LAFAYETTE COLLEGE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Senior Design Project

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Mobile and Autonomous Roadway Guardian Entity (M.A.R.G.E) 2023-2024

Preliminary Project Proposal
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Table of Contents

Common Definitions and Terms.......... 4
1. Abstract.......... 5
2. Operation Overview.......... 5
3. Motivation.......... 7
4. Design Objectives.......... 7
4a. Power.......... 7
4b. Sensing.......... 7
4c. Communication.......... 8
4d. Movement.......... 9
4e. Steering.......... 9
4f. Structure.......... 10
5. Design Constraints.......... 13
6. Relevant Codes and Standards.......... 13
7. Preliminary Operation Manual.......... 13
7a. Set Up.......... 13
7b. General.......... 13
7c. User Interface.......... 14
7d. Remote Control.......... 14
8. Preliminary Safety Analysis.......... 15
8a. Battery Precautions.......... 15
8b. Weight Concerns.......... 16
8c. General Safety Concerns.......... 16
9. Charging Information.......... 16
9a. Plug In Charging.......... 16
9b. Energy Collection and Storage in Dock.......... 17
9c. Energy Storage in Cart.......... 17
9d. Normally Closed Charging.......... 17
9e. Normally Open Charging.......... 18
9f. Scheduled Charging.......... 18
9g. Charging Duration.......... 18
10. Electronics Information.......... 18
10a. Micro-Controllers.......... 18
10b. CV Cameras.......... 19
10c. IR Camera/Beacon.......... 19
10d. Antenna.......... 19
10e. Corral.......... 20
10f.......... 20
10g. Ethernet Switch.......... 21

10h. Encoder.....21
10i. Screen.....21
10j. Knob and Push Buttons.....21
11. Calibration..... 21
12. Estimated Cost.....22
13. Preliminary Test Procedure.....22
13a. Unit Testing.....22
13b. Acceptance Testing.....23
13c. Stress Test.....24
14. Informational Website..... 25

Common Definitions and Terms

MARGE: Mobile and Autonomous Roadway Guardian Entity
Cart: Moveable part of the MARGE system that will control the flow of traffic along driveway
Dock: Stationary part of the MARGE system which will serve several purposes including charging the cart, sensing vehicles, changing modes, etc.
Remote Control: Additional part to the system that will have an override to the MARGE system and what mode it is and/or what position the cart is.
Open: The cart is located on the dock.
Closed: The cart is located on the driveway.
Normally Open Mode: This mode indicates that the cart shall only enter the driveway from the dock when an unauthorized vehicle is present.
Normally Closed Mode: This mode indicates that the cart shall only leave the driveway from the dock when an authorized vehicle is present.
Normally Open MARGE System Set Back (OMSSB): Minimum distance the MARGE system is set back from the entrance of the driveway when in normally open mode.
Normally Closed MARGE System Set Back (CMSSB): Minimum distance the MARGE system is set back from the entrance of the driveway when in normally closed mode.
Recognized Vehicle Sensing Distance (RVSD): Distance from the MARGE system that a recognized car will be sensed.
Unrecognized Vehicle Sensing Distance (UVSD): Distance from the MARGE system that an unrecognized car will be sensed.
Remote Control Sensing Distance (RCSD): Distance from the MARGE system that the remote control will be sensed.

1. Abstract

Lafayette College's Department of Electrical and Computer Engineering (ECE) split the ECE Class of 2024 into two groups requesting for each team to build a Mobile and Autonomous Roadway Guardian Entity (MARGE). The purpose of MARGE is to control the flow of traffic along a driveway. The MARGE system will consist of two pieces, the cart and the dock. The dock will be the housing and charging station for the cart, consisting of solar panels, a 12V battery used for solar charge storage, a charging mechanism, vehicle sensors, and small computers. The cart will move into the driveway as a blocking mechanism and will consist of a 12V battery, wheels, motors, small computers, and sensors to lead it to the dock. The MARGE shall be weatherproof and able to withstand multiple outdoor surfaces.

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2. Operation Overview

The MARGE shall be easy to set up and user-friendly. Its main purpose is to limit vehicular access from the roadway to the driveway. The system shall sit at a user-designated distance away from the roadway. The user should take into consideration that not all distances will ensure the system will operate as intended. The dock shall sit 1.5 ft away from the edge of the driveway's width to ensure no damage will occur should a car drive off the driveway.

The system shall operate in two different operating modes: normally-open and normally-closed. The remote control shall override the operating mode the cart is in and shall move the cart to the desired position. The remote control can override the operating mode and make the cart stay in the open or closed position without vehicle detection until instructed otherwise. It can also be used to temporarily override the operating mode allowing an unidentified vehicle to pass or block an identified vehicle. It can be used to switch operating modes as well. The attributes of each mode are listed below.

Normally-Closed Operating Mode

- The cart shall sit in the middle of the driveway's width.
- The cart shall detect recognized vehicles 60 ft away and shall move back to the dock in time for the vehicle to to pass without stopping.
- The cart shall not move out of the way for unrecognized vehicles unless the remote control overrides the system.
- The cart shall move to the dock when the battery dwindles to the recharge limit (10% battery life remaining) and shall remain in normally-open mode until it has fully charged. Then it shall move back to the center of the driveway and remain in normally-closed mode.
- The cart shall move to the dock at a time designated by the user during set-up to charge for 1 hour or until fully charged.

Normally-Open Operating Mode

- The cart shall remain in the dock.
- The cart shall detect unrecognized vehicles 100 ft away and move to the center of the driveway to block the vehicle's entrance in enough time so as to not cause any immediate stops. The cart shall not move until the vehicle has left the driveway unless the remote control overrides the system.

- The cart shall remain in the dock upon detection of a recognized vehicle, letting it pass safely into the driveway.
- The cart shall charge in the dock when needed.

	Normally-Open Operating Mode	**Normally-Closed Operating Mode**
Cart Location	Dock	Middle of the driveway's width
Recognized Vehicles	Cart shall remain in dock allowing the vehicle to pass.	Cart shall locate back to the dock allowing the vehicle to pass.
Unrecognized Vehicles	Cart shall locate to the middle of the driveway in enough time so as to not cause any immediate stops. Cart shall locate back to dock when the vehicle is not detected anymore.	Cart shall remain in the middle of the driveway.
Charging Information	Cart shall plug into the charger as needed.	Cart shall locate to the dock when the battery dwindles to 10% and shall go into normally-open mode. Cart shall go into normally-closed mode upon full charge. Cart shall move to the dock at a time designated by the user during set-up to charge for 1 hour or until fully charged.

