MECHANICAL ENGINEERING SENIOR DESIGN CAPSTONE FINAL REPORT

SCRAMBLE - Combat Robot

A Design Project Final Report submitted in partial
fulfillment of the requirements for the degree of

BACHELOR OF SCIENCE

in

MECHANICAL ENGINEERING

and

MECHANICAL ENGINEERING TECHNOLOGY

To the Department of Mechanical and Materials Engineering,
College of Engineering and Applied Science at the University of Cincinnati.

Submitted: 11 April 2025

2024-2025 Academic Year

Calvin Kampman, Mechanical Engineering, Team Lead, MECH5052

Parker Frye, Mechanical Engineering Technology, MET5092

Andrew Steckner, Mechanical Engineering, MECH5052

Dr. Jacob Cress, Ph.D.____________
Course Instructor

UC Combat Robotics_____________
Project Sponsor

Dr. Dong and KC Robotics___________
Faculty and Industry Advisor

Table of Contents

1. Problem Statement

The team's problem statement is to construct a combat robot that will cause the maximum amount of damage to opponents while inflicting as insignificant damage on their own robot as possible. The design and construction of the robot must result in a durable and cost-effective robot, while staying within the weight constraints of the competition requirements. The team will design and build a BattleBot in conjunction with the UC BattleBots club advised by Professor Dong.

2. Research

a. Background of the Problem

The concept of robot combat has its roots in various early competitions and events that predate BattleBots. In the 1990s, hobbyists and engineers held small-scale robot combat events, laying the groundwork for what would become a global phenomenon. These early competitions were inspired by the pioneering work of individuals interested in robotics and remote-controlled technology. The official inception of BattleBots came in 1999, when Greg Munson and Trey Roski created it [1]. The show premiered on the US cable network Comedy Central and quickly garnered attention for its innovative approach. BattleBots featured teams building robots to compete in an arena filled with various hazards and obstacles, combining elements of engineering with thrilling combat. At its heart, BattleBots is a competition where teams design and build remote-controlled robots to engage in combat within a specially designed arena. These robots, equipped with various offensive and defensive mechanisms, battle against each other in a gladiatorial-style format. The goal is to disable or outmaneuver the opponent's robot while navigating the challenges and hazards present in the arena.

The format of BattleBots involves several key components. Teams of engineers, hobbyists, and enthusiasts create robots with unique designs and functionalities. Each robot is crafted with specific strategies in mind, whether it involves powerful weaponry, defensive armor, or maneuverability. The competition typically consists of a series of matches, where robots face off in the arena under a set of rules and time limits. The arena itself is designed with various hazards, such as spinning blades and traps, adding an extra layer of challenge to the battles. Judges evaluate the matches based on criteria like control, damage, and aggression, and in some cases, robots may be declared winners by knockout or submission.

b. Applicable Standards

The robot designed must comply with all the rules and regulations listed on the NHRL BattleBot's website at the time of registration [2]. Rules and regulations listed below. The robot must also have a physical disabling device that stops all rotation of the spinner when outside of the combat arena. While working on either the Victory Parkway Campus or UC Main Campus, all engineering safety standards must be followed. All 3D designs and models will be held to industry standards. Below is a brief list of some of the major rules provided by the NHRL website.

- 12lb weight limit
- Bots must have an easily accessible master power cutoff in the form of a switch or removable link
- Nominal battery voltage may not exceed 75 volts for 12lb bot.
- All robots must have an active weapon
    - With tip speed less than 300 Miles per Hour
- All weapon systems must have a lock that stops their actuation, extension, expansion, rotation, ignition, etc.

c. State of the Art

Ram Plan [3] is a plow robot that is designed primarily for direct physical engagement rather than relying on spinning weapons or other elaborate mechanisms. Their core feature is a powerful ram or pushing device, often in the form of a large, sturdy wedge or plow at the front of the robot. Ram Plans front plow is made from AR500 steel. This design allows the robot to make forceful contact with opponents, leveraging sheer force to drive them into hazards or immobilize them by disrupting their mobility. The strategy behind ram BattleBots centers on the effective use of physical force and tactical positioning. Unlike robots that rely on spinning weapons or complex mechanisms, ram bots focus on straightforward but effective tactics. Their primary strategy involves using their ram or wedge to push opponents into hazards like spikes or flippers, thereby causing damage or disorientation. Additionally, by maintaining a strong and aggressive offensive, ram robots can control the pace of the match, dictating the movements and actions of their adversaries. Historically plow bots were allowed to compete, due to recent rule changes, plow bots are no longer viable for competition due to their lack of an active weapon.

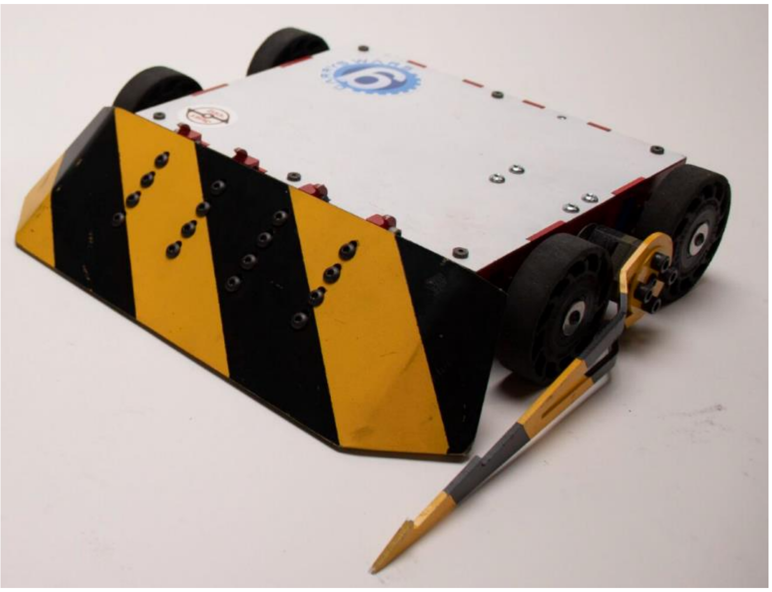


Figure 1: Ram Plan *[3]*

End Game [4] is a vertical spinner designed to deliver powerful, high impact strikes to opponents. The core concept involves a vertically mounted rotating weapon that spins at high speeds, generating significant centrifugal force. This configuration allows End Game to strike with intense force, making it a formidable offensive tool in the BattleBots arena. The vertical spinner's primary function is to inflict damage through concentrated impacts, leveraging its rotational speed to break through defenses and disrupt opponents. End Game's design includes interchangeable front wedges, forks, and small wedges, which enhance the robot's adaptability in combat. These additions help the robot optimize its approach based on the opponent's design, improving the effectiveness of the vertical spinner. The ability to switch between different configurations allows End Game to tailor its strategy to specific matchups and improve its overall performance. As for End Games defensive abilities, the robot is designed out of a 7050 Aluminum frame and a self-righting device that can flip the robot if it is overturned.

Figure 2: End Game *[4]*

Rotator [5] is a heavyweight robot developed by Team Revolution, known for its distinctive design and competitive history in BattleBots. The robot, inspired by Victor Soto's middleweight robot Blue Flame, debuted with an invertible hexagonal shape, and featured horizontal spinners at both the front and back, which could spin at 300mph. Rotator features an undercutter design, this being one of the common designs for horizontal spinners. The other being a mid-cutter, and an upper cutter. While the exact material used to design Rotator is not publicly available, it is assumed to be a combination of steel, aluminum, and plastics. Horizontal spinner BattleBots represent the pinnacle of engineering and strategic ingenuity in robotic combat. Their horizontally mounted spinning weapons deliver powerful, sweeping attacks that can incapacitate opponents and alter the dynamics of a match. By combining destructive force with defensive measures, these robots exemplify the high stakes and complex strategies involved in competitive robot fighting. As the field of BattleBots continues to evolve, the horizontal spinner remains a testament to the relentless pursuit of innovation and excellence in robotic design and combat strategy.

Figure 3: Rotator [5]

Project Liftoff [6] is a 3lb MeltyBrain robot known for its spinning body. MeltyBrain battle bots are distinguished by their unique design and movement mechanisms. Central to their operation is a high-speed spinner, which typically rotates between 2000 and 4000 RPM. This spinning motion generates significant offensive power and enables the robot to maneuver in a distinctive way. Unlike traditional wheeled robots, MeltyBrains uses the spinning mechanism for movement, resulting in a translational drift that allows them to slide and change direction in a manner that’s different from conventional designs. MeltyBrains can be operated manually, where the driver uses an LED heading device to control movement, or autonomously, using onboard sensors and programmed algorithms. Project Liftoff was constructed from durable materials like AR500 steel or TPU plastic, these bots are designed to withstand the rigors of combat. Their effectiveness in battle hinges on both the speed and stability of their spinning mechanism, which provides a powerful offensive capability but requires careful management to avoid being easily flipped or immobilized by opponents.

Figure 4: Project Liftoff *[6]*

d. End User

The end user of this document will be anyone with a background or interest in the design of Combat Robotics. Also, educators may use this document to inform high school or college students about combat robotics as a starting point or a reference for the design and manufacturing of their own combat robot.

e. Summary of Research

From the research found, Battlebots consist of three fundamental areas: the energy transfer device (weapon), armor, and the movement system. The goal of a Battlebot is to beat your opponent. This can be done by inflicting enough damage to render the opponent’s robot unusable, or by indirect combat factors such as control time, and aggression of your robot. The damage you inflict has the highest weight on the scoring. Fights consist of multiple rounds, if both bots remain standing. Teams are given a short window to make any needed repairs to their bots. After all fights are done or one robot is considered unusable, a winner is determined.

A major factor in Battlebot design is your robot’s ability to withstand impact. Not only being attacked by an opponent, but also the force you inflict on your own robot when striking an opposing robot. This is crucial for success because there are cases where some robots destroy themselves. The team has chosen to choose a less traditional path and approach the route of making a melty brain design. The team will be using information about material properties and how things such as moment of inertia and centripetal force come into play to aid in the design of the robot. Also, there is a general “Meta” to battle bots. Typically, Horizontal Spinners beat Vertical Spinners, Vertical Spinners beat Plow Bots, and Plow Bots beat Horizontal Spinners.

The goal of the team is to inflict the most damage on opposing robots while keeping the robot in-tact. Using the diverse backgrounds consisting of: Mechanical Design, Mechanical Manufacturing, and Computer Science, the team hopes to design a robot that can achieve the goal. The team consists of a wide variety of experiences that will be utilized to make a unique robot design. Certain limitations constrain specific parameters of the design to comply with competition rules and weight limits. The team will be competing in the twelve-pound robot league and attempting to accomplish the goal. Something important to note is that melty brain designs are typically only done in the three-pound category.

f. Customer features

The customer was determined to be anyone within or interested in the Battlebots community. Using this community, a survey was conducted asking participants to rank characteristics of Battlebots on a scale of 1-5 (1 being least important, 5 being most important). The list below consists of the top 10 highest rated results from the survey, this is how the customer features were determined.

1. Cost
2. Weight
3. Shock Absorption
4. Aesthetic of Design
5. Center of Gravity
6. Reliability

7. Armor
8. Battery Life
9. Drivetrain (Ability to move)
10. Weapon

3. Quality Function Deployment

a. Survey Methodology and Results

After conducting the survey, it was clear that the most important feature to the customer was the Weapon of a Battlebot and the least important being the Aesthetic of the Battlebot. Overall, the survey showed that most consumers just care about if the Battlebot can take and deal damage. Categories related to either armor or weapon all tended to score higher than any other area.

