ECE 445- Fall 2025

Senior Design Project Proposal

Antweight Battlebot

Team 9

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1.Introduction

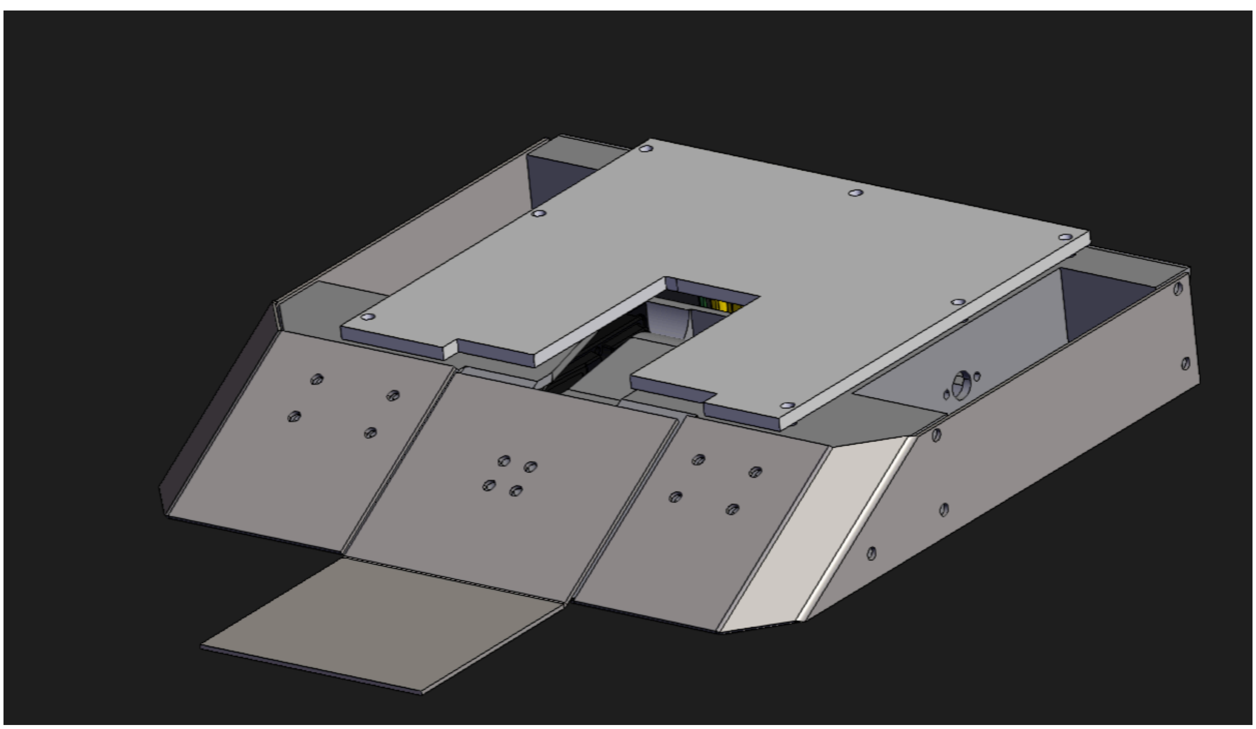
1.1 Problem

The Project is an Ant-weight, 3D-printed BattleBot for BattleBot Competition, where each team aims to design a robot capable of outperforming the others. The BattleBot must meet specific constraints to be eligible, including a weight limit of under 2 lbs and the use of approved materials such as PET, PETG, ABS, or PLA/PLA+. The robot must be controllable via PC through Bluetooth or Wi-Fi, feature a fighting tool powered by a motor, and allow for an easy manual shutdown for safety. To win the competition, a BattleBot must be designed to either outlast or disable the opponent's robot, taking into account factors such as durability, maneuverability, and offensive capability to maximize its chances of success.