Figure 2a. Operating Mode Information Table

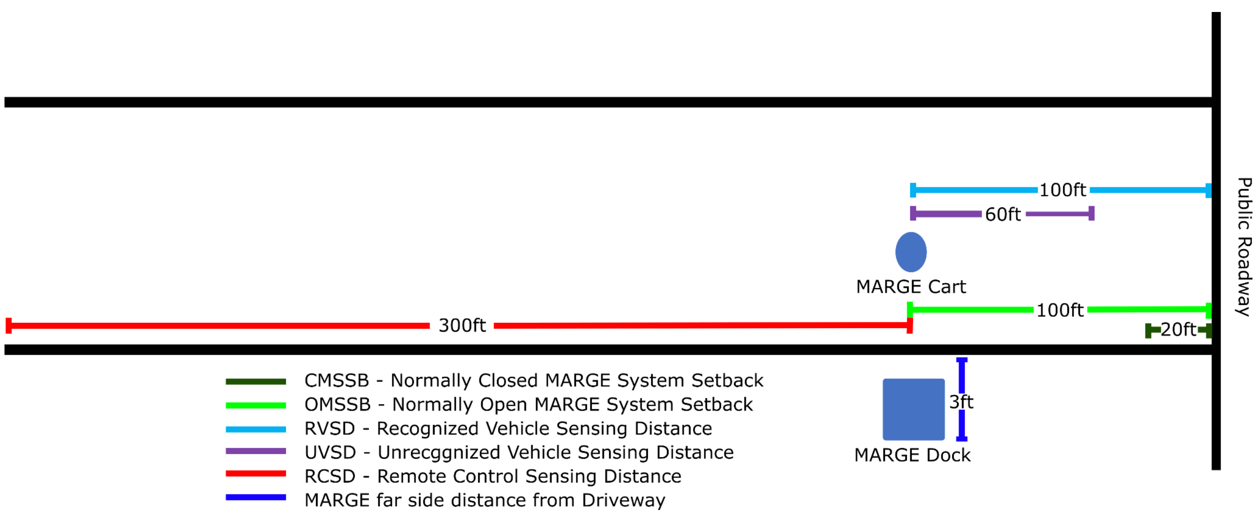

Figure 2b. Sensing Distance Diagram

3. Motivation

If you live in suburbia or out in the country, chances are you have a driveway. It is a part of life outside of cities where you need a car to get to work or school. Unfortunately for you, your driveway is accessible to all cars, not just your cars. These extra cars can block you in, from moving trucks pulling into the wrong spot, to workman's vans sitting in the middle of the driveway, to the late-night driver making a U-turn. If only you had a way to limit the cars that have access to your driveway.

A gate would fix this issue but a gate is expensive to install and maintain if you want something automatic, costing anywhere from $2,500 to $9,000, not including the cost of setting up the gate which must be done by outside contractors. This is not a realistic price for most homeowners and a gate can sometimes look out of place on a person's property. The proposed product solves all problems by being easy to set up by the consumer, cost-effective, and does not take up much space at all.

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4. Design Objectives

4a. Power

The system will run off of a 100W solar panel which will charge a 12V 50 Ah lithium iron phosphate battery in the dock. The battery in the dock will sustain all the equipment on the dock including the sensors, communication systems, and user interface. The battery in the dock will also charge a 12V 10 Ah lithium iron phosphate battery which will power the motors and communication systems in the cart. The system will run on all DC power with the help of step-ups, step-downs, and chargers.

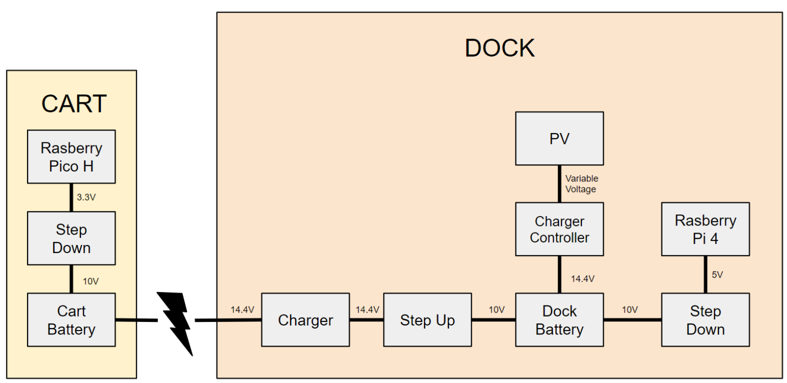

Figure 4a1. High level diagram of power design for MARGE system.

4b. Sensing

The Cart will be able to perform the following sensing functions:

- Detect the Dock's IR beacon at a range of 10ft via an IR camera.
- Detect radio communications from the Dock at a range of 10ft via LoRa (a low-power, long-range detection technology).

The Dock will be able to perform the following sensing functions:

- Detect radio communications from the remote and Cart at a range of 300ft via LoRa.
- Detect a vehicle entering or leaving the driveway at a range of 100ft via computer vision.
- Detect if an entering vehicle is recognized via an IR camera detecting if the car has an IR beacon.
- Detect motion in the entrance of the driveway via a Radar sensor.

The Remote will be able to detect radio communications from the Dock and Cart at a range of 300ft via LoRa. Return to Figure 2b in the Operation Overview to see the sensing distances displayed.