Table 1: Survey Results

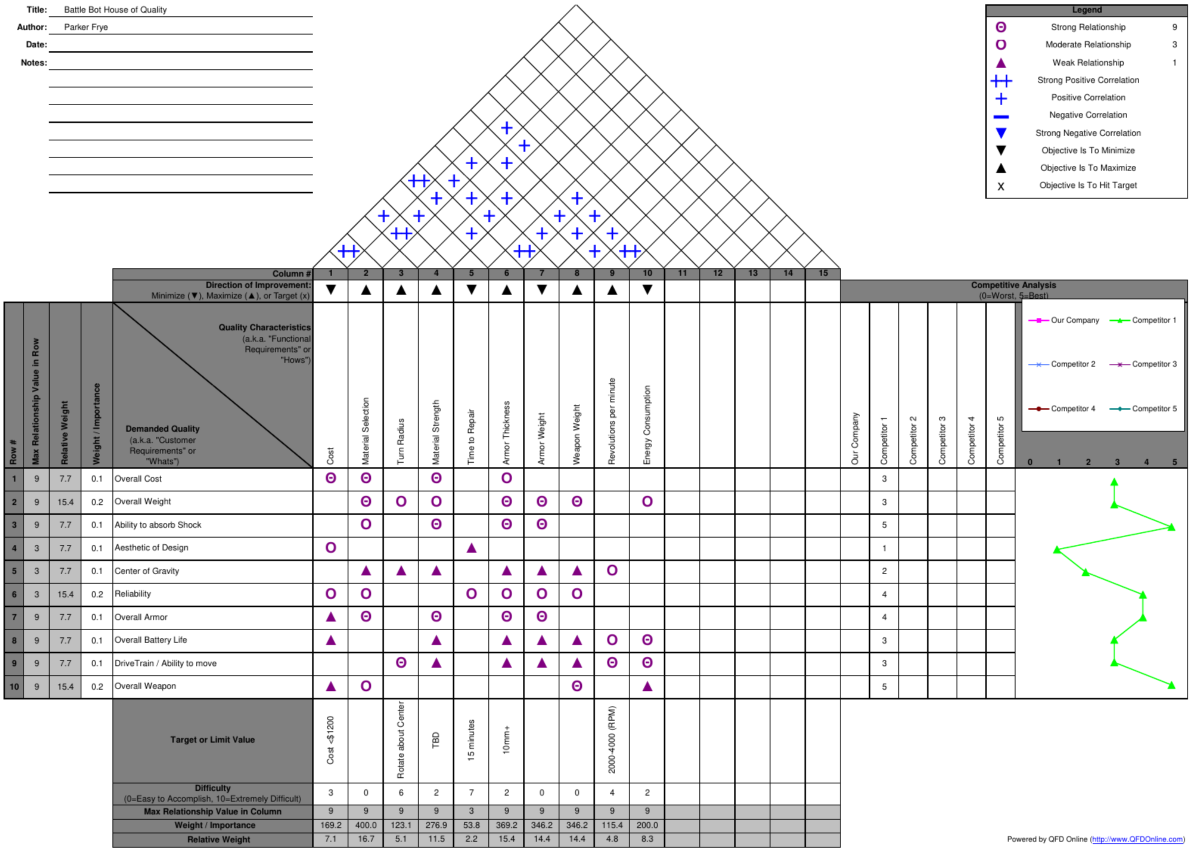
		Importance of the feature		Satisfaction with the feature in the current technology	
Customer Feature	Total Surveyed	Average Rank	Standard Deviation	Average Rank	Standard Deviation
Cost	32	3.0	1.15	2.86	1.7
Weight	32	3.12	1.19	3	1.46
Shock Absorption	32	3.81	1.11	3	1.26
Aesthetic of Design	32	2.81	1.56	2.6	1.5
Center of Gravity	32	3.69	1.01	4.1	1.08
Reliability	32	4.38	0.62	3.3	1.3
Armor	32	4.19	0.75	2.5	1.5
Battery Life	32	3.33	0.98	3.25	1.6
Drivetrain (Ability to move)	32	3.81	0.91	2.62	1.3
Weapon	32	4.5	0.63	2.5	1.63

b. Engineering Characteristics

An engineering characteristic is a measurable or quantifiable feature that directly impacts the product's functionality, performance, or customer perception. These characteristics (listed below) were determined by a discussion within the team to determine the top 10 most significant factors that could impact on the overall performance of the Battlebot.

1. Cost (Dollar amount)
2. Material Selection
3. Turn Radius
4. Material Strength
5. Time to repair
6. Amor Thickness
7. Armor Weight
8. Weapon Weight
9. Revolutions per minute
10. Energy Consumption

4. Product Objectives



Title: Battle Bot House of Quality
Author: Parker Frye
Date:
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	Our Company	Competitor 1	Competitor 2	Competitor 3	Competitor 4	Competitor 5
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	▲	▲	▼	▲	▼	▲	▲	▼						
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Cost	Material Selection	Turn Radius	Material Strength	Time to Repair	Armor Thickness	Armor Weight	Weapon Weight	Revolutions per minute	Energy Consumption						
1	9	7.7	0.1	Overall Cost	Θ	Θ		Θ		O						3				
2	9	15.4	0.2	Overall Weight		Θ	O	O		Θ	Θ	Θ		O		3				
3	9	7.7	0.1	Ability to absorb Shock		O		Θ		Θ	Θ					5				
4	3	7.7	0.1	Aesthetic of Design	O				▲							1				
5	3	7.7	0.1	Center of Gravity		▲	▲	▲		▲	▲	▲	O			2				
6	3	15.4	0.2	Reliability	O	O			O	O	O	O				4				
7	9	7.7	0.1	Overall Armor	▲	Θ		Θ		Θ	Θ					4				
8	9	7.7	0.1	Overall Battery Life	▲			▲		▲	▲	▲	O	Θ		3				
9	9	7.7	0.1	DriveTrain / Ability to move			Θ	▲		▲	▲	▲	Θ	Θ		3				
10	9	15.4	0.2	Overall Weapon	▲	O						Θ		▲		5				
				Target or Limit Value	Cost <$1200		Rotate about Center	TBD	15 minutes	10mm+			2000-4000 (RPM)							
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	0	6	2	7	2	0	0	4	2						
				Max Relationship Value in Column	9	9	9	9	3	9	9	9	9	9						
				Weight / Importance	169.2	400.0	123.1	276.9	53.8	369.2	346.2	346.2	115.4	200.0						
				Relative Weight	7.1	16.7	5.1	11.5	2.2	15.4	14.4	14.4	4.8	8.3						

Powered by QFD Online (http://www.QFDOnline.com)

Figure 5: House of Quality

Below is a list of the product objectives and their importance weighting that was generated from the creation of the House of Quality table and survey results. Product objectives are listed from most to least important based on weighting.

- Material Selection (16.7)
- Armor Thickness (15.4)
- Armor Weight (14.4)
- Weapon Weight (14.4)
- Material Strength (11.5)
- Energy Consumption (8.3)
- Cost (7.1)
- Turn Radius (5.1)
- Revolutions per Minute (4.8)
- Time to Repair (2.2)

5. Project Management

a. Team Members and Responsibilities

Calvin Kampman - R&R Team Lead

- Primary responsibility - Mechanical Design, Secondary Responsibilities - Electronics, manufacturing

Andrew Steckner - R&R Individual Contributor (IC)

- Primary Responsibilities - Code and Electronics, Secondary Responsibilities -Design FEA

Parker Frye - R&R Individual Contributor (IC)

- Primary Responsibilities – Manufacturing, Secondary Responsibilities -Design

b. Project Budget Limit

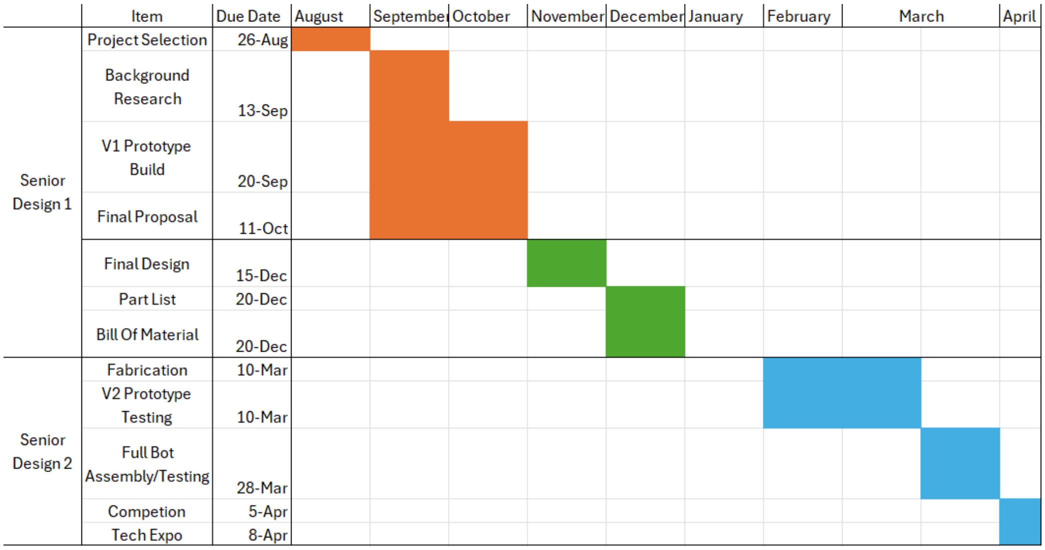
Table 2: Initial Budget Estimation

Preliminary Budget	
Subsystem:	**Cost:**
Weapon	$50
Armor	$50
Frame	$100

Drivetrain	$250
Electronics	$270
Manufacturing	$500
Total:	$1220

c. Key Milestones

Table 3: Gantt Chart Overview



	Item	Due Date	August	September	October	November	December	January	February	March		April
Senior Design 1	Project Selection	26-Aug	🟧									
	Background Research	13-Sep		🟧								
	V1 Prototype Build	20-Sep		🟧	🟧							
	Final Proposal	11-Oct		🟧	🟧							
	Final Design	15-Dec				🟩						
	Part List	20-Dec					🟩					
	Bill Of Material	20-Dec					🟩					
Senior Design 2	Fabrication	10-Mar							🟦	🟦		
	V2 Prototype Testing	10-Mar							🟦	🟦		
	Full Bot Assembly/Testing	28-Mar									🟦	
	Competion	5-Apr										🟦
	Tech Expo	8-Apr										🟦

6. Design Concepts

Based on the QFD process, the most important feature was determined to be the material selection for the design. Based on this data and research the team has chosen to use a mix of materials for different components. For the chassis and frame, Aluminum 6061 will be used. For the weapons steel will be used and for wheels an aluminum hub and steel cleats will be used. These are the most important aspects for us to achieve a successful design. From the state of the art, it was found that most current battle robot designs use a similar mix of materials to those listed above. Aluminum, steel, and 3D printed plastics are the standard materials for most designs. The main exception is the use of Titanium in state-of-the-art designs.

Function #1 – Calvin, Design Lead and Team Lead

Final design for battle bot. Material selection. Lead team to complete robot

Function #2 - Andrew, Electronics Lead

Finish programming and electronics for robot design

Function #3 - Parker – Manufacturing Lead

Build/Assemble bot. Communicate with vendors for manufacturing of needed parts. Budget

Concepts

The team chose to design a variation of a full-body spinner nicknamed a melty brain, because of this a lot of the components throughout the concepts are the same. This is because there are more universal components that all melty brains must contain. All concepts have the same drivetrain consisting of two motors with an ESC (Electronic Speed Controller, is a device that regulates the speed, direction, and braking of an electric motor) to equalize power to the wheels and synchronize them. All designs also consist of an iterated wheel design consisting of a 3D printed “rim” with cast urethane surrounding the rim. Things such as the height, weapon type, and armor were changed throughout the concepts. The chassis and frame will be manufactured out of Aluminum 6061 and the weapon will be made of steel.

Melty brains utilize nontraditional form of movement known as translational drift [7], which is a defining characteristic of melty brains which will be present in all designs. Translational drift allows a continuously spinning object to move translationally while spinning. This is accomplished by pulsing the motor throughout the rotation such that there is a resultant velocity in the desired direction for translation . This is clearly illustrated in Figure 6 below and shows the resultant vector in a desired direction. The red arrows denote the overall magnitude of the motor’s power, with one half the rotation receiving little to no power. The X components denoted in light blue cancel, with the Y components denoted in magenta effectively summing to result in movement in the Y direction, as denoted by the green arrow.

