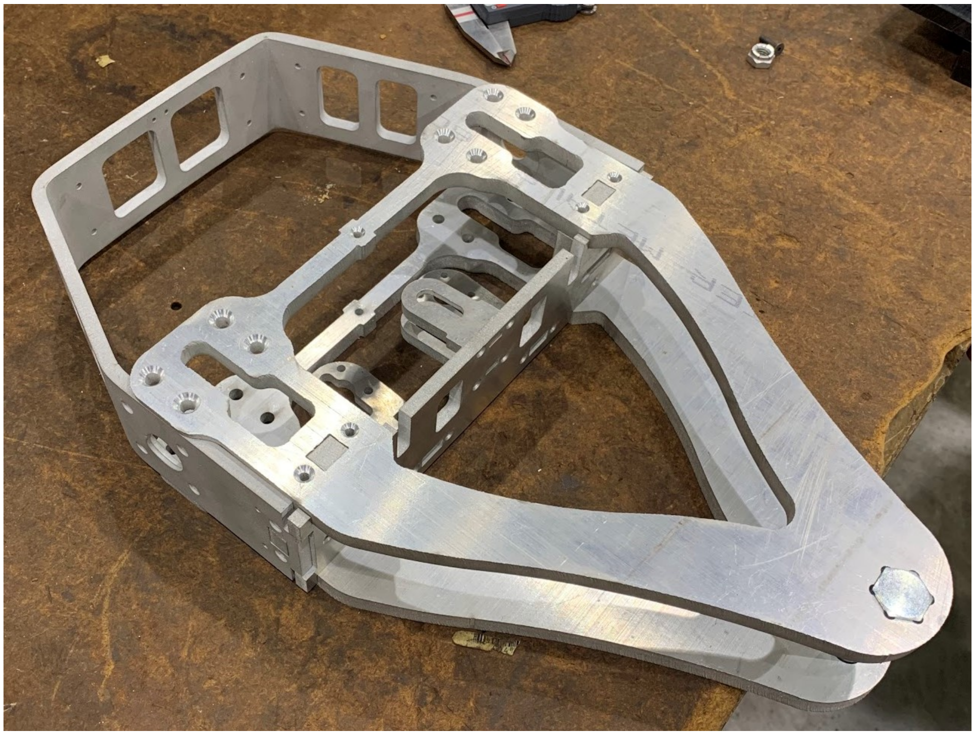
Using a 3D Printed Tool to Check Rear Frame Bend Angle



Battlebot Frame Rear Bar after Bending Process


Milling Slots for the Weapon Belt Tensioner


Drilling Holes in Weapon Belt Tensioner



Fully Assembled Battlebot Frame

Armor

Making the UHMW armor band was also a more unusual fabrication process. To make the UHMW band, our 3’x2” UHMW sheets had to be drilled, chamfered, and formed to our desired geometry The drilling and chamfering processes were done using the drill press at UC’s Victory Parkway campus. To bend the UHMW to our desired shape, a mold was made out of laser-cut wood. The mold consisted of an outer section and an inner section with the UHWM band clamped between the two. To shape the UHMW, it was placed in an oven at 270°F in order to soften the material. The softened UHMW was taken out of the oven and quickly transferred into the mold. The mold was clamped tightly together, and as the UHMW cooled inside, it retained the mold’s shape. This resulted in a UHMW band formed to our battlebot’s design geometry.

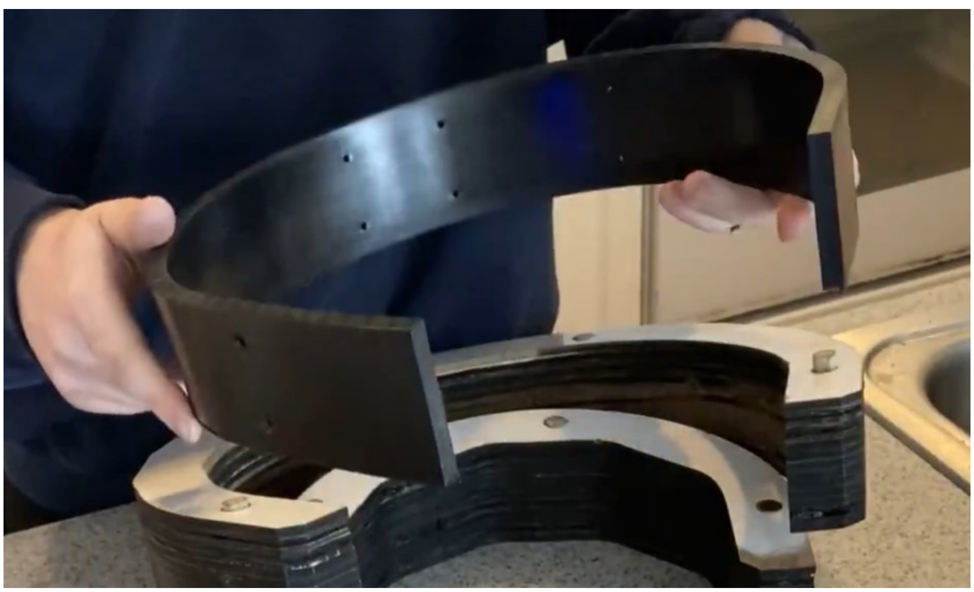
3D Model of UHMW Mold

3D Model of UHMW Mold

Placing the Hot UHMW Band into the Mold

UHMW Band in the Mold

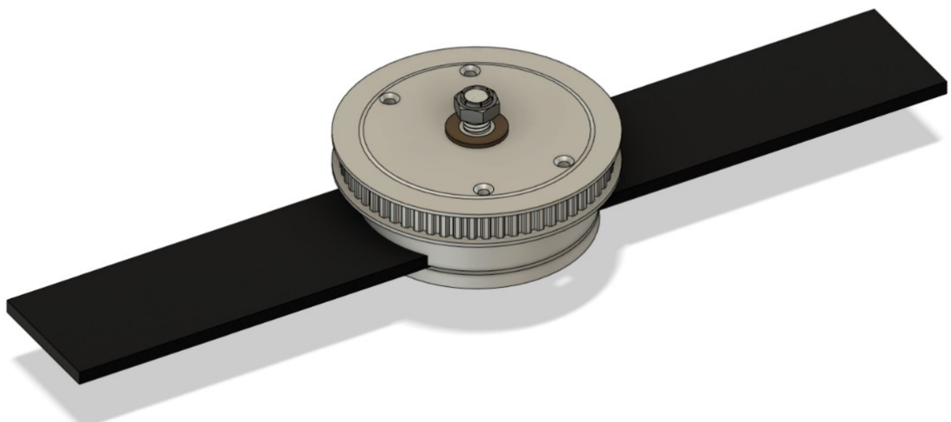
Removing the UHMW Band from the Mold



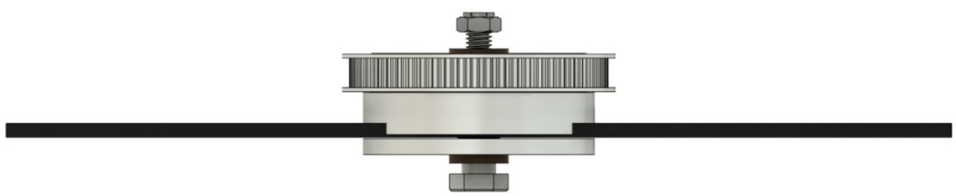
Finished UHMW Armor Band

Weapon

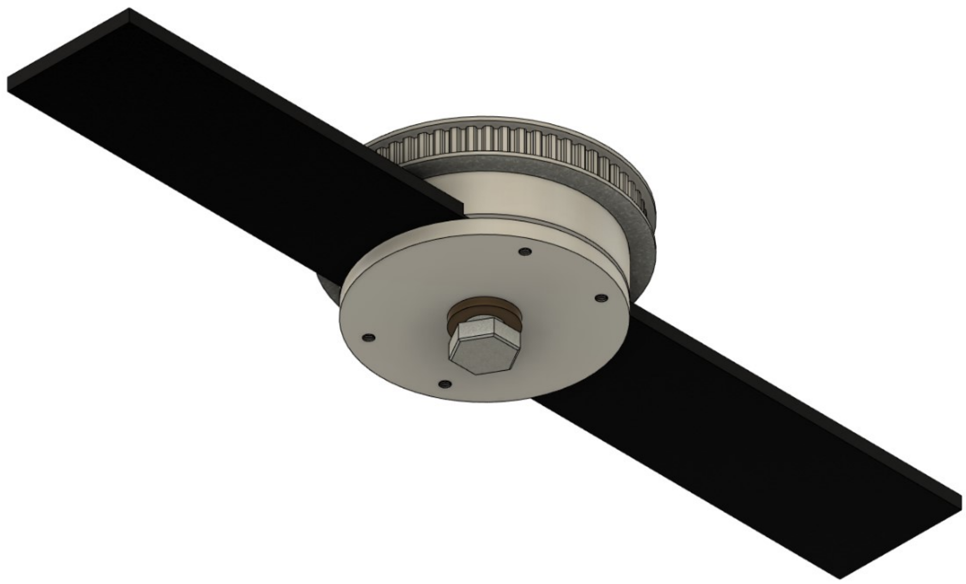
After completing the frame and armor components of the battlebot, our team began fabrication on the weapon systems. Specifically, the weapon "stack" assembly consisting of a sprocket and a lawnmower blade sandwiched between two sections of an aluminum billet. The weapon stack assembly was completed with the use of a lathe and ProtoTRAK® mill at UC's Victory Parkway Campus. There were no challenging or unusual processes used during the weapon stack fabrication.



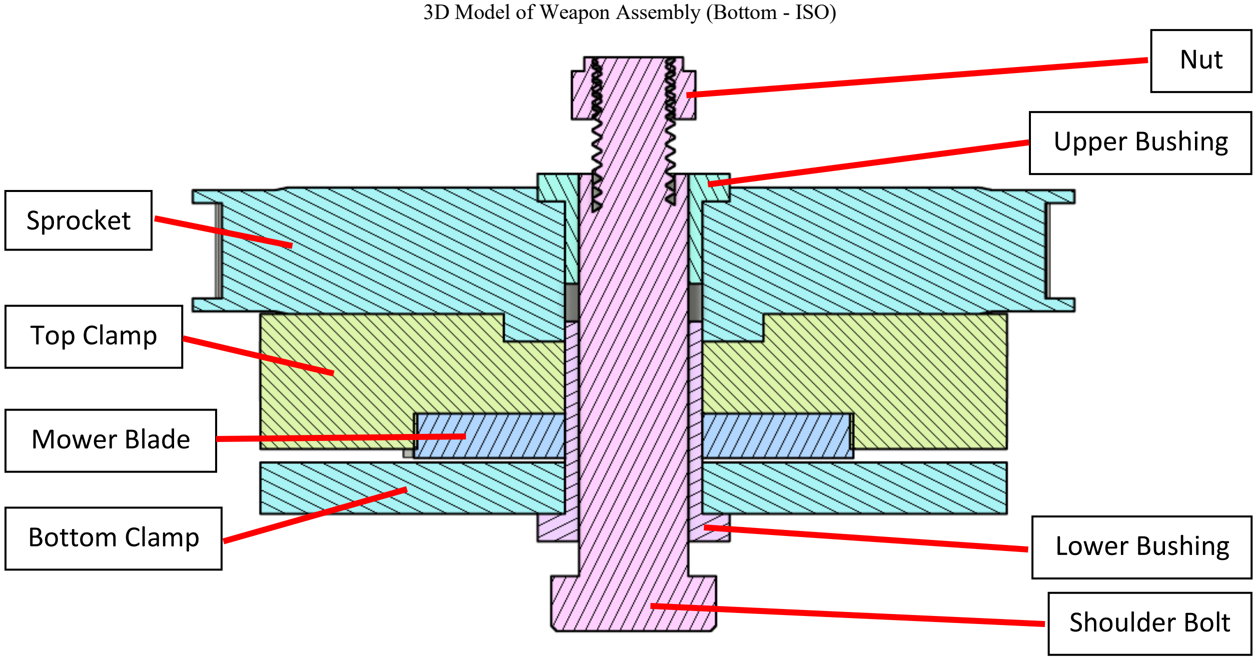
3D Model of Weapon Assembly (Top - ISO)



3D Model of Weapon Assembly (Front)

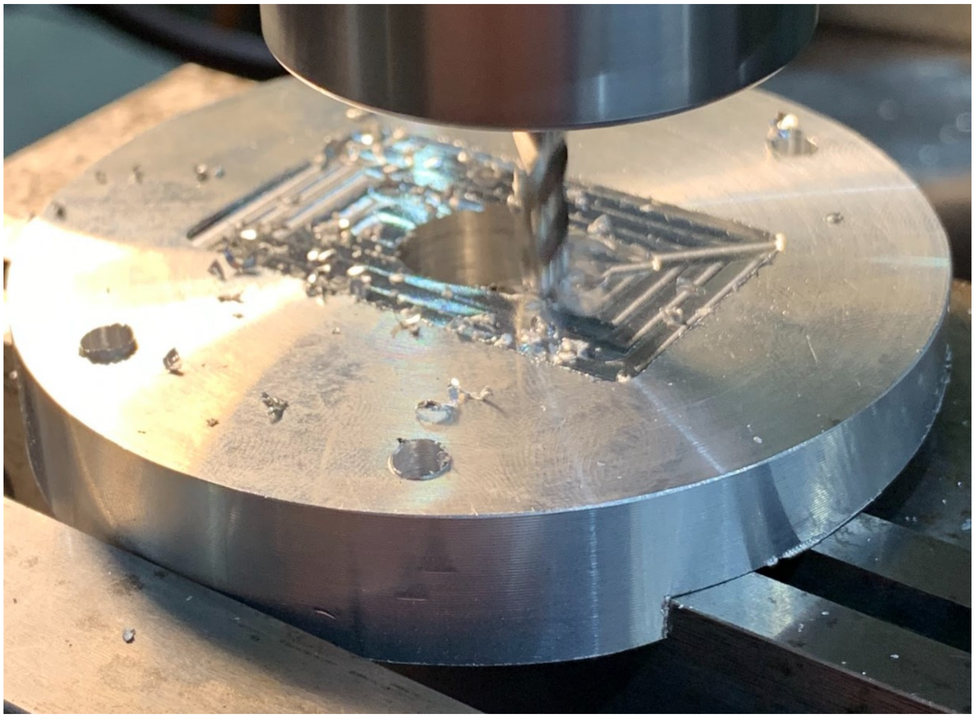


3D Model of Weapon Assembly (Bottom - ISO)



