ECE445
Spring 2025

3D Printed Antweight Battlebot

Team 10
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1. Introduction

1.1 Problem

Combat robotics competitions have experienced a significant increase in popularity in recent years. These competitions offer participants the opportunity to develop and practice engineering, design, and programming skills in an all-hands-on, competitive environment. Professor Gruev's Antweight Battlebot Competition presents a unique challenge where each team must construct a fully functional battlebot with strict design limits and constraints, which are listed below:

1. Battlebot must weigh less than 2 lbs.
2. Battlebot must be 3D printed with the following materials: PET, PETG, ABS, PLA, PLA+.
3. Battlebot must be controlled from the PC via Bluetooth or WiFi.
4. The weapon must be activated using only either motors or pneumatics.
5. Battlebot must have a way of easy manual shutdown and automatic shutdown.
6. Battlebot must adhere to in-competition rules [2].

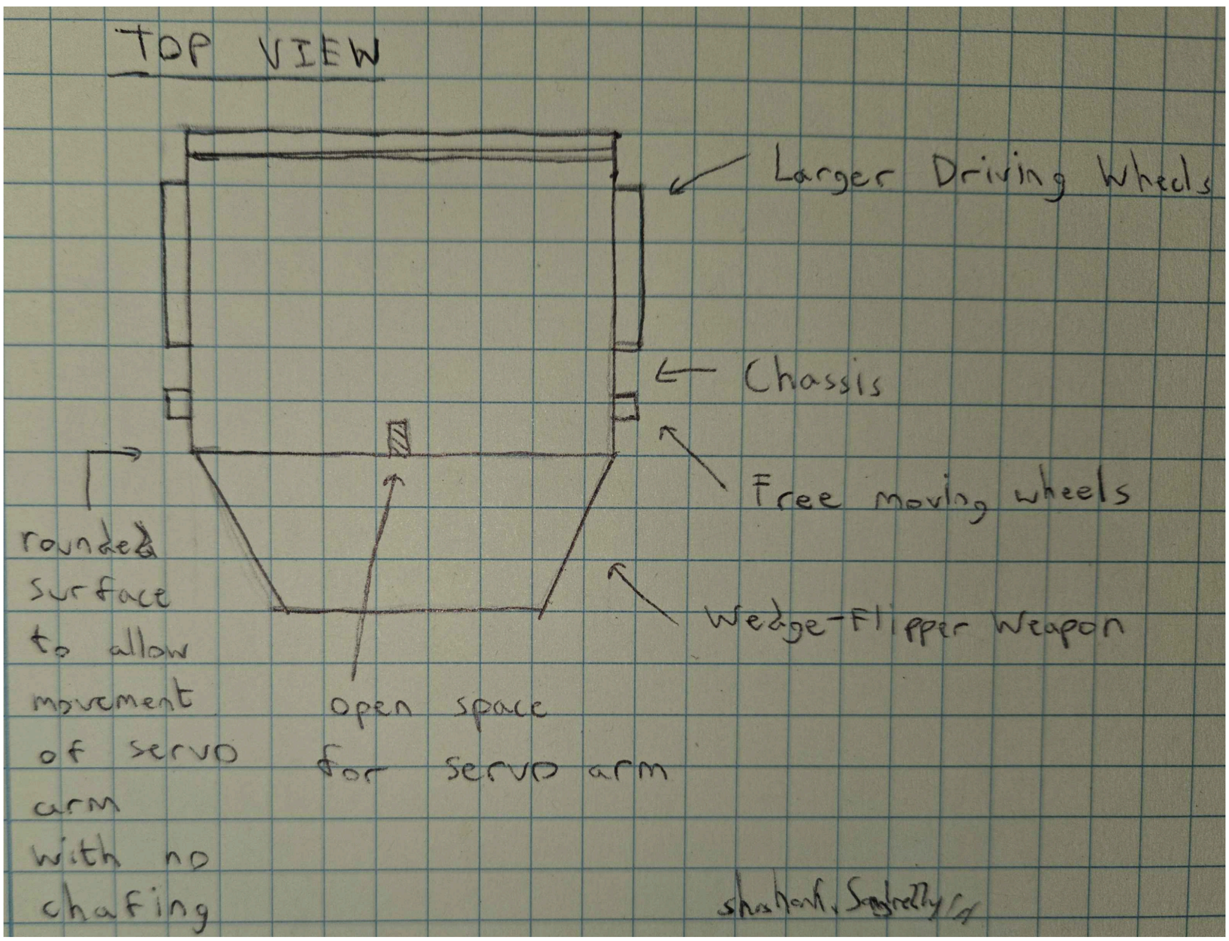
The main challenge lies in developing a battlebot device that not only adheres to these guidelines but also presents strategic combat effectiveness, durability, and precise control.