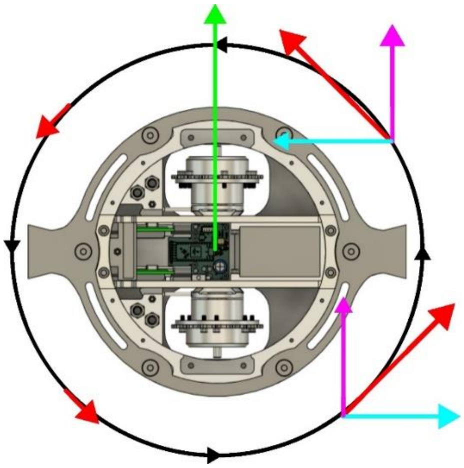


Figure 6: Translational Drift Vector Illustration

Concept 1

Concept 1 is a variation of a full-body spinner melty brain. This design has a large single blade as the weapon. This weapon design allows the robot to have more time to rotate to create a larger impact force, however the trade off with 1 weapon is that you must do a full revolution before you can impact your opponent. The chassis consists of three main pieces, the top and bottom mounting plates with the weapon plate in between them. This concept was built on the basic electronics, material, and wheel design that was used for all concepts.

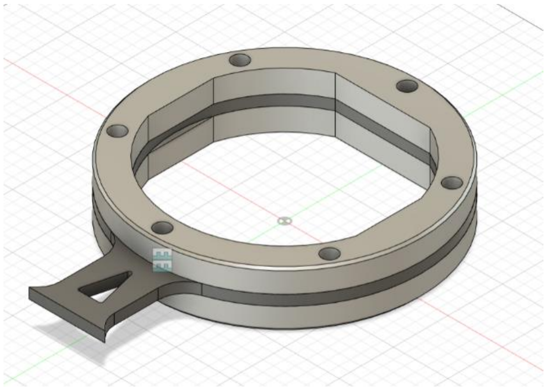


Figure 7: Concept 1

Concept 2

Concept 2 is another variation of a full-body spinner melty brain. This concept consists of two weapon impactors. This requires the robot to only make half a revolution to impact the opponent, unlike a single blade that requires a full revolution. The chassis consists of three parts, a top and bottom mounting plate, and a center weapon piece. However, this concept is that the weapon plate is flared outwards. This allows for the weapon to impact further away from the body of the bot, providing more protection for the bot. This concept was built on the basic electronics, material, and wheel design that was used for all concepts.

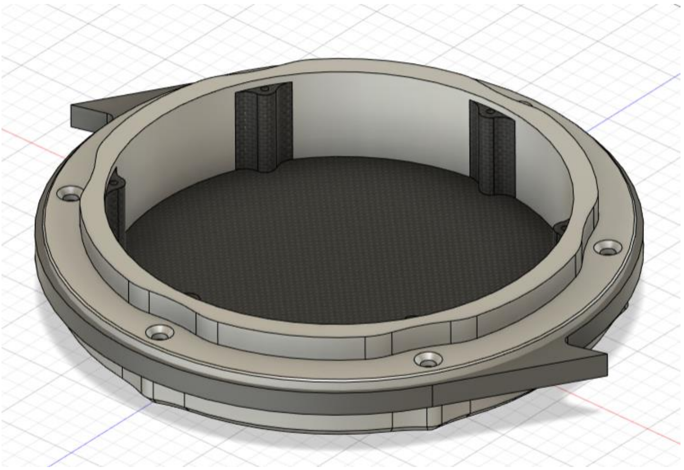


Figure 8: Concept 2

Concept 3

Concept 3 is a combination of concepts 1 and 2. Concept 3 consists of a two-impactor weapon system. The blade design is like the initial iteration on concept 1. This is because the larger area and mass can lead to a larger impact force. The two impactors also require the robot to only make half a revolution to make an impact. The body consists of a top and bottom mounting plate with a middle weapon plate. This concept was built on the basic electronics, material, and wheel design that was used for all concepts.

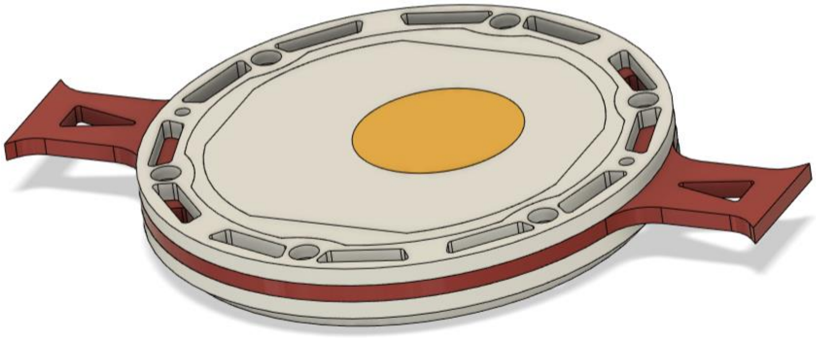


Figure 9: Concept 3

7. Concept Selection

From the concepts and testing it was found that the robot needs to be balanced, which leads to concept 2 or concept 3. The team also wanted a construction that was bolted and keyed to be able to withstand impact, again following concepts 2 and 3. Concepts 2 and 3 were similar but concept 3 had a bi-directional impactor which means the robot can run in either direction. This means that if the robot were to get flipped over, it can still deliver impact effectively.

8. Design Prototype, Material, & Fabrication

The robot consists of three main construction components, the Chassis Ring, Impactor Ring, and Internal Chassis. The Chassis Ring is the main structure of the robot, this was used as the datum piece in the manufacturing process. The Impactor Ring bolts onto the outside of the Chassis Ring and servs as the impactor to transfer energy to the other robots. Internal Chassis slots into the Chassis Ring and holds all electrical components and wiring in place. It also acts as a safety barrier between all electrical components and moving mechanical components. As well as acting as a motor mount.

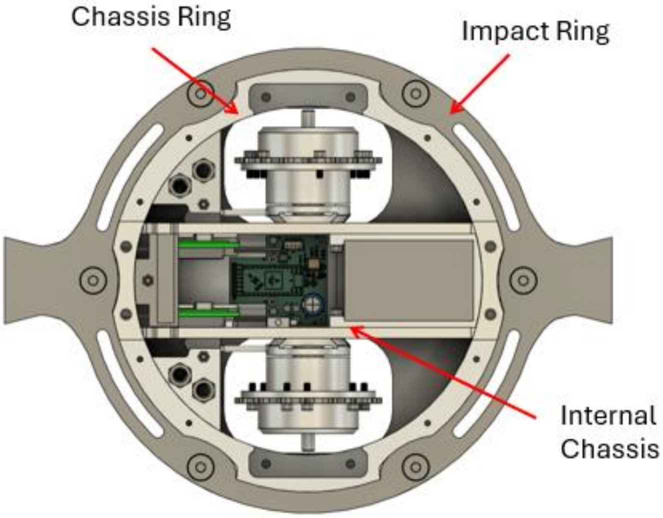


Figure 10: Robot Assembly

a. Chassis Ring:

The Chassis Ring (Figure 11) consists of two major components, the Ring, and the Motor mounts. The Chassis ring is comprised of being 1.63” tall, an ID/OD of 9.25”/10.83” Respectively, and a mass of 3.366lb. The Chassis ring will be manufactured from 6061 Aluminum on a CNC. Since the ring has complex geometry, a CNC operation will allow us to achieve the desired geometry. A keynote is that the entire robot is built around the chassis ring, it is crucial that the machining and tolerancing is precise, this is another reason this process will be done on a CNC.

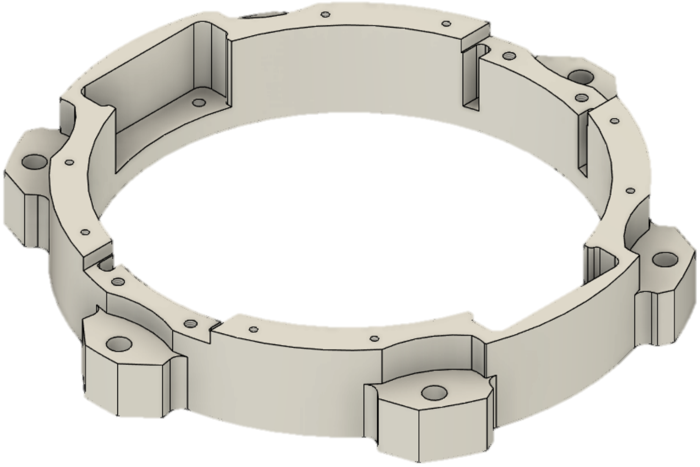


Figure 11: Chassis Ring

Separate from the chassis ring (Figure 11) will be the motor mounts (Figure 12). These are separate to allow for ease of manufacturing as well as increasing the accuracy of the manufacturing process. These pieces allow for the motors to be swapped without having to replace and disassemble the whole chassis ring. These pieces will be made from 6061 Aluminum with a combination of milling and drilling by hand.

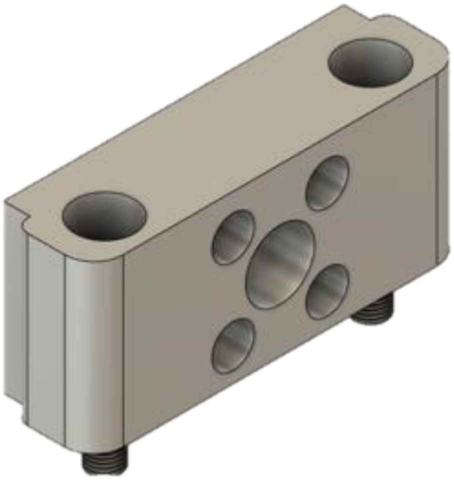


Figure 12: Motor Mount

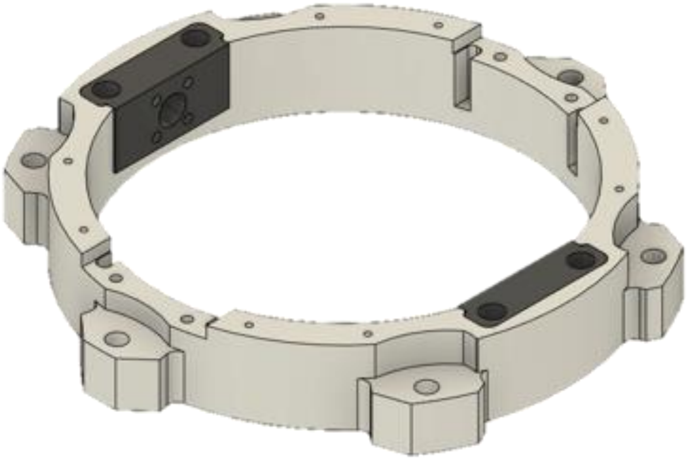


Figure 13: Chassis Ring with Motor Mounts

b. Internal Chassis

The internal chassis (Figure 14) holds all electronic components of the robot as well as provides an internal frame that supports the motors and overall bot. The internal chassis consists of an internal frame, battery holder, keepers, center beams, LED holder, ESC holder, and a PCB holder (Figure 15). Since most of these components are not crucial to the physical integrity of the robot, they will be 3D printed: ESC holders, LED Holders, Batter Holder, and PCB Holder out of thermoplastic polyurethane (TPU). This also saves weight on the robot versus machining these components out of metal.

