ECE445 - Spring 2026
Antweight Battlebot

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1.Introduction

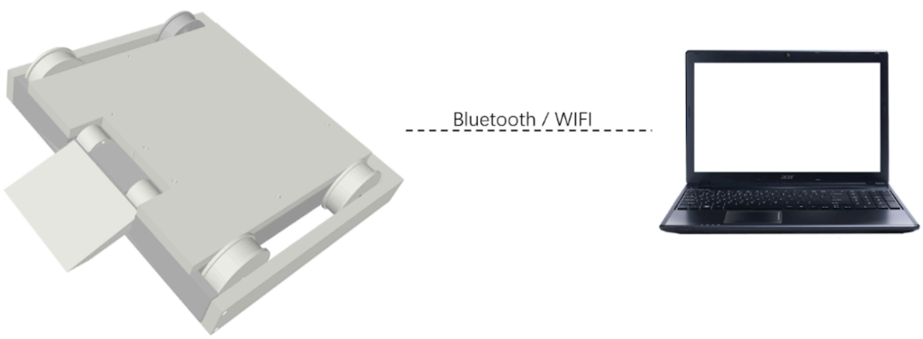
1.1 Problem

Antweight (2-lb) combat robots require a compact, reliable, and competition-legal system capable of maneuvering precisely while surviving repeated high-impact collisions. Many small robots fail in competition due to weak drive control, insufficient traction, unstable power delivery, or unsafe behavior such as unintended motion during boot or loss of communication. In addition, weapon actuation must be responsive and mechanically robust while staying within strict weight and size limits. Our team must design and build a 2-lb battlebot that can drive and steer effectively in a confined arena, engage opponents using a front lifter mechanism, remain safe under failure conditions such as battery sag and motor stall, and integrate mechanical, electrical, and software subsystems into a single robust platform

1.2 Solution

To address these challenges, we propose a modular 2-lb battlebot consisting of four integrated subsystems: Power, Drive, Weapon, and Control. The robot uses a tracked drive base for stable traction and pushing force, and a front lifter weapon designed to get under opponents and apply upward torque. The Control Subsystem is implemented using an ESP32 microcontroller, which receives wireless commands from a user PC via Bluetooth and generates all drive and weapon control signals. The Drive Subsystem uses an H-bridge motor driver (L298N) to independently control the left and right tracks through direction pins and PWM enable signals, enabling tank steering. The Weapon Subsystem uses a servo actuator to drive the lifter mechanism. For safety and reliability, the design includes an ACS758 current sensor to monitor load current and enable protective behavior under stall or over-current conditions, while also enforcing a failsafe that disables motion when communication is
lost.

1.3 Visual Aid



1.4 High-level requirements list

- The robot must demonstrate controlled, repeatable mobility by reaching a forward speed of at least 0.5 m/s on a flat arena surface and completing a 1-meter straight-line drive within 3 seconds.(d = 42mm)

- The robot must maintain reliable wireless control performance by responding to user drive/weapon commands within 100 ms and entering a safe failsafe state within 250 ms if communication is lost.