4c. Communication

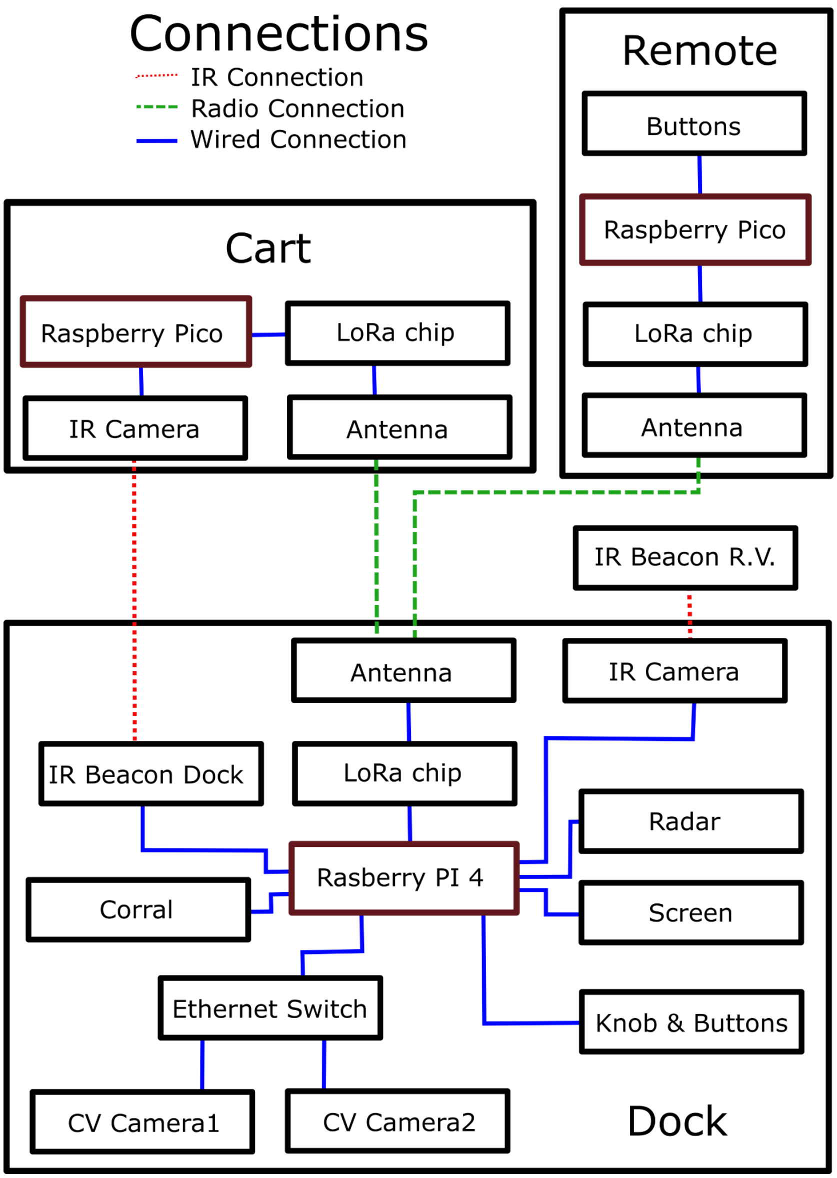

Figure 4c1. High-level diagram of Communication design for MARGE system.

IR connections are limited to the IR cameras identifying the relative position of an IR Beacon. The positional data is the critical aspect of the communication, as it functionally permits the Dock to broadcast its location and a recognized vehicle to broadcast its authentication as it enters the driveway.

Radio Communication is the method that will be used to facilitate the communication between the Dock, Remote, and Cart. Class A LoRa has been selected as the communication protocol that will govern which device can transmit at a given time. Class A LoRa is an ALOHA-style protocol, which means that several devices are asynchronously in communication with one server. For our project, the Dock will act as the server, as its microprocessor is more powerful, so the Cart and Remote will act as devices on the network. The flow of communication will be: A device, the Cart or Remote, will send an uplink transmission to the Server, our Dock. The uplink carries both a payload of data and an expected downlink, server-to-device transmission, time. The Dock will process an uplink and respond via a downlink in the designated window of time. The most common transmission will be the Cart uplinking to the Dock to request a Downlink containing instructions on where it should be. This protocol is required to ensure that the devices are not competing for transmission time, as if the Cart and Remote are trying to transmit at the same time the Dock would fail to receive either transmission. The LoRa chip selected has the necessary built-in processing and available libraries, such that the chips can be successfully controlled via the selected microcontrollers.

Wired communications utilize ethernet, I^2C, and UART. UART is a serial communication protocol that was studied in the embedded systems course. It enables full duplex communication, i.e. two devices connected via UART can send data in both directions simultaneously. UART will connect the three LoRa chips to their respective microcontroller. Ethernet-wired connections will be used to address the high data load of the CV cameras, as transmitting image data is on the critical path for vehicle detection, which must happen swiftly in both operating modes. I^2C will be utilized to connect the remaining sensors to their respective microcontrollers. I^C is chosen for these connections as it functions via a bus, which permits several sensors to communicate with the microcontroller on shared GPIO ports. In this way, I^2C limits the potential risk of an insufficient quantity of GPIO ports.

4d. Movement

The cart will utilize four motors, two on the front wheels and two on the back wheels that allow for more precise turning. The wheels will be 6 inches in diameter and will add around 3 inches to the total height.

4e. Steering

To steer the cart, we will utilize the motors that are attached to each of the wheels. If the cart senses that it is too far to the right, the motors on the right wheels will move faster so that the cart corrects to the left. If the cart is too far to the left, the motors on the left wheels will move faster so that the cart corrects to the right.

4f. Structure

The MARGE is split into two separate structures, the dock and the cart. The cart and the dock will both be made of a lightweight, durable, and weather resistant material. Both the dock and the cart will have internal structures to allow for a multi-levelled stack design to efficiently store all of the internal components. With the dock will be a ramp design in order to allow the cart to easily traverse the difference in height between the dock and the driveway. The dock's dimensions will be 2 ft x 2 ft x 4 ft and have an overhang to prevent the electronics for the charging port from getting damaged by weather. The dock will be approximately 50 lbs. The cart's dimensions will be 1.5 ft x 1.5 ft x 3 ft and have a cone-like shape similar to that of a traffic cone to be more noticeable to cars attempting to enter the driveway. The cart will be approximately 20 lbs.

Below are two sets of Fusion drawings showing the initial design for both the cart and the dock. The first set of drawings shows the different views of the initial design of the cart. The measurements and components on the drawings are all subject to change for the final proposal, but are what we are currently using. The second set of drawings detail the look and measurements of the initial design of the dock. The measurements and components on the drawings are also all subject to change for the final proposal.

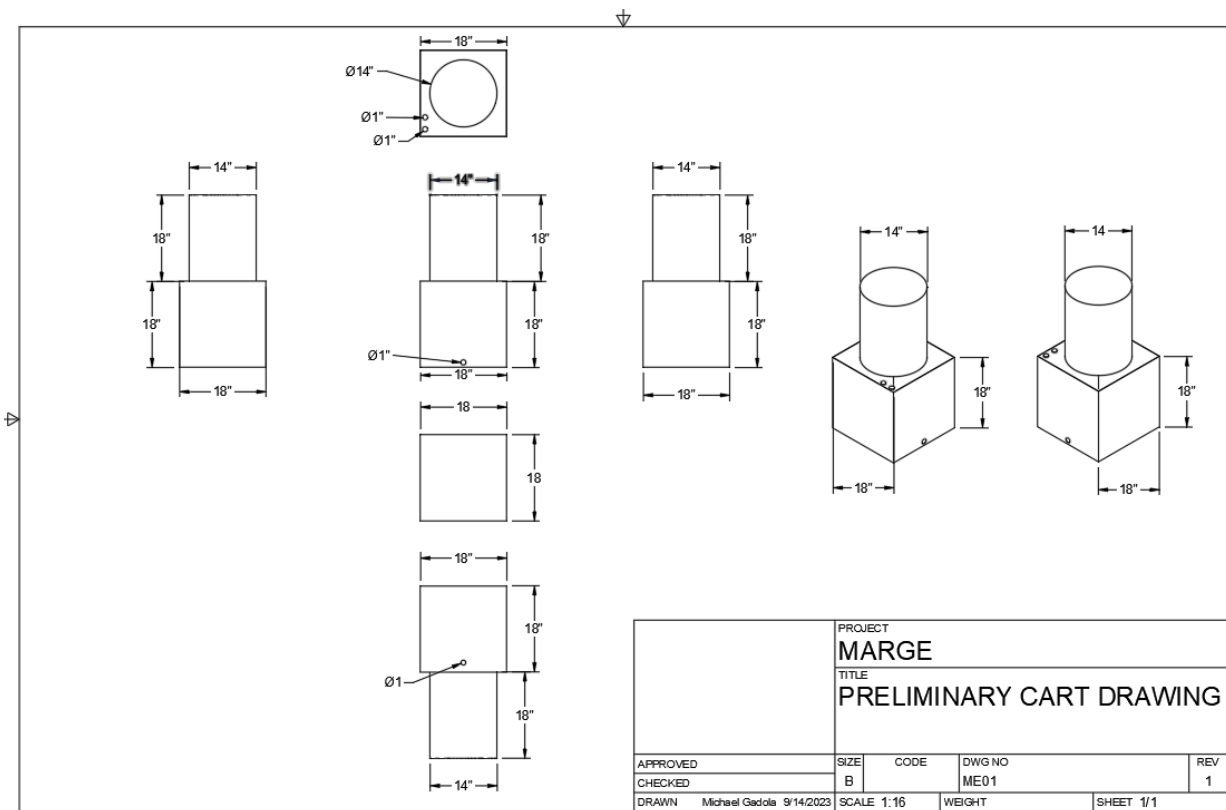

Figure 4f1: Initial cart design

Top View Holes: The drill holes that can be seen on the top of the design will be used for antennas that will be communicating with the WIFI

Front Hole: where the proximity sensor will be located.