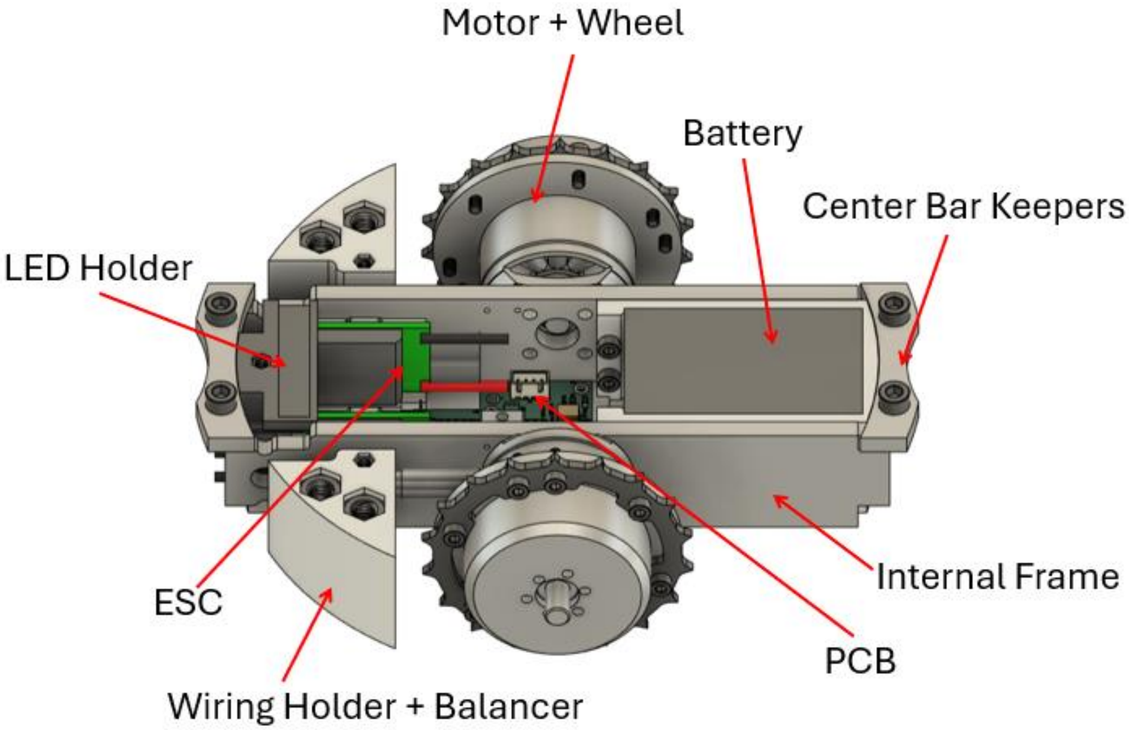


Figure 14: Internal Chassis Overview

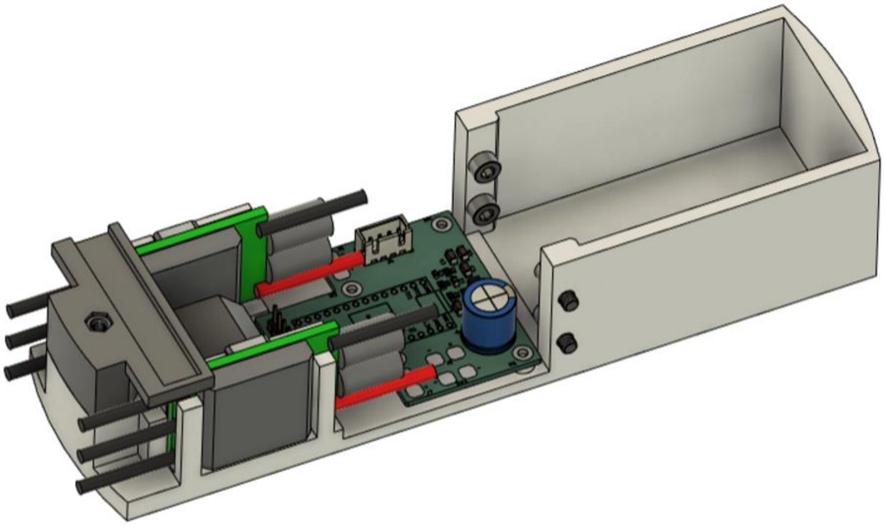


Figure 15: TPU Electronics Holder

The center beams (Figure 16) provide additional support to the motor as well as the overall bot, since these will be put under load, they will be waterjet out of 0.25” thick 6061 Aluminum. The same principle applies to the keepers (Figure 17). The keepers help hold the center beams in place as well as provide more overall structure integrity to the bot. These will also be waterjet out of 0.25” thick 6061 Aluminum.

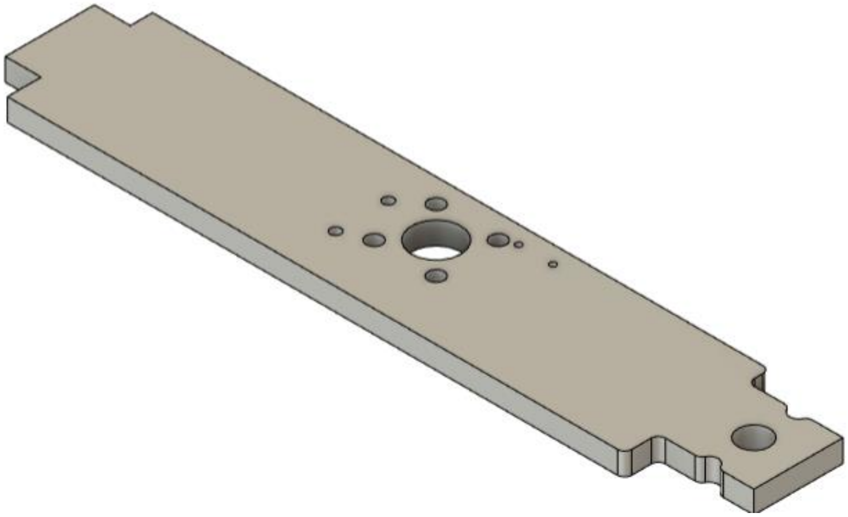


Figure 16: Center Bars

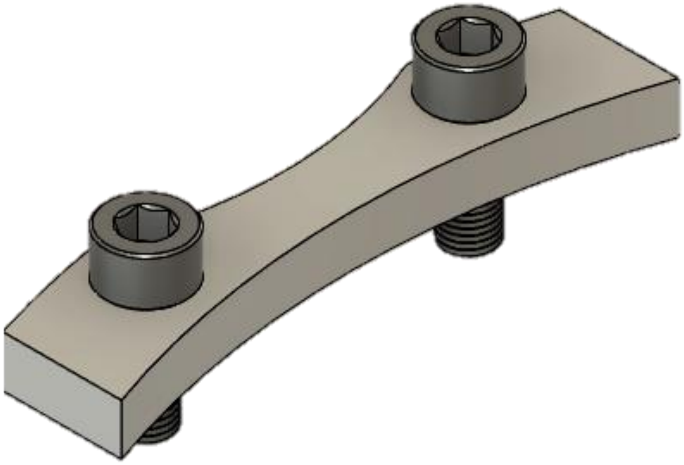


Figure 17: Center Bar Keepers

c. Impact Ring

The Impact ring (Figure 19) consists of a solid piece of sheet metal and is mounted to the Chassis ring of the bot. Since the whole robot rotates, the impactor does not have a direct drive system because the impactor will rotate with the bot. The device is comprised of 3/8" thick AR500 Steel, having a mass of 2.8lbs, a tip diameter of 14.173" and an ID/OD of 9.25"/10.83" respectively. The plate is held onto the chassis ring with six M10 shoulder bolts and keys into chassis ring, shown in Figure 18 below. Since the impactor design has no complex geometry, it will be cut from a sheet of AR500 Steel using a water jet.

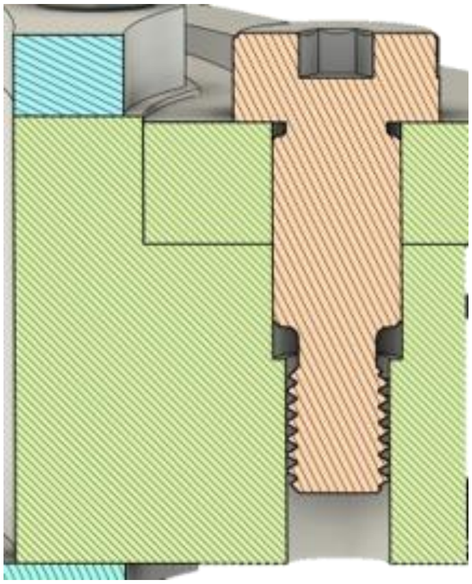


Figure 18: Impact Ring Mounting Cross Section

Figure 19: Impact Ring

d. Drive System

The drive system consists of a two-wheel drive system using two 580KV motors. The assembly in Figure 21 consists of a motor, wheel hub, and cleats. 50 50 prop drive 580KV motors in Figure 20 were used because historically these motors have been used by other 12lb melty brain BattleBot designs and proven to work. This was a major factor in choosing to uprate the motors. Also, with the smaller motors, the robot was unable to produce enough RPM to be effective in movement and combat. These motors are bought as is and require no manufacturing.

Figure 20: 320KV vs 580KV Motor

The wheel hubs have a diameter of 50.25mm, just slightly larger than the diameter of the motors, and a bore depth of 20mm to allow for more space inside the robot. The wheel hubs will be machined on a CNC and are made from 6061 Aluminum. The wheel hub is designed so that the motor sits inside, and the motor is then bolted to the wheel hub.

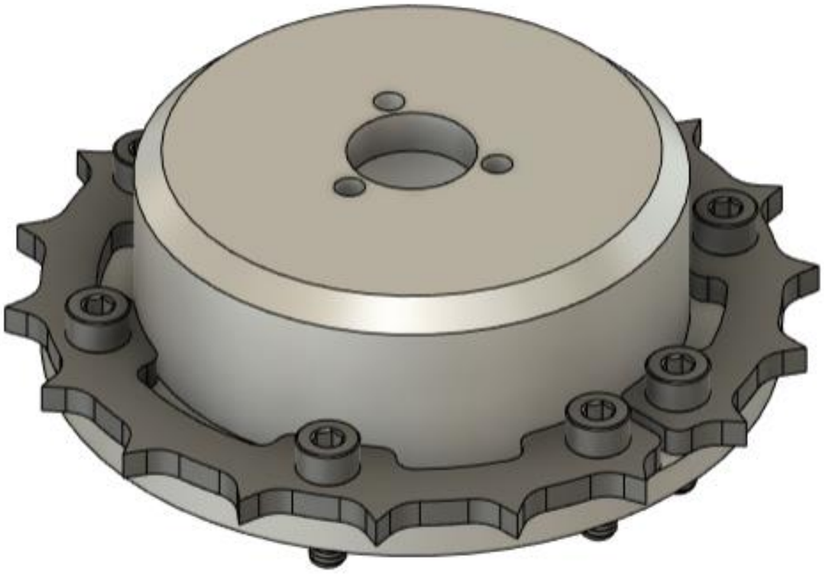


Figure 21: Wheel Assembly

The last part of the drivetrain assembly is the wheel cleats. The cleats in Figure 22 are a piece of metal that sits on the outer ring of the wheel hub. The cleats are what contact the ground instead of the aluminum wheel hub. Cleats provide a significantly higher amount of grip and bite on the NHLR areas floor. Since the arena floors are made of wood, cleats allow for much more control of the robot. The cleats have an ID/OD of 60.15mm and 85mm respectively. The 85mm is the outer profile dimension of the tip of the cleat that will contact the ground. The cleats will be waterjet out of 1/8” thick 4140 Steel. The cleats are manufactured as two separate pieces, this is because if the cleats were one solid piece the team would have to disassemble the whole wheel/motor assembly to replace the cleats. The split design allows us to change out the old cleats with new ones quickly and easily. The mounting holes along the cleat profile will be used to bolt into the wheel hub.

Figure 22: Cleat

e. Electronics

Melty brain battle robots require more electronics than the traditional type of battle robot designs. The electronics consist of: A buck converter to reduce the battery voltage down to 5V, or as it's commonly known in battle bots, a battery elimination circuit. This is based around the Texas Instruments chip TPS54302. The Microcontroller used is a Teensy 4.0, this is one of the few microcontrollers which have a sufficiently high clock speed, in this case 600 MHz, which is necessary to handle the computational demands of a melty brain. For an accelerometer, the ST Microelectronics H3LIS331 was used. This is a cost-effective option widely used within melty brains. With a max acceleration of 400g, the accelerometer creates a theoretical limit of about 5000 RPM for a melty brain. With better accelerometers, this could be raised higher, however 5000 RPM is already capable of exceeding the tip speed limits imposed by NHRL. A Spektrum AR620 is used for the RC receiver. Rhino 80A electronic speed controllers are used to operate the motors, which are PropDrive 5060s in the final implementation of the robot. The selection of electronic hardware was based off previously successful MeltyBrain robots like Halo [8] and Project Liftoff [6] with a change for higher power battery, ESCs and motors. All the aforementioned electronics plus an LED and a small number of necessary passive components are combined into a custom designed Printed Circuit Boards (PCB). The following PCBs Figure 23 and

Figure 24 are used to make everything fit within the given space constraints. The PCB was made by JLCPCB with the supplied PCB layout.

