ECE Senior Capstone Project

GPS Data Logger

ECE Project Document

ECE 44x

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Xiang Wang
Andre Zhu

1 Overview

1.1 Executive Summary

The GPS data logger is a 3"x 4" device that is attached to a backpack/harness. The tacker box is equipped with a GPS module that will acquire the GPS location of the tracker every minute and store this in a data log for examination by the user when the tracker is charging. The GPS module will be used to obtain the current date and time as well as the longitude and latitude. The collected data will be stored in a MicroSD card that is connected to the microcontroller via a MicroSD Card adapter. The goal is for this GPS data logger is to have a cheap device capable of logging data that is easily readable by the user.

1.2 Team Protocols and Standards

1.2.1 Team Contact information:

Project Point of contact: Aaron Chung: chunga@oregonstate.edu

Team Member	Project Role	Email
Aaron Chung	Microcontroller System and PCB Design	chunga@oregonstate.edu
Xiang Wang	Power Supply and MicroSD Adapter Design	xiangw@oregonstate.edu
Andre Zhu	GPS Module and Enclosure Design	zhuan@oregonstate.edu

Table 1: A table of team's contact information

1.2.2 Communication Analysis

- The main method of communication will be a private Discord server containing all members of the group.
- A secondary method of contact will be through email.
- All group members have no restrictions on when they are available for contacting.

1.2.3 Roles and Expected Contributions

- Aaron Chung: Microcontroller System Design. Responsible for testing and development of the microcontroller and its code. Also responsible for designing the accompanying PCB.
- Xiang Wang: Power Supply and MicroSD Card Adapter design. Responsible for testing and development of the power supply unit and the MicroSD Card Adapter interfacing with the microcontroller.
- Andre Zhu: GPS Module and Enclosure Design. Responsible for testing and developing a GPS module to interact with the microcontroller. Also responsible for designing, testing, and fabricating an enclosure to house all components.

All group members contained herein are responsible for the timeliness of the development of their blocks and meeting deadline requirements placed by the project partner.

Protocol	***Standard***	***Team Signatures***
Full participation during weekly meeting (reflect on the previous week's progress for each member and questions)	Team members should agree and find times to meet at least once a week, for at least an hour.	Andre Zhu Aaron Chung Xiang Wang
Sharing Ideas during a meeting or via a message	Team members should encourage others to voice their ideas regarding an aspect of the project.	Andre Zhu Aaron Chung Xiang Wang
Setbacks Occurring regarding team progress	Team members should not be afraid to admit setbacks or troubles when dealing with their own blocks or parts of the project.	Andre Zhu Aaron Chung Xiang Wang
Team Communication in a group setting and interpersonal experiences	Team members should not be afraid to communicate on anything. Team members should spend at least one hour a week communicating about the project's development in order to ensure that every member understands the project plan. If someone does not understand, the team should reconsider continuing further and should focus on making sure the individual is up to speed.	Andre Zhu Aaron Chung Xiang Wang
Code (commenting, structure, readability)	Members should comment their code well enough for another member to understand. (Does not have to be every line, but maybe each section or function headers).	Andre Zhu Aaron Chung Xiang Wang
Member availability and communication etiquette for tardiness and absence.	Members should communicate at least 24 hours before if they cannot meet a commitment (meeting/lecture/etc).	Andre Zhu Aaron Chung Xiang Wang
Respectfulness and Inclusion in all settings (group or interpersonal)	Members will all be treated with respect when communicating and in-general and will always be included in all tasks in order to be a better team.	Andre Zhu Aaron Chung Xiang Wang
Discord Communication	Members will strive to check the discord server at least once a day. When a meeting is scheduled, members will either react to a message or respond to ensure acknowledgement.	Andre Zhu Aaron Chung Xiang Wang
Punctuality	Members should comply with their agreements to submit their work on-time and will communicate if that deadline cannot be met. It would be best to have work done before the deadline.	Andre Zhu Aaron Chung Xiang Wang
Personal Matters and Outstanding Circumstances	A team member should notify the team of anything personal that might affect progress. Identifying these issues quickly can help the team develop good solutions to solve the matter at hand. Other group members should be considerate of that group member and give help or advice.	Andre Zhu Aaron Chung Xiang Wang
Team Environment and Conflict	A team member should not be afraid to address any issues they feel are not being dealt with, such as work loads, work quality, or even the work environment itself. If a group member feels that the current workload or difficulty is too high, they can ask for help from other group members.	Andre Zhu Aaron Chung Xiang Wang

Table 2: Team standards

1.3 Gap Analysis

1.3.1 Motivation behind development

The GPS data logger was proposed to fill a market hole in which GPS data loggers are not readily available for an affordable price. Nearly all of the commercially available GPS data loggers are $150 dollars or more. Our GPS data logger will be able to record GPS locations every minute on the minute for a much cheaper price and without any monthly fees. Our GPS data logger will be able to fill the market for anyone who might want to log where they or their pet goes.