Cross-Section of Weapon Assembly

Turning Aluminum in Lathe for Lower Clamp of Weapon Assembly

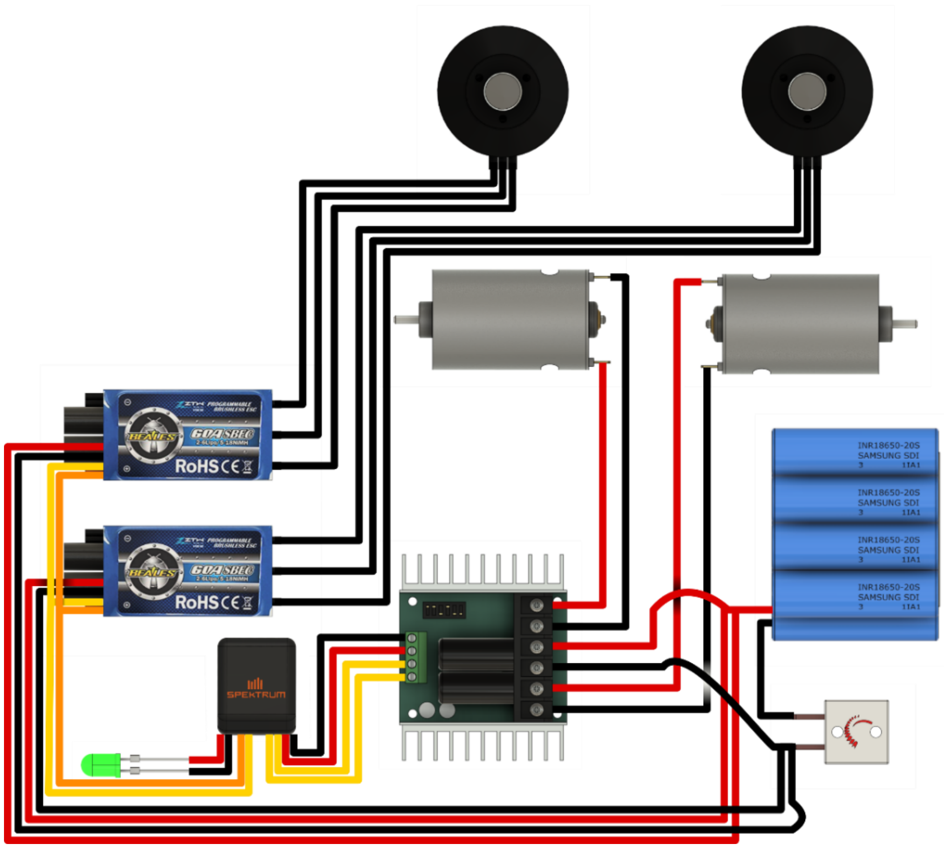


Milling Rectangular Fitment for Sprocket Top Clamp Interface

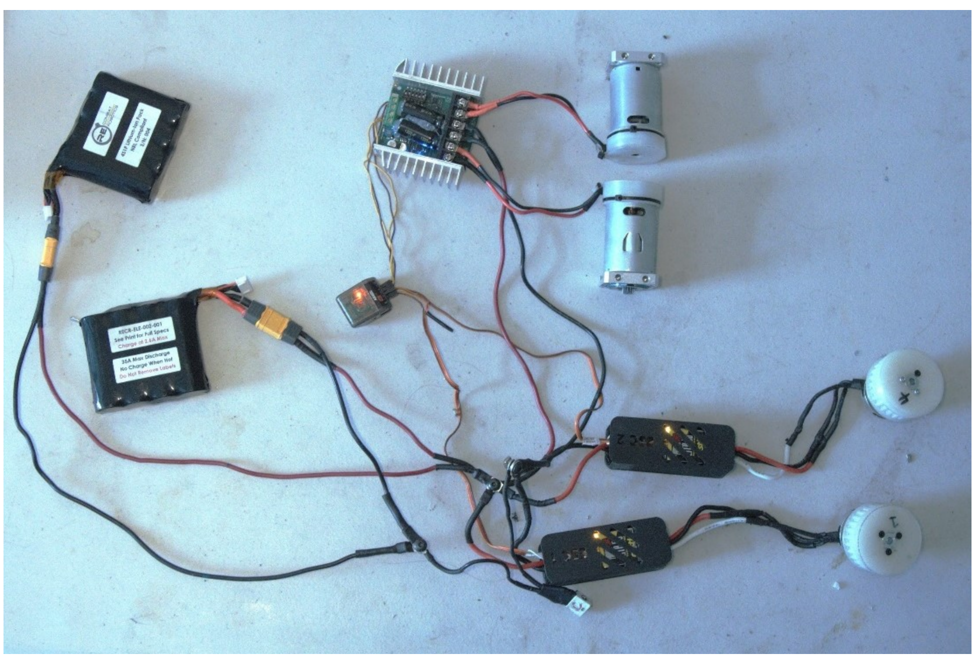
Completed Weapon Assembly

Electronics

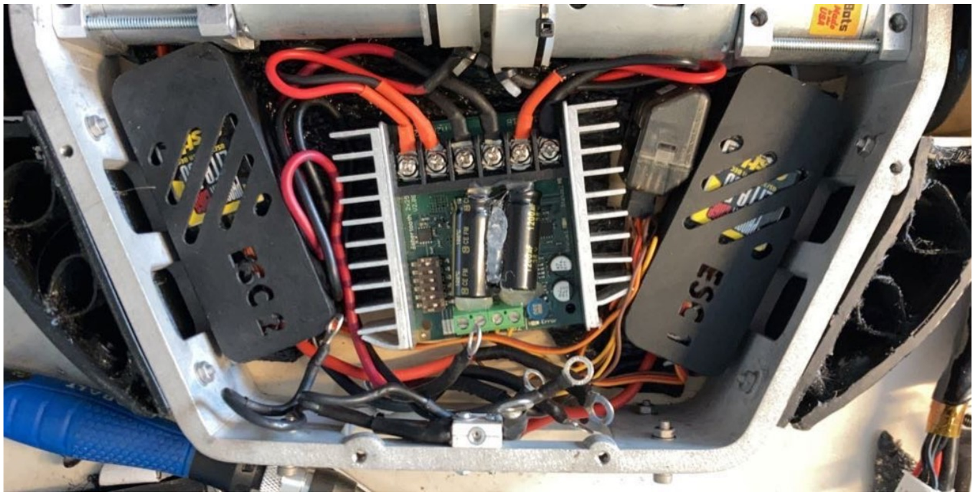
With the frame, armor, and weapon fabrication complete, our team began work on the internal components of the battlebot. This mostly consisted of cutting and soldering wires to match the wiring schematic we created for our battlebot. Along with wiring/electrical tasks, our team also snipped the shafts of our weapon motors so they could fit inside the frame of the bot, added epoxy to the weapon motor magnets to help keep them from shattering during hits, and cut foam inserts to keep our internal components snug and protected from heavy impacts.



Battlebot Wiring Schematic



Battlebot Electronics and Wiring



Weapon ESC, Drive ESC, and Receiver Configuration


Foam Divider

Battery Packs on Top of Foam Divider

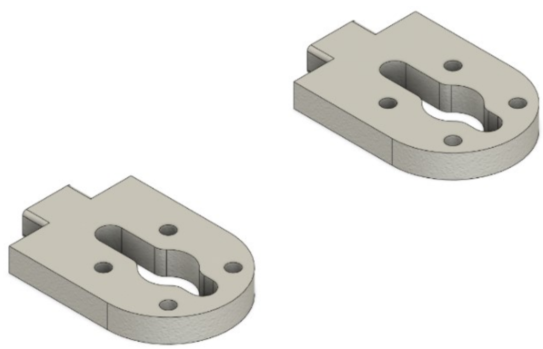
After completion, all our electronic systems were powered and checked for arcing, shorts, overheating, voltage, and current. Our team experienced small issues with sparking/arcing which was easily fixed by adding heat shrink to the affected areas. With our electronics in proper working order, preliminary fabrication of our battlebot was complete.

Modifications

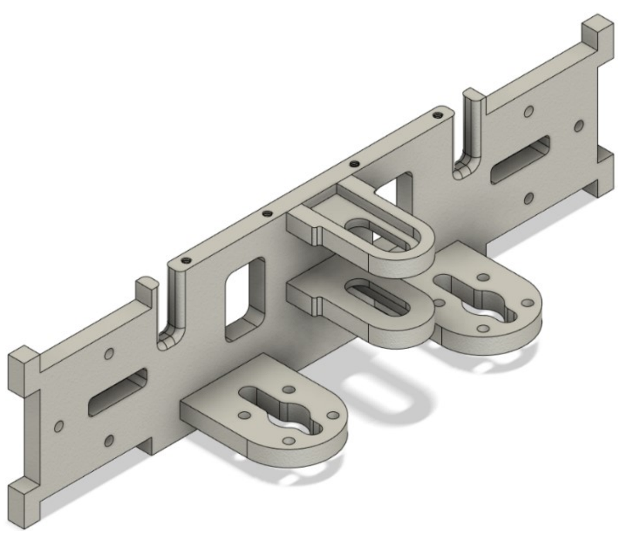
Modifications include any design changes and/or adjustments made to our battlebot during the fabrication and initial testing procedures.

Weapon Motor Mounts

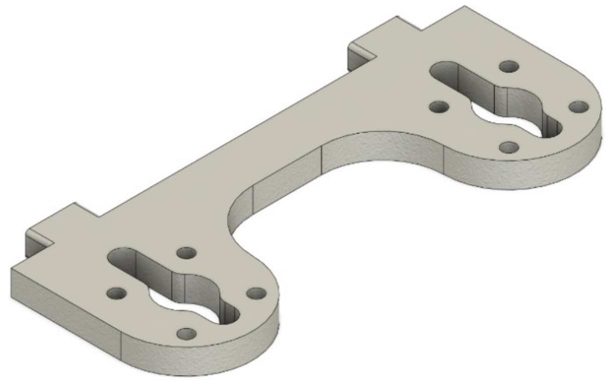
The only modification made to Doomba was the weapon motor mounts. We found that the belt, when under tension, pulled the weapon motors in towards the front plate and the tensioner assembly. When the weapon was activated for the first time, the 3D printed sprockets on the weapon motors rubbed against the front plate of the battlebot. We found the root of this problem to be the weapon motor mounts as they flexed too much when the weapon was active. To address this issue, we redesigned the two individual motor mounts into one larger mounting piece. We also tightened up the clearance where the new motor mount keyed into the front plate. The new single-piece weapon motor mount was much sturdier, and solved flexing issue we were having.



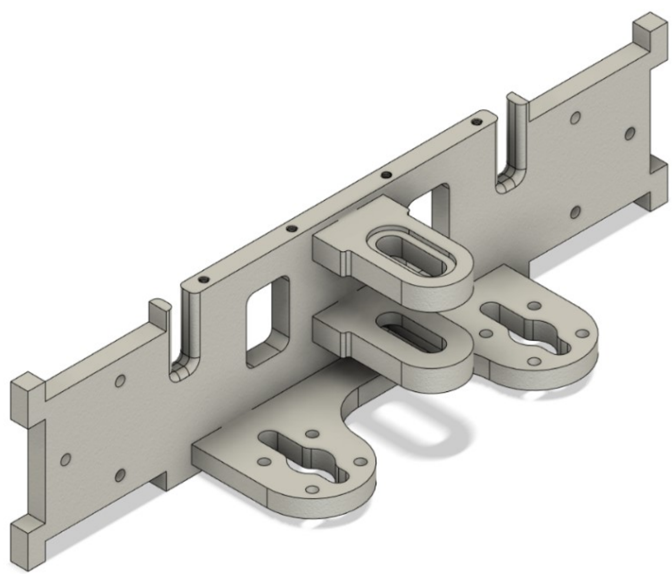
Original 2-Piece Motor Mount Design



Original 2-Piece Motor Mount Design as Assembled



Modified Single-Piece Motor Mount Design



Modified Single-Piece Motor Mount as Assembled

Final Assembly

Having completed all necessary fabrication and modification processes, our team worked to assemble Doomba. The Doomba assembly process breaks down into 8 steps:

1. Assemble the frame

First, we assemble the frame while omitting the belt tensioner. The frame components include the rear bar, front bar, weapon motor mount, the two "puzzle" pieces, and the top and bottom weapon bars. Though the tensioner was fabricated with the rest of the frame components, it is part of the weapon system. Therefore, the tensioner is added to the assembly later on with the rest of the weapon components.

2. Mount shock absorbers

We mount the 3D printed shock absorbers after the frame has been assembled. It is important to complete this step early in the assembly process while the inside of the frame is open and spacious. The inside frame space is needed to fasten nuts onto the bolts used to fasten the shock absorbers.

3. Fasten the bottom plate pieces

The bottom plate pieces are assembled after the shock absorbers and armor band to help simplify the installation of electronic components. The bottom plates will give wires something to rest on when the motors, ESCs, batteries, and receiver get installed. Installing the bottom plates also helps us decipher what side of the bot is the bottom versus the top. Keeping track of the top and bottom of Doomba can be tricky since it is designed symmetric for invertibility.

4. Mount/fasten motors, gearboxes, and wheels

After the frame is assembled and fitted with armor, we install the weapon motors, followed by the drive train gearboxes and motors. We assemble in this order because it is easier for routing the weapon motor wires, which run underneath the drive motors with very minimal clearance. Together, the motors and gearboxes take up the entire front half of the space within Doomba's frame. We attach the wheels during this step, or any following step before attaching the armor band. This is important to remember, because it is impossible to attach the wheels after the UHMW armor band has been mounted.