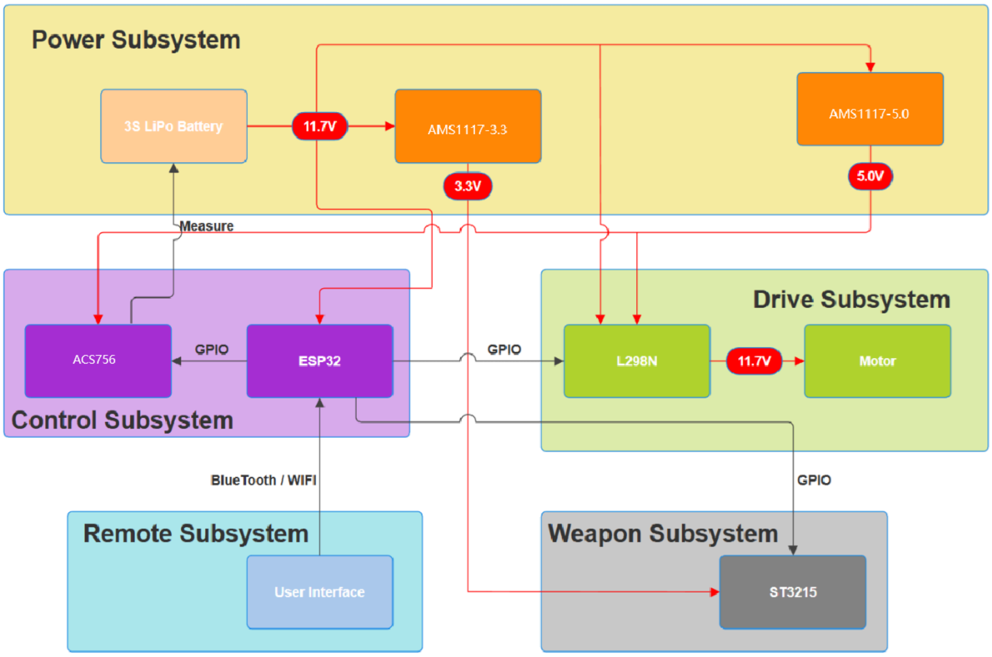
- The robot must safely deliver functional weapon actuation by completing a full lifter (servo) motion from neutral to maximum extension in 0.5 seconds or less.

- The robot must operate continuously for at least 3 minutes on a fully charged battery while performing normal driving and at least 10 weapon actuations.

- The robot must enforce electrical safety by monitoring motor current using the ACS758 and automatically limiting or shutting down drive output within 50 ms if current exceeds 20 A.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview

Power Subsystem

The Power Subsystem supplies energy to the entire robot and distributes it into separate voltage rails required by different loads. The 11.1V (3S LiPo) battery provides high-power energy for the drivetrain and is also converted into regulated 5V and 3.3V rails for the weapon servo and ESP32 controller. Because the drivetrain and weapon can generate large current spikes (wheel stall, weapon jam, impact loads), the power subsystem must be designed to prevent voltage sag that could reset the ESP32 or cause loss of control.

Control Subsystem

The Control Subsystem is the "brain" of the robot and is responsible for generating all low-level control signals. The ESP32 receives operator commands through bluetooth signal from pc and converts them into two sets of outputs: (1) drive commands that control the left and right tracks, and (2) weapon commands that control the weapon servo. It connects to the drive subsystem via GPIO/PWM signals and connects to the weapon subsystem via a servo control signal. The ESP32 depends on the power subsystem for a stable 3.3V supply.

Drive Subsystem

The drive subsystem is implemented using an L298N dual H-bridge motor driver, which receives the 11.1V battery rail as its motor power input and 5v for the logic input. The ESP32 does not provide motor power; instead, it provides GPIO/PWM control signals (direction and speed commands) that tell the L298N how to route the battery voltage to the motors. The L298N then outputs high-current drive voltages to the left and right track motors, enabling forward motion, reverse motion, and skid steering. This subsystem therefore interfaces electrically with the Power Subsystem through the 11.1V, 5v rail and interfaces logically with the Control Subsystem through control signals.

Weapon Subsystem

The Weapon Subsystem provides the robot's offensive/defensive mechanism located in the center of the chassis (lifter shown above). It is actuated by a servo that receives power from the 5V rail and command signals from the ESP32. The weapon must produce fast and repeatable motion while surviving mechanical shock.

2.3 Subsystem Requirement

2.3.1 Power Subsystem

Block description / contribution:
The Power Subsystem supplies and regulates all voltages required by the robot. It enables continuous operation of the controller, drive, and weapon under dynamic loads without brownout.

Interfaces:

- Input: 3S LiPo battery **11.1V nominal**, **12.6V max**
- Outputs:
    - Drive rail: **11.1V battery rail**
    - Logic rail: **5.0V ± 0.2V (through AMS1117-5.0v)**
    - Controller rail: **3.3V ± 5% (through AMS1117-3.3v)**

Subsystem requirements:

- Must provide **3.3V ± 5%** to ESP32 continuously.
- Must provide **5.0V ± 0.2V** to servo, ACS758, and L298N logic continuously.
- Must maintain **V3.3 ≥ 3.1V** during drive/weapon transients (prevent reset).
- Must provide a **common ground reference** shared by ESP32, L298N, ACS758, and servo.