Figure 23: PCB V2

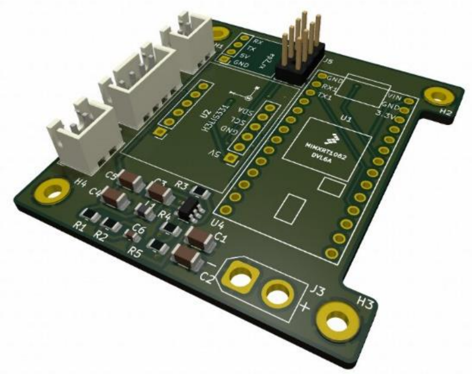


Figure 24: PCB V1

The older V1 board is functionally identical to its successor, however it was inefficient with the layout of the components and could be significantly improved. This was done by increasing to a four-layer design from the previous two to eliminate the need for a separate high voltage wiring harness to supply power to the motors. The ELRS module that was being considered for use as the RC receiver was also eliminated due to insufficient time to solve the challenges associated with ELRS.

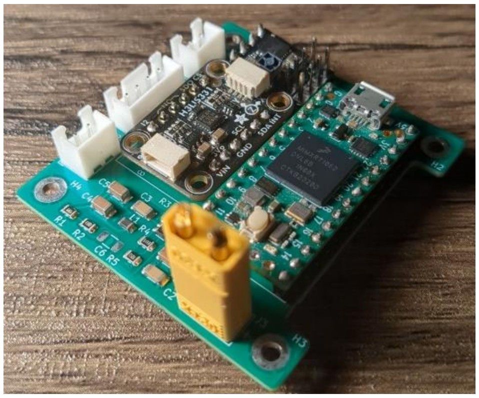


Figure 25: PCB V1 – Assembled

By changing from PCB V1 to PCB V2 the electronics and internal chassis changed substantially. This changed allowed all of the electronics (besides motors) to fit inside the aluminum center bars. This before and after can be seen in Figure 26 below.

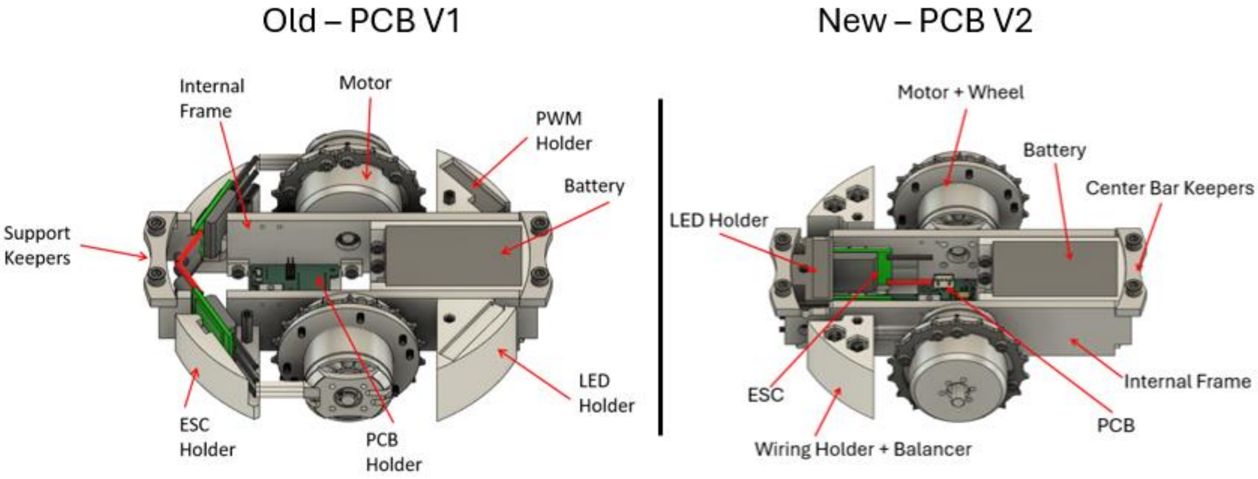


Figure 26: Old vs New Internal Chassis

f. Material Selection

The robot consisted of five main materials for construction, these materials are listed below in Table 4 with the component and their respective material.

Table 4: Component Materials

Item Name	Material
Impactor Ring	AR500 Steel
Top Plate	G10
Bottom Plate	G10
Cleats	Titanium or AR500
Center Beams	6061 Aluminum
Center Keepers	6061 Aluminum
Chassis Ring	6061 Aluminum
Wheel Hub	6061 Aluminum
Motor Mount	6061 Aluminum
Electronics Chassis	3D Printed TPU

The Bottom ring, wheel hubs, motor mounts, center beams, and center keepers will all be made from 6061 Aluminum. With the center beam and keepers being waterjet and the rest being machined. 6061 Aluminum was ideal for these components because it has a yield strength of 276 MPa and an ultimate strength of 310 MPa. These components are all structure components to the robot and will be taking load, not only from impact but from the strain created by the force of the robot spinning. 6061 Aluminum was the ideal compromise between strength, weight, and cost. It will allow the robot to withstand impact while also keeping us within a reasonable budget price.

The impactor ring will be made from AR500 Steel and will be cut using a waterjet. AR500 Steel has a yield strength of 1,289 MPa and an ultimate strength of 1,703 MPa. Since the robot will be spinning at 4000 RPM, a material was needed that would be able to withstand the impact of the force being created. The impactor ring is what contacts the other battle bots, and because of this AR500 Steel was chosen. This will maximize the damage given while also minimizing the risk of the Impact ring breaking.

The top and bottom cover plates will be made from G10 fiberglass. The two major reasons for this are needing a material that the RC transmitter would be able to transmit through, and weight savings. If there is a failure to communicate with the RC transmitter, there will be no ability to control the robot, which would result in losing the battle. It is also unlikely that the robot will ever get hit on the top or bottom plate, because of this there was no concern with armoring these sections of the robot.

The cleats will be made from 4140 Steel and will be waterjet. As well as the motor rods which will be machined. 4140 Steel has a yield strength of 655 MPa and an ultimate strength of 1020 MPa. The cleats are the actual contact point with the ground for the robot's rotation, because of this, the material needs to be able to withstand the load created by spinning at 4000 RPM. From internal discussion and external research, it was found that no matter what material picked for the wheel cleats, the material would get worn through very quickly. Because of this, it was decided to pick 4140 Steel because of its cost. One sheet of 4140 Steel with dimensions of 12x12x1/8" costs $280.11. With this sheet, there will be at least 6 sets of cleats produced for the robot. This was the most cost-effective way to achieve the goal of competing while also picking material that would sustain through a battle. The motor rods that came prefabricated with the motors were too long, because of this custom motor rods were needed. 4140 Steel was chosen here to reduce the risk of the motor rods snapping under load.

The electronics holding fixtures will be 3D printed out of Nylon. These fixtures consist of a Battery holder, PCB holder ESC holder, and LED holder. Nylon was the best material for this because these fixtures provide no structure integrity to the robot design. They are simply there to hold the electronics components and keep them from flying around inside the robot. Nylon is a lightweight material, having a density of 1.14g/cm^3. This allows for minimal weight to be added to the robot.

9. Design Analysis

a. Tip Speed and Energy

Part of the NRHL requirements consist of staying below a maximum tip speed of 300MPH, these calculations are shown in full in the appendix (Sample Calculations). The moment of inertia (MOI) of the robot was obtained from Fusion 360 and was used for kinetic energy calculations, this shows the level of energy in the spinning robot and what could potentially be delivered to other robots. The kinetic energy of the impactor for a 12lb robot is typically in the range of 1-3 kilojoules (kJ). With all 12lbs of mass going towards the MOI, double than average kinetic energy is achieved.

Table 5: Speed and Energy Results

Wheel RPM	Body RPM	Tip Speed (MPH)	Kinetic Energy (kJ)
5460	4230	123.4	5.67

b. FEA

The finite element analysis for the Impact ring was done as an impact study with an initial rotational velocity of 3000 RPM contacting a static block. The static block simulates another robot that the ring would impact. The ring and chassis were connected by six bolts and an initial clearance of 0.1mm. From the FEA it was found that the max stress on the impactor was 240 MPa, this is well below are ultimate and yielding strength for AR500 steel. With this simulation the design will be able to withstand any impact it deals or takes. While the simulation is not 100% accurate to reality, it is believed the robot should not face issues with material shearing or breaking during combat.

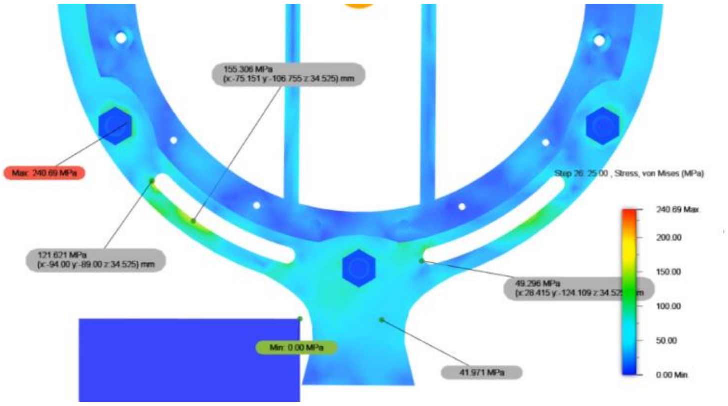


Figure 27: Impact Ring FEA

10. Fabrication

The manufacturing of all parts was done internally at UC, at the 1819 Innovation Center. Of the components to be made there were three different types, CNC, lathe/mill, and waterjet. The main component of the bot, the chassis ring (Figure 11) was made on a CNC machine using Fusion 360 CAM program shown in Figure 28 below.

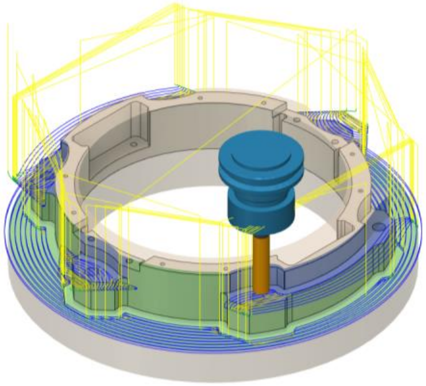


Figure 28: Chassis Ring OD Roughing CAM

This piece required custom soft jaws (Figure 29) to hold in place during manufacturing but had no complications in the manufacturing process.

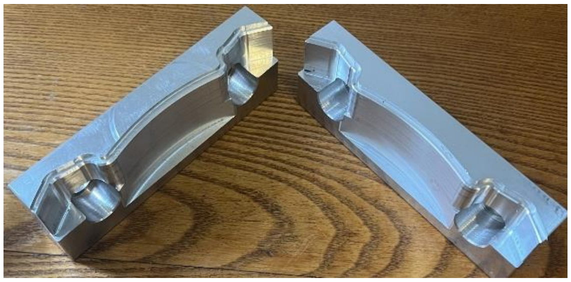


Figure 29: Custom Soft Jaws

One component was manually made on the mill and one on the lathe. The mill consisted of manually turning down stock material to make the motor mount blocks. This consisted of a 3-side facing operation and a drilling operation (Figure 32). These blocks were not used in the final design because of a last-minute design change. However, they were manufactured and used as a safety option. The wheel hubs were made on the lathe, this consisted of a turning operation and a boring operation to fit over the motor as well as a drilling operation done in the mill (Figure 30 and Figure 31)so that cleats can be attached onto the outside of the piece. The impactor ring, center bars, and cleats were all cut on a waterjet.

A DXF file was made from CAD and ran. The top and bottom plate made from G10 were made on a CNC router using a DXF file made from CAD.

11. Testing

Testing for the robot consisted of three areas, mechanical, electrical, and software. Mechanical testing consisted of fit and finish. Verifying that all components sat properly and that there was no interference between components. During testing there were minimal complications, some minor grinding and sanding had to be done to allow all components to seat properly. Electrical testing for the final version of the robot began with a flying probe test to ensure that there was continuity between those connections which should have continuity, and no continuity between those that do not. Then, power testing was performed to ensure that the correct voltages were reaching each of the supply pins when the board was hooked up to the main supply voltage from the battery. Finally, component level validation was performed for each individual part, making sure the correct signals were being sent and received by the radio receiver, LED, accelerometer, and microcontroller. During hardware testing it was discovered that some colors on the LED were brighter than others. While using red had originally planned for visibility in the arena, blue was brighter and therefore selected as the final LED color. With all components verified, software testing could be conducted with confidence that hardware would not be the cause of any issues discovered. The OpenMelt firmware [9] was flashed onto the board while connected to everything except the motors. In place of the motors, a logic analyzer was used to safely confirm that the correct signals were being sent to the motors, without the hazard's motors pose. Once it was established that the motors were receiving the correct signals, a bench test with the motors was conducted to ensure that everything was behaving as expected. The final test performed before the competition was a maneuverability and speed test to verify that translational drift was functional at speed. This was conducted at Victory Parkway with the TPU safety bumper installed. Final testing was performed on site the day prior to the competition and was combined testing of mechanical, electrical, and software systems. The university doesn’t have a cage rated to handle 12lb robots, prohibiting us from carrying out final testing until this point. Connection failsafe was tested to ensure the robot would power down if connectivity were lost, and this was also the first opportunity the team had to test the robot fully assembled at full speed. The robot was able to demonstrate functionality and pass NHRL safety inspections required to compete.