5. Insert ESCs, receiver, LED light, power switch

None of the electronic components besides the motors get mounted. Instead, they are carefully inserted into the open space in the rear of Doomba's frame. First, a piece of foam is placed to cushion the electronics and keep them snug. Then the drive ESC, referred to as the Sabretooth, is placed in the middle of the open space, flanked by weapon ESCs on both sides. The receiver and LED light may be inserted to any open spot where they will fit. After each of these electronic components have been placed, and the wires have been hooked up properly, another piece of foam is placed on top.

6. Insert the batteries and mount the power switch

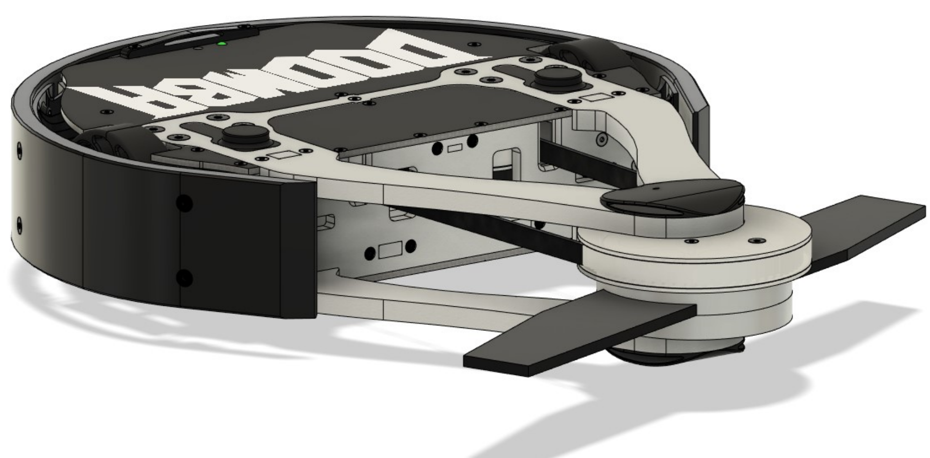
The 2 battery packs will be paced on top of the foam which covers the ESCs and other electronic components. The power switch is mounted to the top rear of the frame. This is done so that the power switch lines up with a hole in Doomba's top plate. When done correctly, this will allow us to toggle Doomba's power switch after it has been fully assembled. After the batteries have been placed and the power switch mounted, a third and final piece of foam will be placed on top.

7. Mount the weapon assembly

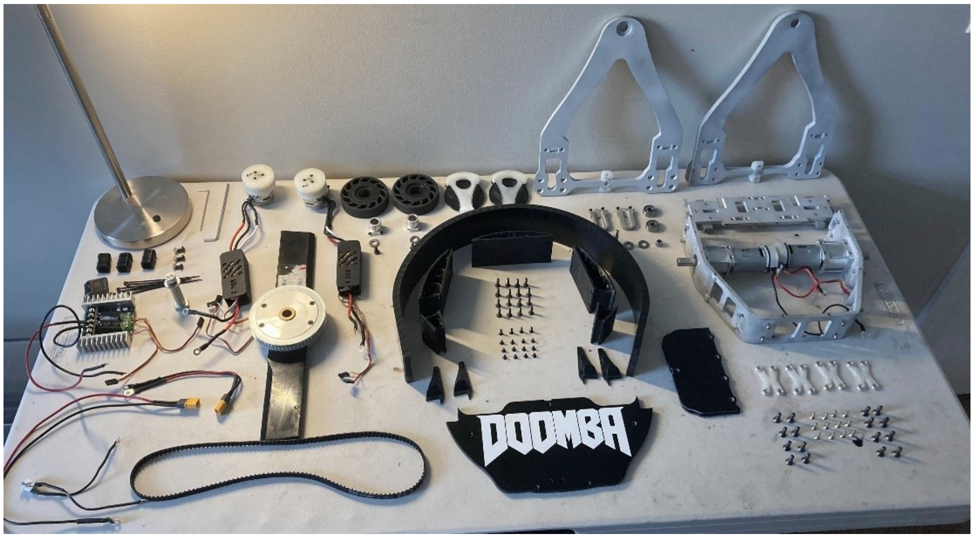
The weapon assembly consists of the weapon subassembly, the tensioner, the 3D printed weapon sprockets, and the belt. We start by mounting the weapon sprockets to the weapon motors. After this, the weapon subassembly is mounted onto the weapon bar. It is important to wrap the belt around the weapon subassembly before fastening it to the rest of the bot. Otherwise, the belt cannot be inserted. After the weapon subassembly has been fastened, the belt is placed around the weapon motor sprockets, and the tensioner is inserted to keep the belt in place and properly tensioned.

8. Fasten the top plate pieces and the armor band

This is the last step in the Doomba assembly process. After the top plate pieces have been installed, and the UHMW armor band has been mounted, Doomba is ready to fight its opponent.



Doomba 3D Model



Fully Disassembled Doomba BattleBot


Fully Assembled Doomba Battlebot

Testing

The XtremeBOTS Collegiate Clash is set to take place on April 30, 2022 – the day after we graduate from UC. With this being the case, testing for our bot was conducted through the UC BattleBot Club. Club testing included a safety check using the exact same criteria as the XtremeBOTS safety check, weapon tests for functionality and performance, and drive testing for control, speed, and maneuverability. A scan of our safety check results was produced after testing and can be found in the appendix section of this report.

In the safety check, our team scored 85 points out of a possible 150 points. Under the XtremeBOTS safety check scoring system, a score of 0 would be the minimal passable score for a bot to compete. Our team lost points during the safety check due to exposed sharp edges and for having no failsafe configured on our bot's controller. The exposed sharp edges on our battlebot were due to the sharp edges and corners on our lawnmower blade weapon. This was an oversight which will be addressed by 3D printing a sheath to cover the ends of our lawnmower blade. An easier solution to this issue, such as wrapping a rag around our lawnmower blade, would also suffice. The failsafe on our battlebot's controller refers to the way our bot behaves when the controller is powered off. Ideally, when the controller is powered off, our battlebot should stop all movement as a failsafe. During the UC BattleBot Club safety check, we did not have our controller properly configured so our bot continued to run even when the controller was powered off. We quickly found the solution to this problem in the controller's instruction manual and adjusted our settings to include the failsafe. This solution was successful, and our bot now stops all movement when controller is powered off. With these changes in place, our bot should be in compliance with all XtremeBOTS safety check criteria. When it is time for the competition, we expect to receive a perfect score of 150 points during the XtremeBOTS safety check.

The weapon and drive testing procedures were created solely by the UC BattleBot Club to test battlebot functionality for senior design teams. During the weapon test, our battlebot experienced no issues. Our lawnmower blade spun up to full speed in just under 3 seconds, which is good for competition, and spun down in under 30 seconds, which is an XtremeBOTS safety criterion. Our team elected to hit pieces of wood inside the battlebot cage with our weapon. This demonstrated both the effectiveness and durability of our weapon system. We ran our weapon for close to 2 and a half minutes while battering wooden blocks all around the test cage and our bot did not experience any damage or issues whatsoever.

Our battlebot's drive testing was slightly less successful than the weapon testing. Immediately when we began drive testing our battlebot, we experienced high-pointing issues due to the slightly uneven hallway floor surface. What this means is that our bottom of our bot would make contact with the high points in the floor which prevented our wheels from making proper contact. Whenever our bot was high-pointed, the wheels would continue to spin but the bot would remain stationary. This issue was primarily due to our wooden top and bottom panels. Wood panels were used during testing because our team did not wish to damage our nice garolite black ones prior to the competition. However, the wood panels used for testing were about 2x as thick as our garolite panels. After swapping the wood panels out for the garolite panels, our high-point issue was solved. Despite the high-point issue being fixed, our team continued to experience some issues during drive tests. Specifically, traction was found to be a significant issue for our battlebot. By design, most of Doomba's weight is concentrated in its weapon assembly which sits far out in front of the wheels. Because the bulk of Doomba's weight is far from the wheels, it experiences poor traction. Additionally, the 3D printed floor runner, the Doomba's 3rd point of floor contact, experiences greater friction because it is located directly under the weapon assembly. This extra friction in the front of the bot increases the importance of having good traction at the wheels. Our team has come up with 2 solutions to this problem. The first is to switch our wheels to a softer rubber. We noticed right away during the drive tests that our compliant black wheels did not have a lot of grip on the floor surface due to their hard rubber composition. To fix this, we will switch to green wheels which are made up of a softer rubber composition with a lot more friction/grip. Another solution our group is considering is the addition of magnets. At the XtremeBOTS Collegiate Clash, the arena floor is made of steel. By adding magnets to the bottom of our bot, the attractive force will increase the effective weight of our bot. This means that our bot will have significantly increased traction with the potential to push other bots around the arena. However, the magnets could attract and accumulate steel debris as the fighting takes place, which could cause potential issues. Magnets also interfere with electronics. Currently, our team is planning to do testing with and without magnets to decide if this is an avenue worth pursuing.

Test Results	
Safety Inspection	Pass
Weapon Spin-Up Time	2.92 sec
Weapon Spin-Down Time	6 sec
Weapon Speed	6842 rpm (285 mph)
Peak Voltage	15.1 V
Horizontal Pushing Force	16.1 lb

Aside from the UC BattleBot Club testing procedures, our team did informal testing for Doomba off school grounds. For our team's informal testing, we faced Doomba against an unarmed iLife® robot vacuum. The idea of this test was to test the overall durability of our weapon system. More specifically, our team was testing how our bot held up while striking blows. Historically, horizontal spinner battlebots face a lot of issues when striking blows, such as snapping their weapon or frying internal components. We used our weapon at full force against the robot vacuum to see whether or not our bot would experience any such issues while striking blows its weapon.

Our bot struck several devastating blows to the iLife® vacuum during our test and our weapon systems held up strong. Doomba did not experience any electrical or physical problems whatsoever. Our team understands that attacking a robot vacuum with our battlebot does not accurately simulate an actual battlebot fight, but this helped to give us an idea of our bot's firepower and build quality. When it is time for the competition, we expect Doomba to perform very well.

Project Management

Budget

Preliminary Budget

Our team will be granted $1,200 by the UC BattleBots Club to complete this project. Based on research, our team's survey results, and advice given by professional battlebot hobbyists, we have come up with the following preliminary budget:

Preliminary Budget	
Subsystem	**Expenses**
Frame & Armor	$300
Weapon	$200
Drivetrain	$200
Electronics	$300
Manufacturing	$200
Total	$1,200

Actual Budget

Our team was granted an additional $200 from the UC BattleBots Club, amounting to a new total budget of $1,400. Because of our design's focus on armor, the expenses for frame & armor ended up being higher than originally anticipated. Unlike most teams, our frame and armor will be separate entities. This makes for a more complex and therefore more expensive build.

Actual Budget	
Subsystem	**Expenses**
Frame & Armor	$420
Weapon	$500
Drivetrain	$215
Electronics	$260
Manufacturing	$205
Total	$1,600

Our team's total expenses surpassed out allotted $1,400 budget by $200. This is because the other battlebot teams in the UC BattleBot Club spent far below their allotted budget. Cole Powell, the president of the UC BattleBot Club, generously allowed our team to use the funds leftover by the other teams. This allowed us to purchase higher quality parts for our build and purchase spare parts for use in the competition.

Timeline

Milestone dates have been set by Senior Design due dates, XtremeBOTS Collegiate Clash competition, and the UC Tech Expo. Below is our team's project timeline.

	Preliminary Schedule									
	Item	**Due Date**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Senior Design I	Advisor Agreement	9/3/2021								
	Background Research	9/17/2021								
	Survey Results	9/24/2021								
	QFD	10/1/2021								
	Final Proposal	10/8/2021								
Senior Design II	Senior Design Report 1	10/17/2021								
	Bi-Weekly Report 1	10/31/2021								
	Bi-Weekly Report 2	11/14/2021								
	Final Design	11/25/2021								
	Senior Design Report 2	12/5/2021								
	Senior Design 2 Presentation	12/9/2022								
	Parts List	12/10/2021								
	Parts Ordered	12/15/2021								
	Bill of Materials	12/17/2021								
Senior Design III	Parts Arrived	1/24/2022								
	Fabrication Started	2/1/2022								
	Fabrication Finished	3/1/2022								
	Testing Started	3/8/2022								
	Testing Completed	4/8/2022								
	Tech Expo	4/14/2022								
	Final Presentation	4/26/2022								
	Competition	4/30/2022								

Recommendations

Our team worked hard over the course of the Fall 2021 and Spring 2022 semesters to complete this project. Thanks to good communication, generous time commitments, and rigid scheduling, we were able to produce a high-quality battlebot while staying within all required design and budgetary parameters. This being the case, we would like to share the following recommendations to help the success of future UC battlebot teams/projects:

1. **Utilize Web/Cloud Based CAD Services**

   One of the largest obstacles to overcome with team projects, especially at the university level, is file sharing. This issue is extremely prevalent when it comes to CAD files. Senior design projects for engineering students will generally involve dozens of CAD files which need to easily accessible to all team members. While UC grants NX and SolidWorks licenses for CEAS students, UC does not offer cloud-based CAD services of any kind. For many UC senior design teams, this results in a file-sharing nightmare. From the very beginning of senior design, our team elected to use Autodesk Fusion 360 as our primary CAD software for this project. Fusion 360 allows team members to open and edit CAD files which are saved in a cloud-based drive, similar to Google Drive. This made sharing and editing CAD files a breeze for our team and, in many ways, was the backbone to our overall success.

2. **Meet Regularly**

   Meet regularly with your team to touch base, discuss issues, and talk about the project. This helps keep team members focused on senior design. The longer the span between meetings, the more distracted team members will become. Try to meet at least once per week with your senior design team, even if its just to touch base. Meeting regularly requires a big time commitment, but it will make your senior design experience much easier and more successful.