1.3.2 Assumptions made

Our team is assuming that the end user will have access to the device itself at the beginning and the end of the recorded journey. This means that if the user wants to record their animal, the user will need to have a pet animal that returns to their home or at a designated spot in order for the user to be able to retrieve the data from the device. We are also assuming the user is frugal and does not want to pay a hefty purchase price or monthly fee.

1.4 Timeline/Proposed Timeline

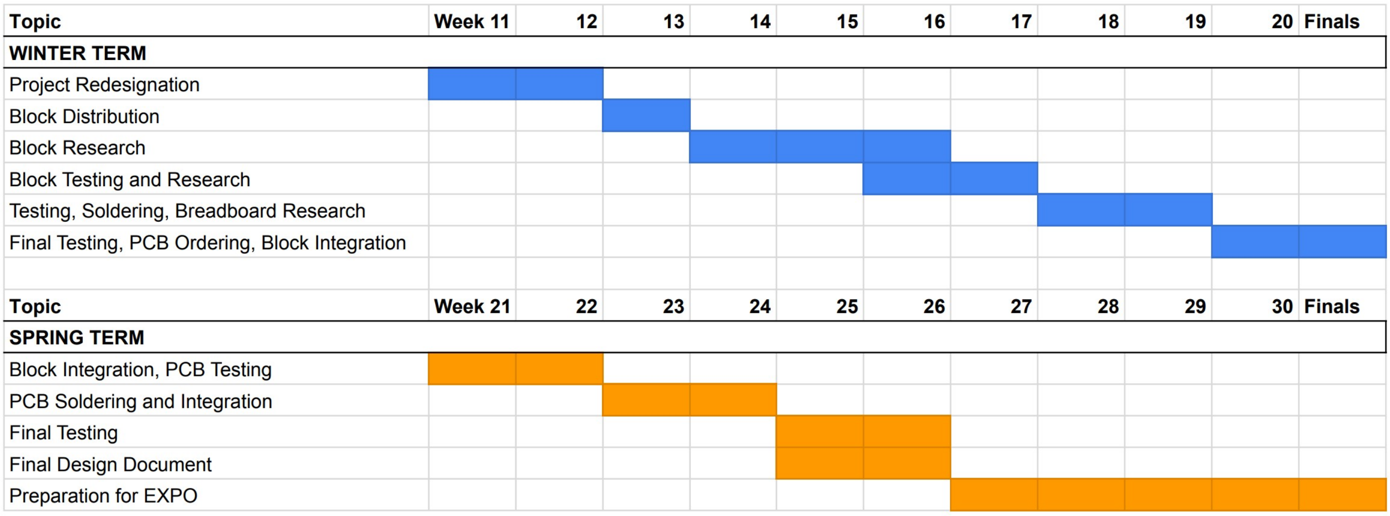

Figure 1: The revised timeline for the project.

1.5 References and File Links

[1] "Setting team standards," Google. [Online]. Available: https://tinyurl.com/7dtjepx3 [Accessed:22-Oct-2021]

[2] P. Permenter and J. Bigley, "Should I buy a GPS dog collar?," DogTipper. [Online]. Available: https://www.dogtipper.com/tip/2019/10/gps-dog-collar.html . [Accessed: 03-Dec-2021].

1.6 Revision Table

Date	Responsible Member	Revision Made
5/6/2022	Aaron Chung	Uploaded revised project timeline.
3/6/2022	Aaron Chung	Revised summary, Roles, Team contact info, standards, motivations for development, and assumptions made.
12/3/2021	Wang Xiang	Added problem statement and proposed solutions
12/3/2021	Wang Xiang	Revised Gap analysis and Market Research.
12/2/2021	Aaron Chung	Revised Team Standards and Protocols.
11/12/2021	Aaron Chung	Revised Team Standards and Protocols.
11/12/2021	Wang Xiang	Revised Team Standards and Protocols.
11/10/2021	Junior Velasco	Revised Timeline.
11/10/2021	Junior Velasco	Added in table captions and revised small section of executive summary.
11/06/2021	Declan O'Hara	Added in team contact information table
11/06/2021	Declan O'Hara	Rewrote executive summary.
10/28/2021	Junior Velasco	Fixed timeline image.
10/21/2021	Declan O'Hara	Fixed spacing problems with team standards table.
10/21/2021	Junior Velasco	Added Timeline and team protocols table.
10/21/2021	Aaron Chung	Added initial team protocols.
10/21/2021	Declan O'Hara	Added Gap Analysis.
10/21/2021	Declan O'Hara	Added Executive summary.
10/12/2021	Junior Velasco	Created Initial document.

Table 3: The revision table for section 1.