2.3.2 Control Subsystem

Block description / contribution:
The Control Subsystem generates all drive and weapon control signals and enforces safety behavior through the monitoring of the current sensor.

- **Power inputs:**
  - ESP32 supply: **3.3V ± 5%**
  - ACS758 supply: **5.0V ± 0.2V**
- **Sensor input (ACS758 → ESP32):**
  - Analog voltage output to ESP32 ADC
- **Outputs to Drive:**
  - Left track: **IN1/IN2 + ENA (PWM)**
  - Right track: **IN3/IN4 + ENB (PWM)**
- **Output to Weapon:**
  - Servo PWM: **1.0–2.0 ms pulse width**, **50–333 Hz**

Subsystem requirements:

- Must generate independent left/right drive control (required for steering).
- Must output valid servo PWM timing (weapon actuation).
- Must implement failsafe: **≤ 250 ms** comms loss.
- Must boot into a safe state (no unintended motion).

2.3.3 Drive Subsystem

Block description / contribution:
The Drive Subsystem converts ESP32 low-power PWM/direction signals into high-current power delivered to the left and right track motors, enabling locomotion and skid steering.

Interfaces:

- Power inputs:
  - Motor supply: **11.1V nominal** (**12.6V max**)
  - Logic supply: **5.0V ± 0.2V**
- Control inputs: ESP32 PWM + direction
- Outputs: motor terminals for left and right track motors

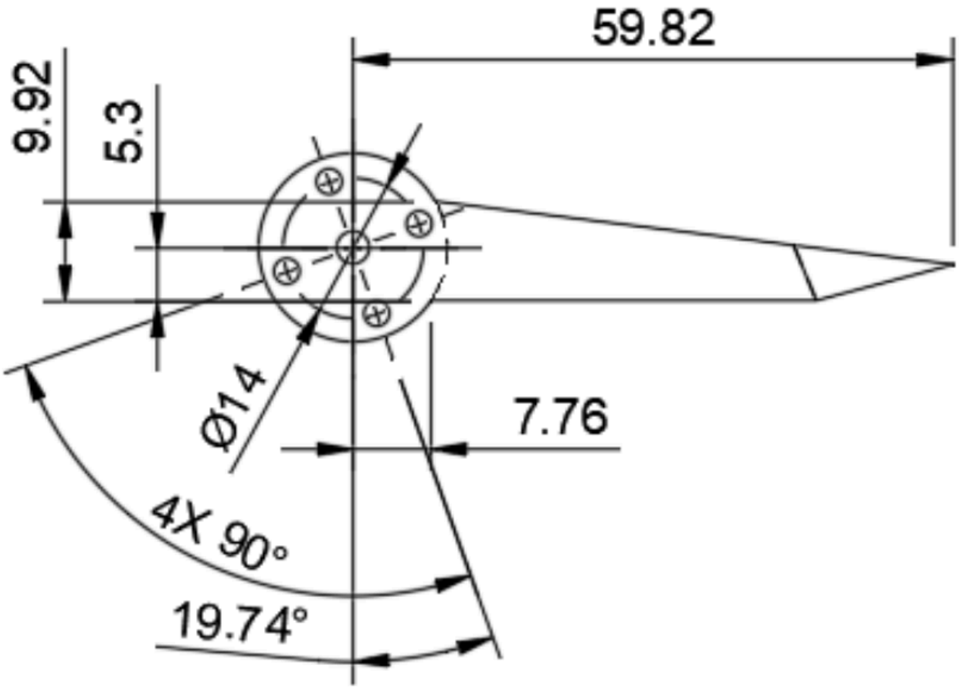
Subsystem requirements:

- Must provide **two independent bidirectional channels** (left and right).
- Must accept **PWM** control inputs from ESP32.
- Must support motor current at least:
  - **≥ 0.3A continuous per channel**
  - **≥ 1.4A peak per channel**

2.3.4 Weapon Subsystem

Block description/contribution:

The Weapon Subsystem converts electrical power and an ESP32 command signal into weapon motion. It provides the robot's main interaction mechanism. A schematic diagram of the weapon system is shown below.