3. **Take Advantage of Your Resources**

   The UC BattleBots Club was an invaluable resource for our senior design team. Before senior design, none of our team members had any robotics experience whatsoever. The UC BattleBot Club taught us everything we need to know about battlebots and make our senior design experience much easier. If you are building a battlebot for your senior design project, engage with the UC BattleBot Club as much as possible. Share your ideas with the club, get opinions, ask questions, and let them help you. This made our lives much easier, and the teams that chose not to engage with the club struggled immensely.

4. **Do Your Research**

   One of the great things about battlebots is that there are videos of them everywhere on the internet and on the BattleBots TV show. Take some time to watch videos and identify which design choices work and which ones don't. Also, read through old UC senior design reports, like this one, which discuss battlebot projects. Battlebot projects have a huge advantage when it comes to research because it is entertaining and abundant. Do not waste this advantage.

5. **Schedule a Generous Amount of Time for Building**

   Assuming your team is working through the UC BattleBot Club, you must wait for the club to order and receive your build materials. Whatever the case may be, have a manufacturing plan before parts even arrive. Identify what should be fabricated first and how you are going to fabricate it. Estimate the time it will take to fabricate each component. Our battlebot team decided to give generous time estimations for the fabrication processes. The thought behind this is that we would rather run undertime than overtime. For example, if our team expected that a component would take 10 minutes to fabricate, we budgeted an hour for it. Our team also worked long hours to get the build done in a timely manner. Doing this was a big time commitment, but it allowed us to complete the build early and get right into testing and modifications. Be sure to plan our your fabrication, budget a generous amount of time for each step, and commit a lot of time to the build. This gives you more time to iron out any issues you may find during testing and be less stressed as you get closer to graduation.

Conclusion

Working to design and build Doomba in a span of 8 months was no easy task, but we are thrilled with our final product. Doomba looks to be a strong competitor for the upcoming XtremeBOTS tournament, and we hope to place in the top 3 once the event has concluded. Despite not having yet competed, we consider our battlebot, Doomba, to be a great success for our team. We attribute the success of this project to good time management, good leadership, and practical engineering.

Time management is fundamental for the success of any senior design project. From the very start of senior design back in Fall of 2021, our team met at least once a week to touch base and discuss what needed to get done. Doing this required a significant time commitment from each team member, but it allowed our team to progress much faster than other senior design teams. Meeting at least once a week kept all team members on-task allowed us to help each other whenever we encountered problems or felt overwhelmed by the work. Regular meetings also ensured our work progressed at a moderate and consistent pace. Rarely, if ever, did our team fall behind on work and/or feel rushed to meet any deadlines. Thanks to our regular meeting schedules, team dynamic, and overall work ethic, our project tasks were always completed in a timely manner with as little stress as possible. As it turns out, most of the stress we experienced during this project was due to our classes outside of senior design rather than senior design itself.

Time management is especially critical to success when it comes to the fabrication and testing procedures in Senior Design III. From reading through previous battlebot senior design projects, our team learned to anticipate a lengthy fabrication period. With this in mind, we budgeted time very generously for all fabrication and manufacturing processes needed to complete our build. Our team also took the time to plan out our fabrication. This helped us to complete our build much faster than other senior design teams, and as a result, our team had plenty of extra time to test and modify our bot as necessary. Developing and maintaining good time management during the course of senior design was critical to our overall success.

Good leadership was another key to success for our senior design project. Henry Tran, the leader of this project, did an excellent job at communicating with the team, scheduling meeting times, and assigning tasks and deadlines. Good leadership helped our team stay focused on our battlebot project and allowed us to progress faster than many other senior design teams. Senior design teams with poor leadership, or no leadership at all, struggled to stay on task and meet important senior design deadlines. It is fundamental to designate a good leader from the very start of senior design.

Besides our team dynamic, as exemplified by our leadership and time management, success in our senior design battlebot project can also be attributed to clever and practical engineering methods. A great example of this was our decision to use Fusion 360 as our dedicated CAD software for this project. Fusion 360 is cloud-based which means every member of our team had access to our CAD files and could edit them from any computer with ease. This saved us from the nightmare of trying to share CAD files based in other software and also served as a failsafe in case any of our computers died during senior design. Another practical engineering method we employed during our build was designing for manufacture. Because every member of our team is was MET student, we knew exactly what equipment was available to us at UC's Victory Parkway campus. This being the case, every aspect of our battlebot was designed around with this equipment in mind. Designing in this fashion made fabrication very easy for our team and we never experienced any snags along the way. Along with designing for manufacture, we designed our battlebot with fitment in mind as well. Structural components, such as our battlebot's frame, armor, and weapon, were designed to key or slot together so that we have more than just fasteners holding everything together. This is especially important for a project like ours which must endure bot-to-bot combat involving forceful hits and huge impacts. Practical engineering is something UC has taught us for the last four and a half years. Applying what we have learned to our senior design project made all aspects of this project much easier. Practical engineering based on fundamental concepts and project parameters helped our team create a successful battlebot with as little complexity or stress as possible.

Through the course of this project, our team maintained a great team dynamic based on good time management, good leadership, and practical engineering. These three principles allowed us to build one of the best battlebot projects UC has seen in several years. We are very proud of the work we put into this project and could not be more pleased with our final product: Doomba. We hope that our hard work pays off when it is time to compete in the XtremeBOTS Collegiate Clash on April 30.

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Appendices

XtremeBOTS 15lb Technical Regulations

1. **General**

1.1. All participants build and operate robots at their own risk. Combat robotics is inherently dangerous. There is no amount of regulation that can encompass all the dangers involved. Please take care to not hurt yourself or others when building, testing and competing.

1.2. If you have a robot or weapon design that does not fit within the categories set forth in these rules or is in some way ambiguous or borderline, please contact info@xtremebots.org. Safe innovation is always encouraged, but surprising the event staff with your brilliant exploitation of a loophole may cause your robot to be disqualified before it ever competes.

1.3. Compliance with all event rules is mandatory. It is expected that competitors stay within the rules and procedures of their own accord and do not require constant policing.

1.4. Each event has safety inspections. It is at their sole discretion that your robot is allowed to compete. As a builder you are obligated to disclose all operating principles and potential dangers to the inspection staff.

1.5. Cardinal Safety Rules: Failure to comply with any of the following rules could result in expulsion or worse, injury and death.

1.5.1. Proper activation and deactivation of robots is critical. Robots must only be activated in the arena, testing areas, or with expressed consent of the event personnel or its safety officials.

1.5.2. All robots must be able to be FULLY deactivated, which includes power to the drive and the weaponry, **within 60 seconds by a manual disconnect**. (Removable link or Main Power Switch)

1.5.3. All robots not in an arena or official testing area must be raised or blocked up in a manner so that their wheels or legs cannot cause movement if the robot were turned on. Runaway bots are VERY dangerous. (We strongly suggest a custom designed block that ensures the robot will not be inadvertently dislodged from the block)

1.5.4. Locking devices: Moving weapons that can cause damage or injury must have a **clearly visible** locking device in place **at all times** when not in the arena. Locking devices must be painted in neon orange or another high-visibility color. Locking devices must be clearly capable of stopping, arresting or otherwise preventing harmful motion of the weapon. C- Clamps and locking pliers are not allowed.

1.5.5. *Weapon locking pins must be in place when a robot is placed in the arena. However, the locking pin may be removed before weapon power is applied during a robot's power-on procedure. This includes all powered weapons regardless of the power source.*

1.5.6. It is expected that all builders will follow basic safety practices during work on the robot at your pit station. Please be alert and aware of your pit neighbors and people passing by. *A special area in or near the pits will be provided for repeated drilling and or grinding. These operations should not be performed at your pit table if a special area is designated.* Continued failure to follow safety directions could result in an individuals or the entire team disqualification for the event. (This includes and is not limited to wearing SAFETY GLASSES at ALL times while in the pit area.)

1.5.7. Any sharp-edged weapon must have the edge effectively covered until the bot is in the ring.

2. **Weight Classes**. These events offer the 15 pound weight class only.

3. **Mobility**

3.1. All robots must have easily visible and controlled mobility in order to compete. Methods of mobility include:

3.1.1. Rolling (wheels, tracks or the whole robot)

3.1.2. Non-wheeled: non-wheeled robots have no rolling elements in contact with the floor and no continuous rolling or cam operated motion in contact with the floor, either directly or via a linkage. Motion is "continuous" if continuous operation of the drive motor(s) produces continuous motion of the robot.

3.1.3. Shuffling (rotational cam operated legs)

3.1.4. Ground effect air cushions (hovercrafts)

4. **Robot control requirements**

4.1. *Tele-operated robots must be radio controlled via2.4GHz Spread Spectrum radio systems, or similar radio/receiver systems that require binding between a single specific radio and receiver.*

4.2. Tethered control is not allowed.

4.3. Radio system restrictions for this event with corresponding weight and or weapon restrictions:

4.3.1. Radio systems that stop all motion in the robot (drive and weapons), when the transmitter loses power or signal, are required for all robots. This may be inherent in the robots electrical system or be part of programmed fail-safes in the radio.

4.3.2. *All robot radio systems must be Spektrum (preferred) or Hobby King 2.4 ghz spread spectrum radio systems. Those with similar binding systems other than the preferred Spektrum or Hobby King systems must explain the binding properties of their specific system during inspections.*

5. **Autonomous/Semi-Autonomous Robots:** Any robot that moves, seeks a target, or activates weapons without human control is considered autonomous. If your robot is autonomous contact league personnel.

5.1. Autonomous robots must have a clearly visible light for each autonomous subsystem that indicates whether or not it is in autonomous mode, e.g. if your robot has two autonomous weapons it should have two "autonomous mode" lights (this is separate from any power or radio indicator lights used).

5.2. The autonomous functionality of a robot must have the capability of being remotely armed and disarmed. (This does not include internal sensors, drive gyros, or closed loop motor controls.)

5.2.1. While disarmed, all autonomous functions must be disabled.

5.2.2. When activated the robot must have no autonomous functions enabled, and all autonomous functions must failsafe to off if there is loss of power or radio signal.

5.2.3. In case of damage to components that remotely disarm the robot, the robots autonomous functions are required to automatically disarm within one minute of the match length time after being armed.

6. **Batteries and Power**

6.1. The only permitted batteries are ones that cannot spill or spray any of their contents when damaged or inverted. This means that standard automotive and motorcycle wet cell batteries are prohibited. Examples of batteries that are permitted: gel cells, Hawkers, NiCads, NiMh, dry cells, AGM, LIon, A123 LiFe Nano Phosphate. **Lithium Polymer batteries (LiPo) are prohibited (Fire and explosion hazard exists when incorrectly charged, shorted, or punctured).** If your design uses a new type of battery, or you are not sure about it, contact info@xtremebots.org.

6.2. *The maximum on-board voltage, from a single battery or combination thereof is **28.8 volts** for 15# class robots for this league. (It is understood that a charged battery's initial voltage state may be above their nominal rated value)*

6.3. All electrical power to weapons and drive systems (systems that could cause potential human bodily injury) must have a manual disconnect that can be activated within **15 seconds** without endangering the person turning it off. (E.g. No body parts in the way of weapons or pinch points.) Shut down must include a **manually** operated mechanical method of disconnecting the main battery power, such as a switch (Hella, Whyachi, etc.) or removable link. Relays may be used to control power, but there must also be a mechanical disconnect. Please note that complete shut down time is **within 60 seconds by a manual disconnect** , as specified in section 1.5.

6.4. All efforts must be made to protect battery terminals from a direct short and causing a battery fire.

6.5 *All robots must have a separate light per circuit that is **easily visible from the outside** of the robot and shows that its circuit's power is activated. LED's and fiber optics are good, low power options for this.*

7. **Pneumatics**

7.1. All 15# robots must use Low Pressure Air systems. (LPA)

7.2. Pneumatic systems on board the robot must only employ non-flammable, nonreactive gases (compressed air or disposable CO_2 cartridges are permissible).
7.3. Example diagrams of typical pneumatic systems:
7.3.1. 15# class robots - CO_2 based systems, see attachment below
7.4. Pneumatic system refilling process:
7.4.1. You must have a safe way of refilling the system and determining the on-board pressure.
7.4.2. The maximum pressure that may be stored or used for the 15# class robot is 150 PSI or less. The maximum total volume of pressurized gas is 8 cubic feet at standard temperature and pressure.
7.4.3. All components must be used within the specifications provided by the manufacturer or supplier. If the specifications aren't available or reliable, then it will be up to the Safety Official to decide if the component is being used in a sufficiently safe manner.
7.5. You must have a safe and secure method of refilling your pneumatic system. All LPA systems must have the standard Schrader valve for refilling; all CO_2 systems must use single use tanks.
7.6. All pneumatic components on board a robot must be securely mounted. Particular attention must be made to pressure vessel mounting and armor to ensure that if ruptured it will not escape the robot. (The terms "pressure vessel, bottle, and source tank" are used interchangeably)
7.7. All pneumatic components within the robot must be rated or certified for AT LEAST the maximum pressure in that part of the system. You may be required to show rating or certification documentation on ANY component in your system.
7.8. All pressure vessels must be rated for at least 120% of the pressure they are used at. (This is to give them a margin of safety if damaged during a fight.) It is not permissible to use fiber wound pressure vessels with liquefied gasses like CO_2 due to extreme temperature cycling.
7.9. All primary pressure vessels must have an over pressure device (burst/rupture disk or over pressure 'pop off') set to no more than 130% of that pressure vessels rating. (Most commercially available bottles come with the correct burst assemblies, and use of these is encouraged.)
7.10. If regulators or compressors are used anywhere in the pneumatic system there must be an (additional) over pressure device downstream of the regulator or compressor set for no more than 130% of the lowest rated component in that part of the pneumatic system.
7.11. All pneumatic systems must have a manual main shut off valve to isolate the rest of the system from the source tank. This valve must be easily accessed for robot deactivation and refilling. It must also be out of any danger areas.
7.12. All pneumatic systems must have a manual bleed valve downstream of the main shut off valve to depressurize the system. This bleed valve must be easily accessed for deactivation. This valve must be left OPEN whenever the robot is not in the arena to ensure the system cannot operate accidentally.

7.12.1. It is required to be able to easily bleed all pressure in the robot before exiting the arena. (You may be required to bleed the entire system if it is believed that you have any damaged components.)