2 Requirements, Impacts and Risks

2.1 Requirements

2.1.1 All data to be logged on a MicroSD Card

PPR: The system must use a MicroSD Card.
ER: The system will log all GPS location data into a MicroSD Card.
Verification:

1. User will power on unit.
2. User will place a MicroSD Card into the adapter.
3. User will wait at least 3 minutes.
4. User will power off the device and insert MicroSD card into a computer to read the data.

2.1.2 Monitor Device Connections

PPR: The unit's successful device connections must be displayed to the user.
ER: The system will display its connections via LEDs. Green or red will be used to show failed or successful connections.
Verification:

1. User will power on the unit.
2. User will make sure the MicroSD Card is correctly in place.
3. User will verify that the LEDs are displaying green.

2.1.3 Frequency of Updating Location

PPR: The location of the pet will be obtained at a set interval.
ER: The system will gather the pet's location data at a minimum of every minute.
Verification:

1. User will power on the device.

2. User will wait at least 3 minutes to gather 3 points of data.
3. User will power off the device and insert MicroSD card into a computer to read data.

2.1.4 System life duration

PPR: The dog's location must be gathered for 8 hours
ER: The system will operate normally for at least 8 hours on one full charge.
Verification:

1. User will charge battery until full or buy new batteries.
2. User will measure full battery voltage.
3. User will plug the battery into the unit.
4. User will power on the unit.
5. User will run tracker for 20 minutes.
6. User will measure voltage level of battery after the 20 minutes of run time.
7. User will take the full voltage and subtract voltage after 20 minutes of running to calculate how much power was used in 20 minutes
8. Multiply the above result by 24 to get 8 hour run time estimate for power usage
9. Verify that the battery has 5% battery capacity above 8 hour estimated run consumption

2.1.5 Weatherproof design with a rugged enclosure that protects the device from environmental damage

PPR: The inner circuitry of the board is fully enclosed and there are no exposed connections
ER: The system will (rated IP54) withstand water splashing against the enclosure from any direction shall have no harmful effect. It must also withstand an ingress of dust (some dust entering the system is not prevented) and must still operate normally.
Verification:

1. User will spring sand over enclosure like a sugar cookie
2. User will verify that GPS data is still being transmitted and received by reception unit.
3. User will use spray bottle to spray water over the enclosure to simulate rain fall.
4. User will verify that GPS data is still being transmitted and received by reception unit.
5. User will open enclosure to verify prevention of sufficient quantity of water and dust entering the enclosure.

2.1.6 Accuracy of GPS acquisition of location

PPR: When user reads data from the SD card, the location information will not be too different from the actual
ER: The module will maintain an accuracy of 2.5m or more.
Verification:

1. User will power on GPS Data Logger and place outside
2. Users are able to properly remove the SD card from the GPS Data Logger and insert it into the computer for information reading.
3. Users are able to verify that the location information read by GPS does not differ by more than 2.5m from the current position of the data logger.

2.2 Design Impact Statement

2.2.1 Introduction

This document will list and discuss the potential societal and environmental impacts of developing and releasing a GPS Dog Collar. The GPS Dog Collar will allow a user to remain connected to their pet wherever they might be in the local area. It utilizes GPS tracking to continuously chart the pet's position. The collar will then transmit this data via ham radio signal to a receiver that the user will be connected to via bluetooth. The user will then be able to track their pet if they are simply wandering the neighborhood or if they are lost. Our group aims to make a product that is recreatable and competitive with current market items.

One big aspect that makes our product extremely competitive is the fact that the collars transmit data through radio signals, not through the use of cellular towers which require a SIM card. A highly portable and free product like this can have many impacts: the safety of not only the pet using the collar, but other pets that interact with said pet, the safety of the environment, and the privacy and safety of the user and its pet. In the following sections I will go over the different welfare, societal, environmental, and economic impacts our project can have and will conclude with a recommendation for future research.

2.2.2 Public Health, Safety, and Welfare Impacts

There are some risks involved with having GPS dog collars on pets. One issue involves the pet itself. The pet can reject the collar or feel irritated by it, leading to stress and increasing anxiety in the pet. Raised irritation levels like these can lead to erratic behavior from the pet and can result in violent responses when interacting with owners or other animals. Another issue involves how other pets interact with the pet who has a GPS collar attached to it. Some animals can see the collar and reject the pet for looking different. If everything goes well, and pets play with each other regardless of the collar being worn, other hazards that threaten the pets exist. For example, if two pets, one wearing a collar, are playing, and the pet without the collar somehow breaks the collar open via playful biting or scratching, both pets are at risk of getting shocked. This can be mitigated by using more robust and durable materials that are not prone to shattering. Negative issues regarding annoyance with wearing a GPS collar will always be a possibility when introducing it to the pet at first. However, research done on wild Oryx's wearing GPS collars found that any rejection of the collars was resolved within a matter of hours [8]. The research team found that any abnormal hormone levels were reduced to their normal state after a couple hours with the collar. Any rejection of the animal itself by other animals in the herd was also resolved [8]. While our project does not have the timeline to continually study pets who wear the collar for long periods of time, future implementations should keep in mind the practices used by researchers who have done long term studies on wild animals wearing GPS collars. However, GPS collars do not impact just the pet wearing them. They also impact the people around them, including public health, safety, and wellness.