12. Competition

a. Battle 1: Cherri

The first fight of Scramble was against Cherri. Cherri is a four-wheeled Horizontal spinner, specifically a Beater-Bar robot. Beater-bars robots are a subclass of a horizontal spinner where they have a long bar that spins. Beater-bars have a much heavier impactor than traditional horizontal spinners which allows them to deliver a much bigger impact by storing more energy in the impactor. Cherri also went on to win the tournament in the 12lb weight class.

Scramble was unfortunately defeated very quickly in this fight, but not because of impacts obtained. Scramble’s weapon ended up getting one impactor stuck in the wood on the arena cage. After calling for an unstick from the 250lb house robot, the house robot unfortunately rammed Scramble deeper into the wooden arena wall. Sticking not only both impactors into the wall, but as well as the impactor ring. Scramble was so stuck that the referee had to get a crowbar to remove Scramble from the cage after the battle.

The big takeaway from this battle was to first drive to the center of the arena, then start spinning Scramble. This fight started with Scramble spinning in the corner. After impacting Cherri, Scramble was knocked closer to the wall which is what resulted in Scramble getting stuck. Also, there was a design oversight and the impactor blades on Scramble had a much larger rake angle than needed which caused Scramble to get stuck. This was circumvented by grinding down the impactors after the battle.

b. Battle 2 Big-ish

The second fight was against Big-ish. Big-ish is a vertical spinner with large wheels that creates a high ground clearance from their robot and the floor. This was a unique design from traditional vertical spinners. Vertical spinners typically are close to the ground, this unique design was hard for Scramble to make impacts with since Scramble sits low to the ground.

Scramble unfortunately lost his battle as well. However, Scramble lost because during the battle the electronics, specifically the high voltage distribution in the PCB, burnt out. This happened from an increased amperage of 80 amps passing through 4mm of copper on the PCB. The absolute minimum amount of copper required on a PCB to handle 80 amps is about 15mm, depending on the maximum allowable temperature increase. This burn out cut power to all components and rendered the robot inoperable without repairs. The key takeaways from this battle were a design oversight in the PCB and lack of testing. UC currently does not have the facilities to safely test a 12lb Meltybrain style robot. Because of this Scramble made it to competition with limited testing. This was something that would have been caught with more robust testing.

13. Conclusion

The current design of Scramble was a mechanical success. Mechanically, Scramble was very robust and took minimal damage to the robot overall. The outer ring, made of AR500 Steel, took virtually no damage. The only parts of Scramble that were damaged were the wheel hubs and cleats. Cleats were always viewed as an expendable part and made to be replaced. The wheel hubs were damaged in the second fight with Big-ish since it is designed to hit the top of low-sitting robots and during the fight the exposed hubs through the top plate were hit. Against any other type of robot, the wheel hubs would not have been damaged. Going forward, the wheel hubs would be changed to hub motors. The cleats would be directly attached to the hub and the wheel hub piece would no longer be needed. It was also found that the inner chassis ring, made of 6061 Aluminum, was not needed. This could be replaced by a 3D printed piece of TPU which would save a significant amount of weight. With this weight savings, the outer impactor ring made of AR500 could be increased in thickness.

The current electrical design of Scramble is where most issues were found. Since this project was done by two mechanical engineers and one mechanical engineering technology major, there was simply a lack of electrical knowledge. The two key issues faced with electrical components were the wiring and the PCB. The wind was extremely tight within the robot. This was partly from mechanical design constraints that caused the team to have to work the electronics into the mechanical design. Going forward the team now roughly knows the amount of wiring required, which would allow for more spacing to be made in the mechanical design. The second major electrical issue was the PCB. The team burnt out two PCB's by running 80 amps through a 4mm trace on the PCB. This was simply a design oversite when designing Scrambles PCB's. The team realized after the conclusion of the competition that this issue could have been resolved with bypassing the poorly designed region of the PCB with some external wiring. However, moving forward the main objective is to correct this issue so that no additional external wiring will be required.

Overall, the team was incredibly happy with the outcome of Scramble. With the inherent complexity of a Meltybrain style robot, it was an impressive feat to be able to create a working robot given the time constraints of senior design. The team found the major design issues with Scramble at the competition and believe that going forward these can be corrected. With these issues corrected the team believed that Scramble will be able to return to NHRL as a competitive and dependable robot. The robot still has more electrical and coding issues to be resolved, however with the experience level of team Scramble, the team made it much further than anyone expected. Talking to fellow competitors at the event, everyone was astonished that team Scramble was able to create a full working Meltybrain style robot in less than 8 months. It is unprecedented for first time robot makers, let alone first time Meltybrain robot makers to pass safety and compete with moderate success at their first event.

References

[1] BattleBot, "WIKI - Greg Munson," [Online]. Available: https://battlebots.fandom.com/wiki/Greg_Munson.

[2] NHRL, "NHRL," [Online]. Available: https://wiki.nhrl.io/wiki/index.php?title=NHRL_Open_Rules_-_2025.

[3] W. NHRL, "NHRL," September 2024. [Online]. Available: https://wiki.nhrl.io/wiki/index.php?title=NHRL. [Accessed September 2024].

[4] N. Mabey, "End Game Battlebot," [Online]. Available: https://endgamebattlebot.com/about-endgame/.

[5] Battlebots, "Rotator," [Online]. Available: https://battlebots.com/robot/rotator-2021/.

[6] N. WIKI, "Project Liftoff," [Online]. Available: https://wiki.nhrl.io/wiki/index.php/Project_LiftOff.

[7] S. Allen, "Spencer's Hardware Blog," 29 April 2018. [Online]. Available: https://www.swallenhardware.io/battlebots/2018/4/29/halo-pt2-meltybrain. [Accessed 22 September 2024].

[8] S. Allen, "Spencer's Hardware Blog," 29 April 2018. [Online]. Available: https://www.swallenhardware.io/battlebots/2018/4/29/halo-pt-3-the-big-idea. [Accessed 22 September 2024].

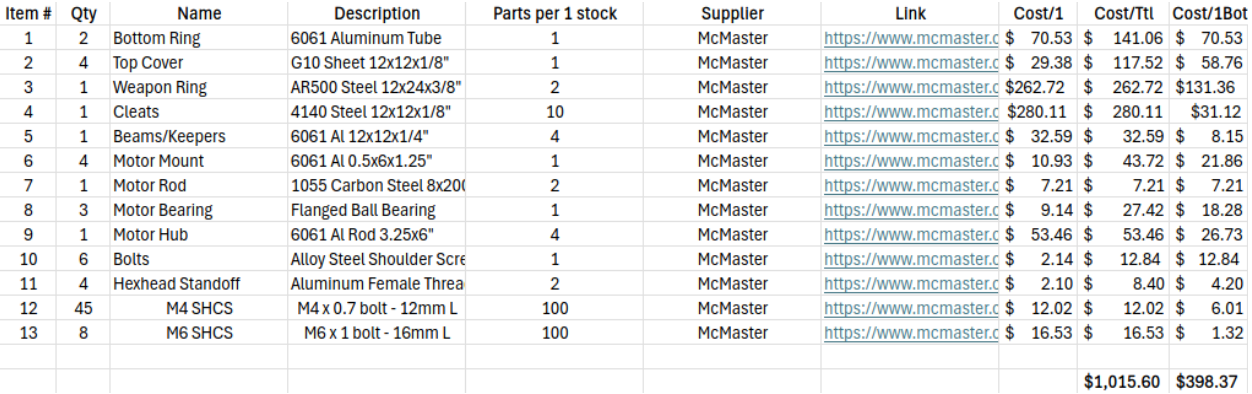
[9] R. Olsen, "github Nothing Labs - Open Melt 2," December 2023. [Online]. Available: https://github.com/nothinglabs/openmelt2. [Accessed 26 September 2024].

Appendices

BOMs

The following two tables (Table 6 and 7) are the final cost estimate for the robot parts before a purchase order was submitted. The cost per robot totals to $881.22. This cost does not include machining costs because that was done in-house with assistance from the 1819 Innovation hub.

Table 6: Mechanical BOM



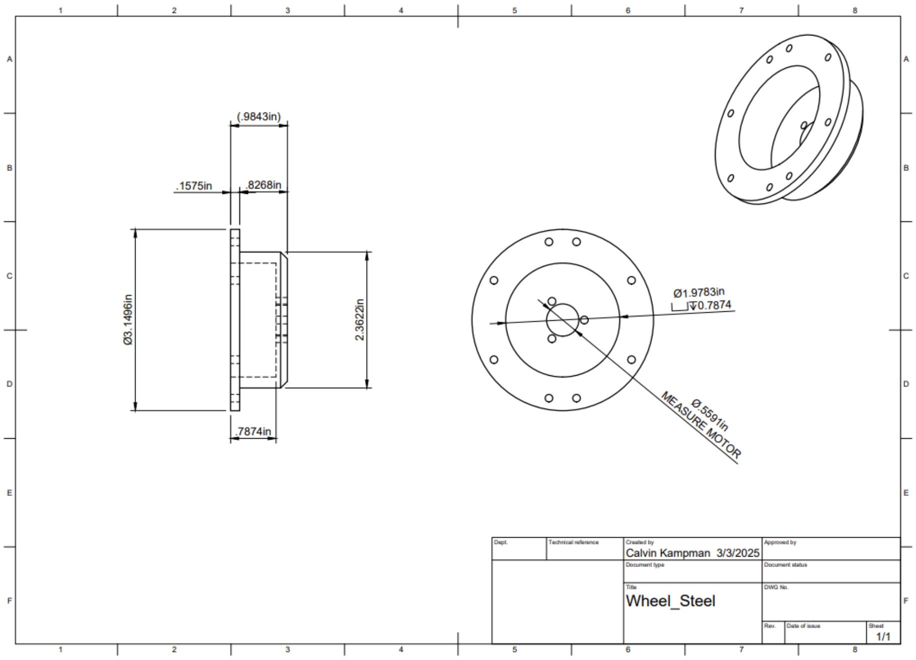
Item #	Qty	Name	Description	Parts per 1 stock	Supplier	Link	Cost/1	Cost/Ttl	Cost/1Bot
1	2	Bottom Ring	6061 Aluminum Tube	1	McMaster	https://www.mcmaster.c	$ 70.53	$ 141.06	$ 70.53
2	4	Top Cover	G10 Sheet 12x12x1/8"	1	McMaster	https://www.mcmaster.c	$ 29.38	$ 117.52	$ 58.76
3	1	Weapon Ring	AR500 Steel 12x24x3/8"	2	McMaster	https://www.mcmaster.c	$262.72	$ 262.72	$131.36
4	1	Cleats	4140 Steel 12x12x1/8"	10	McMaster	https://www.mcmaster.c	$280.11	$ 280.11	$31.12
5	1	Beams/Keepers	6061 Al 12x12x1/4"	4	McMaster	https://www.mcmaster.c	$ 32.59	$ 32.59	$ 8.15
6	4	Motor Mount	6061 Al 0.5x6x1.25"	1	McMaster	https://www.mcmaster.c	$ 10.93	$ 43.72	$ 21.86
7	1	Motor Rod	1055 Carbon Steel 8x20	2	McMaster	https://www.mcmaster.c	$ 7.21	$ 7.21	$ 7.21
8	3	Motor Bearing	Flanged Ball Bearing	1	McMaster	https://www.mcmaster.c	$ 9.14	$ 27.42	$ 18.28
9	1	Motor Hub	6061 Al Rod 3.25x6"	4	McMaster	https://www.mcmaster.c	$ 53.46	$ 53.46	$ 26.73
10	6	Bolts	Alloy Steel Shoulder Scre	1	McMaster	https://www.mcmaster.c	$ 2.14	$ 12.84	$ 12.84
11	4	Hexhead Standoff	Aluminum Female Threa	2	McMaster	https://www.mcmaster.c	$ 2.10	$ 8.40	$ 4.20
12	45	M4 SHCS	M4 x 0.7 bolt - 12mm L	100	McMaster	https://www.mcmaster.c	$ 12.02	$ 12.02	$ 6.01
13	8	M6 SHCS	M6 x 1 bolt - 16mm L	100	McMaster	https://www.mcmaster.c	$ 16.53	$ 16.53	$ 1.32
								$1,015.60	**$398.37**