7.13. All pneumatic systems must have appropriate gauges scaled for maximum resolution of the pressures in that part of the system.

7.14. If back check valves are used anywhere in the system you must ensure that any part of the system they isolate can be bled and has an over pressure device.

8. **Hydraulics**

8.1. Robots in the 15# class are NOT allowed to use hydraulics.

9. **Internal Combustion Engines (ICE) and liquid fuels.**

9.1. Robots in the 15# class are NOT allowed to use ICE.

11. **Springs and Flywheels**

11.1. Springs used in robots will use the remaining rules in this section.
Safe operation, good engineering and best practices must be used in all systems.

11.2. Any large springs used for drive or weapon power must have a way of loading and actuating the spring remotely under the robots power.

11.2.1. Under no circumstances must a large spring be loaded when the robot is out of the arena or testing area.

11.2.2. Small springs like those used within switches or other small internal operations are exempt from this rule.

11.3. Any flywheel or similar kinetic energy storing device must not be spinning or storing energy in any way unless inside the arena or testing area.

11.3.1. There must be a way of generating and dissipating the energy from the device remotely under the robots power.

11.4. All springs, flywheels, and similar kinetic energy storing devices must fail to a safe position on loss of radio contact or power.

Survey

- How important is a self-righting capability for a 15lb competition? (1-10)

- What type of weapon is most ideal in a 15lb competition?
  - Full body spinner
  - Inertial spinner
  - Flipper
  - Blunt force weapon
  - Saw
- Given a limited budget, what is the best material to use for armor in your experience?

- How important is modularity in the design process? (1-10)

- Rate the main components of the battlebot on importance. (1-10)

- In the design process what is the best way to prevent being flipped?

- How important is accounting for traction when designing a battlebot? (1-10)

- What factors are the most important to be considered when designing? (1-10)

- For a 15lb battlebot where should the weight be distributed to the most? (1-10)

Survey Results

- What type of weapon is most ideal in a 15lb competition?
  - Full body spinner
  - **Inertial spinner**
  - Flipper
  - Blunt force weapon
  - Saw

- Given a limited budget, what is the best material to use for armor in your experience?
  - **Aluminum**
- In the design process what is the best way to prevent being flipped?
  - **Invertibility**

	How important is: (1-10)			
	self-righting capability for a 15lb competition?	modularity in the design process?	the aesthetics of the battlebot?	traction when designing a battlebot?
Average	**7.8**	**4.7**	**5.8**	**7.8**
Standard Deviation	**1.7**	**2.6**	**2.2**	**1.3**
Reddit r/battlebots	8	7	6	7
	7	7	5	6
	8	3	6	7
	6	6	10	9
	6	4	7	9
	8	3	7	9
	7	5	9	8
	10	10	1	10
	3	6	4	9
	10	10	4	10
	8	3	7	6
	8	4	2	8
	8	3	4	6
	7	4	10	8
	8	7	4	6
	4	1	8	10
	8	3	5	9
	6	3	2	8
	8	5	6	8
	5	7	3	8
	10	9	8	9
	9	3	5	6
	8	2	7	8
	10	1	6	6
	7	3	6	7
	9	6	5	8
UC BattleBot team	10	9	8	9
	9	3	5	6
	8	2	7	8
	10	1	6	6

Rate the main components of the battlebot: (1-10)			What factors are the most important to be considered when designing? (1-10)			For a 15lb battlebot where should the weight be distributed to the most? (1-10)		
Drive Train	Weapon	Armor	Material cost	Material strength	Material machinability	Drive Train	Weapon	Armor
8.9	**7.2**	**7.5**	**6.6**	**7.6**	**7.8**	**6.6**	**6.6**	**6.7**
1.3	**1.7**	**1.9**	**1.9**	**1.5**	**1.9**	**2.1**	**2.0**	**1.9**
10	7	10	8	9	7	5	6	9
8	7	6	8	7	9	8	6	7
6	5	7	7	8	9	3	5	7
10	6	8	7	8	5	8	4	6
8	7	6	7	7	6	5	8	6
10	7	7	7	7	5	4	7	7
10	8	10	6	9	9	10	7	5
10	5	10	6	10	10	6	6	6
7	9	8	7	8	9	4	4	7
8	10	10	10	10	10	8	10	10
9	4	7	6	7	6	7	4	6
10	7	5	4	5	7	4	6	6
9	6	8	5	7	9	3	8	6
9	7	9	4	8	8	5	8	9
10	6	6	5	6	8	5	6	3
10	7	9	7	9	6	7	4	7
10	9	8	1	8	8	5	5	5
10	7	7	5	8	2	10	6	5
10	6	8	8	7	8	7	8	9
10	4	8	5	8	6	8	5	7
8	10	10	9	10	9	9	10	10
9	10	6	9	6	7	7	10	7
9	6	8	5	8	10	10	4	7
6	8	3	8	5	10	5	7	3
9	7	7	6	6	8	7	8	6
9	6	8	7	8	8	7	6	8
8	10	10	9	10	9	9	10	10
9	10	6	9	6	7	7	10	7
9	6	8	5	8	10	10	4	7
6	8	3	8	5	10	5	7	3

Calculations

Weapon Motor Parameters:

- KV = 1000rpm/volt
- 45Amax
- 670W

Weapon Speed Calculations:

- Motor sprocket = 28 teeth
- Weapon sprocket = 60 teeth
- Weapon diameter = 13 7/8”

$$Motor\ rpm = \ 1000\frac{rpm}{volt} \times 14.8V = 14{,}800\ rpm$$

$$Weapon\ rpm = \frac{28\ teeth}{60\ teeth} \times 14{,}800\ rpm = 6{,}907\ rpm$$

$$Weapon\ tip\ speed = \frac{13.875in}{12} \times \pi \times 6{,}906rpm \times \frac{1mi}{5280ft} \times \frac{60min}{1hr} = 285\ mph$$

Battery Calculations:

$$Estimated\ battery\ usage = 8 * 20A * 3min * 1000mAAmp * \frac{1hr}{60min} = \ 8000\ mAh$$

Drivetrain Parameters:

- Max Wheel Motor RPM: 19300 RPM
- Rated Wheel Motor RPM: 17100 RPM
- Wheel Diameter: 2 ⅞” = 2.875”
- Gearbox Ratio: 26:1 = R = 26
- $\boldsymbol{\mu}_{static}$ = 0.95 (rubber and dry steel)

Drivetrain Calculations:

$$Wheel\ rpm = \frac{17100rpm}{26} = 658\ rpm$$

$$Wheel\ circumference = 2.875in \times \pi = 9.032\ in$$

$$Linear\ velocity = 9.032 \times [(658/60)/12] = 8.25ft/\sec = 5.625\ mph$$

$$Wheel\ load = \frac{15lbs}{2wheels} = 7.5\ lbs/wheel$$

$$Friction\ force = 0.95 \times 7.5 \frac{lbs}{wheel} = 7.125\ lbs/wheel$$

$$Wheel\ friction\ torque = 7.125 \frac{lbs}{wheel} \times \left(\frac{3.875in}{2}\right) = 13.8\ in - lb$$

Bill of Materials

Status	Instructions	School Year	Starting Budget	Remaining Budget
Received	This form Is to be filled out by the presidents and the treasurer when a group submits a purchase req to keep track of orders being shipped and ordered. All fields with a * next to them are required to be filled out. When an order status needs to be changed just use the fill color tool to match the color of the status. Once a tracking number is made make sure it goes in the last column.		$1,400.00	-$5.37
Ordered				
Processing				
Problem / Canceled				

P/N*	Description*	Hyperlink*	Quantity	Price Per Unit	Total	Manufacture	Vender*	Subassembly
	RS550 Motor - No pinion	Motor	3	$9.00	$27.00	Andy Mark	Banebots	Drive Train
	BaneBots Wheel, 2-7/8"x0.8" Blue	Wheels	4	$3.50	$14.00		Banebots	Drive Train
	P6S 26:1 Gearbox - Input RS-5nn Motor	Gearbox	2	$63.65	$127.30		Banebots	Drive Train
91294A484	M4 x 0.7x45 mm Flat head screw - 100 pack	https://www.mcmaster.com/standard-fla	1	$12.86	$12.86	McMaster Carr	McMaster Carr	Frame
92125A134	M3 x 0.5mm Flat head screw - 100 pack	M3 x 0.5 Flat Head Screws	1	$10.00	$10.00	McMaster Carr	McMaster Carr	Frame
91253A006	10 - 32 Flat head screw - 100 pack	10-32 Black Oxide Flat Head Screw	1	$13.36	$13.36	McMaster Carr	McMaster Carr	Frame
96505A116	M8 Washer - 100 pack	M8 Oversized Washer	1	$11.43	$11.43	McMaster Carr	McMaster Carr	Weapon
92981A203	8 mm shoulder bolt	8 mm Shoulder Bolt	4	$2.06	$8.24	McMaster Carr	McMaster Carr	Weapon
6338K418	0.5" Oil-Embedded Flanged Sleeve Bearing	0.5" Flange	4	$1.38	$5.52	McMaster Carr	McMaster Carr	Weapon
6338K421	1" Oil-Embedded Flanged Sleeve Bearing	1" Flange	4	$1.73	$6.92	McMaster Carr	McMaster Carr	Weapon
94496A370	1/2" Steel Hex Head Shoulder Screw	1/2" Steel Hex Head Screw	3	$7.70	$23.10	McMaster Carr	McMaster Carr	Weapon
27535A38	Drill bit for Screws, Drill-Point, 82 Degree, 1/2" Body Diameter	82 Degree 1/2" Diameter	1	$24.62	$24.62	McMaster Carr	McMaster Carr	Frame
27535A48	Drill bit for Screws, Drill-Point, 90 Degree, 3/8" Body Diameter	90 Degree 3/8"	2	$19.08	$38.16	McMaster Carr	McMaster Carr	Frame
91292A834	2mmx 1218-8 Stainless Steel Socket Head Screw	https://www.mcmaster.com/91292A834	1	$3.82	$3.82	McMaster Carr	McMaster Carr	Drive Train
86375K113	Resilient Polyurethane Foam Sheet	https://www.mcmaster.com/86375K113	2	23.32	46.64	McMaster Carr	McMaster Carr	Frame
8975K154	3/8"x12"x24" Multipurpose 6061 Aluminum Sheets and Bars	https://www.mcmaster.com/sheets/leng	1	$205.00	$205.00	McMaster Carr	McMaster Carr	Frame
8975K142	1/2"x12"x24" Multipurpose 6061 Aluminum Sheets and Bars	https://www.mcmaster.com/sheets/leng	1	$0.00	$0.00	McMaster Carr	McMaster Carr	Frame
6484K237	28" XL Timing Belt (3/8" width)	https://www.mcmaster.com/6484K237/	4	$9.98	$39.92	McMaster Carr	McMaster Carr	Weapon
94830A530	Steel Thin Flex-Top Locknut for Heavy Vibration	https://www.mcmaster.com/94830A530	1	$9.83	$9.83		McMaster Carr	Weapon
91294A020	Black-Oxide Alloy Steel Hex Drive Flat Head Screw, 90 Degree Count	https://www.mcmaster.com/screws/thre	1	$8.00	$8.00	McMaster Carr	McMaster Carr	Weapon
	Turnigy Aerodrive SK3 - 3542-1000kv Brushless Outrunner Motor	Outrunner Motor	2	$42.99	$85.98		Hobby King	Weapon
	Lawnmower Blade	Mower Blade	4	$13.24	$52.96	Oregon	Walmart	Weapon
	SAMSUNG INR 18650 20S 30A 2000MAH HIGH DRAIN FLAT TOP	Batteries	4	$60.00	$240.00	Samsung	M&A BD Electron	Electronics
	Skateboard Bearings - 8 pack	Skateboard Bearings	1	$19.95	$19.95	Bones	Amazon	Weapon
	50A ESC	50A ESC	2	$25.99	$51.98	ZTW	Amazon	Weapon
	Chanzon 100pcs (10 colors x 10pcs) 5mm LED Diode Lights	5v LED	1	$7.39	$7.39	Chanzon	Amazon	Electronics
	.123" x 3.142" x 28" CP Grade 2 Titanium	Titanium	2	$74.01	$148.02	TMS Titanium	TMS Titanium	Armor
-	Top and bottom sheet	https://app.sendcutsend.com/	1	$106.06	$106.06	Send Cut Send	Send Cut Send	Armor
8974K88	3.5" OD 1/2ft long aluminum rod	https://www.mcmaster.com/8974K88-8	1	$57.31	$57.31	McMaster Carr	McMaster Carr	Weapon