Many people cannot afford the cost of buying a GPS collar, so they allow their pet to roam free. The biggest causes of stray animals are lost pets and pets who are allowed to roam freely mating with other strays [9]. Strays can contract and transmit deadly diseases, such as rabies, creating a huge health concern for the public. GPS collars have already been implemented with stray dogs in research studies, where in some areas unvaccinated strays can be the difference between life and death. In a province of the Dominican Republic bordering Haiti, 3 kids under the age of 10 had died from contracting rabies [2]. By attaching GPS collars to dogs, a team of researchers were able to determine where the dogs went throughout the day. They were also able to determine if dogs in the province were free-roaming or were confined in a house. By crossing the data, the province was able to launch a vaccination campaign and lower deaths for both dogs and humans [2]. In another study in N'Djamena, Chad, researchers were able to track hundreds of dogs with GPS collars and create a rabies transmission model to vaccinate dogs and reduce transmission of the deadly disease [6]. While our project unfortunately does not have answers to solving the poverty gap, by creating a cheaper product, our project can aim to help give pet owners who are disadvantaged a cheaper yet effective solution to obtaining GPS collars. By creating a cheaper GPS collar, future implementations can hopefully mitigate the negative effects of having unaffordable collars which lead to more strays.

2.2.3 Cultural and Social Impacts

There are numerous cultural and social impacts of creating a GPS dog collar. One impact is the rise of a technological gap between those who are privileged and those who are disadvantaged. This falls under issues of accessibility. Those who do not have access to readily disposable funds to purchase GPS devices puts them at a disadvantage in a society where devices become more GPS dependent. This can also lead to a more notable and broader impact associated with creating and implementing a GPS product: privacy.

The increase in readily available GPS devices in society and the rapid development of the Information Age create huge issues regarding privacy. Privacy is an issue because data collected by GPS devices contain private material, such as location at a specific time. This falls under a category which has gained much attention, Geoslavery. This is where a person, the master, uses GPS and location tracking devices to exert control over another individual, the slave [3]. The formerly mentioned issue of accessibility only exacerbates this issue. GPS was launched by the US Military, however, the military does not control the use of GPS for the public. This means that the responsibility of creating inclusive and equitable products lies with the manufacturer. Countries and companies already have the equipment to begin real time tracking of people in society for more corrupt reasons. All it takes is one manufacturer to begin developing GPS devices for that specific purpose. This issue is already seen in the public. Police authorities use GPS devices for more justified reasons to track criminals, probationees, and sex offenders [3]. There are also GPS devices that can be freely implemented on children so that parents can track their whereabouts [4]. While police tracking is justifiable and parental control is arguably unjustifiable, this already illustrates the huge impact that GPS devices have on privacy. There is a possibility that the device we develop can be used in a similar way that breaches privacy. While our cheaper product can mitigate the issues of accessibility for disadvantaged users, research and testing should be done alongside police and civil officials to ensure that the GPS device or future ones manufactured do not infringe on human rights.

2.2.4 Environmental Factors

There are some risks regarding environmental standards if a pet wears a GPS dog collar created by our team's project. For example, if a pet's collar is somehow broken or is not manufactured correctly, water can leak into the collar and be contaminated by the metals in the wiring or circuit boards, and then drip down into the grass or ground. If the battery falls out and is damaged, the battery acid can leak out into the ground and create serious hazards. In addition to this, the collars themselves transmit data through radio waves. This raises concerns about exposure to RF signals. A study with devices like these found that the exposure to RF was well below the international limits, making health issues very unlikely to occur [5]. To mitigate these issues even further, the consumer could only attach the collar to the pet at minimal times, such as whenever they are leaving the house. In addition, on the manufacturer's side, the producer could implement a sleep state where the collar is off until needed, minimizing the amount of time the RF signals are active. While our project is not focused on the direct impact of a single collar to the environment, future developers and companies should ensure that e-waste and environmentally friendly electronics are researched if the collar is moved to an industrial level of production.

Outside of issues that GPS dog collars can cause for the environment, there are things that GPS collars can do to help the environment. In a study done in 2020, researchers used GPS collars to measure the adrenaline and hormone levels of the scimitar-horned Oryx, an animal which is extinct in the wild [8]. The researchers found that the Oryx had abnormal readings of hormones and adrenaline shortly after attaching the collars, but these levels normalized after a short period of time [8]. GPS collars allow researchers access to highly detailed information about animals, including their movements and habitats necessary for species survival. Collars are still being used to ensure protection for endangered species such as Cheetahs, Wild African Dogs, Rhinos, Leopards, and more [7]. Equipment like this allows organizations to constantly track animal locations and ensure that they receive the proper response if they are injured, sick, trapped in a poacher's snare, or if they escape a conservation area.