（**59.82 mm** is the lever length from the servo shaft center to the tip (your torque lever arm)）

Interfaces:

- Power input: **5.0V ± 0.2V**
- Control input: PWM from ESP32, **1.0–2.0 ms**, **50–333 Hz**

Subsystem requirements:

- Must receive stable 5V under load).
- Must accept ESP32 PWM timing and respond predictably.
- The weapon must be able to lift 2 lb of weight by at least 10 mm from flat ground when the load is stationary.
- The weapon span (tip-to-tip width in the deployed configuration) must be less than 70% of the robot's overall width.

- The weapon must be able to return to its default position within 3 seconds after activation.
- The weapon servo must provide at least 2.13 N·m of output torque at the weapon joint under worst-case loading. The actuator must tolerate short peak current near locked-rotor conditions without causing controller brownout. (Reference to calculation below)

Calculation of torque requirement:

- m = 0.907 kg (2Lb)
- $F = mg = 0.907 \times 9.81 = 8.9$ N
- Effective lever arm to shovel tip: r = 59.82 mm = 0.05982 m
- Required joint torque (ideal): $T_{ideal} = Fr = 8.9 \times 0.05982 = 0.532$ N·m
- To account for friction, mechanical losses, misalignment, and battery sag, we apply a 4× safety factor.
- Required design torque: $T_{req} = 4 \times 0.532 = 2.13$ N·m
- Available servo torque (ST3215 @ 12 V): $T_{servo,max} = 30$ kg·cm $= 30 \times 0.0981 = 2.94$ N·m
- Margin check: Margin $= T_{servo,max} / T_{req} = 2.94 / 2.13 = 1.38$
- Therefore, the ST3215 provides sufficient torque margin to lift 2 lb at the shovel tip under worst-case assumptions.

Test / Verification:

We will use a calibrated scale (or hanging weights) to measure the lift force at the shovel tip and verify that the wedge can consistently lift a 2 lb weight by at least 10 mm. We will repeat the test for at least 10 trials to confirm consistency. We will also measure return time by recording a high-frame-rate video from activation to full retraction and verify the return occurs within 3 seconds. Finally, we will monitor the ESP32-S3 supply voltage during actuation to ensure no brownout/reset occurs during short peak load events.

2.4 Tolerance Analysis

Inputs:

- ESP32-S3 peak current I_{esp32} =0.2A
- 2*Drive motors, (no load current 0.08A, max load current 0.3A, stall current 1.4A, 12V, 508 rpm gear motors I_{motor_stall} =1.4 A
- Servo (ST3215, 6–12.6V) locked-rotor current I_{servo_LR} =2.7 A
- Battery: 3S LiPo, C=2.2 Ah , 50C

Total peak current (Worst-case peak current assumes both motors at stall and the servo at locked-rotor):

$$I_{total\ peak}=I_{esp32}+2*I_{motor,stall}+I_{servo,LR}=0.2+2*(1.4)+2.7=5.7\ A$$

Battery continuous current capability:

$$I_{continous,max}= C \times C_{rating} = 2.2\ Ah\times 50=110\ A$$

Safety margin:

$$\text{Margin} = I_{continous,max}/I_{total,peak}\ =110/5.7=19.3$$

Theoretical runtime at continuous peak draw:

Convert capacity to A·s: 2.2 Ah×3600=7920 As

$$t = 5.77920\approx 1389\ s\approx 23.2\ min$$

Interpretation:

With a 3S 2200 mAh 50C LiPo battery, the system’s worst-case peak current is approximately 5.7 A, while the battery’s continuous current capability is approximately 110 A, providing a 19× current margin. This indicates the battery can comfortably supply the peak current demanded during short high-load events. Even under the unrealistic assumption of continuously drawing worst-case current, the theoretical runtime is ~23 minutes, which exceeds typical short-duration mission needs.