Doomba Guide

DOOMBA

DOOMBA MACHINING GUIDE

REVISION 5

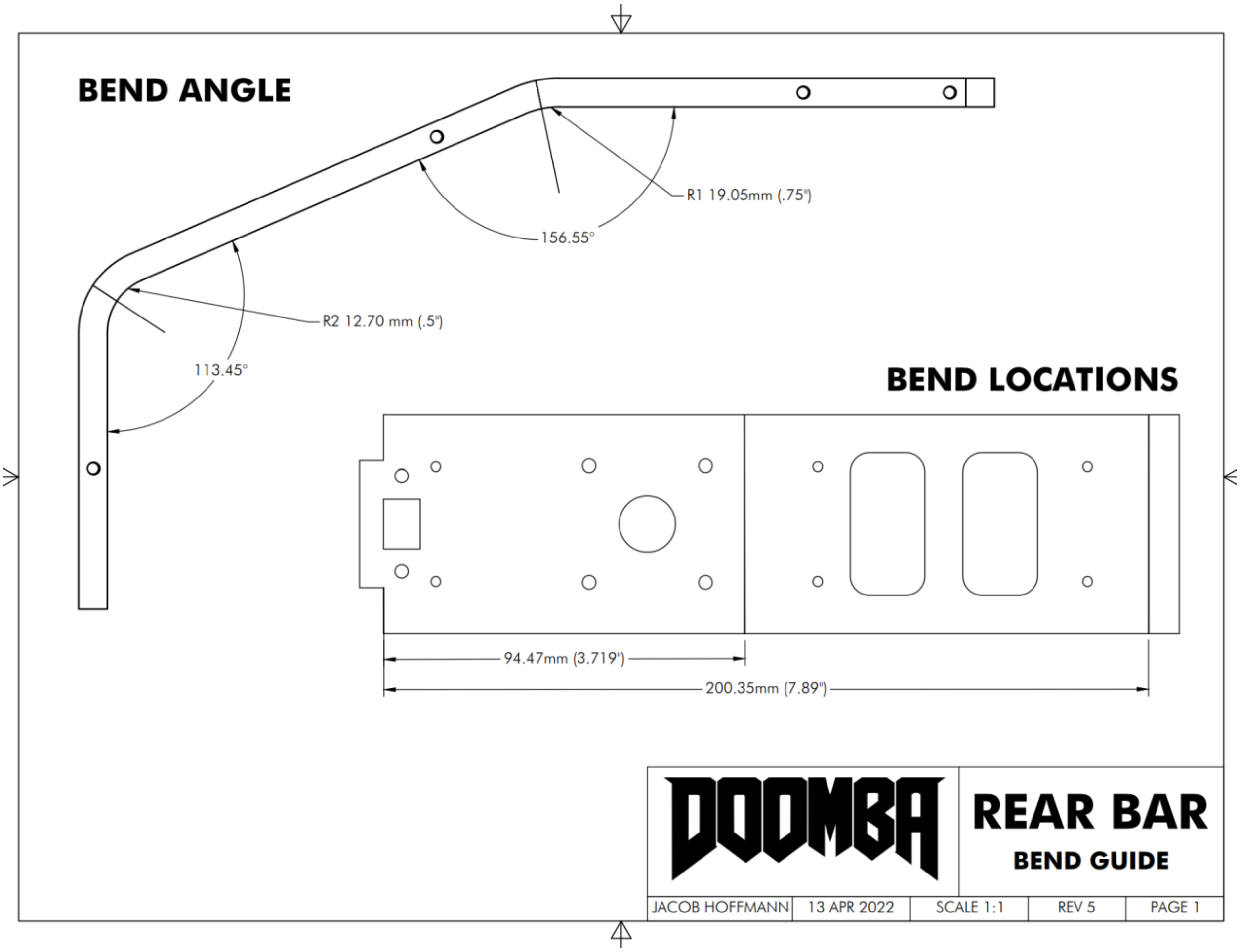
APRIL 2022

JOE MURPHY • JACOB HOFFMANN • HENRY TRAN

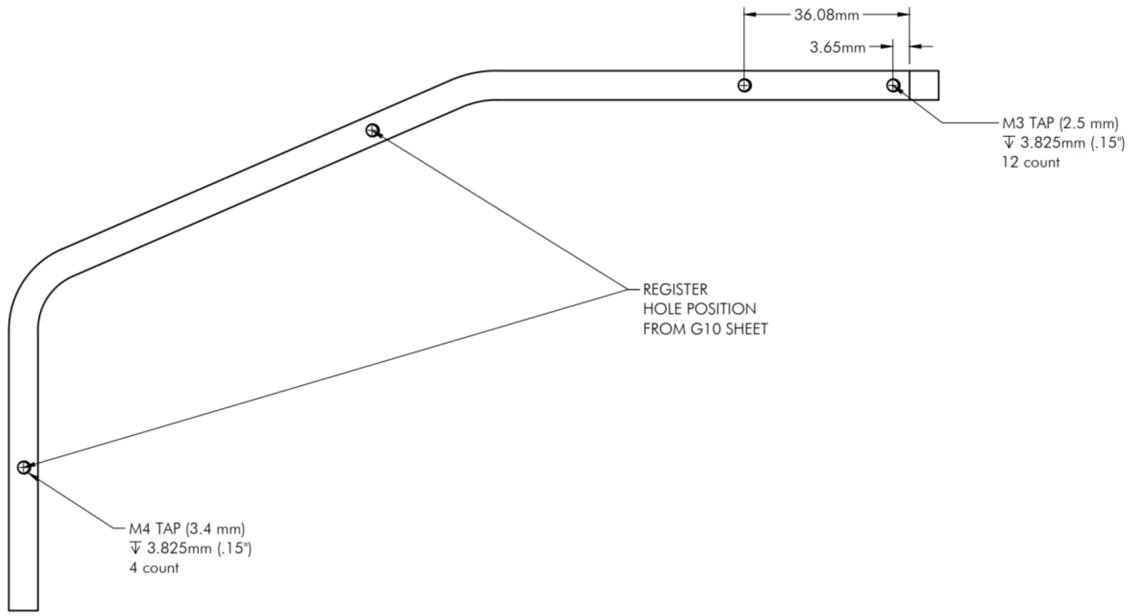
UNIVERSITY OF CINCINNATI

1" calibration square

30mm calibration square


BEND ANGLE
R1 19.05mm (.75")
156.55°
R2 12.70 mm (.5")
113.45°
BEND LOCATIONS
94.47mm (3.719")
200.35mm (7.89")
DOOMBA
REAR BAR
BEND GUIDE
JACOB HOFFMANN
13 APR 2022
SCALE 1:1
REV 5
PAGE 1

TOP & BOTTOM GEOMETRY



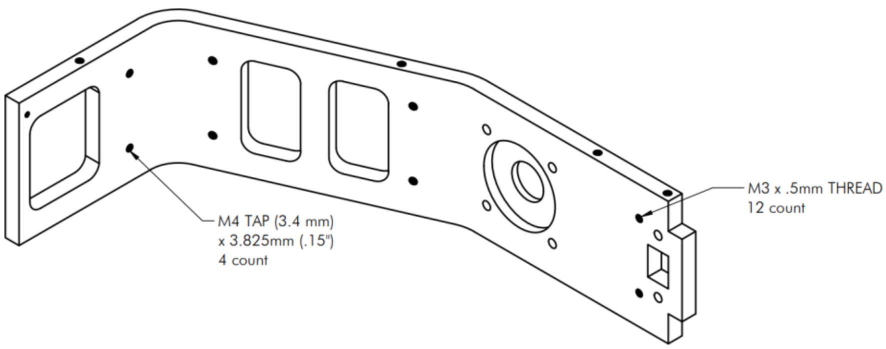
DOOMBA

REAR BAR

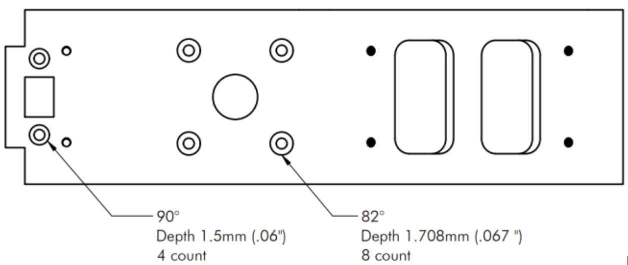
TOP & BOTTOM HOLE GUIDE

JACOB HOFFMANN	13 APR 2022	SCALE 1:1	REV 5	PAGE 2

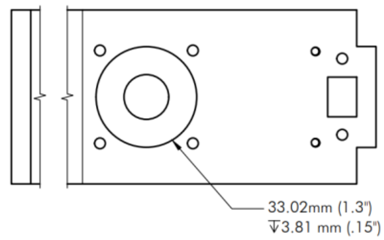
INSIDE GEOMETRY



OUTSIDE GEOMETRY



MOTOR MOUNT GEOMETRY



DOOMBA

REAR BAR

MACHINING GUIDE

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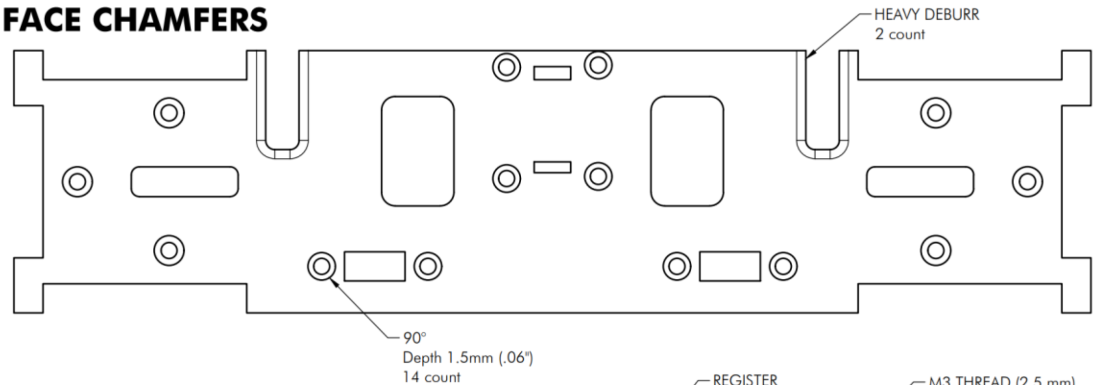
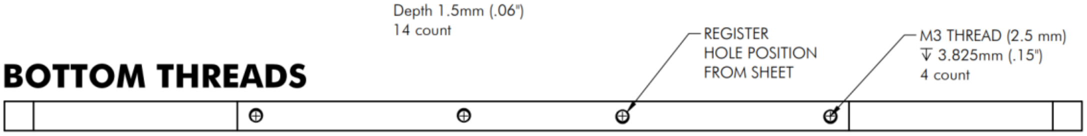
TOP THREADS

FACE CHAMFERS



BOTTOM THREADS



DOOMBA

FRONT BAR
MACHINING GUIDE

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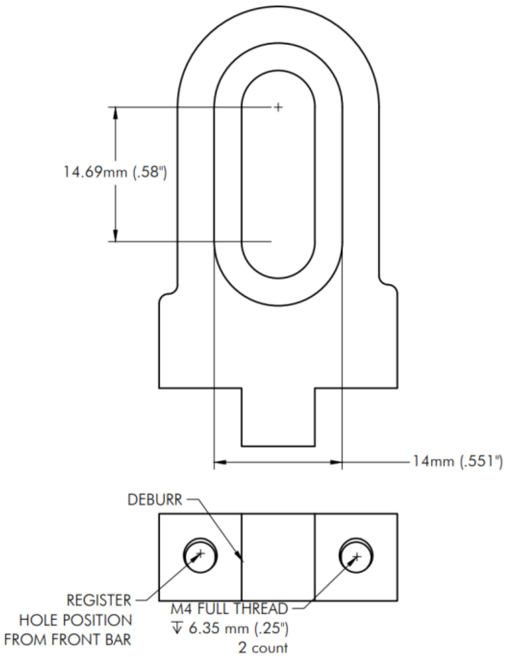
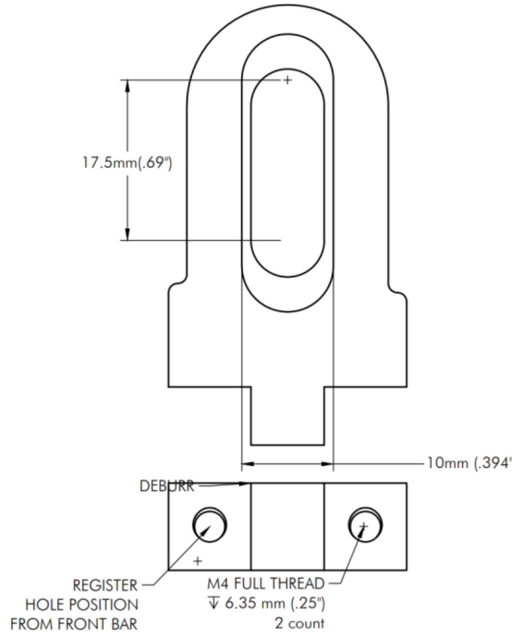
TOP SLIDER



BOTTOM SLIDER



DOOMBA

SLIDERS

MACHINING GUIDE

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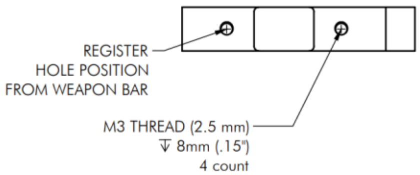
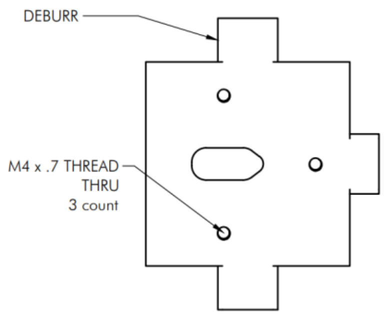
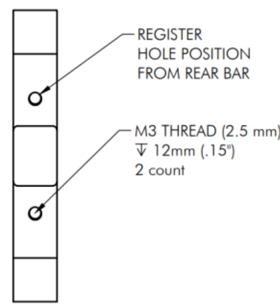
TOP & BOTTOM GEOMETRY



FACE GEOMETRY



SIDE GEOMETRY



DOOMBA

BLOCK

MACHINING GUIDE

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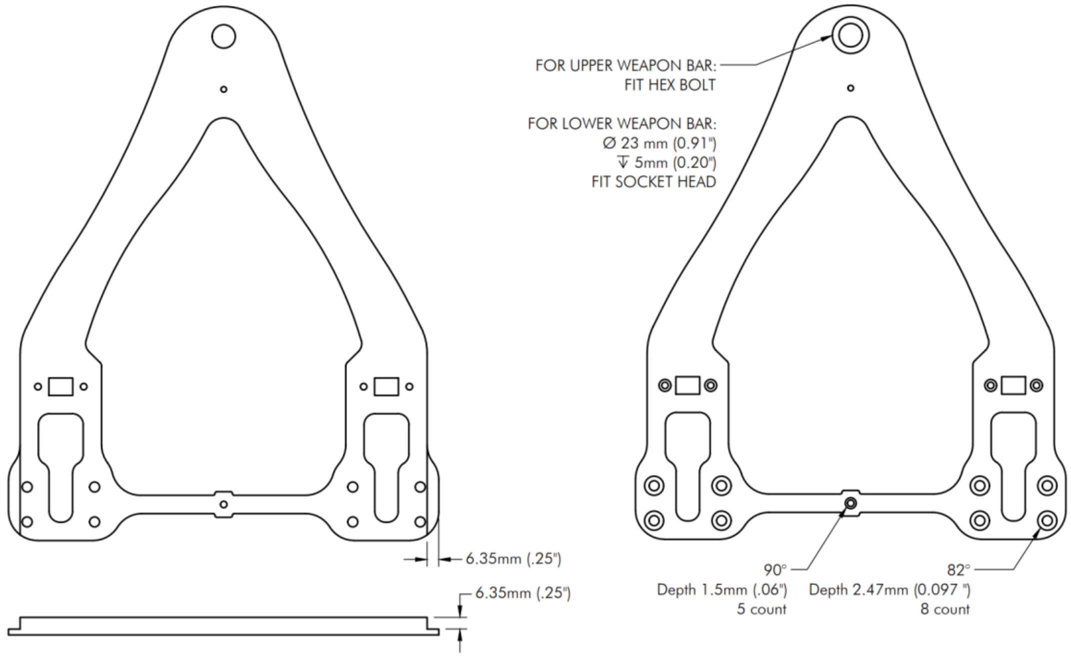
BOTTOM GEOMETRY