2.2.5 Economic Factors

Economic factors play an important role in the development of the GPS dog collar. GPS dog collars are not new. There are hundreds of options available on the market today, ready for use. The main issue with these kinds of collars is that they cost money. Not only can they be upwards of $200, but they also charge a monthly subscription fee in order to use their services [10]. Sometimes there are options readily available that advertise a one time purchase fee and no subscription penalties, but, upon closer inspection, one can see that these options are being phased out. Companies realize that it is hard to compete with other products and also allow users to use their products for free. Which really means that the company is taking the hit to allow users free access.

Other products do exist where monthly subscription fees are not required, but they require a SIM card. In a way, this is also a monthly subscription fee, but the money goes to a cellular provider rather than the GPS collar manufacturer [1]. Regardless of the option consumers choose, they should expect to pay a pretty penny up front and pay monthly subscription fees later. Our product aims to completely abolish monthly subscription fees. It can do this by transmitting the data via radio waves and then decoding the data at home for the pet owner. Our GPS collars may transmit data through radio waves used by ham radio, which are reserved specifically for ham radio frequencies. However, gaining access to these frequencies requires the user obtaining a FREE ham radio license, which can be a much more attractive option as opposed to paying real money to ensure the safety of their pet.

2.2.6 Conclusion

There are many impacts that a GPS dog collar can have on a society. It would be good practice to test and investigate a variety of scenarios to ensure that the dog collar does not negatively affect public health, safety, and environmental attributes. I recommend testing the dog collar on a variety of pets, also varying in age, to ensure that the collar does not affect the safety of the pet or pets around it. To ensure minimal environmental impacts from broken or damaged collars, I also recommend testing the collar in different environments, such as those that receive rain daily and those that receive much sunlight, in order to ensure that the product performs in a variety of environmental factors. Finally, the collar should be readily available in areas that are disadvantaged, such as those in poverty, and areas that are privileged in order to study the effect a cheaper GPS collar would have on public safety and pets. I believe that the GPS dog collar can be implemented broadly and be used in the scenarios described above, but only with significant testing.

2.3 Risks

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact
R1	GPS Accuracy	Technical	15%	H
R2	Dog Health	Owner/Dog Safety	5%	H
R3	Loss of Personnel	Team Function	25%	H
R4	Public Health	Owner Safety	5%	H
R5	Effect of temperature on device	Environment Risks	20%	H
R6	Dog Collar Comfort	External Risk	10%	H
R7	Delay of Manufacturing/Shipping	Timeline	25%	H
R8	Collar Falls off dog	Owner/dog Safety	25%	M
R9	Environmental impact of discarded batteries	Environment problem	20 %	M

Table 4: A table of the Risk Assessment regarding the project (1/2).

Risk ID	Performance Indicator	Responsible Party	Action Plan
R1	The system can report the correct area of the collar	Junior V.	Improve the accuracy of equipment positioning
R2	System can no longer power on and function	Junior V.	Use a hard enough enclosure.
R3	Delay of Project Development	Junior V.	Be proactive and communicate with all members.
R4	Frequencies are unsafe for User	Junior V.	Understand the risk and use certain frequencies to work at.
R5	Device can work in non-extreme temperature conditions	Wang	Use a material with good heat dissipation as housing
R6	Dog willing to wear the collar	Wang	Find softer and more comfortable materials for the collar
R7	Delay of Project Development	Aaron C.	Picking parts that are not delayed, or ordering ahead.
R8	Collar breaks and falls easily when dog moves or walks	Aaron C.	Creating a sturdy and sealed case for the collar.
R9	Test exposing a battery to water and monitor the battery for hazards	Declan O.	Verify that enclosure is indeed water poof

Table 5: A table of the Risk Assessment regarding the project (2/2).

2.4 References and File Links

No references or file links to display yet.

2.5 Revision Table

Date	Responsible Member	Revision Made
03/06/2022	All members	Rewrote the requirements
11/29/2021	Junior Velasco	Revised Engineering Requirements
11/28/2021	Declan O'Hara	Added verification steps to all requirements
11/27/2021	Junior Velasco	Revised Engineering Requirements and Verification
11/12/2021	Declan O'Hara	Added requirements 2.4-2.7
11/12/2021	Junior Velasco	Added Requirements 2.1-2.3
10/28/2021	Aaron Chung	Added requirements R7, R8, R9.
10/28/2021	Wang	Added requirements R5,R6.
10/28/2021	Junior Velasco	Added requirements R1-R4.
10/28/2021	Declan O'Hara	Added requirements R10,R11,R12.
10/27/2021	Junior Velasco	Created Initial section.

Table 6: The revision table for Section 2.