Table 7: Electrical BOM

Item #	Qty	Name	Description	Parts per 1 stock	Supplier	Link	Cost/1	Cost/Ttl
1	2	Propdrive 580kv Motor	PROPDRIVE v2 5050 580	-	Hobbyking	https://hobbyking.com/e	$ 56.99	$ 113.98
2	2	Teensy 4.0	Micro-Controller	-	Microcenter	https://www.microcente	$ 23.99	$ 47.98
3	2	H3LIS331	Accelerometer	-	Adafruit	https://www.adafruit.coı	$ 24.95	$ 49.90
4	5	PCB	Circuit Board	-	jlcpcb	https://jlcpcb.com/	$ 7.00	$ 35.00
5	4	Rhino 80A	Speed Controller	-	Just 'Cuz Robotics	https://justcuzrobotics.c	$ 38.00	$ 152.00
6	1	6S Battery	Tattu 1550mAh 5S 120C	-	Tattu	https://genstattu.com/ta	$ 33.99	$ 33.99
7	2	EP2 RX	ELRS	-	Happymodel	https://www.happymode	$ 25.00	$ 50.00
8	1	Zorro	Remote Controller	-	Radiomaster	https://www.amazon.ca/	-	-
								$ 482.85

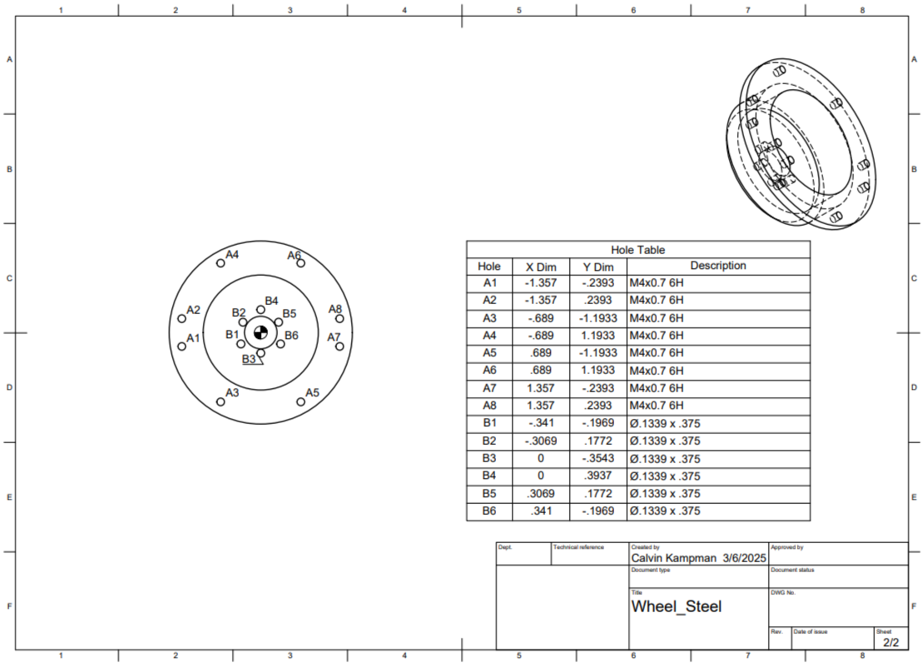
Mechanical Drawings

The following three figures (Figure 30, 31, and 32) are mechanical drawings of the wheel hub and motor mount. These drawings were used as a guide when the parts were manually machined on the lathe and mill.



Dept.
Technical reference
Created by: Calvin Kampman 3/3/2025
Approved by
Document type
Document status
Title: Wheel_Steel
DWG No.
Rev.
Date of issue
Sheet: 1/1

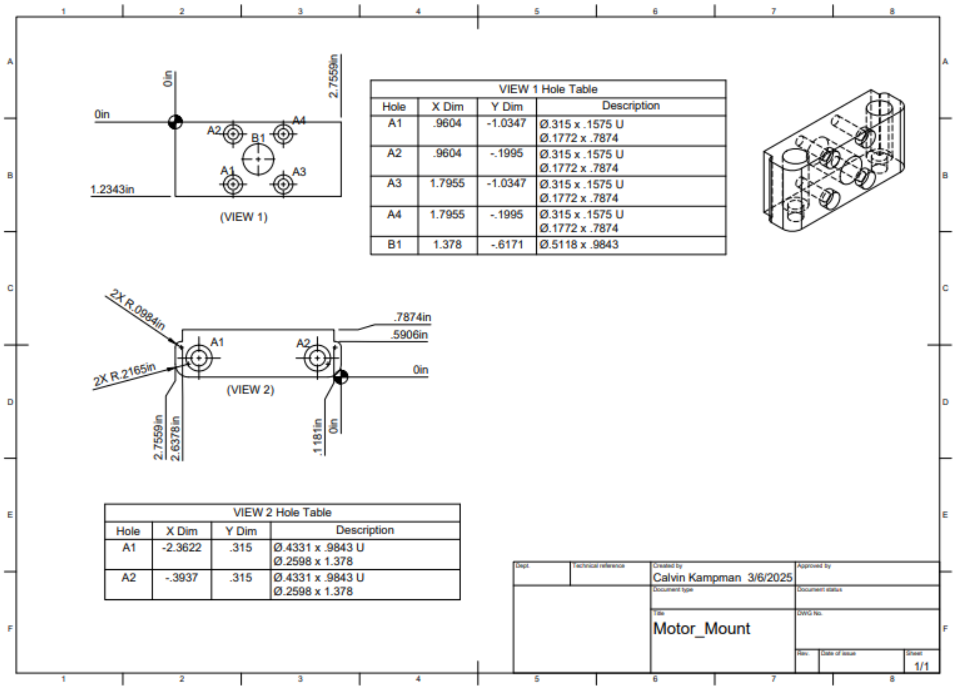
Figure 30: Wheel Hub Turning and Boring Drawing



Hole Table			
Hole	X Dim	Y Dim	Description
A1	-1.357	-.2393	M4x0.7 6H
A2	-1.357	.2393	M4x0.7 6H
A3	-.689	-1.1933	M4x0.7 6H
A4	-.689	1.1933	M4x0.7 6H
A5	.689	-1.1933	M4x0.7 6H
A6	.689	1.1933	M4x0.7 6H
A7	1.357	-.2393	M4x0.7 6H
A8	1.357	.2393	M4x0.7 6H
B1	-.341	-.1969	Ø.1339 x .375
B2	-.3069	.1772	Ø.1339 x .375
B3	0	-.3543	Ø.1339 x .375
B4	0	.3937	Ø.1339 x .375
B5	.3069	.1772	Ø.1339 x .375
B6	.341	-.1969	Ø.1339 x .375

Dept.
Technical reference
Created by: Calvin Kampman 3/6/2025
Approved by
Document type
Document status
Title: Wheel_Steel
DWG No.
Rev.
Date of issue
Sheet: 2/2

Figure 31: Wheel Hub Hole Patterns



VIEW 1 Hole Table			
Hole	X Dim	Y Dim	Description
A1	.9604	-1.0347	Ø.315 x .1575 U Ø.1772 x .7874
A2	.9604	-.1995	Ø.315 x .1575 U Ø.1772 x .7874
A3	1.7955	-1.0347	Ø.315 x .1575 U Ø.1772 x .7874
A4	1.7955	-.1995	Ø.315 x .1575 U Ø.1772 x .7874
B1	1.378	-.6171	Ø.5118 x .9843

VIEW 2 Hole Table			
Hole	X Dim	Y Dim	Description
A1	-2.3622	.315	Ø.4331 x .9843 U Ø.2598 x 1.378
A2	-.3937	.315	Ø.4331 x .9843 U Ø.2598 x 1.378

Created by: Calvin Kampman 3/6/2025
Title: Motor_Mount
Sheet: 1/1

Figure 32: Motor Mount Drawing

Sample Calculations

The following calculations show the full working of motor RPM to body RPM, Tip Speed and Energy calculations. These calculations are the background and expansion of the results shown in Table 5: Speed and Energy Results.

Body RPM

$$\text{Wheel Diamter} = 90\text{mm}$$

$$\text{Mounting Diamter} = 120\text{mm}$$

$$\text{Wheel RPM} = 5640\text{ RPM}$$

$$\text{Body RPM} = \frac{\text{Wheel RPM} * \text{Wheel Diamter}}{\text{Mouning Diamter}}$$

Equation 1

$$\text{Body RPM} = \frac{5640\text{RPM} * 90\text{mm}}{120\text{mm}} = 4230\text{RPM}$$

Tip Speed

$$\text{Wheel RPM} = 4000\text{ RPM}$$

$$\text{Wheel RPM} = \frac{4000\text{RPM} * 2 * \pi}{60} = 418.87\text{ Rad/s}$$

$$\text{Wheel Diamter} = 90\text{mm}$$

$$\text{Ground speed} = 18.85\,\frac{\text{m}}{\text{s}}$$

$$\text{Distance from cetner} = 61.5\text{mm}$$

$$\text{Tip Radius} = 180\text{mm}$$

$$\text{Body}\,\frac{\text{Rad}}{\text{s}} = \frac{\frac{18.85\text{m}}{\text{s}}}{61.5\text{mm} * 1000\text{mm}} = 306.5\,\frac{\text{Rad}}{\text{s}}$$

$$\text{Tip Speed} = \text{Tip Radius(m)} * \text{Body(RAD/S)}$$

Equation 2

$$\text{Tip Speed} = \left(\frac{180\text{mm}}{1000}\right) * 306.5\,\left(\frac{\text{rad}}{\text{s}}\right) = 55.17\,\frac{\text{m}}{\text{s}}\ \text{or } 123.4\text{mph}$$

Total Energy Transfer (Rotational KE)

$$\text{KE} = \frac{1}{2}\text{I}\omega^2$$

Equation 3

$$\text{MOI (Moment of Interia)} = 5.78\text{e}^7\,\frac{\text{g}}{\text{mm}^2}$$

