# Triangle Sign Deployer Car

- ECE445 Project Proposal

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## Introduction

### Problem

In the event of a traffic emergency, alerting oncoming traffic to the hazard ahead is critical to prevent accidents. One measure involves placing a warning sign 10~100m away from the emergency site, per the traffic laws in many countries. However, walking against the incoming traffic with the warning sign is extremely risky, especially during times of high volume. The need for a safe, efficient, and practical method to deploy these warning signs without endangering human lives is therefore paramount.

### Solution

Our proposed solution is the development of a deployable, remotely controlled electric vehicle(referred to later as “car”) designed specifically for the task of carrying and deploying warning signs at the required distance from a traffic emergency site. This vehicle would be capable of traveling distances ranging from 10 to 100 meters, in accordance with local traffic regulations, to place the warning sign accurately and safely. Our design prioritizes low power consumption, ease of storage, a manual control system, and a backup autonomous navigation system. This approach not only mitigates the risks associated with manual sign placement but also enhances the rapid deployment of essential warnings, thereby contributing to road safety and the prevention of further incidents.

## Visual Aid

The following is our intended outfitting of the car platform. It has a camera mounted on the front, and a sign mounted on the top of the chassis, linked to the servo. Upon deployment, the servo will turn and lift the sign up. This action is performed manually when connected to the phone, and automatically when specified distance is reached when the auto-navigation algorithm is active. Notice that the auto navigation algorithm will be disengaged when it cannot correctly recognize lanes, and if human control is not possible, the procedure will be reduced to simply halt and deploy the sign.

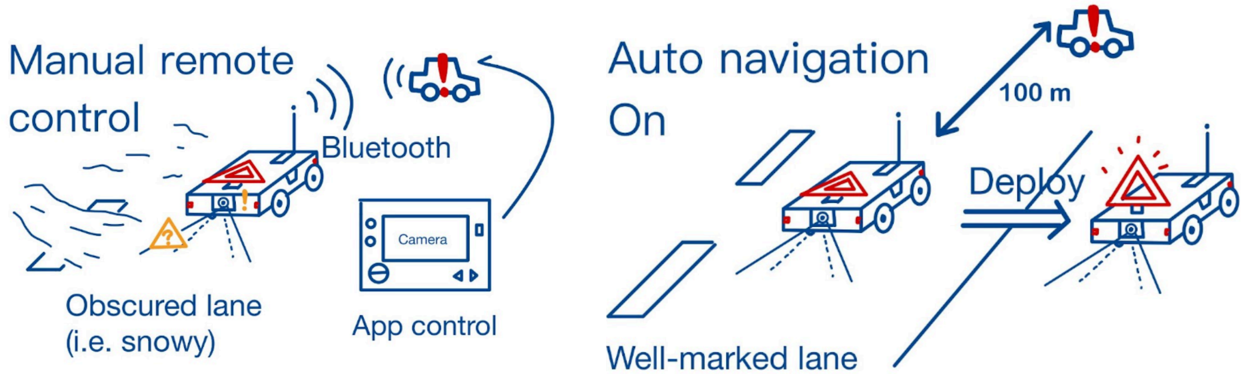


*Figure 1. Visual representation of the project. Relative component placements and difference in autonomous/manual operations are listed.*

The physical design of the vehicle's chassis features a typical four-wheel, all-wheel drive setup with a robust frame and an omni-directional wheel system, as visualized in the detailed schematics indicating precise measurements and assembly specifications. The chassis is equipped with Mecanum wheels, enabling omnidirectional movement, allowing the vehicle to traverse complex terrains with agility and precision, as illustrated in the accompanying technical diagrams.