Back Hole: where the IR camera will be located.

Overall this is a rough design just to get the dimensions we are using on paper. The cylinder on top of the main part of the cart will be shaped more like a cone structure giving the MARGE more of a traffic cone appearance. Also it should be noted that the wheels are not included in this drawing since we haven't fully decided on a size we will be using.

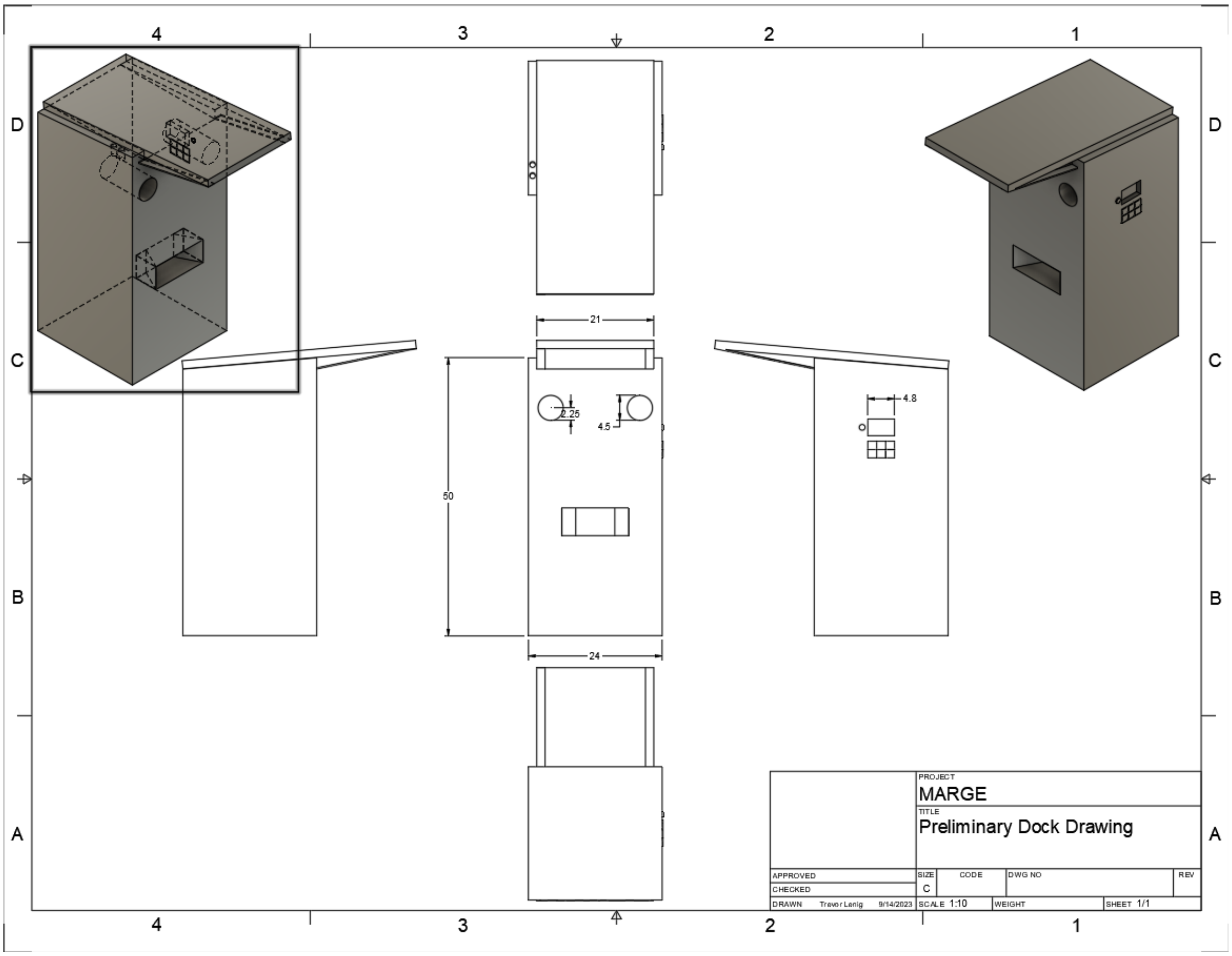

Figure 4f2: Initial Dock Design

Top View: the top shows the initial design for how our solar panel will sit on top of our main Dock unit. There are two holes cut in the top to allow for antennas to protrude out of the unit.

Front View: The front shows a potential look at the charging port where the cart will drive into so it can recharge. Also visible on the front are two circular holes where our cameras will be looking out of.

Side View: The side view shows an initial layout for our screen, a set of six buttons, and a dial next to the screen for easy scrolling through the menus. Also visible from the side is an initial design for a stability measure for the solar panel. We have two ramps coming out of the main unit to the end of the solar panel so there isn't a significant portion of the solar panel overhanging the unit.

We are still in the beginning stages of design, and are still working through any part changes and still have aspects (such as a potential ramp/bridge) in development.

5. Design Constraints

The MARGE cart shall be able to move from the dock to the center of the driveway to block a moving vehicle. The cart needs to not be too heavy, allowing it to move both fast and efficiently. In this move, the cart needs to be able to scale a curb of approximately 2 inches. The motors need to have high enough torque to move over the curb at ease. The cart should not exceed 25 lbs. The cart will run off a 12V 10Ah battery. All electronics and movements need to be powered by this battery.

The MARGE dock will be stationary, sitting beside the owner's driveway. The dock will have to withstand the weight and dimensions of the solar panel, approximately 15 lbs and 4 ft x 2 ft. The dock will also have to be water-proof, making sure the batteries and electronics inside are not affected by weather conditions. The dock shall not exceed 100 lbs. The electronics in the dock will run off a 12V 50Ah battery. All electronics in the dock, including the cart's battery, need to be powered by this battery.