The dominant risk is therefore not battery rating, but voltage sag and brownout caused by transient current spikes through wiring, connectors, PCB traces, and regulator dynamics. To mitigate this, we will (1) use wide power/ground traces with clean return paths, (2) place low-ESR bulk capacitance at the battery input and near the motor/servo supply nodes plus local decoupling near the ESP32-S3, and (3) implement firmware stall/jam detection to prevent sustained stall or locked-rotor conditions

3. Cost and Schedule

3.1 cost analysis

Parts:

Product	Manufacturer	Quantity	Price/unit	Link
ESP32-S3-WROOM-1-N16R8 (MCU)	Espressif Systems	1	$7	ESP32-S3-WROOM-1-N16R8 Espressif Systems | RF and Wireless | DigiKey
ACS756KCB-050B-PFF-TACS756KCB-050B-PFF-T (current sensor)	Allegro MicroSystems	1	$9	ACS756KCB-050B-PFF-T Allegro MicroSystems | Sensors, Transducers | DigiKey
AMS1117-3.3 (3.3 V converter)	UMW	1	$0.5	AMS1117-3.3 UMW | Integrated Circuits (ICs) | DigiKey
AMS1117-5.0	EVVO	1	$0.2	AMS1117-5.0 EVVO | Integrated Circuits (ICs) | DigiKey
11.1V 80C 450mAh 3S Lipo Battery	OVONIC	1	$22	Ovonic USA | RC & FPV Heli LiPo Batteries & ChargersOvonic USA | RC & FPV Heli LiPo Batteries & Chargers
L298N (Motor Driver)	STMicroelectronics	1	$13	L298N STMicroelectronics | Integrated Circuits (ICs) | DigiKey
508 RPM Mini Econ Gear Motor (Motor)	servocity	2	$15	508 RPM Mini Econ Gear Motor - ServoCity®
ST3215 Serial Bus Servo (servo)	DFROBOT	2	$25	ST3215 30kg Serial Bus Servo | 360° Magnetic Encoder | DFRobot

In case for safety and easy replacement, except for servo, battery, and motor, we plan to order 3X needed.

Total cost = (15+25+22) + (7+9+0.5+0.2+13)*3 = 151.1

Labor:

1. PCB design and soldering: 30h
2. 3D printing: 30h
3. Software development: 30h
4. Testing: 10h

As shown on the ECE official website, the average graduate salary is $100000/year. As a result, the hourly salary should be approximately $50/h

Total cost = 100*50 = 5000

Grand total:

Grand total = 5000 + 151.1 = 5151.1 usd

3.2 Schedule

Week1: Feb22 - Feb28	1. Refine CAD design 2. Start 3D printing design 3. Finish and refine Design document
Week2: Mar1 - Mar7	1. Use ESP32 development board to validate driver and Bluetooth connection
Week3: Mar8 - Mar14	1. Finish the driver for L298N 2. Finish develop Bluetooth connection
Week4: Mar15 - Mar21	1. Finish the UI for the human-bot interaction 2. First time Soldering and debug
Week5: Mar22 - Mar28	1. Refine 3D printing design 2. Second time Soldering and debug 3. Finish servo driver
Week6: Mar29 - Apr4	1. Finish develop current measurement

	design 2. Finish the shutdown safety control
Week7: Apr5 - Apr11	1. Assemble all the parts 2. Test locomotion / weapon/ control and all subsystems.
Week8: Apr12 - Apr18	1. Finish reliability and durability testing and making final improvement. 2.Finish all backup preparation and document troubleshooting procedures.
Week9: Apr19-Apr25	1.Finish final demo testing and data collection. 2.Doing performance analysis and prepare for documentation.
Week10: Apr26 - May2	1.Finish final design document, results, and analysis. 2.Final presentation and demonstrate complete battlebot working condition.