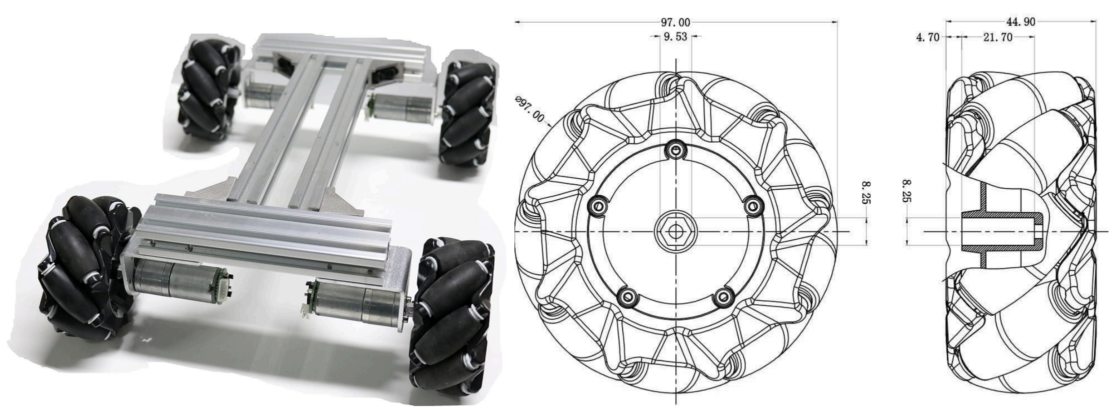


*Figure 2. Example visual representation of the chassis and wheel details in our system*

### Product Criteria

- The car can travel up to 100 meters from the user.
- The phone controller can deliver instructions within the operational range and maintain a consistent camera feed.
- After receiving the instruction from the user or the Auto-Navigation System, The car can automatically raise the sign and deploy props.
- The Auto-Navigation System can operate correctly when traffic conditions are not complex and road markings are clear. It should drive to its destination under the above conditions in the scenario of a connection loss.