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6. Relevant Codes and Standards

In our design safety of the building team and clients is of utmost importance. For those reasons we intend to follow several standards including FCC regulations for title 47, regulations outlined in the IEC 60335-1 standard for household appliances, and all safety information provided by manufacturers of parts of the design. Our standards will also abide by any applicable laws. Other standards we will comply with are ones outlined by IEEE. The relevant IEEE standards to our project include, IEEE 1874-2013, IEEE/IEC 82079-1-2019, IEEE 1872.2-2021, IEEE 1375-1998, IEEE 1657-2009, IEEE 1562-2021, and IEEE 2836-2021.

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7. Preliminary Operation Manual

7a. Set Up

When the MARGE system is first deployed, the screen will display the default midpoint of a driveway, 6 ft. The user will be prompted to either accept the default settings via a button press or rotate the knob until the correct midpoint distance is displayed before pressing a button to confirm the distance. The next prompt will be to select the desired operating mode, once one has been selected general operation will begin.

7b. General

Within general operation, the screen will display a list of options that can be scrolled through via the knob. Based on the current selection the Info-display section shows relevant choices; using the buttons the user can interact with the relevant selected option. In this way the user can alter the active operation mode and also input temporary open or close overrides.

7c. User Interface

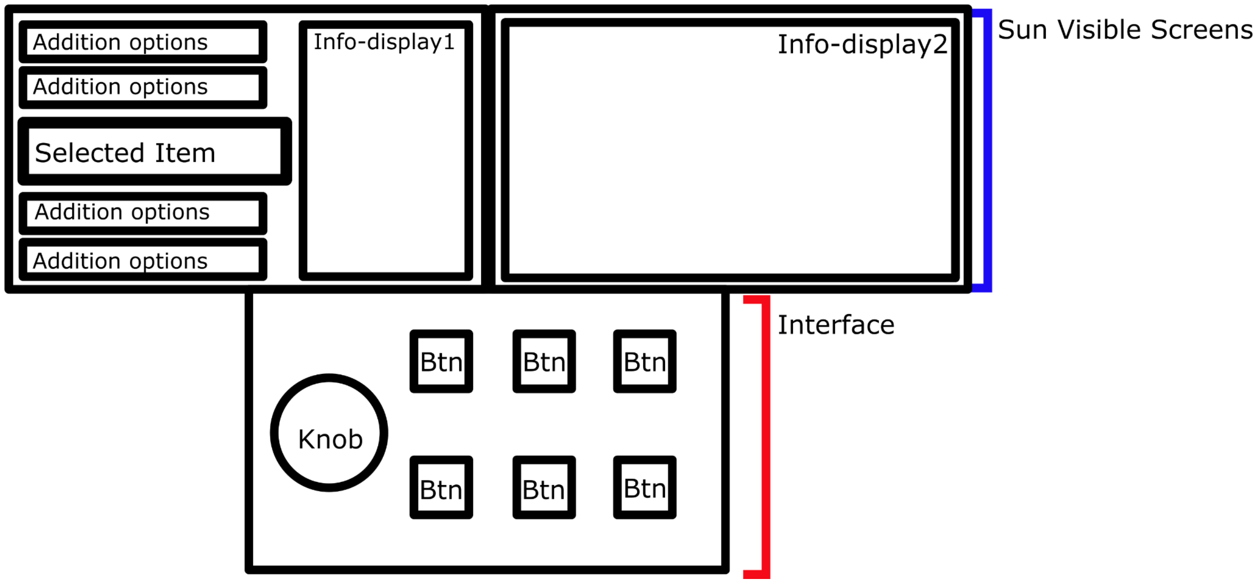

Fig. 7c 1: User Interface on the Dock

7d. Remote Control

- The remote control will have a more limited selection of four buttons:
  - Btn1: pressed - change operating mode to normally open
  - Btn2: pressed - change operating mode to normally closed
  - Btn3:
    - pressed - override to force closed until no vehicle detected
    - Held for 3 seconds - override to force closed until operating mode reselected
  - Btn4:
    - pressed - override to force open until no vehicle detected
    - Held for 3 seconds - override to force open until operating mode reselected

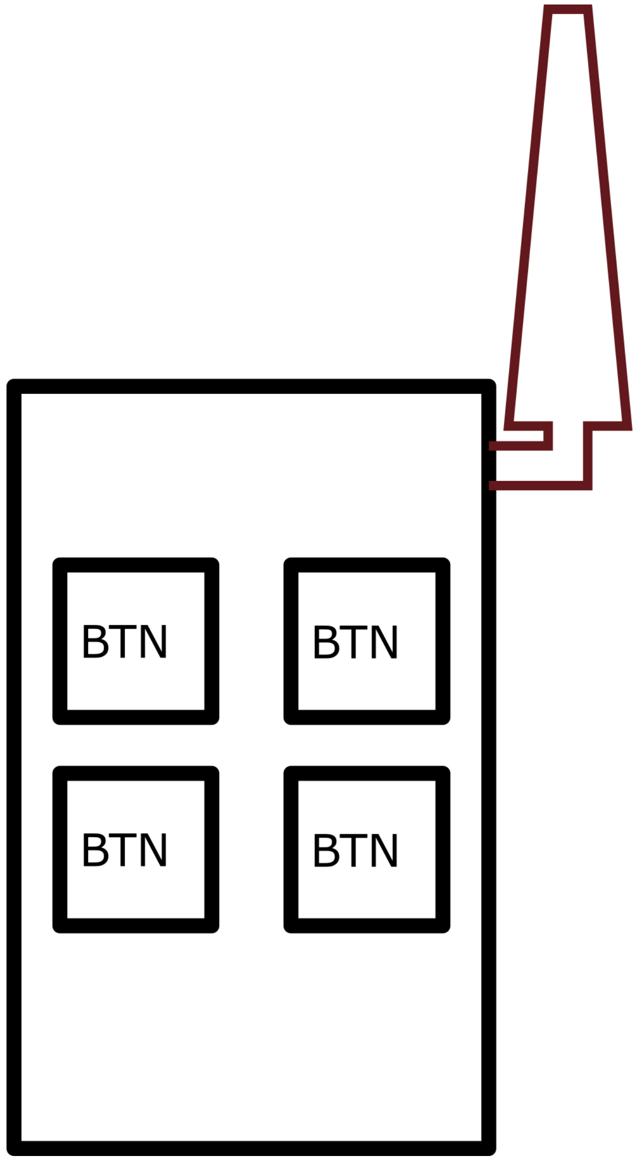

Fig. 7d 1: User Interface on the Remote Control

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8. Preliminary Safety Analysis

8a. Battery Precautions

The batteries we will be using are Lithium-Iron Phosphate (LiFePO4). LiFePO4 batteries are the safest option, as they are not prone to overheating or exploding due to their strong covalent bonds in the cathode of the battery. Our batteries will be stored in a closed environment, shielded from weather conditions and other hazards that could affect the battery or the MARGE user.

8b. Weight Concerns

The MARGE system will weigh around 75lbs. The cart will be around 25 lbs and the dock will be around 50lbs. We will make sure the cart is light enough to move quickly but heavy enough to not be blown away by a storm. The dock will be heavy enough to stay in place beside the owner's driveway, not having to be moved for weather conditions.