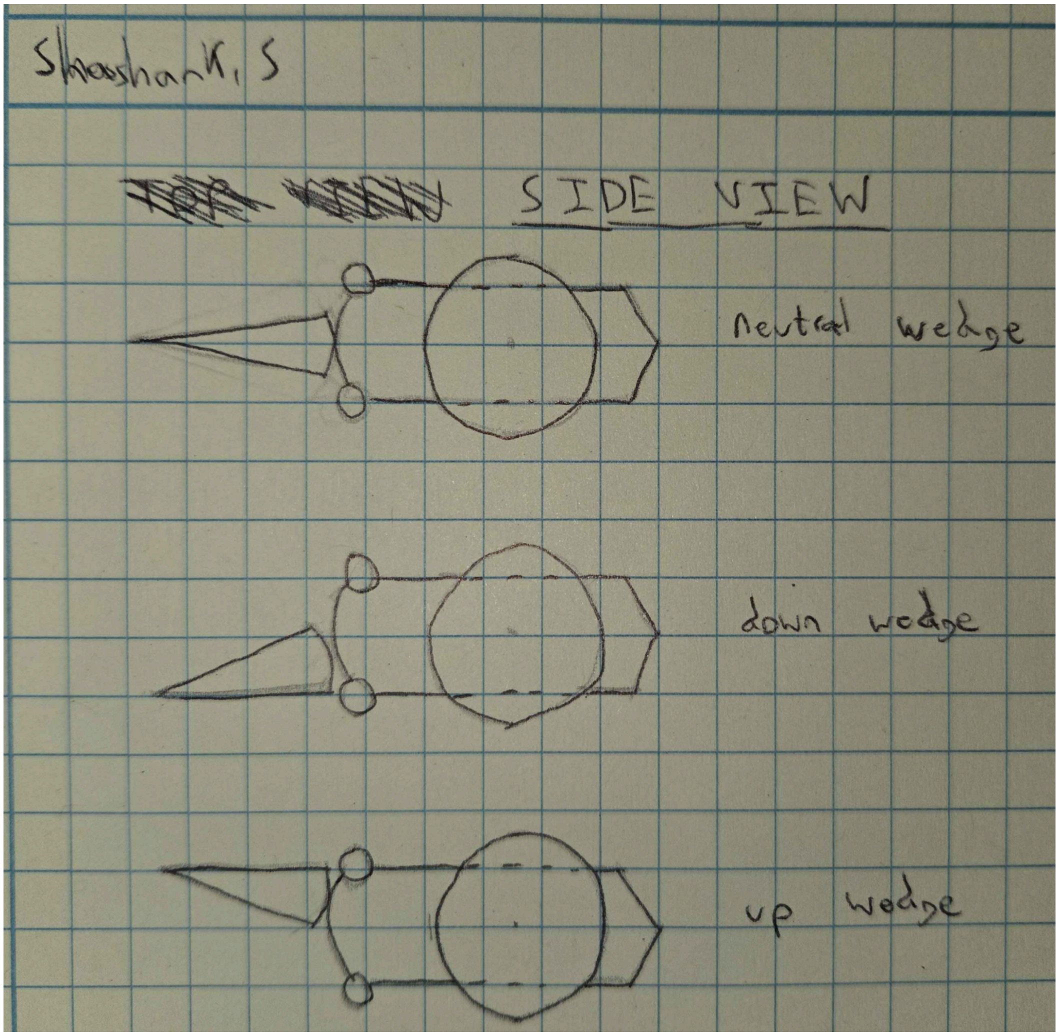
1.2 Solution

Our overall solution to this task is to design and construct a combat-ready battlebot equipped with an opponent-destabilizing wedge weapon, a durable yet lightweight 3D-printed chassis body, and a wireless control system. Our battlebot will be powered by a microcontroller with built-in Bluetooth capabilities, allowing seamless remote operation and communication. The controller we plan on investing in will be the ESP32-S3-WROOM-1. The battlebot's movement system will be controlled via two N20 motors driving the wheels with DRV8231 motor controllers, which have integrated h-bridges, to control the wheel direction.