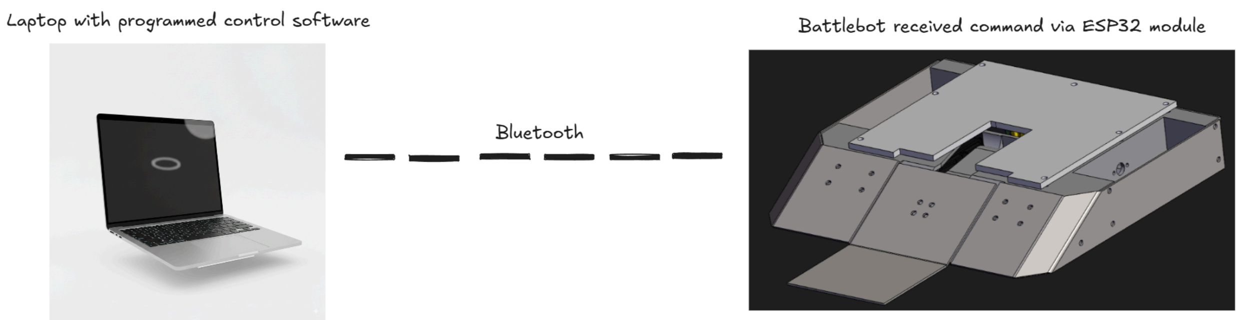
1.2 Solution

We will build a 2-lb, 3-D printed BattleBot with a front-hinged lifting wedge (shovel) as the weapon to flip and destabilize other robots. The main structure will be ABS for toughness, PLA for non-critical connectors, and PETG around the power system and microcontroller for heat resistance. Control is via PC over Bluetooth using an ESP32-S3-WROOM-1-N16 microcontroller. The bot will have at least three motors: Two DC-powered motors to control the robot's wheels for mobility. One geared lifter motor for the shovel, controlled through H-bridge drivers.

1.3Visual aid



Sample of how the battlebot would look like with 4 wheels and main structure made of ABS

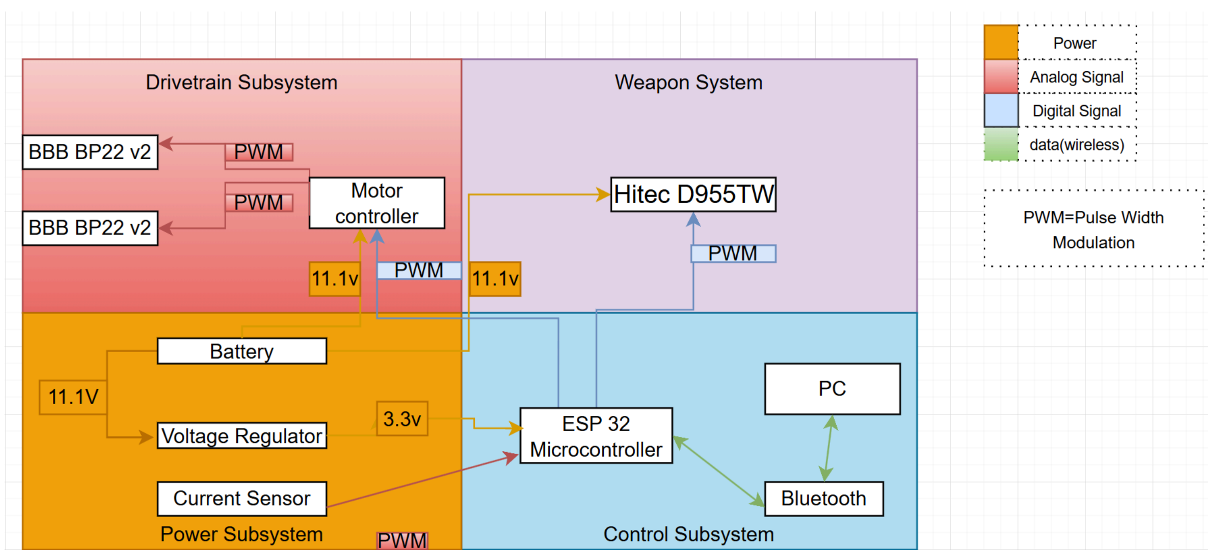


1.4 High-level requirements

- **1. Performance requirement:** The lifting wedge must generate at least 1.8 Nm of torque and be able to lift a 2 lbs load to 30° within 0.5 seconds and return to the starting position within seconds.
- **2. Control requirement:** The control system must process commands and actuate movement/weapon within 300 ms of a PC command and maintain stable wireless communication over at least 10 meters without signal loss.
- **3. Mobility requirement:** The drivetrain must move the bot at a minimum forward speed of 1 m/s on a flat surface and produce at least 0.5 Nm torque per wheel, enough to push against an opposing 2 lbs bot without stalling.