4. Ethics and Safety

4.1 Ethics

Our project follows the IEEE Code of Ethics and the ACM Code of Ethics to ensure responsible engineering practice. The primary ethical concerns for our indoor mobile delivery robot include public safety, reliability, responsible wireless operation, misuse prevention, and honest communication of limitations. We will prioritize the health and safety of users and bystanders by designing the robot to fail safely under foreseeable faults, including communication loss, actuator stall, or low battery conditions. We will avoid overstating the system's capabilities and will clearly document operating constraints such as maximum speed, payload limits, and required supervision during testing.

Because the robot uses Bluetooth/Wi-Fi and may operate in shared indoor spaces, we will also uphold ethical responsibilities related to security and privacy. We will implement basic authentication/pairing procedures to reduce the risk of unauthorized control and ensure the robot defaults to a safe stop if a trusted connection is lost. Finally, we will consider broader societal impacts: our design aims to reduce repetitive manual transport work and improve operational efficiency while minimizing environmental impact by using rechargeable power and establishing safe battery handling and disposal practices.

4.2 Safety

Safety is the most important aspect of a battery-powered mobile robot operating around people. Our team will follow relevant electrical safety practices, wireless compliance requirements, and UIUC lab/shop policies to minimize risk. Key measures include:

- Electrical Safety (LiPo + Power Regulation):
  The 3S (11.1 V nominal) LiPo battery will be housed in an insulated, mechanically protected enclosure and secured against vibration/impact. The battery will be charged only with an approved balance charger, never unattended, and stored/transported in a fire-resistant LiPo bag. We will add a main power switch and a fuse (or resettable polyfuse) on the battery output to reduce short-circuit/fire risk. Because AMS1117 is a linear regulator with thermal limits, we will ensure it is only used where its power dissipation remains within safe bounds (e.g., 5 V → 3.3 V), with adequate PCB copper for heat spreading. Wiring will be sized for expected current, and all power connections will be strain-relieved to prevent intermittent faults.

- Mechanical Safety (Wheels + Shovel/Servo Mechanism):
  Moving parts (wheels, shovel/weapon linkage, and servo-driven components) will not be operated near hands or face, and testing will be performed in a designated area with a clear perimeter. We will implement an emergency stop/kill switch that immediately disables motor drive outputs. The robot will enforce a low maximum speed during indoor operation, and the shovel mechanism will include software limits to prevent repeated impacts and reduce the chance of pinch points. If a jam/stall is detected (e.g., sustained high current or lack of movement), the system will stop actuators to prevent overheating or mechanical damage.

- Wireless Communication Safety (Wi-Fi/BLE):
  Since the robot is controlled via Bluetooth/Wi-Fi, we will enable secure pairing/authentication and avoid leaving the device openly discoverable in public spaces. The firmware will implement a watchdog + link-loss failsafe: if valid control messages are not received within a defined timeout window, the robot will immediately stop (motors off, shovel motion halted) and require a deliberate re-enable action to resume. We will also log critical fault states (brownout reset, link loss, stall events) to support safer debugging and continuous improvement.

- Battery Abuse and Thermal Risks:
  LiPo batteries can be dangerous under over-discharge, short-circuit, puncture, or overheating. We will set a conservative low-voltage cutoff in firmware (and/or use a battery alarm/monitor) to prevent deep discharge. The battery will be mechanically isolated from sharp edges and fasteners to reduce puncture risk, and all components that may heat up (motor driver, regulators, wiring) will be placed with airflow/spacing and checked for safe operating temperature during load tests.

- Lab and Shop Safety (Build/Integration):
  During assembly and testing, we will wear appropriate PPE (safety glasses during machining and cutting, gloves as appropriate for handling sharp materials), follow safe soldering practices (ventilation, iron stand, burn prevention), and comply with

UIUC lab/shop safety rules. Power will be disconnected before mechanical adjustments, and a checklist will be used for “power-on” testing to reduce accidental activation.

- Misuse Prevention and Responsible Operation:
  We will design the system to discourage intentional misuse (e.g., unauthorized remote driving) through basic access control and by limiting maximum speed/torque. Testing will be supervised, and the robot will not be operated in crowded public areas. Documentation will include clear warnings, safe operating procedures, and emergency shutdown steps.4. Reference List

5. Citations

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