TOP GEOMETRY



DOOMBA

WEAPON BAR

MACHINING GUIDE

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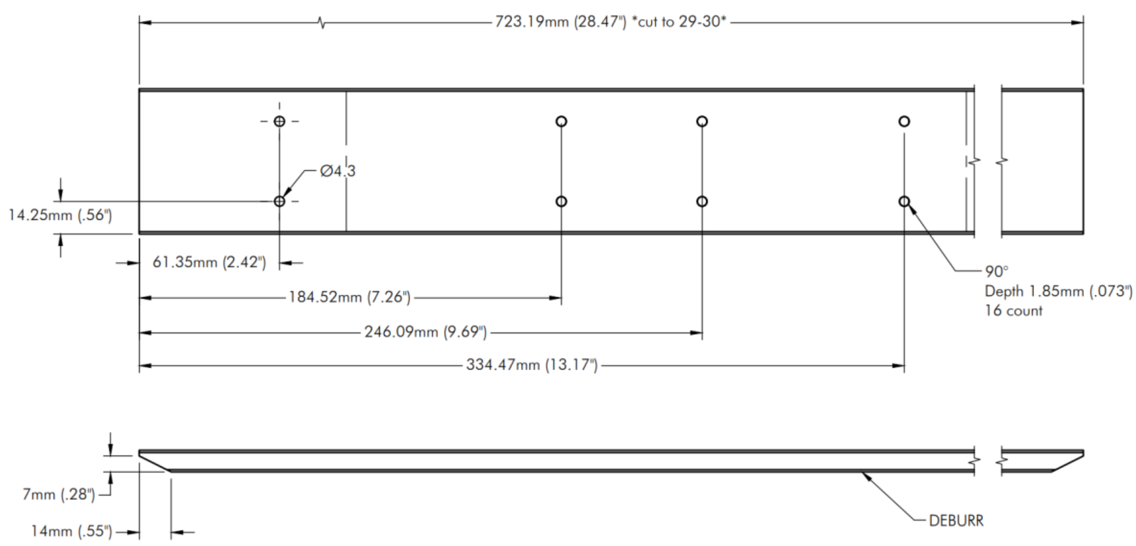

DOOMBA		ARMOR MACHINING GUIDE		
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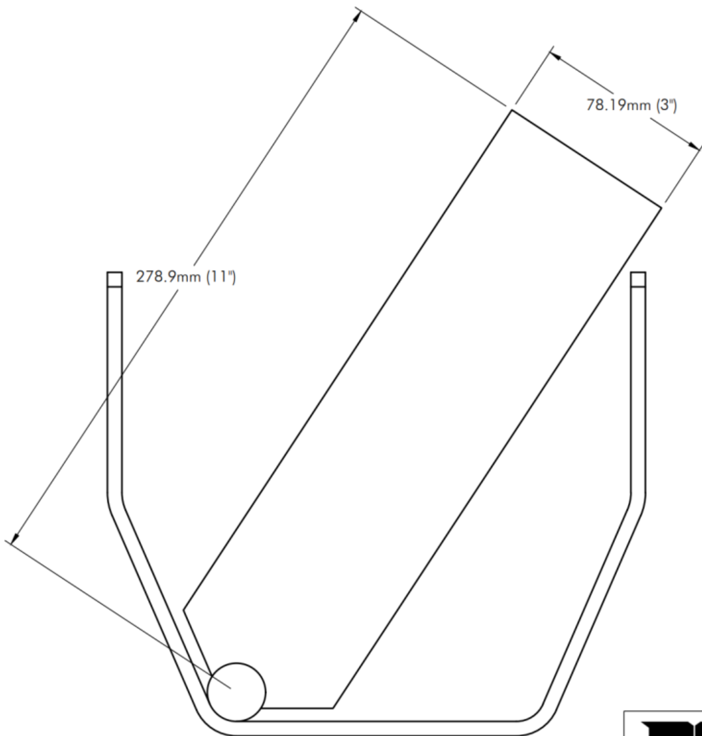
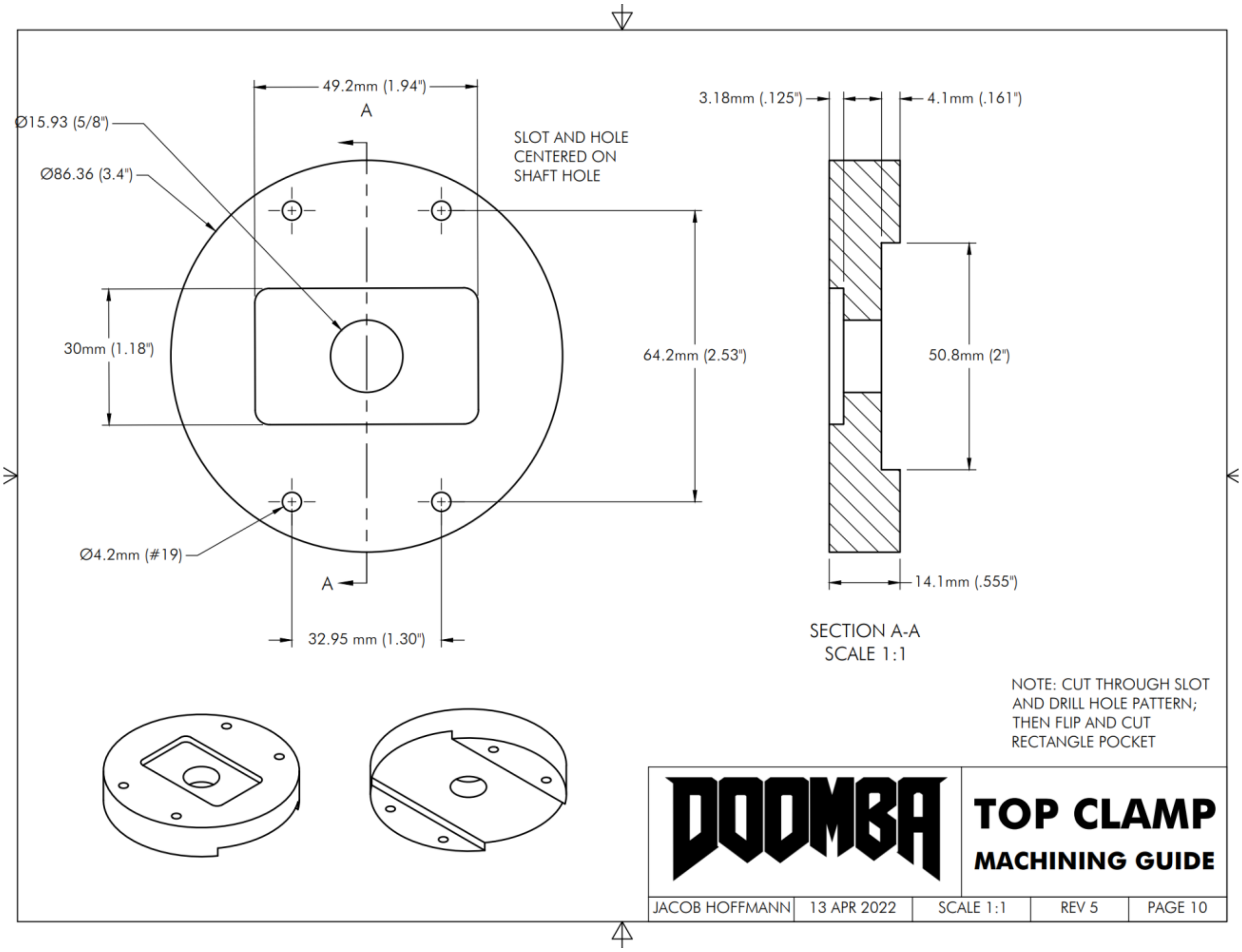


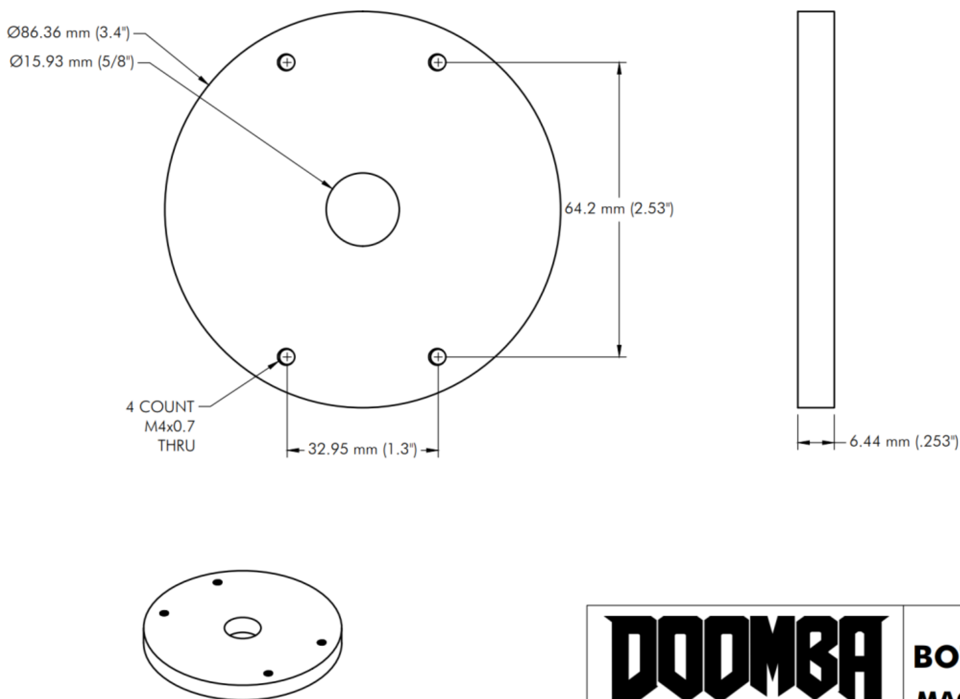
DOOMBA

REAR BAR

BEND TOOLING GUIDE

JACOB HOFFMANN	13 APR 2022	SCALE 1:2	REV 5	PAGE 9


49.2mm (1.94")
A
Ø15.93 (5/8")
Ø86.36 (3.4")
SLOT AND HOLE CENTERED ON SHAFT HOLE
30mm (1.18")
64.2mm (2.53")
Ø4.2mm (#19)
A
32.95 mm (1.30")
3.18mm (.125")
4.1mm (.161")
50.8mm (2")
14.1mm (.555")
SECTION A-A
SCALE 1:1
NOTE: CUT THROUGH SLOT AND DRILL HOLE PATTERN; THEN FLIP AND CUT RECTANGLE POCKET
DOOMBA
TOP CLAMP
MACHINING GUIDE
JACOB HOFFMANN
13 APR 2022
SCALE 1:1
REV 5
PAGE 10



DOOMBA

BOTTOM CLAMP

MACHINING GUIDE

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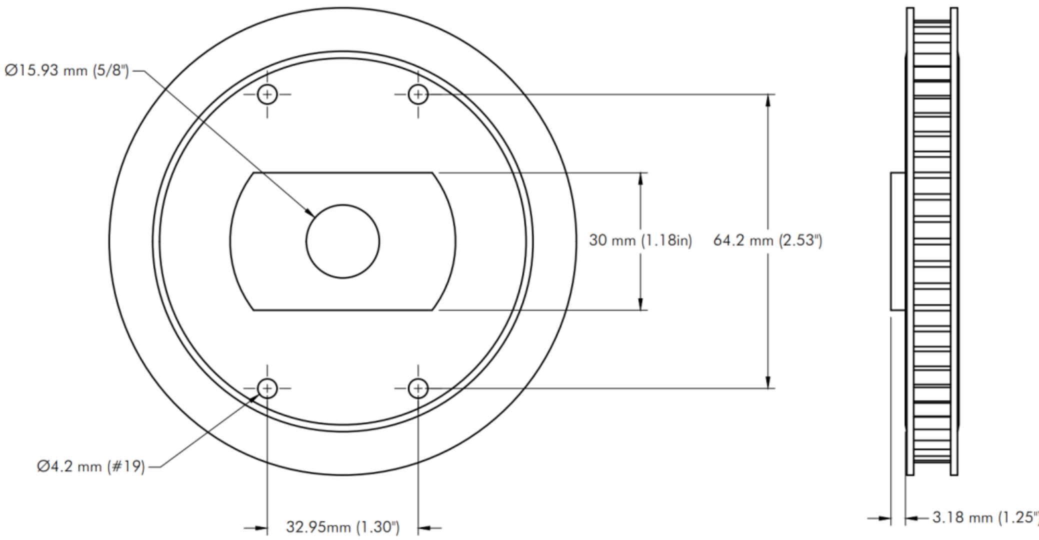
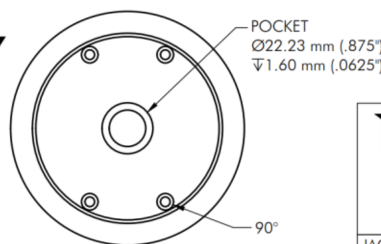


TOP GEOMETRY

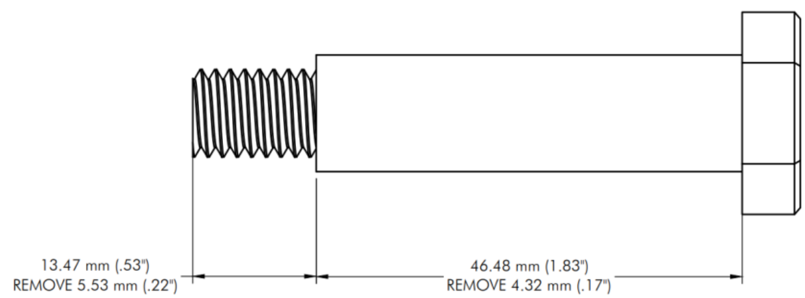


NOTE: MILL KEY; THEN DRILL HOLE PATTERN AND POCKET

DOOMBA

WEAPON GEAR
MACHINING GUIDE

JACOB HOFFMANN	13 APR 2022	SCALE 1:1	REV 5	PAGE 12



DOOMBA

WEAPON BOLT

TURNING GUIDE

JACOB HOFFMANN	13 APR 2022	SCALE 2:1	REV 5	PAGE 13

UC Battlebot Club Test Results

1 D

RE Combat Robotics

recombatrobotics@gmail.com

1938 W Alex Bell Rd

Dayton, OH 45459

UC Battlebots Club 15 lb. Bot Testing Form (Xtremebots)

Doomba 85 pts

To: University of Cincinnati Battlebots Club
From: Owen Cokley, RE Combat Robotics
Date: March 21, 2022

This form shall be used to evaluate a 15lb (Xtremebots) bot's speculative performance in the case that attending a competition is not available, or as a pre-event check. If used to evaluate a senior design team, interpretation of this form's results shall be left to the relevant faculty member.