8c. General Safety Concerns

The MARGE cart will be moving into the center of the driveway in front of a moving vehicle. The cart will be large enough to be seen, with bright colors to be seen at night. If the cart is hit, it will be damaged, but it will not damage the car enough to hurt any of the passengers in it. The goal of MARGE is to stop incoming vehicles into a driveway, but it is safe to come in contact with.

While building MARGE, the team will wear closed toed shoes, safety glasses, and no loose accessories. The team will also adhere to all laboratory safety rules set forth by Lafayette College.

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9. Charging Information

9a. Plug In Charging

In the mechanical structure of the MARGE system, a pivotal component is the mating charger socket system, designed to facilitate seamless energy transfer and ensure operational safety. This system will be integrated with an off-the-shelf MPPT solar charge controller, a reliable unit responsible for managing the power supply from the solar panel to the battery. The core of this system comprises of two substantial sets of metal contacts, directly connected to the battery outputs, functioning as conduits for power transmission.

To enhance the system's reliability and safety, an additional floating center sensing pin will be incorporated, constructed from a strip of metal. This innovative feature is designed to monitor the moisture levels within the socket continuously, acting as a safeguard against potential water-induced damages and other fault conditions. Through this mechanism, the MARGE system ensures not only efficient energy utilization but also prioritizes the longevity and safety of the entire setup.

In the power segment of our project, a specialized PCB will be developed for the socketing system, central to MARGE's efficient operation. This PCB will feature a floating center pin in the contact assembly, a critical element designed to detect moisture and other fault conditions, enhancing the system's resilience against weather and potential tampering. It also includes current monitoring and communicates through a 3.3v i2c bus.

To ensure safety and energy efficiency, the system will not maintain a high nominal charging voltage on the contacts constantly. This prevents arcing and electrolysis of the contacts. Instead, it will employ a low standby communication mode, initiating a main power connection only through a secure handshake sequence with the cart. This approach not only conserves energy but also fortifies the system against unauthorized access and potential malfunctions, promising a secure and sustainable operation.

9b. Energy Collection and Storage in Dock

The main source of energy collection in the MARGE system is the 100W solar panel. The solar panel will be south facing, getting around 5 peak hours of sunlight per day. The energy collected by this solar panel will run through an MPPT solar charge controller into a 12V 50Ah battery with a maximum of 20A. This 12V battery will be used as our energy storage unit in the dock. Through a DC-DC charger and the socket system, this 12V battery will charge the 12V battery on the cart with a minimum of 10A.

9c. Energy Storage in Cart

A 12V 10Ah battery will be used as our energy storage unit on the cart. When the cart is in normally closed mode, the cart will be in idle mode, using minimal energy. The reasoning behind the selection of this battery is provided by the math supplied below:

Variables

40 trips per day

Each trip is 30sec (a high estimate but we want to design for worst case)

Motor Current 7A max 0.35A min

- Assume 3A is drawn by each motor per trip (a high estimate but we want to design for worst case)

Raspberry Pi Pico Current 0.5A max

- Assume a constant 0.2A is drawn (a high estimate but we want to design for worst case)

Total Amin = 10 * 60 = 600Amin

Total current drawn by motors: 240Amin

4 motors x 3A x 0.5min x 40 trips = 240Amin

Total current drawn by Raspberry Pi Pico: 288Amin

23hr x 60min x 0.2A = 276Amin

Battery Comparison

600Amin > 240Amin+276Amin = 516Amin

Thus the battery we have selected can handle the necessary amount of current required by the system in the day with some wiggle room.

9d. Normally Closed Charging

When the cart is in the normally closed option, it sits in the center of the driveway until a recognized vehicle comes into range. The small solar panel on the cart will not be the main source of power for the cart, so in normally closed mode the cart will have to travel back to the dock to charge its battery. During setup, the owner of MARGE will be given options and decide a charging cycle for their cart. During this charging cycle, MARGE will leave the driveway to enter into the dock to be charged for 1 hour. MARGE will also leave the driveway to enter into the dock to be charged for 1 hour if the battery dwindles to 10% battery life remaining. If an unrecognized vehicle appears during this charging time, MARGE will act as if it is in a normally open state and move to the center of the driveway.

9e. Normally Open Charging

When the cart is in the normally open option, it sits in the dock until an unrecognized vehicle comes into range. While the cart is sitting in the dock, it will be charging. The cart's rested position in the dock will have it positioned on the charger. The cart battery will stop charging when it reaches full to optimize battery life.

9f. Scheduled Charging

When the cart is in the scheduled option, it sits in the driveway for a set amount of time, moving when a recognized vehicle comes into range. During setup, the owner of MARGE will decide a schedule for their cart. This schedule must account for the time MARGE needs to charge. During this charging time, MARGE will leave the driveway to enter into the dock to be charged for 1 hour or until fully charged. If an unrecognized vehicle appears during this charging time, MARGE will act as if it is in a normally open state and move to the center of the driveway.

9g. Charging Duration

The 12V 10 Ah battery in the cart will take 1 hour maximum to charge from no battery percentage left. The 12V 50 Ah battery in the dock will continuously charge. However, with a steady output current of 20A from the solar panel, it will take approximately 2.5 hours minimum to charge fully from no battery percentage left. The calculations for the charging time is provided by the math below:

Equation:
Charge Time (hours) = Capacity of Battery (Ah) / Charger Output (A)

12V 10Ah Cart Battery

10 Ah / 10 A = 1 hour maximum

12V 50Ah Dock Battery

50 Ah / 20 A = 2.5 hours minimum

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10. Electronics Information

10a. Micro-Controllers

The Raspberry PI 4 has been selected for the microcomputer within the Dock. It was selected primarily because of its effective and numerous interfacing options. The Ethernet port will enable it to communicate with the cameras that are monitoring the driveway. The USB ports enable it to communicate with the Google Corral, which will be handling Computer Vision calculations. The multi-role GPIO pins allow for UART, to communicate with the LoRa chip, SPI, I^2C, and PWM. Having such versatility ensures that as the project develops the micro-computer can communicate with the vast majority of devices that may need to be added or changed.

The Raspberry Pico H was chosen as the microcontroller within the Cart and the Remote control. It has lower power consumption while maintaining the capacity to communicate with LoRa chips via UART due to it also having multi-role GPIO. These same GPIO pins can also command motors and take input from an IR Camera via I^2C.

10b. CV Cameras

Cameras will be used to collect data for incoming and outgoing car recognition. Cameras will be connected to Raspberry Pi through lan network, operated by the Ethernet Switch. The cameras selected are powered over Ethernet connection, via the Ethernet Switch as well.

The expected frame rate for computer vision is 2 frames per second. The image resolution is 2560 x 1440 pixels with 8-bit RGB colors. The total size of one image is 11 megabytes with no compression. These images will not be stored in the memory of Raspberry Pi, only routed to the Corral. The image processing itself is happening at the Google Corral USB Accelerator. Yolo v8 nano will be the model used for image processing on Raspberry Pi and Google Coral, run through TF-Lite runtime. Yolo v8 nano is a pre-trained model that detects vehicles over a long range. Both Yolo v8 nano and TF-Lite runtime are designed for use on mobile devices with limited power consumption.