2. Design

2.1 Block diagram



2.2 Subsystem Overview

2.2.1Weapon subsystem

To attack, destabilize, and flip opponent bots, we will use a front-hinged lifting wedge (“shovel”) as our primary weapon. The wedge will be 3D-printed in PETG for impact resistance and will be reinforced at hinge and linkage points to withstand stress. It will span approximately 50–70% of the bot’s width and feature a low, angled tip to slide effectively under opponents. A small geared lifter motor will actuate the wedge through a lever linkage that amplifies the motor’s torque to lift a 2-lb target. For the weapon’s movement, we plan to use a Hitec D955TW servo, with the shovel arm length of around 70 mm. Hitec D955TW weighs around 66g, ideal for our battlebot that has a maximum weight of 2 lb. At 7.4 volts, we can drive the torque of the servo up to 2.84 N · m, which would be enough to easily flip the opponent’s battlebot. The servo also has a speed of 0.12 seconds per 60 degrees, the full 90-degree flip would only take 0.18 seconds (x1.5 to be around 0.27 seconds to account for outside variables. However, realistically, the tipping point is around 75 degrees before gravity does the rest of the work, so it might even take less time, between 0.23 seconds with load.

2.2.2Drivetrain subsystem

We will use four small wheels (2.25″), with the two rear wheels driven by high-torque 600 RPM, 12 V DC motors. The small wheels lower the bot’s ride height, reducing the center of gravity to improve stability and decrease the chance of being flipped, while still providing good traction. The selected motors strike a good balance between speed and torque, offering sufficient pushing power to maneuver our heavily armored bot effectively.

With these specifications, we plan to use the BBB Beetleweight Planetary 22mm Gearmotor v2. The motor is a good fit because it can be used with a 3S battery, lighter than other standard motors with similar specifications, simple wiring with a brushed motor, and enough speed with a load at around 750 rpm.

Additionally, we will integrate a motor current sensor (e.g., INA219 or ACS712) into the motor driver circuits to monitor current draw. The ESP32 will read these values in real time, allowing us to detect stalling conditions and trigger manual or automatic shutdowns to protect the motors and electronics.

2.2.3Power subsystem

The Power subsystem is responsible for supplying the necessary voltage for the other subsystems. We plan on using Lithium-Polymer (LiPo) batteries: 3S, 11.1 V, 450 mAh with a continuous discharge rate of 70C(Turnigy Nano-Tech Plus). This amount of capacity will ensure that the battlebot can last for 2 minutes in the competition. Since it has three cells and an 11.1V nominal voltage, we can power our motors directly. We would have a voltage regulator to step down the voltage to 3.3 V for the ESP32 microcontroller. Its nominal voltage is 11.1 V, and its voltage will be 12.6 V when it is fully charged.

2.2.4Control subsystem

Our control subsystem will use the ESP32-S3-WROOM-1-N16 because it integrates Wi-Fi and Bluetooth, eliminating the need for separate modules. Its dual-core processor and ample RAM/flash provide sufficient processing power to handle motor control, PWM generation, weapon actuation, and sensor processing simultaneously. At ~6.5 g, its weight is well-suited for a 2-lb bot, and it supports the required peripherals. The ESP32 enables wireless control communications between the PC and our BattleBot. We will use the DRV8952 H-bridge to drive the motors and implement the bot’s movement modes. The ESP32’s Bluetooth range comfortably reaches 10 m (and can increase with higher transmit power), so it should cover the arena without disconnecting.