Scoring will be broken down into multiple categories:

- **Rules Compliance**: Does your bot break or follow the "15lb Technical Regulations" document? (General info not covered in following inspections).
- **Internal Inspection**: Does your bot pass or fail the items on the "Internal Inspection Checklist" document?
- **Functions Test**: Does your bot pass or fail the items on the "Functional Test Checklist" document?
- **Weapons Test**: A subjective analysis of a bot's weapon performance in the UC Battlebots Club test cage. Performance should be compared to bots that have previously competed at Xtremebots. Possibility for multiple opinions.
- **Drivetrain Test**: A subjective analysis of a bot's drive performance. Performance should be compared to bots that have previously competed at Xtremebots. Possibility for multiple opinions.
- **Matchup Analysis**: A subjective analysis on how your bot would theoretically preform against an array of common designs at Xtremebots. Possibility for multiple opinions.

The following pages will be filled in by a UC Battlebots "Judge" and returned to teams for evaluation purposes.

UC Battlebots Club Judge: Owen Cokley

Team Being Evaluated: Doomba

Robot Name: Doomba

Rules Compliance:

Are there any rules a team is in violation of? See https://www.xtremestem.org/xtreme-bots for rule details.

no

A "**Pass**" should be awarded to teams where no rules were broken. A "**Minor Fail**" should be awarded if rules were broken, but the bot could be altered into compliance within 2 hours' time. A "**Fail**" should be awarded if a bot is in violation of Xtremebots rules, with no ability to fix the violation within 2 hours.

Pass	**Minor Fail**	**Fail**

Internal Inspection:

General Inspection	Low-Pressure Pneumatic System
☐ Secure covers on all sharp points/edges/corners ☐ Secure restraints for all pinch/motion hazards ☐ No use of disallowed construction materials ☐ Any restricted-use materials are used correctly ☐ No Internal Combustion Engine ☐ No stored high-pressure pneumatics ☐ No hydraulic system ☐ Bot name on exterior in 1/4" or larger letters **Electrical Inspection** ☐ Master switches mechanically shut off batteries ☐ Master switches are 2-position & fully-enclosed ☐ Master switch access requires no parts removal ☐ Access to all switches is outside weapons paths ☐ Batteries are allowed type (SLA, NiCd, NiMH, Li-on) **Lithium Polymer (LiPo) batteries are prohibited** ☐ Batteries are mounted securely within chassis ☐ Battery terminals/connections are insulated ☐ Primary electrical terminals are covered/insulated ☐ All wiring properly installed and insulated ☐ Maximum voltage does not exceed 28 VDC **Radio Control Equipment** ☐ Uses IFI, FM R/C or allowed custom controller ☐ R/C system not AM, pre-1991, or 72MHz ☐ R/C system has two sets of crystals ☐ Custom equipment complies with FCC regulations	***Verify that system is depressurized*** ☐ Tank is rated for at least 1.5x stored pressure ☐ Tank max volume less than 8 Cu ft. ☐ Tank has pressure-reliefs or blowout plugs ☐ Tank has a shut-off valve ☐ Pneumatic components are correctly rated ☐ Components are mounted securely within chassis ☐ Components are undamaged ☐ Actuators are attached properly ☐ Pressure purge valve to relieve pressure ☐ Purge and shut-offs are outside weapons paths ☐ Access for tank filling is safe and stable **External Equipment** ☐ Equipment setup/removal takes less than 2 minutes ☐ Equipment does not interfere with operations ☐ Homing/Targeting laser is class II or below **Additional Items** ☐ MultiBot meets all specific requirements ☐ StompBot complies with 'Walker' requirements ☐ Any lighting/sound system can be deactivated
Powered Weapons ☐ Weapons are not electrical/electromagnetic ☐ Weapons do not use heat, fire or explosive ☐ Weapons are non-fouling and non-obscuring ☐ Weapons/Flywheels are securely attached ☐ Spring-powered weapon has manual safety release ☐ Deactivated weapons pose no hazard to people nearby ☐ Projectile tether length does not exceed 4' ☐ Less than 30 minutes to change modular weapon	Notes: Pool noodle needed on weapon

A "**Pass**" should be awarded to teams where no rules were broken. A "**Minor Fail**" should be awarded if rules were broken, but the bot could be altered into compliance within 2 hours' time. A "**Fail**" should be awarded if a bot is in violation of Xtremebots rules, with no ability to fix the violation within 2 hours.

Pass	Minor Fail	Fail

Drive Did not failsafe 1st time

Functions Test:

Bot Weight and Appearance	Powered Weapon Systems Testing
❑ Bot total weight is: 146 4.6oz pounds > ***For a MultiBot, weigh segments separately and attach stickers indicating the weights*** ❑ Appearance is acceptable ❑ Name of bot is easily readable	> ***Start each weapon system moving*** ❑ Weapons systems are reliably controlled > ***Transmitter OFF while weapon is moving*** ❑ Drive power to weapon systems stops when transmitter is shut off ❑ Spinning part comes to a full stop within 30 seconds after transmitter shut-off. ❑ Weapon will not cause damage to Bot
Pneumatics Check > ***Pressurize the system*** ❑ No problems pressurizing ❑ Verify pressures do not exceed 150 psi	**Large Spring Arming/Disarming** > ***Arm the spring using radio control*** ❑ Large spring can be armed remotely > ***Transmitter OFF while spring is armed*** ❑ No motion or disarming at transmitter turn-off > ***Manually release the spring*** ❑ Spring can be manually released in 30 seconds ❑ No body part in weapon path during release
no wheel chalks **Activation of Bot** ❑ Bot is in full battle-ready configuration > ***Verify that Bot is completely deactivated*** > ***Mount bot on a support that suspends the wheels, tracks or legs in the air.*** > ***Check that all Master Switches are OFF*** > ***Turn the transmitter ON*** ❑ No bot movement when transmitter turned on > ***Activate the Bot*** ❑ Activation requires no more than 1 person ❑ Person not in weapons path during Activation ❑ Activation can be done within 30 seconds ❑ No panels/parts removal during Activation ❑ Activation safety is not sequence-dependent	**Autonomous Features** > ***Cycle the transmitter OFF, then ON*** ❑ Autonomous features start up disabled > ***Remotely activate autonomous features*** ❑ Light indicates autonomous features activated ❑ No erratic behavior during autonomous operation > ***Shut OFF transmitter*** ❑ All autonomous features cease functioning
Motion System Fail-Safe Test > ***Move the motion system forward/backward*** ❑ Bot motion control is continuous, not on/off ❑ Reliable control of the motion-producing parts ❑ Motion speed greater than 6 inches-per-second > ***Move the motion system at high speed*** > ***Transmitter OFF with motion at speed*** ❑ Drive power to motion system stops when transmitter is shut off.	**Deactivation of Bot** > ***Turn Transmitter ON (if necessary)*** > ***Deactivate the Bot*** ❑ Deactivation requires no more than 1 person ❑ Person not in path of weapons during deactivation ❑ Complete deactivation in less than 45 seconds ❑ No panels/parts removal during deactivation ❑ Deactivation safety is not sequence-dependent

A "**Pass**" should be awarded to teams where no rules were broken. A "**Minor Fail**" should be awarded if rules were broken, but the bot could be altered into compliance within 2 hours' time. A "**Fail**" should be awarded if a bot is in violation of Xtremebots rules, with no ability to fix the violation within 2 hours.

Pass	**Minor Fail**	**Fail**

Weapons Test:

A weapons test should be performed in the UC Battlebots club test cage in a safe and controlled manner. Make sure to film the weapon test and provide the video to the team being evaluated. If safe, have teams hit an object to simulate a hit more accurately in competition. The primary UC Battlebots club judge should record their thoughts on the following aspects below. If not applicable to the weapon type, skip that segment.

Spin-up time:

1-2 second spin up, look to stutter on start

Impact energy:

no spindown

Hit consistency:

good bite + balance

Recovery time between attacks:

no spin down

Damage done to weapon:

low/ visual

Heat from electronics or bearings:

light heat on bearings

Drive performance with weapon on:

Consistent

Other notes or worries:

high centered esily

Assign the team a value between 0 and 20, with 20 being the best, of their overall performance. If a robot has no active weapon, this value should be -10 (negative ten). If a robot's weapon stops working during testing, this value should be 0. Gather multiple opinions on this value if desired, and write the value below:

Weapons Test Value:

17 pts

Drivetrain Test:

A drivetrain test should be performed in a designated flat area at the discretion of a UC Battlebots Club Judge. Concrete, floor tile, or steel is preferred over asphalt. Set up a series of tests such as an obstacle course, a drag race, pushing a heavy item, and a 12' x 12' simulated arena to evaluate a bot. If a robot uses magnets to increase drive performance, preform an additional test in the UC Battlebots club test cage to account for this. The primary UC Battlebots club judge should record their thoughts on the following aspects below. If not applicable to the drive type, skip that segment.

Controllability:

Hard to drive in straight line

Top speed:

good

Ground clearance:

very poor

Tire wear:

fine

Pushing performance:

low pushing

Other notes or worries:

Assign the team a value between 0 and 20, with 20 being the best, of their overall performance. If a robot's drive stops working during testing, this value should be -10 (negative ten). Gather multiple opinions on this value if desired, and write the value below:

Drive Test Value:

10 pts

Matchup analysis:

How would this robot fair against other popular design at Xtremebots? The primary UC Battlebots club judge should record their thoughts on each matchup. Gather info from multiple sources to assign each matchup a value of 0 through 10, where 0 is a devastating loss, and 10 is an easy win.

Wedge:

Consider a bot similar to "Blade Wedge" in this video: https://www.youtube.com/watch?v=P9dFBxgJ3HU

Matchup thoughts:

Easy win

Matchup score:

9 pts

Beater Bar Vertical Spinner:

Consider a bot similar to "Mars" in this video: https://www.youtube.com/watch?v=PT-b6F_6-KU

Match thoughts:

Slow drive on dcomba

Matchup Score:

5pts

Vertical Disk Spinner:

Consider a bot similar to "Onyx" in this video: https://www.youtube.com/watch?v=id9iZAkNF9E

Match thoughts:

No guard against ramps / forks

Matchup Score:

3pts

Horizontal Spinner:

Consider a bot similar to "Slay Jay" in this video:
https://www.youtube.com/watch?v=aK6DNhrRwNk

Match thoughts:

Heavier blade + armor on Doomba

Matchup Score:

8 pts

Overhead Bar Spinner:

Consider a bot similar to "Cyclone" in this video:
https://www.youtube.com/watch?v=umZeTJrUhN4

Matchup thoughts:

Doomba is low profile

Matchup Score:

9 pts.

Drum Spinner:

Consider a bot similar to "Razors Edge" in this video:
https://www.youtube.com/watch?v=pBzOgmaPqcw

Matchup thoughts:

Armor would hold, blade would not

Matchup Score:

4 pts

Overall Score:

To give a bot an overall score, add up the point values as follows:

Rules Compliance:

Pass = 20 points

Minor Fail = 0 points

Fail = -100 points

Internal Inspection:

Pass = 15 points

Minor Fail = 0 points

Fail = -100 points

Functions Test:

Pass = 15 points

Minor Fail = 0 points

Fail = -100 points

Weapons Test:

Use scored Value (0 to 20 or -10 points).

17

Drivetrain Test:

Use scored Value (0 to 20 or -10 points).

16

Matchup Analysis:

Sum all scores (0 to 60 points)

38

Overall Score:

85 pts

UC Battlebots Judge Signature:

Oliver Ahly

Reading a team's score:

A team's score can range from -320 points to 150 points.

Anything below zero points is consider ineligible to compete. Teams scoring less than 0 points did not read the required rules, or properly prepare their bot for competition.

A zero-point robot is considered the minimum bar. This robot may not do well but will at least show up to competition and fight a couple of losing matches.

A 75-point robot is pretty good. A 75-point bot should be able to qualify for the round of 16 tournament, and consistently fight an entertaining match.

A 150-point robot should win an event. This should be the best 15 lb. robot anyone has ever seen.

There is a lot of grey area between zero points and 150 points, and that is by design. Outside of competition some things are impossible properly quantify. This form should help to create a comparative standard for bot to be evaluated against but should not be the sole means of judging a robot or team.