10c. IR Camera/Beacon

The infrared cameras we will use in our design are PixArt IR models taken from a Wii Remote. The camera frame ratio is 128 x 96 and its resolution is 1024 x 768. Its onboard image processing analyzes the IR image data to track the X and Y positions of up to four IR sources in the camera's field of view. The camera communicates via I^2C, so it can easily receive updates, like altering sensitivity settings, and transmit the position of detected IR sources. By transmitting the positional information of IR sources instead of the full array of IR image data, computational load is significantly reduced for the microcontroller that the IR Camera is connected to.

The IR source that we will be using along with an IR camera, are IR 940nm LED beacons that will flash a signal. Considering that the IR camera is specialized for 940nm IR light, in combination with filtering for the correct signal, the IR camera will be able to detect our IR beacons at a range of 60ft.

10d. Antenna

The antenna selected is able to transmit and receive the bandwidths that the LoRa Chips are designed to work within. The two channels utilized are centered at 433 MHz and 868 MHz. Beyond that they are able to transmit and receive data at distances far greater than the target range of 30ft.

10e. Corral

Google Corral is a Tensor Processing Unit (TPU), designed specifically for tasks, which involve intensive matrix calculations, such as computer vision. This ASIC allows us to perform mathematical calculations in parallel. The chip can perform 4 trillion operations per second using 0.5 Watts for each trillion of operations. This device allows us to speed up the computations and perform them with high power efficiency. The ecosystem has to offer 11 pre-compiled CV models, trained on the COCO dataset. Also, we can optimize any other publicly available model for this hardware, or develop our own custom model.

For example, a Computer Vision model, SSD MobileNet V1, is 7.0MB, and latency of only 6.5ms. These parameters highlight how the Corral will quickly process image data for vector products perfectly and we have a lot of room for other necessary tasks.

10f.

The IC providing LoRa functionality for this project is the RN2483 from Microchip. LoRa is a network protocol set optimized for low-power devices on wireless networks. For the purposes of this project, LoRa will facilitate radio communication between the dock, remote, and cart. This chip handles creating a network stack, performing modulation, performing power amplification, and performing signal detection. While addressing all those communication roles, the chip communicates with the Raspberry PI 4 through UART. Via the UART connection the Raspberry PI 4, is routed to all received data and can issue transmission data to the chip for broadcast.

More specifically, the LoRa Class A communication protocol will be implemented in our project. LoRa Class A provides the functionality for asynchronous multi-device communication with no interference. This type of communication protocol is also commonly referred to by the term ALOHA (Advocates of Linux Open-source Hawaii Association), which is a multi-access protocol whose rules dictate how all the terminals can access the radio band in use without interfering with each other. In our system the Dock will act as the server; the Remote and Cart will act as devices

In LoRa Class A, all transmissions from a device to the server (cart to dock or remote to dock) are called uplinks, while all transmissions from server to device (dock to cart or dock to remote) are called downlinks. Downlinks and uplinks are always the same size including the space allocated for payloads. Here is a sample of how the process would flow:

A consumer uses the remote to send an override command to open the driveway. The first transmission sent is an uplink from the remote to the dock. The Dock will receive the command and prepare to send it to the Cart. The Cart is passively transmitting uplinks to the Dock at a high frequency. These uplinks instruct the Dock as to when Cart is expecting to receive a transmission. The Dock would transmit into one of the Cart's expected receive windows, prompting it to return to the Dock.

10g. Ethernet Switch

TP-link power over ethernet (POE) is necessary to connect cameras to Raspberry Pi, and power them. The Ethernet Switch selected is equipped with POE and provides an opportunity for network devices to communicate with each other. The Ethernet Switch supports up to 4 devices, which is enough to connect both CV cameras to the Raspberry Pi.

10h. Encoder

Hall effect motor encoders will be integrated into the robot's wheel assembly to count the motor rotations and to assist in evaluating the cart's position. This method is computationally efficient and provides high-accuracy data under ideal conditions.

10i. Screen

Two five-inch screens have been selected for the display aspect of the UI. Two-five inches was determined to be the size as it enables the necessary information to be displayed concisely at a readable font size while maintaining a reasonable price. In addition, the screen selected is able to be seen in daylight, as per design requirements. It will communicate with the microcontroller via I^2C.

10j. Knob and Push Buttons

A knob will be integrated as part of the user interface. Having physical components for the UI will work better in adverse weather conditions that could interfere with a touchscreen. A 10 Kohm potentiometer will be the electronic device used to detect the position and movement of the knob. This enables the potentiometer to be safely within the dock while a shaft connects it to a knob on the outside of the dock. Outdoor use push buttons have been selected for their capacity to ensure a waterproof seal between themselves and the material they are mounted on.

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11. Calibration

The owner will be able to enter the width of the driveway in the screen while setting up the dock. From there the midway point of the driveway will be calculated which will become a stored value for each time the cart enters the driveway. Since the cart will have a distance sensor, each time the cart enters the driveway the distance from the dock will be calculated and the cart will be placed in the center of the driveway.

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12. Estimated Cost

Quantity	Item	Manufacturer	Part Number	Cost Per Item	Total Cost	Website	Datasheet	Total Cost
1	Lithium Iron Phosphate Battery 12 Volt 50 Ah	Renogy	*RNG-BATT-LFP-*	$299.99	$299.99	https://www.reno	https://www.reno	$2,459.48
1	12V 20A/40A/60A DC to DC On-Board Battery Charge	Renogy	RNG-DCC1212-	$149.99	$149.99	https://www.reno	https://www.reno	
1	DAKOTA LITHIUM 12V 10AH BATTERY	Dakota Lithium	N/A	$99.00	$99.00	https://dakotalith	https://dakotalith	
1	USB Accelerator	Coral	G950-01456-01	$69.99	$69.99	https://coral.ai/pı	https://coral.ai/d	
1	Raspberry PI 4	Raspberry PI	N/A	$88.90	$88.90	https://www.rasp	https://datasheet	
2	Raspberry Pico H	Raspberry PI	N/A	$6.00	$12.00	https://www.spar	https://datasheet	
2	Screen	Crystalfonts	CFAF800480E1	$32.93	$65.86	https://www.crys	https://www.crys	
2	Camera	EVERSECU	N/A	$36.60	$73.20	https://www.amazon.com/Detectio		
1	Knob	adafruit	562	$0.95	$0.95	https://www.adafruit.com/product/		
6	Button	adafruit	481	$4.95	$29.70	https://www.adafruit.com/product/		
2	Wii IR camera	Nintendo	N/A	$13	$25.00	https://www.ama	https://www.rese	
4	Motor	DigiKey	FIT0186	$30	$120.00	https://wiki.dfrob	https://mm.digike	
4	Wheels			$20	$80.00			
1	Framing/Casing	Various	Various	$1,000	$1,000.00	Various	Various	
3	Antenna	Wishiot	B0C1N1FTSV	$10.59	$31.77	https://www.ama	----------	
3	LoRa Module	Microchip	RN2483	50	$150.00	https://www.micr	https://ww1.microchip.com/downlo	
1	POE switch	TP Link	TL-SG1005P	44.99	$44.99	https://www.ama		
1	POE injector	DSLRKIT	B07TJ3ZNJ4	12.5	$12.50	https://www.amazon.com/DSLRKIT-Splitter-IEEE80		
1	DC DC Step up	EAGWELL	B0BY1L5FD7	21.99	$21.99	https://www.amazon.com/Converter-EAGWELL-Re		
1	Outdoor Radar Motion Sensor	Bosch	ISC-PDI1-WC30	83.65	$83.65	https://www.a1se	https://www.a1securitycameras.co	