2.3Subsystem Requirements

2.3.1Weapon subsystem

- The weapon must be able to lift 2lb of weight at least 10 mm from flat ground when the opponent is standing still.
- The weapon span must be less than 70% of the battlebot's width.
- The weapon must be able to return to its default position within 3 seconds after activation.
- The weapon motor must provide at least 1.869 Nm torque. The motor must handle continuous current and short peak stall current. (Reference to calculation below)
  - F = mg = 0.907kg (2lb) * 9.81 m/s^2 = 8.9 N
  - T = Fr = 8.9N (70mm) = 0.623 Nm
  - To account for inefficiency, frictional losses, etc., we add a 3X safety factor.
  - T = 1.869 Nm

Test: We will use a calibrated scale to measure the lift torque and check that the wedge can consistently lift a 2lb weight to a height of at least 5 cm. We will test this both statistically by lifting the weight and dynamically during the operation to ensure that the weapon can meet the specified torque requirement of 1.869 Nm.

2.3.2Drivetrain subsystem

- The battlebot must be controllable both forward and backward.
- When the battlebot needs to make a turn, the motor has to have a latency of less than 300ms from PC command. The motor must handle continuous current and short peak stall current.
- The drivetrain motor must provide at least 0.63 Nm torque. Based on our selected wheels and motor (2.25'', 600 rpm), it should support 1.797 m/s of linear speed. For safety, the design linear speed capacity is 1.4 m/s.
  - F = 8.9 N
  - F_rear,max = μpF (μ = coefficient of friction, p = percentage of battlebot weight on the rear wheels), let's assume μ = 1 for the competition, 65% of the weight on rear wheels, p = 0.65.
  - F_rear,max = 1(0.65)(8.9) = 5.79 N, F_rear,wheel = F_rear,max/2 = 2.95 N
  - T,wheel = F_rear,wheel r = 2.95N(70mm) = 0.21 Nm
  - Again, to account for inefficiency, frictional losses, etc., we add a 3X safety factor.
  - T,wheel = 0.63 Nm
  - v = 2πr (RPM/60) = 2π * 0.0286(2.25'') (600/60) = 1.797 m/s
  - Safety speed capacity v_safe = 0.8v = 1.44 m/s

Test: We will test the drivetrain by measuring the torque produced by the motors using a torque sensor while the wheels are running under load. The battlebot will also be driven across a flat surface, and we will use a stopwatch and distance markers to measure the speed and ensure it meets the 1.4 m/s specification. Additionally, maneuverability can be tested by performing turns.

2.3.3Power subsystem

- The power subsystem must be able to deliver power to all motors. It must provide enough peak current to handle simultaneous stall conditions of both drive and weapon motor, including
  - Two drive motor(peak current 4.3A)
  - One weapon motor(peak current 5.2A)
  - Esp 32 microcontroller(peak current 0.8A)
- It must be able to supply power to finish 2 2-minute battlebot competition
- It has to include a step-down regulator for a stable 3.3V supply for the ESP-32 microprocessor.

Test: We will run both stress tests on the peak current test and the continuous operation test. In terms of the peak current stress test, we will intentionally stall both drive motors and engage the weapon motor simultaneously to simulate the worst-case load. For the continuous operation test, we will run the drivetrain and weapon motor at a combat-like duty cycle for 2 minutes, replicating an actual match duration.

2.3.4Control subsystem

- We plan to use ESP32-S3-WROOM-1-N16 for wireless communication. It is equipped with both bluetooth and WiFi.
- For stability and limited power, we will only be using bluetooth for wireless control from our laptop.
- The microcontroller operates at 3 volts to 3.6 volts.
- The ESP32-S3 will use Bluetooth 5 LE in the 2.4 GHz band for all control.
- Commands will be sent every 20ms or around 50 Hz using small packets, enough for driving, controlling the shovel, and basic telemetry with low delay.
- Bluetooth power use is our main budget item: about 95-97 mA while receiving and up to 285-355 mA in short transmit bursts.

Test: We will perform a communication range test in the competition environment to ensure that the control signal is stable at distances of 10 meters or more with similar obstacles like in the competition. The test will involve commanding the battlebot to perform a series of movements while monitoring the latency, responsiveness, and reliability of the communication link. We will also simulate packet loss and ensure that the bot responds appropriately such as entering a safe shutdown state if communication is lost, etc.