3 Top-Level Architecture

3.1 Block Diagram

3.1.1 Black Box Diagram

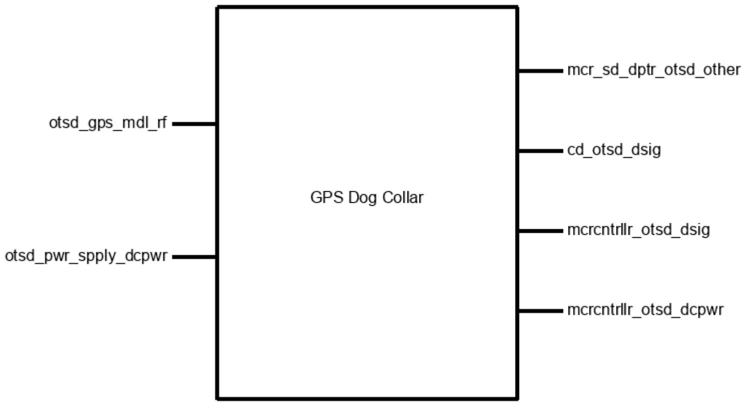

Figure 2: Black Box Block Diagram

3.1.2 Block Diagram

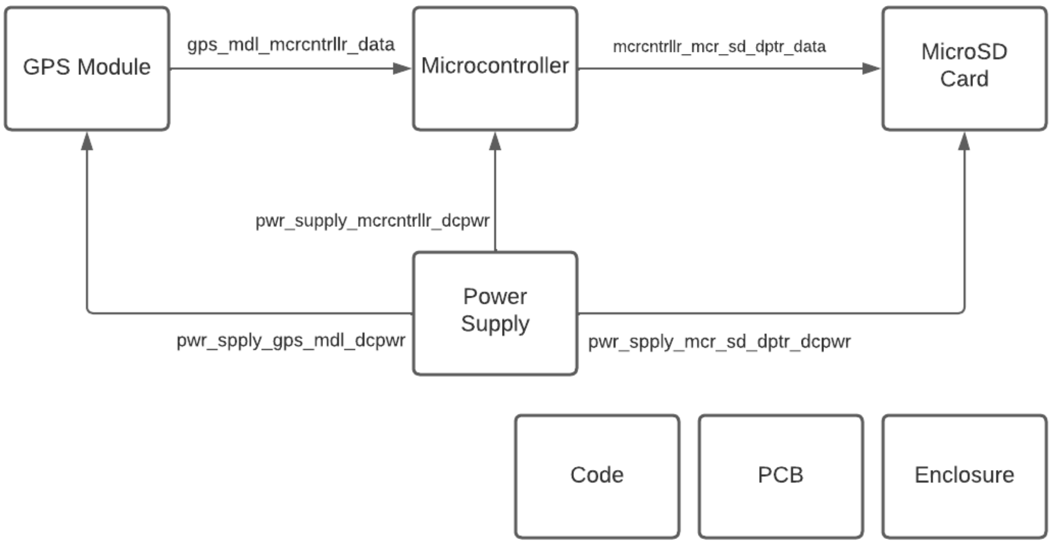

Figure 3: Top-level Block Diagram

3.2 Block Descriptions

3.2.1 Microcontroller

The microcontroller is the main brain of the system. It is an ESP32-WROOM development board with WiFi and bluetooth capability. It requires 5V in its Vin pin and can supply 3.3V output. It has 2 Spherical Peripheral Interface (SPI) pins for double the full duplex capabilities as a regular microcontroller.

3.2.2 Code

The code is the DNA of the microcontroller. The code is configured to communicate with all devices of the system. It will first listen to the GPS module and sift through the data. The sorted data will then be written and stored onto the MicroSD card. If either device is not connected or is not communicating, the code is configured to alert the user via LED pins.

3.2.3 Power supply

The power supply will be using a LiPO battery using a MCP73812T-420I/OT: Lithium Ion/Polymer charge controller and a MCP1642B-50I/MC: Fixed 5V output boost converter. The power supply must supply power for 8-12hours. The power supply must charge the LiPO battery and then when not charging the boost converter must be enabled to supply 5v to the transmitter and receiver units.

3.2.4 SD Card Adapter

The MicroSD Card Adapter is the memory of the system. It stores all data sent from the microcontroller. It is imperative that this data is stored, as the user needs to access the data through the MicroSD Card.

3.2.5 GPS

The GPS module is one of the most critical blocks of this project as it receives the latitude, longitude as well as the date and time from the GPS satellites. This information will be sent to the micro controller in the transmitter block for packaging and compiling. The location and time data will also be stored locally to keep a hard backup of the trackers position.

3.2.6 Enclosure

The enclosure is one of the most important parts of the project. It will keep the components inside and protect them from impact forces and weather. The enclosure will be made out of plastic or thin metal.

3.2.7 Printed Circuit Board (PCB)

The PCB is the main board used to eliminate the use of air wires for the system. It will allow the devices in the system to communicate with each other while also saving space and allow for a more compact system.