Our wedge will serve as our primary combat mechanism. This weapon will be designed to lift and destabilize opponent robots by utilizing its mass and motor-driven activation. To ensure the bot remains functional regardless of its axis orientation, the chassis will be symmetrically structured about its horizontal axis. This will allow our robot to remain functional even if it is flipped. A rechargeable 3S LiPo battery will provide power to all subsystems of the design. In regards to the power distribution of the circuit, we plan on implementing step-down circuitry to regulate voltage throughout the different subsystems as necessary. Additionally, the control system will implement a kill-switch function, which involves manually disabling the bluetooth connection, to comply with competition safety requirements and constraints. By integrating mechanical engineering principles with embedded systems and wireless communication, our battlebot will be a competitive and well-engineered entry into Professor Gruev's Antweight Battlebot Competition.

1.3 Visual Aid



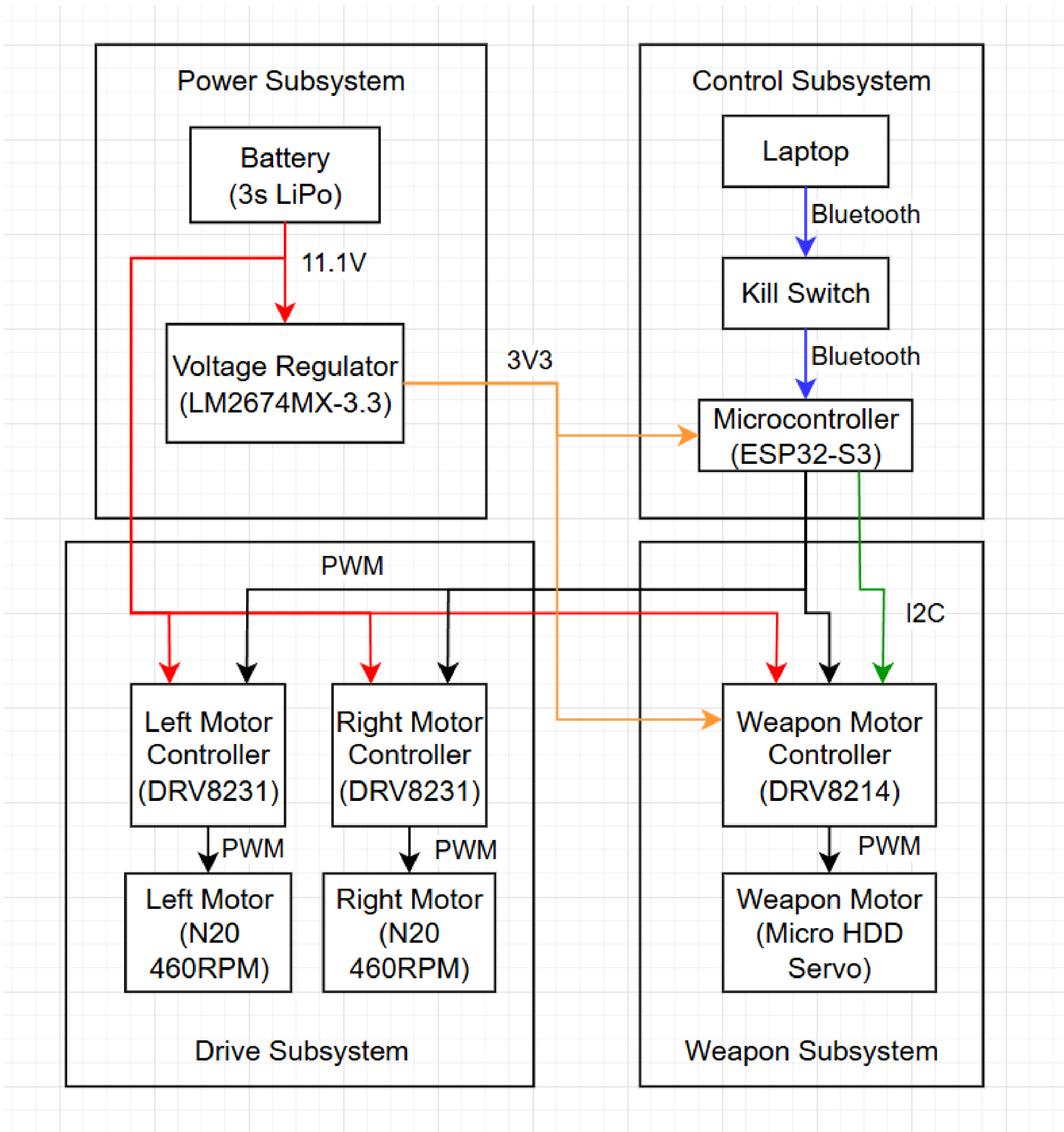


1.4 High-Level Requirements List

- The battlebot must accelerate at a minimum rate of 2 m/s^2 to ensure quick maneuverability across the competition arena.
- The wedge weapon system must be capable of lifting and displacing objects of up to 2 lbs and must return to its original position within 2.5 seconds after activation.
- The battlebot's Bluetooth connection must maintain reliability with the control PC at a range of at least 15 feet, with a command response time of less than 200 milliseconds in order to ensure real-time and precise control.

2. Design

2.1 Block Diagram



Our robot consists of 5 total subsystems: power, control, drive, weapon, and chassis. The block diagram displays the interconnections between our different subsystems. The chassis subsystem is not depicted in the block diagram as it is a mechanical component and does not directly interact with any of the other subsystems electrically.

2.2 Subsystem Overview and Requirements

2.2.1 Power Subsystem