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13. Preliminary Test Procedure

13a. Unit Testing

Dock Battery

Ensure that the battery will provide the proper amount of voltage on fully charged.

Pass: Voltage across the battery is 10V +- 5%.

Fail: Voltage across the battery is not 10V.

Ensure that the battery will provide the proper amount of voltage to Raspberry Pi after step down.

Pass: Voltage after step down is 5V.

Fail: Voltage after step down is not 5V.

Ensure that the battery will provide the proper amount of voltage to the charger after step up.

Pass: Voltage after step up is 14.4V.

Fail: Voltage after step up is not 14.4V.

Cart Battery

Ensure that the battery will provide the proper amount of voltage on fully charged.

Pass: Voltage across the battery is 10V +- 5%.

Fail: Voltage across the battery is not 10V.

Ensure that the battery will provide the proper amount of voltage to Raspberry Pico after step down.

Pass: Voltage after step down is 3.3V.

Fail: Voltage after step down is not 3.3V.

Solar Panel

Ensure that the solar panel will charge the battery of the dock after being in the sun.

Pass: A current is able to be drawn from the battery.

Fail: No current is drawn from the battery.

Cart Movement

Ensure that the cart is able to move the required distance of the driveway.

Pass: The cart is able to move out into the driveway and return to the dock.

Fail: The cart is unable to make it out to the driveway or unable to return.

IR connections

Ensure that the IR camera can detect the IR Beacon.

Pass: The IR camera can detect the IR Beacon at a range of 60ft.

Fail: The IR camera can not detect the Beacon at a range of 60ft.

LoRa radio connections

Ensure that the LoRa radio connections operate correctly at the necessary ranges

Pass: The LoRa radio connections operate correctly at a range of 300ft.

Fail: The LoRa radio connections don't operate correctly at a range of 300ft.

CV camera

Ensure that the CV camera can detect a vehicle at the necessary range.

Pass: The CV camera can detect a vehicle at a range of 100ft.

Fail: The CV camera can not detect a vehicle at a range of 100ft.

Radar motion detector

Ensure that the Radar Sensor can detect a vehicle at the necessary range.

Pass: The Radar Sensor can detect a vehicle's motion at a range of 100ft.

Fail: The Radar Sensor can not detect a vehicle's motion at a range of 100ft.

Corral

Ensure the Corral can process data fast enough to prevent buffer overflow

Pass: The corral can process 22 megabytes of data per second

Fail: The corral processes under 22 megabytes of data per second

13b. Acceptance Testing

In normally open mode the cart moves in front of an unrecognized vehicle.

Pass: Cart moves in front of car before car gets to MARGE location.

Fail: Cart does not move in front of car before car gets to MARGE location.

In normally open mode the cart does not move in front of a recognized vehicle.

Pass: Cart does not move in front of car before car gets to MARGE location.

Fail: Cart moves in front of car before car gets to MARGE location.

In normally closed mode the cart does not return to the dock when an unrecognized vehicle is present.

Pass: Cart doesn't return to dock.

Fail: Cart returns to dock.

In normally closed mode the cart returns to the dock when a recognized vehicle is present.

Pass: Cart returns to dock.

Fail: Cart doesn't return to dock

Microprocessor (Dock)

The Microprocessor can send and receive data from all the connected devices

Pass: Can communicate with Ethernet Switch, LoRa chip, Corral, UI, Radar motion detector, and IR Beacon

Fail: Can't communicate with Ethernet Switch, LoRa chip, Corral, UI, Radar motion detector, and IR Beacon

Microprocessor (Cart)

The Microprocessor can send and receive data from all the connected devices

Pass: Can communicate with motors, LoRa chip, encoder, and IR camera.

Fail: Can't send or receive from one of the following: Motors, LoRa chip, encoder, and IR camera

Microprocessor (Remote)

The Microprocessor can send and receive data from all the connected devices

Pass: Can communicate with UI and LoRa chip.

Fail: Can't send or receive from one of the following: UI and LoRa chip

13c. Stress Test

Cart

Ensure that the selected material can support the weight of devices and batteries inside of Cart.

Pass: Weight is supported and the cart is able to function.

Fail: Weight is not supported or supported, but cart can not move.

Dock

Ensure that the selected material can support the weight of devices and batteries inside of Dock

Pass: Weight is supported by the dock.

Fail: Weight is not supported and the dock either moves or breaks.

Wheels

Ensure that the selected wheels on the Cart are able to hold the weight of the Cart and will be able to move

Pass: Wheels hold the weight of the cart and move.

Fail: Wheels buckle under the weight or do not meet minimum speed.

IR connections

Ensure that the IR camera can detect the IR Beacon in high sunlight conditions.

Pass: The IR camera can detect the IR Beacon at a range of 60ft in high sunlight conditions.

Fail: The IR camera can not detect the Beacon at a range of 60ft in high sunlight conditions.

CV camera

Ensure that the CV camera can detect a vehicle at the necessary range in low light conditions.

Pass: The CV camera can detect a vehicle at a range of 100ft in low light conditions..

Fail: The CV camera can not detect a vehicle at a range of 100ft in low light conditions.

LoRa radio connections

Ensure that the LoRa radio connections operate correctly under high-load conditions

Pass: The LoRa radio connections operate correctly when both LoRa devices are competing to send an uplink.

Fail: The LoRa radio connections don't operate correctly when both LoRa devices are competing to send an uplink.

Corral

Ensure the Corral can process data fast enough to prevent buffer overflow if oversampling occurs

Pass: The corral can process 30 megabytes of data per second

Fail: The corral processes under 30 megabytes of data per second

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14. Informational Website

To store the information on our Senior Design Project we have created a website. On the website you can find the members of the senior design team, the goal of the project, and the progress we make. Our progress on MARGE will be shown on the website through displaying our preliminary and final proposals and designs. As we dive further into the project the website will continue to be updated. The website will be accessible to the public, being a catchall of information regarding MARGE.

The link to our website can be found here: Senior Design 2023 - MARGE
(https://sites.lafayette.edu/ece491-fa23-02/)