## Design

### High-Level Block Diagram

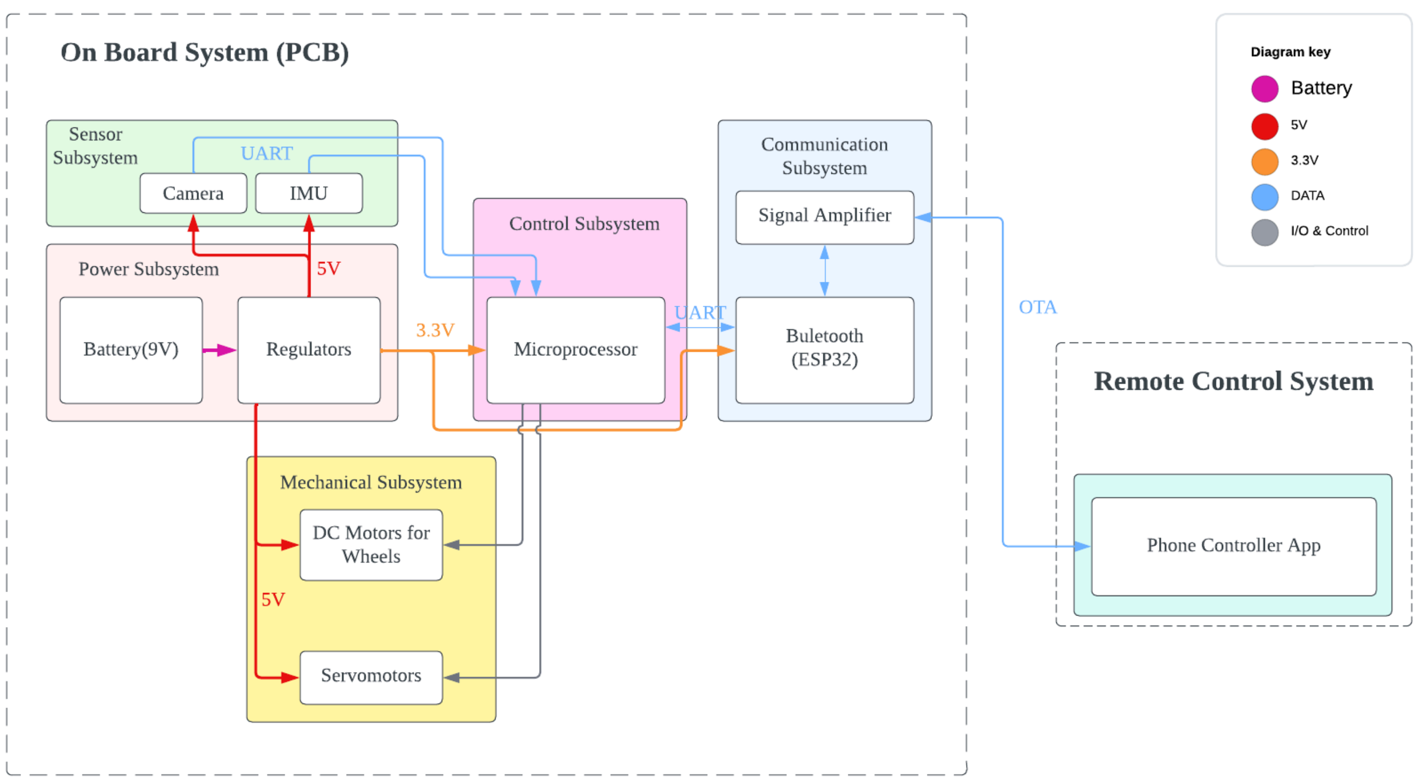


*Figure 3. High-Level Block Diagram*

## Block Descriptions

### *Internal Subsystem #1: Central Control (Microchip)*

Serving as the vehicle's brain, this subsystem incorporates a state machine to ensure that the vehicle responds appropriately to commands and environmental conditions, avoiding unnecessary movements.

It utilizes a processor to run algorithms, interpret user inputs received from Bluetooth comm, control motor actions, and send sensor data back to the phone.

The requirements associated with the microchip will be:

- Can transceive data via configured GPIOs and UART ports, to the Bluetooth transmitter and from the camera/IMU;
- Can calculate displacement based on direction and acceleration data, within a 5% room of error at a 100m distance;
- Can start the auto nav algorithm in the event of a connection loss.

### *Internal Subsystem #2: Power Supply & Distribution (Battery, Regulators)*

A battery will be attached inside the car frame, serving as the power supply to the entire circuitry. Voltage regulators will be added to deliver power to respective components.

Requirements for the power distributions are:

- Can Supply various input voltages(3V3/5V) to corresponding modules.

### *Internal Subsystem #3: Sensors (Camera & Accelerometer)*

The camera provides visual feedback as the user drives the car toward its destination. Considering the size limitations of phone screens and transmission allowance, a low-resolution, low-refresh rate camera should do the job.

Its data will be fed into the microchip, which then sends it through Bluetooth to the phone.

Requirements for the camera will be:

- Can stream at 1280*720(subject to change) resolution, 15hz(subject to change) refresh rate

The accelerometer and gyroscope are used in combination to calculate the total distance traveled since startup. Due to regulation requirements, the warning signs are supposed to be deployed a certain distance away from the vehicle. They are thus in place to keep track of the total displacement.

Requirements for the gyroscope and accelerometer will be:

- Can send angle and acceleration data to microchip
- Meets the desired error criterion(5% at 100m)

***Internal Subsystem #4: Communications (Bluetooth)***

Typical remote controls at ~30-100m distances require class 1 Bluetooth signals. Alternative protocols can be considered, but in this instance, this is the most extensively developed type of wireless comm, therefore we have a higher chance of acquiring compatible software libraries.

Requirements for the Bluetooth transceiver will be:

- Can send calculated displacement data and camera feed to the phone
- Can receive control inputs from the phone

***Internal Software Subsystem #5: Auto Navigation Algorithm***

In the event of a connection loss at 50+m away due to propagation noise, the car should call this algorithm stored in the microchip, which can guide it to reach its destination if clear vision is present (visible lane markings). If the lane markings are obscured, the system will deploy the sign on-site to maximize safety.

Since this algorithm is a backup plan, we intend to keep it simple, and will only consider expanding it when remaining time allows. Possible expansion may include a simple autonomous lane following from camera data that allows auto navigation from the starting point.

Requirements for the auto navigation will be:

- Can travel along the total displacement vector since task initialization, up to destination(100m)
- Can deploy(raise) the warning sign without user input
- Can determine whether the lane markings are present for safe operation and respond correctly

*Internal Subsystem #6: Mechanicals (Motors)*

Our entire platform is actualized on a small, four-wheeled electric vehicle. Using the PWM method from ECE110 to control the wheels should suffice, despite that this time PWM signals will be fed by the microchip.