Functional Description: The Power Subsystem is responsible for supplying power to the entire robot. This subsystem consists of a 3S 650mAh 75C LiPo battery and a LM2674MX-3.3 voltage regulator for stepping the battery voltage down to 3V3, which is required for the microcontroller. The 3S LiPo battery is nominally 11.1V, but can reach a maximum of 12.6V when fully charged.

Contribution to Overall Design: This subsystem contributes to the overall design by ensuring that the robot is capable of operating for at least the 2-minute competition time. Use of a battery is paramount as the robot needs to be able to move in the competition arena without being hindered by wired connections to a PC or power supply.

Interfaces: This subsystem interfaces directly with the control, drivetrain, and weapon subsystems as it supplies power to the control circuit and motors. It provides 3V3 and 500mA to our ESP32-S3 microcontrollers and 12V to the drivetrain motor controllers to the weapon motors controllers.

Requirements:

- The battery must be able to supply at least 6.7A at 12V ± 0.6V
- The voltage regulator must be able to accurately step down the battery voltage to 3V3 ± 0.3V
- The battery must be able to power the robot for at least 2 minutes

2.2.2 Drivetrain Subsystem

Functional Description: The Drivetrain Subsystem is responsible for the battlebot's movement and maneuverability. It utilizes two N20 micro motors each rated for 12V DC operation that provides a no-load speed of approximately 460 RPM and a current draw between 100 mA to 1600 mA. The DRV8231 motor driver chip utilizes an H-bridge mechanism and operates within a voltage range of 4V5 to 33V and supplies a continuous current of up to 3.7A per motor channel. The driver receives control signals from the microcontroller and manages the speed and direction of the motors which enables precise maneuverability.

Contribution to Overall Design: This subsystem enables the battlebot to perform movement such as optimal acceleration, deceleration, and turns. All of which are essential for both offensive and defensive maneuvers in combat scenarios. The selection of the lightweight N20 motors contributes to the overall weight efficiency of the design which ensures our battlebot is in compliance with the 2 lb weight limit restriction.