3.3 Interface Definitions

Name	Properties
otsd_gps_mdl_rf	• **Datarate:** 1s • **Other:** The signals transmitted to the GPS Module from acquiesced satellites.
otsd_pwr_spply_dcpwr	• **Inominal:** 1.3A • **Ipeak:** 2A • **Vmax:** 9.6V • **Vmin:** 7V
gps_mdl_mcrcntrllr_data	• **Datarate:** 9600 baud rate • **Messages:** GPS Coordinates (latitude, longitude, degrees) • **Protocol:** SPI
mcr_sd_dptr_cd_data	• **Datarate:** 9600 baud • **Messages:** Numbers and letters • **Protocol:** Serial Peripheral Interface (SPI) synchronous protocol with 4 wires: Master out Slave in, Master in Slave out, clock, and chip select.
pwr_spply_gps_mdl_dcpwr	• **Inominal:** 38mA • **Ipeak:** 67mA • **Vmax:** 3.6V • **Vmin:** 2.7V
pwr_spply_mcr_sd_dptr_dcpwr	• **Inominal:** 80mA • **Ipeak:** 200mA • **Vmax:** 5.5V • **Vmin:** 4.5V
cd_otsd_dsig	• **Logic-Level:** Active High when being used (at least 1.8V), and Active low when not being used (0V) • **Vmax:** 2.04V • **Vmin:** 0V
mcrcntrllr_otsd_dcpwr	• **Inominal:** 3.3mA • **Ipeak:** 3.31mA • **Vmax:** 3.26V • **Vmin:** 3.23V
mcrcntrllr_otsd_dsig	• **Vmax:** 3.28V • **Vmin:** 0V • **Vnominal:** 3.28V
mcrcntrllr_mcr_sd_dptr_data	• **Datarate:** 9600baud • **Messages:** Numbers • **Protocol:** Serial Peripheral Interface (SPI)

Figure 4: Interface Properties

3.4 References and File Links

3.4.1 References

[1] Espressif Systems, "ESP32-WROOM-32D & ESP32-WROOM-32U Datasheet," ESP32 Datasheet Version 2.2, Nov. 2017 [Revised Aug. 2021].

3.4.2 File Links

No team files or artifacts to display yet.

3.5 Revision Table

Date	Responsible Member	Revision Made
5/5/2022	Aaron Chung	Revised interface definitions.
5/5/2022	Aaron Chung	Revised black box diagram and top-level block diagram.
12/2/2021	Aaron Chung	Revised top-level block diagram.
11/19/2021	Wang Xiang	Added Android Application description, and modify the requirement slightly based on the last feedback.
11/19/2021	Aaron Chung	Added top-level block diagram.
11/19/2021	Aaron Chung	Added Receiver block descriptions.
11/19/2021	Junior Velasco	Added Battery block descriptions.
11/19/2021	Declan O'Hara	Added GPS and transmitter block descriptions.
11/19/2021	Junior Velasco	Revised Interface table layout.
11/19/2021	Declan O'Hara	Added revision table.
11/18/2021	Aaron Chung	Created Section 3 Outline/framework.

Table 7: The revision table for Section 3.

4 Block Validations

4.1 Block 1 - Micro SD card adapter

4.1.1 Description

The name of this block is micro SD card adapter, and it includes an SD card and an adapter specifically for connecting to an Arduino board, as well as an Arduino board. The input voltage will be 3.3V/5V. Any standard micro SD card operates at 3.3V, so we can't connect it directly to a circuit that uses 5V. So, the module has an on-board ultra-low dropout voltage regulator that converts from 3.3V - 5V to 3.3V. Also, this adapter has a logic level conversion, it means we can use the board to interact with 3.3V and 5V microcontrollers such as Arduino. The purpose of this block is to collect the information (GPS data) from the microcontroller processing and then import and store it to the micro SD card so that the customer can read the location the pet has traveled through the micro SD card.

4.1.2 Design

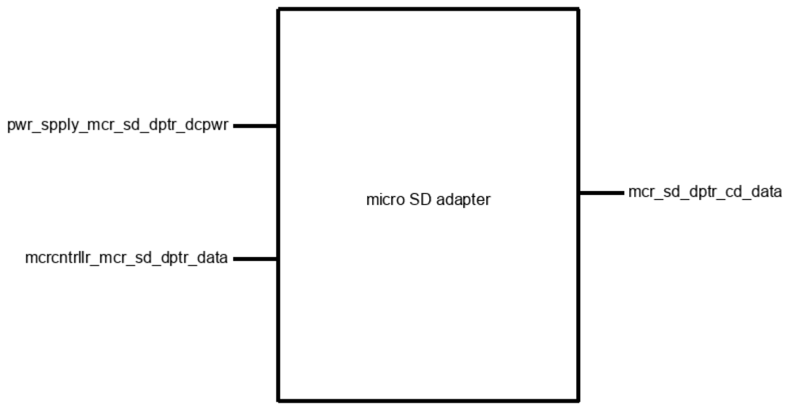

Figure 5: Block 1 diagram

4.1.3 General Validation

In this project, we are building a small electronic device which does not require too high a voltage, usually 3.3V-5V is sufficient. For the micro SD card, it can only work at 3.3V, so the level shifter and voltage regulator built into this micro SD card adapter can be of good help. The adapter's built-in voltage regulator is a good choice, it has a high enough efficiency, and it is already built into the adapter, which saves a lot of time, and it is also able to be easily purchased on Amazon or elsewhere for a relatively cheap price. The main function of the micro SD card is to store the GPS data obtained from the microprocessor so that the user can easily view the information.