$$\text{Body } \omega \text{ Max} = 986.6\,\frac{\text{Rad}}{\text{s}}$$

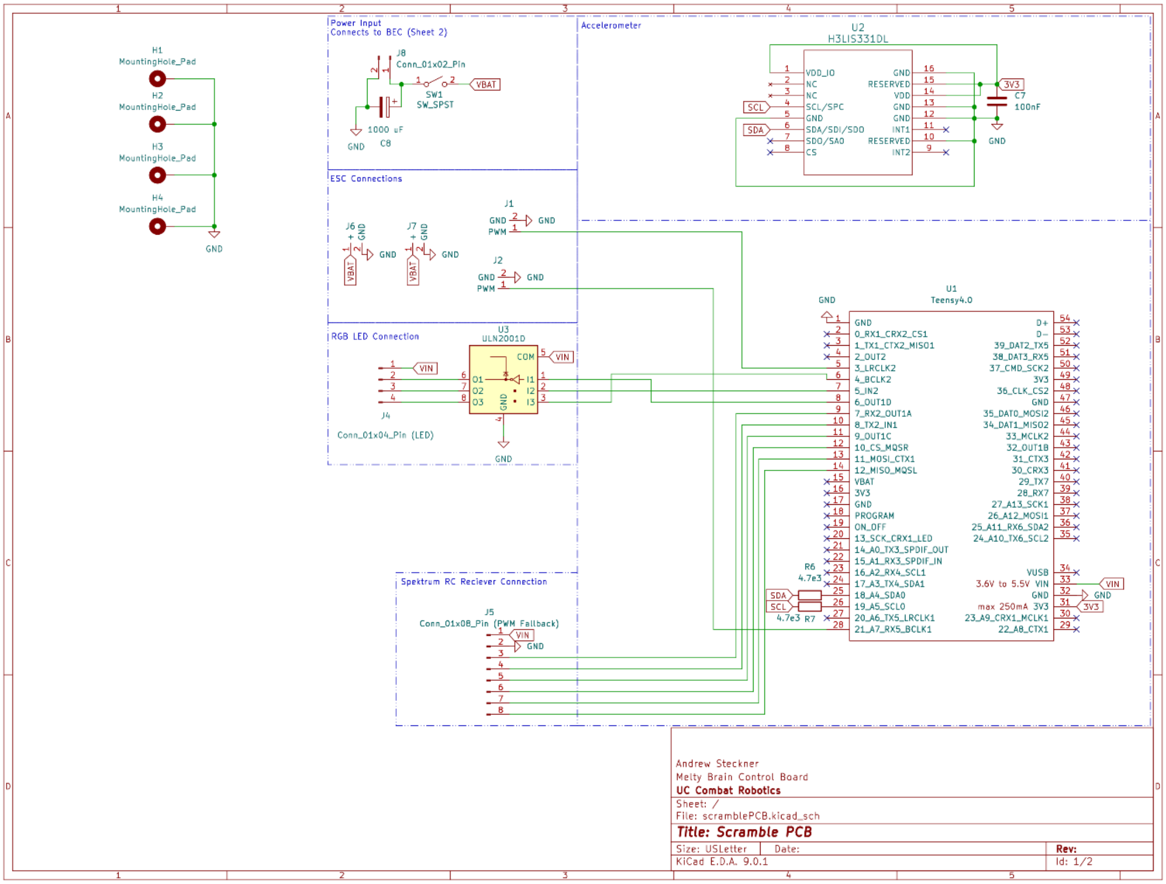
$$\text{KE}_{\text{Max}} = \frac{1}{2}5.78\text{e}^7 * 986.6^2 = 28.14\text{Kj}$$

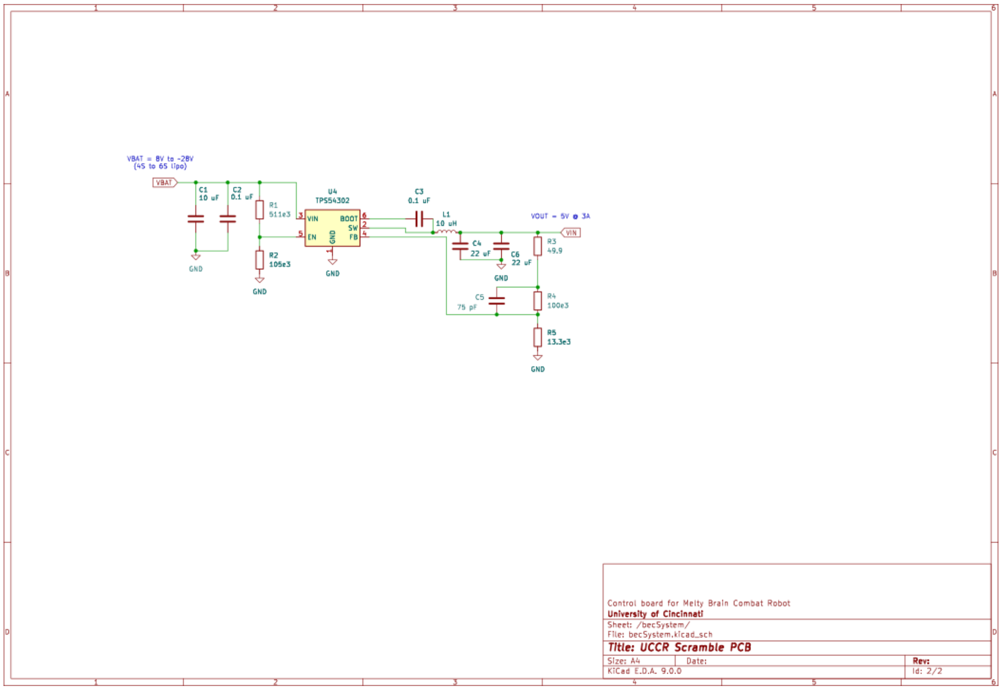
$$\text{Body } \omega \text{ Actual} = 442.96\,\frac{\text{Rad}}{\text{s}}$$

$$\text{KE}_{\text{actual}} = \frac{1}{2}5.78\text{e}^7 * 442.96^2 = 5.67\text{Kj}$$

Electronics Schematics

The following electrical schematics were designed in KiCAD, these schematics show all of the detailed level electrical connections between the system. These schematics serve as the blueprint for physical PCB design by allowing the KiCAD software to ensure all of the electronic components are connected properly when loading in the physical reference components int eh CAD side of the software.

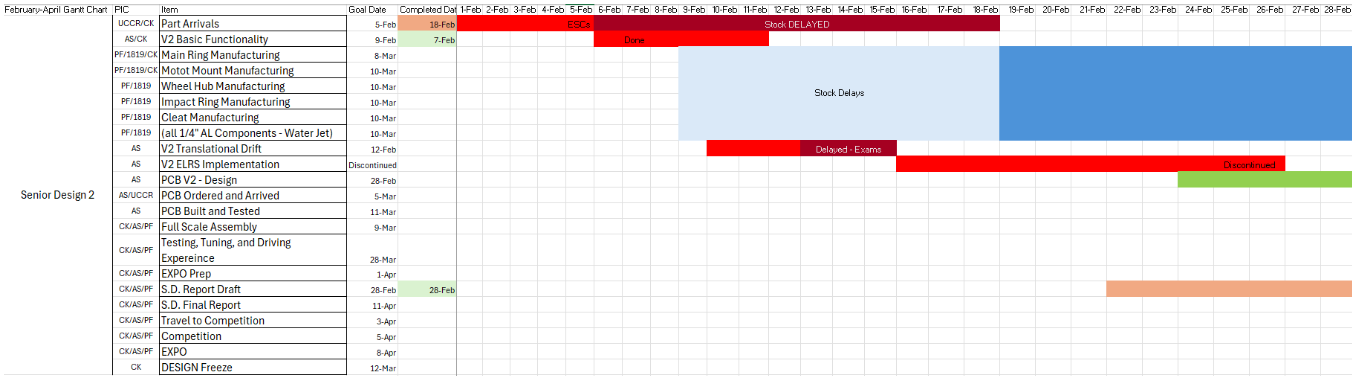



VBAT = 8V to -28V
(4S to 6S lipo)
VBAT
C1
10 uF
C2
0.1 uF
GND
R1
511e3
R2
105e3
GND
U4
TPS54302
3
VIN
5
EN
GND
1
BOOT
6
SW
2
FB
4
GND
C3
0.1 uF
L1
10 uH
C4
22 uF
C6
22 uF
GND
VOUT = 5V @ 3A
VIN
R3
49.9
C5
75 pF
R4
100e3
R5
13.3e3
GND
Control board for Melty Brain Combat Robot
University of Cincinnati
Sheet: /becSystem/
File: becSystem.kicad_sch
Title: UCCR Scramble PCB
Size: A4
Date:
Rev:
KiCad E.D.A. 9.0.0
Id: 2/2
1
2
3
4
5
6
A
B
C
D

Detailed Gantt Chart

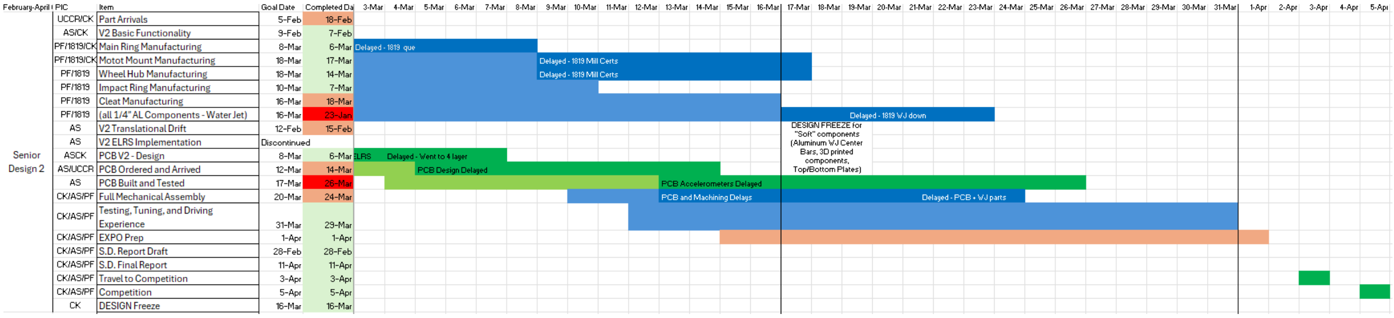
The following tables (Table 8 and 9) are the Gantt chart for the spring semester of the senior design project. This was used extensively by the team to keep track of tasks for the robot. Additionally, it allowed the team to look visually at tasks and track if they were on schedule, completed, or falling behind (and why).

Table 8: Detailed Project Schedule



February-April Gantt Chart	PIC	Item	Goal Date	Completed Dat
Senior Design 2	UCCR/CK	Part Arrivals	5-Feb	18-Feb
	AS/CK	V2 Basic Functionality	9-Feb	7-Feb
	PF/1819/CK	Main Ring Manufacturing	8-Mar	
	PF/1819/CK	Motot Mount Manufacturing	10-Mar	
	PF/1819	Wheel Hub Manufacturing	10-Mar	
	PF/1819	Impact Ring Manufacturing	10-Mar	
	PF/1819	Cleat Manufacturing	10-Mar	
	PF/1819	(all 1/4" AL Components - Water Jet)	10-Mar	
	AS	V2 Translational Drift	12-Feb	
	AS	V2 ELRS Implementation	Discontinued	
	AS	PCB V2 - Design	28-Feb	
	AS/UCCR	PCB Ordered and Arrived	5-Mar	
	AS	PCB Built and Tested	11-Mar	
	CK/AS/PF	Full Scale Assembly	9-Mar	
	CK/AS/PF	Testing, Tuning, and Driving Expereince	28-Mar	
	CK/AS/PF	EXPO Prep	1-Apr	
	CK/AS/PF	S.D. Report Draft	28-Feb	28-Feb
	CK/AS/PF	S.D. Final Report	11-Apr	
	CK/AS/PF	Travel to Competition	3-Apr	
	CK/AS/PF	Competition	5-Apr	
	CK/AS/PF	EXPO	8-Apr	
	CK	DESIGN Freeze	12-Mar	

Table 9: Gantt Chart March-Competition



February-April (	PIC	Item	Goal Date	Completed Da
Senior Design 2	UCCR/CK	Part Arrivals	5-Feb	18-Feb
	AS/CK	V2 Basic Functionality	9-Feb	7-Feb
	PF/1819/CK	Main Ring Manufacturing	8-Mar	6-Mar
	PF/1819/CK	Motot Mount Manufacturing	18-Mar	17-Mar
	PF/1819	Wheel Hub Manufacturing	18-Mar	14-Mar
	PF/1819	Impact Ring Manufacturing	10-Mar	7-Mar
	PF/1819	Cleat Manufacturing	16-Mar	18-Mar
	PF/1819	(all 1/4" AL Components - Water Jet)	16-Mar	23-Jan
	AS	V2 Translational Drift	12-Feb	15-Feb
	AS	V2 ELRS Implementation	Discontinued	
	ASCK	PCB V2 - Design	8-Mar	6-Mar
	AS/UCCR	PCB Ordered and Arrived	12-Mar	14-Mar
	AS	PCB Built and Tested	17-Mar	26-Mar
	CK/AS/PF	Full Mechanical Assembly	20-Mar	24-Mar
	CK/AS/PF	Testing, Tuning, and Driving Experience	31-Mar	29-Mar
	CK/AS/PF	EXPO Prep	1-Apr	1-Apr
	CK/AS/PF	S.D. Report Draft	28-Feb	28-Feb
	CK/AS/PF	S.D. Final Report	11-Apr	11-Apr
	CK/AS/PF	Travel to Competition	3-Apr	3-Apr
	CK/AS/PF	Competition	5-Apr	5-Apr
	CK	DESIGN Freeze	16-Mar	16-Mar