Interfaces: The Drivetrain Subsystem interfaces with the Power Subsystem and the Control Subsystem. Through the Power Subsystem, this subsystem receives the battery voltage from the power supply to effectively power the drive motors through the motor drivers. Through the Control Subsystem, this subsystem receives PWM (Pulse Width Modulation) signals from the ESP32-S3 microcontroller in order to control motor speed and directional maneuvers.

Requirements:

- The N20 motor must operate within at 6V providing a no-load speed of approximately 600 RPM and a pull current between 25-40 mA.
- The subsystem must allow for the battlebot to achieve a minimum acceleration of $2m/s^2$ allowing it to travel 10 meters in approximately 5 seconds.
- The subsystem must respond to control inputs within 200 milliseconds to ensure accurate, precise maneuverability.

2.2.3 Control Subsystem

Functional Description: The Control Subsystem is responsible for processing user command inputs and translating them into movement commands for the battlebot. This subsystem uses the ESP32-S3-WROOM-1 microcontroller. This controller utilizes a Bluetooth module which will be used to wirelessly communicate with the laptop. We are choosing Bluetooth as a communication protocol to ensure a reliable connection between the laptop and the battlebot. The ESP32-S3-WROOM-1 processes these commands and sends appropriate control signals to the motor driver chips via PWM and I2C. This will allow for synchronized communication connection between components. The Control Subsystem also includes a kill-switch: the user can manually disconnect from Bluetooth, which will terminate the connection to the robot, causing it to stop operating.

Contribution to Overall Design: This subsystem very simply enables us to remotely operate the other subsystems of the robot. From the user's perspective, the robot should be able to traverse its environment, activate and reset its combat tool, and manually shut off its functionality in response to a dedicated kill-switch.

Interfaces: The microcontroller will be powered directly by the power subsystem, receiving 3V3 from the voltage regulator. This subsystem also interfaces with the drivetrain and weapon subsystems, providing the control signals to their respective motor controllers to activate the motors.

Requirements:

- The microcontroller connection must maintain reliability with the control PC at a range of at least 15 feet, with a command response time of less than 200 milliseconds.
- The subsystem must be able to provide control signals to the motor drivers for the drive and weapon motors.
- The kill-switch mechanism must deactivate the robot within 1 second.

2.2.4 Weapon Subsystem

Functional Description: The weapon subsystem consists of a Micro HDD Servo with a high power to weight ratio, a TI DRV8214 servo controller, and the physical wedge that is part of the robot's body, located directly in front of the chassis. These three parts work in tandem to act as a high-power lever with wide surface area, fit to lift and displace objects of up to 2 pounds. The weapon motor operates within 4.8V to 8.4V with a current draw of up to 3A. This motor is able to jolt up to 60 degrees within .22 seconds with no load. The weapon motor is controlled by the DRV8214 motor controller which ensures precise control and rapid acceleration.

Contribution to Overall Design: This subsystem enhances the battlebot's offensive capabilities. This subsystem allows for the battlebot to destabilize and lift opposing battlebots of up to 2 lbs. The choice of the wedge weapon maximizes potential to destabilize other opponents while properly managing weight and power consumption.

Interfaces: The weapon subsystem interfaces directly with the power and control subsystems, primarily receiving both power and control signals from the respective sources. The weapon subsystem may also send data back to the control subsystem, specifically the position of the servo arm. This data can be used by the microcontroller to more easily and accurately reset the position of the weapon subsystem for repeated use.

Requirements:

- The Weapon Subsystem must be capable of lifting and displacing objects of up to 2 lbs.
- The weapon must return to its original position within 2.5 seconds after activation.
- The physical wedge must not compromise its structure after any actuation, such that this subsystem can be activated repeatedly.

2.2.5 Chassis Subsystem

Functional Description: This subsystem provides the structural base for the battlebot. It holds the main circuit, motors, weaponry, and power source of the battlebot. This subsystem will be 3D printed and constructed using PLA+ filament in order to balance durability and weight management. Its symmetrical design along the horizontal axis ensures continuous operation even if flipped. The square structure of the chassis minimizes weak points which enhances durability against opposing impacts.

Contribution to Overall Design: The chassis is the robot's main structural frame, housing critical components such as the power supply and central processing unit. The robot's body will be 3D printed using PLA+.