Driving with the sign facing front will experience significant wind resistance, drastically increasing power consumption of wheels, and in extreme cases might even push it back. To minimize the impact of wind on our platform, we decided to initially mount the sign facing up and use a lever to rotate it to face front once it reached its destination.

Simultaneously, structural support would be set up to prevent uncertain weather conditions(rain/wind) from displacing it. Reflective material will be attached to the body to ensure the system's visibility. We've discussed with the machine shop using stepper motors to extend and retract some props, like those tiny support legs of standalone warning signs.

*Figure 4. A typical warning triangle sign. The footholds prevent it from being displaced by wind.*

Requirements for the regular and stepper motors will be:

- Can receive PWM signals from microchip to turn forward/backward or rotate
- Can control the extension and retraction of the prop beam to raise/lay the sign
- Can be visible (with the sign facing up) to incoming traffic with high or low beams on, from 25 meters away when environment visibility is poor.

***External Software Subsystem #7: Phone Controller App***

This app serves as the primary control method of the car. Auto navigation algorithms may be prone to varying traffic conditions, and in addition to that, robust algorithms might not fit into a standalone microchip. Thus human control is almost always preferable.

Requirements for the phone app will be:

- Contains all the necessary input buttons to drive the car
- Displays camera feed
- Displays total distance traveled

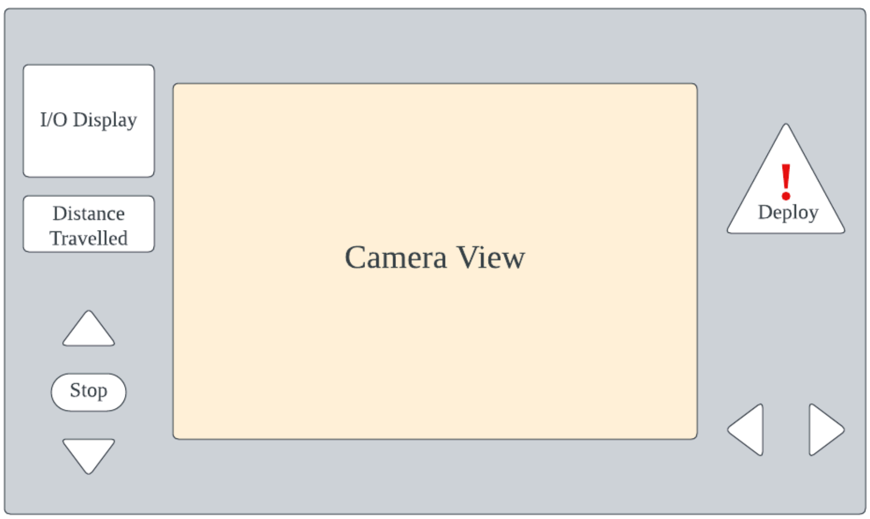


*Figure 5. Phone app UI preview*

## Risk Analysis

***Current Ratings***

A convenient choice for regulators, AZ1117I family linear voltage regulators, have a current rating of 1.35A. To ensure all subsystems remain functional during operation, at any moment of time the current load on 5V supply must never exceed this limit. All the modules that use a non-5V supply voltage draw significantly less current.

Typical choice of wheel motors have a stall current of 900mA at nominal voltage 6V, according to manufacturer specifications, and have an operating range from 3 to 9V. Given that two motors are needed to drive the car, the combined current draw when stalled at our supplied voltage(which is 5V) will be approximately twice that of 900mA. Due to the nonlinear nature of motor electrical characteristics, we have yet to test out their current draw at non-nominal supply voltage.

Proceeding with the assumption that stall current will not significantly drop at 5V, it can be seen that to guarantee current supply to other modules, the maximum current ratings of these motors must be limited. Preliminary estimates suggest that we can reserve around 300mA of current for other subsystems, resulting in approximately 500mA of current limit to the motors. More measurements of electrical characteristics of these motors are required as part of our future work.