2.4Tolerance analysis

We flagged energy consumption as a potential problem because of how the design stacks high-power elements onto a very small energy source. Our weapon strategy needs large, short bursts of torque, while the drivetrain must also deliver high currents for pushing and maneuvering, and both are serviced by a single 3S, 450 mAh LiPo battery. High-power bursts from the weapon and high-current drive pushes could stress the battery if it cannot supply enough current. Besides, we also need to calculate if the battery could last for a two-minute game.

Computation:

Inputs:

ESP32 peak current : 0.8 A
Rear drive motors: 2 × 4.3 A = 8.6 A
Weapon motor peak: 5.2 A
Battery: Turnigy Nano-Tech Plus 450 mAh 3S 70C (450 mAh, 11.1 V, 70C continuous, 150C burst)

Total peak current (sum):

$$I_{total}=0.8+8.6+5.2=14.6\ A$$

Battery continuous current capability:

$$I_{cont}=0.45\ Ah\times70\ C=31.5\ A$$

Safety margin:

$$Margin=I_{cont}/I_{total}=31.5/14.6=2.16$$

Burst capability:

I burst = 0.45Ah * 150C = 67.5A(1-3s)

Theoretical runtime at continuous 14.6 A:

$$t=0.45\ Ah\times3600\ s/h14.6\ A$$
1620/14.6 = 110.959s

The Turnigy Nano-Tech Plus 450 mAh 3S 70C battery is well-suited for our BattleBot design because it can comfortably handle both the continuous and burst current demands. The total system peak current is 14.6 A, while the battery's continuous rating is 31.5 A, providing a safety margin of over 2×. Its burst capability of 67.5 A for 1–3 seconds easily accommodates short, high-torque weapon strikes without risking voltage sag or damage. Additionally, the theoretical runtime at a continuous draw of 14.6 A is approximately 111 seconds, which is nearly sufficient to cover a full two-minute match, and in realistic conditions, average currents will be lower than the peak. Overall, both the burst capacity and the runtime of this battery are sufficient for the demands of the drivetrain and weapon system.

3. Ethics and safety

3.1 Ethics

Our project follows the IEEE Code of Ethics (IEEE, 2025) and the ACM Code of Ethics (ACM, 2025) to ensure responsible engineering practice. Key ethical considerations for our BattleBot include safety of participants and bystanders, fair competition, respect, and team integrity. We will prioritize the health and safety of all team members, competition officials and bystanders. Risks such as LiPo batteries, high speed motors, and weapon systems will be addressed with proper handling procedures and kill-switch buttons. For fair competition, we will comply with all rules in BattleBot and make sure we don't exceed weight or use materials other than allowed ones. For Respect and Team Integrity, we will treat all participants fairly and with respect, avoiding harassment, discrimination, or misconduct in any form.

3.2 Safety

Safety is the most important aspect of combat robotics. Our team will comply with NFPA electrical safety standards (NFPA, 2025) and competition rules (NHRL, 2025) to minimize risks. Key measures include:

- Electrical Safety: The 11.1V LiPo battery will be housed in an insulated, impact-resistant enclosure and charged only with approved balance chargers. We will follow IEEE 1725-2011 battery management guidelines to prevent overheating, short-circuits, or fire hazards.

- Mechanical Safety: Moving parts such as wheels and weapons will not be activated outside of enclosed test zones. A kill switch will be implemented to immediately cut power in emergencies.

- Wireless Communication: Since the robot uses Bluetooth/Wi-Fi, we will configure secure authentication to prevent unauthorized access and ensure the robot enters a safe shutdown state if communication is lost.

- Lab and Shop Safety: We will wear PPE (goggles, gloves) while handling batteries, soldering, or machining parts, and follow UIUC lab safety rules. Lockout/tagout (LOTO) procedures will be followed during maintenance.

4. References

[IEEE Code of Ethics | IEEE]

[Code of Ethics]

[NFPA | The National Fire Protection Association]

[NHRL]