Interfaces: The chassis securely mounts and shields the Drivetrain, Control, Power, and Weaponry Subsystems.

Requirements:

- The Chassis Subsystem must be made from PLA+ filament for durability and weight efficiency.
- The Chassis must be able to withstand impact forces to protect internal components.
- This subsystem must maintain functionality in both upright and flipped orientations.

2.3 Tolerance Analysis

One of the risks facing our battlebot is ensuring that the robot remains operational for the full 2 minute competition. To ensure this, we must make sure that our battery can sufficiently power our robot for at least 2 minutes.

The ESP32-S3-WROOM-1 microcontroller that we are planning to use draws 500mA at 3V3. The N20 motors for the drivetrain individually draw a maximum of 1600mA, for a combined 3200mA. Lastly, our Micro HDD Servo motor for the weapon draws a maximum of 3000mA. Combined, the absolute maximum current draw of our robot is 6.7A. Thus, our battery should be able to accommodate this for at least 2 minutes, even though the expected current draw will be much less.

$$I_{max} = I_{ESP} + I_{Drive} + I_{Weapon} = 500mA + 3200mA + 3000mA = 6700mA$$

The required capacity can be calculated as follows:

$$Required\ Capacity = (6.7A) * (1/30\ hours) = 67/300\ Ah \approx 223\ mAh$$

The required C rating can be calculated as follows:

$$C\ Rating = (6.7A)\ /\ (67/300\ Ah) = 30C$$

Since our chosen battery has a capacity of 650mAh and a C rating of 75C, the battery should be able to sufficiently power our robot at absolute maximum current draw for at least two minutes.

3. Ethics and Safety

3.1 Ethics

As described by Section I Part 1 of the IEEE Code of Ethics [1], we will always put the safety and health of the public first and disclose any potential risks where appropriate. Combat robots pose an inherent threat to public safety, so we will be responsible for ensuring that the robot is designed, handled, and operated responsibly so as to eliminate any risk to the safety of ourselves and others.

As described by Section I Parts 5 and 6 of the IEEE Code of Ethics [1], we will act responsibly as engineers, making sure to openly accept criticism and feedback and to ensure that we have the proper knowledge to accomplish things safely and correctly. Making a robot is a multi-disciplinary effort that requires knowledge in many different fields and technologies. We will make sure that we are doing the proper research, learning, and asking for help in order to complete our project safely and responsibly.

As described by Sections II and III in their entirety of the IEEE Code of Ethics [1], we will make sure to create and maintain a positive, healthy, and collaborative working environment. This includes avoiding using harmful language and holding each other accountable for our actions. We will strive for open and frequent communication and a willingness to help each other in order to make a positive working experience for all those involved.

3.2 Safety

Combat robots and battlebots are inherently dangerous and require thorough safety guidelines to ensure they do not pose a threat to the public. We will be following the safety regulations outlined by the NRC, specifically regarding antweight battlebots [2]. Additionally, we will also be abiding by the safety guidelines for batteries given by the ECE445 course staff [3] as our robot will be battery-powered. On top of the existing guidelines and rulesets, we will be exercising caution during testing and operation. As our design uses motors and weaponry, we will make sure that they are only operational when being actively powered and controlled by a human operator. Additionally, we will not be operating the robot or its motors outside of a safe competition environment or testing area. Finally, we will be implementing a kill-switch that will give the user control to disable the robot at any time as needed.

4. References

[1] IEEE, "IEEE Code of Ethics," *ieee.org*, Jun. 2020. https://www.ieee.org/about/corporate/governance/p7-8.html

[2] National Robotics Challenge, "2025 Contest Manual," Jan. 06, 2025. https://irp.cdn-website.com/9297868f/files/uploaded/NRCContestRules2025-7677ffcb.pdf (accessed Feb. 10, 2025).

[3] ECE445 Spring 2016 Course Staff, "Safe Practice for Lead Acid and Lithium Batteries," Apr. 13, 2016. https://courses.grainger.illinois.edu/ece445/documents/GeneralBatterySafety.pdf (accessed Feb. 10, 2025).