However, in case of the risk that current ratings exceed standards, It would be possible to include multiple voltage regulators to evenly distribute load, or revise our component selection, whether these approaches work better is up to future inspections.

***Bluetooth Communication Range***

To calculate the effective transmission distance of the mounted bluetooth antenna, we use the Friis transmission equation, which takes into account the transmit power, receiver sensitivity, frequency, and path loss:

$$Pr = Pt + Gt + Gr - L$$

Where Pr is the received power at the receiver (in dBm), Pt is the transmitted power at the transmitter (in dBm), Gt is the gain of the transmitter antenna (in dB), Gr is the gain of the receiver antenna (in dB), and L is the path loss (in dB).

The equation for path loss is:

$$L = 20log10(d) + 20log10(f) + 20log10(4\pi/c)$$

Where d is transmission distance, f is operating frequency, and the last term is a constant.

Receiver sensitivity can be amplified without consequences, however transmitter sensitivity is limited to its sensitivity labeled in the datasheet. In the datasheet provided by Espressif Systems(manufacturer), the antenna can send a signal with a maximum of +20dBm power [3]. This value is the combined effect of Pt, Gt, and 20log10(f)+20log10(4π/c) terms of the Friis equation. The only term left is the distance-related term, which attenuates signals by -40dB at receiver end. This results in a -20dBm power at the receiver end, which is a lot higher than typical receiver sensitivity(~-80dB). Therefore, transmission of bluetooth signals at ~100m is theoretically possible.

Undoubtedly many additional constraints will apply in reality. We have yet to test this on an ESP32 evaluation kit.

**Table 23: Transmitter Characteristics - Bluetooth LE 2 Mbps**

| Parameter | Description | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| RF transmit power | RF power control range | –24.00 | 0 | 20.00 | dBm |
| | Gain control step | — | 3.00 | — | dB |
| Carrier frequency offset and drift | Max $\|f_n\|_{n=0,\ 1,\ 2,\ ..k}$ | — | 2.50 | — | kHz |
| | Max $\|f_0 - f_n\|$ | — | 2.00 | — | kHz |
| | Max $\|f_n - f_{n-5}\|$ | — | 1.40 | — | kHz |
| | $\|f_1 - f_0\|$ | — | 1.00 | — | kHz |
| Modulation characteristics | $\Delta\ f1_{avg}$ | — | 499.00 | — | kHz |
| | Min $\Delta\ f2_{max}$ (for at least 99.9% of all $\Delta\ f2_{max}$) | — | 416.00 | — | kHz |
| | $\Delta\ f2_{avg}/\Delta\ f1_{avg}$ | — | 0.89 | — | — |
| In-band spurious emissions | ±4 MHz offset | — | –42.00 | — | dBm |
| | ±5 MHz offset | — | –44.00 | — | dBm |
| | >±5 MHz offset | — | –47.00 | — | dBm |

*Figure 6. Transmitter characteristics at 2Mbps, as given by the datasheet.*

### Ethics and Safety Declarations

The IEEE Code of Ethics emphasizes the need for engineers to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, the first of which is precisely what this device is aimed for to reduce the risk of setting up warning signals to other cars.

In the development of the Triangle Sign Deployer Car, we prioritize ethical considerations and safety measures to uphold standards set forth by the IEEE and ACM Code of Ethics. Ethics would involve discussing the responsibility of deploying an autonomous or semi-autonomous vehicle in public spaces(highways), including ensuring it does not endanger human lives or disrupt traffic flow unnecessarily. The importance of designing the vehicle to respect privacy and not to collect or transmit sensitive data without consent should also be considered.

Detailing the safety protocols implemented to prevent accidents, such as safety measures that bring the vehicle to a stop if it loses connection or encounters an obstacle it cannot navigate around. Additionally, compliance with traffic laws and regulations, ensuring the vehicle is visible to other drivers, especially in poor weather conditions, and incorporating features to prevent the vehicle from causing traffic disturbances.

## References

[1] esp32-wroom-32e_esp32-wroom-32ue_datasheet_en.pdf (espressif.com)