4.1.4 Interface Validation

Interface Property	why is this interface this value	Why do you know that your design details for this block above meet or exceed each property?
SD.write()	The microcontroller will continually write data to the mircro SD card.	This function is used by the ESP32 when it begins logging data.
SD.ready()	The microcontroller is able to write data to the mircro SD card when the adapter is ready.	The function is used by the ESP32 when it begins logging data continually.
SD.begin()	The mircocontroller will begin to establish connection with the micro SD card.	This function is used by the ESP32 during startup.

Table 8: mcr-sd-dptr-cd-data (output)

Interface Property	why is this interface this value	Why do you know that your design details for this block above meet or exceed each property?
Inominal: 80mA	In the features of micro SD card adapter [1].	It is in the range of operating current of micro SD card adapter.
Ipeak: 200mA	In the features of micro SD card adapter [1].	It is in the range of operating current of micro SD card adapter.
Vmax: 5.5V	In the features of micro SD card adapter [1].	It is in the range of operating voltage of micro SD card adapter.
Vmin: 4.5V	In the features of micro SD card adapter [1].	It is in the range of operating voltage of micro SD card adapter.

Table 9: pwr-supply-mcr-sd-dptr-dcpwr (input)

Interface Property	why is this interface this value	Why do you know that your design details for this block above meet or exceed each property?
logic level high: 3V	The ESP32 transimits data through binary, it depends on logic level high or low.	0.8 * VDD = 2.64V.
logic level high: 0V	The ESP32 transimits data through binary, it depends on logic level high or low.	0.1 * VDD = 0.33V.
Inominal:20nA	The ESP32 transimits data through binary, it depends on logic level high or low.	datasheet states the range is 20-40nA.

Table 10: mcrcntrllr-mcr-sd-dptr-data (input)

4.1.5 Verification Process

1. Prepare a micro SD card and connect the USB power.
2. Use CardInfo in Arduino to check the micro SD card is available or not.
3. Use Arduino code to check if the testing data is stored in the micro SD card, we can find the information on the Serial monitor.
4. If it works correctly, the data will be store into a txt file.

5. Check the voltage and current through the voltage regulator.

4.1.6 References and File Links

[1] "Micro SD Card Adapter Module" [Online]. Available: https://components101.com/modules/micro-sd-card-module-pinout-features- datasheet-alternatives Accessed on: Feb 16, 2022

4.1.7 Revision Table

Date	Responsible Member	Revision Made
05/06/2022	Wang Xiang	Integrating content into project documentation.
01/27/2022	Wang Xiang	Due to a change in the original group, the responsible block was changed, and a new block validation was edited differently from the last one.
01/07/2022	Wang Xiang	Created the original Document and wrote the first draft.

Table 11: The revision table for block 1.

4.2 Block 2 - Microcontroller

4.2.1 Description

This device will be responsible for handling and processing all information in the system. As the only brain of the system, its role is important in making sure that devices are communicating with each other. The microcontroller will receive information from the GPS module and decode the information. After processing and sifting the data, the microcontroller will then store it onto a MicroSD card via a MicroSD card adapter. This block is championed by Aaron Chung.

4.2.2 Design

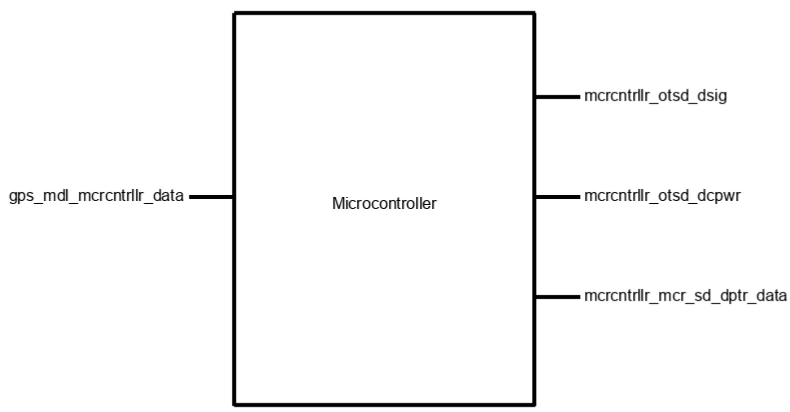

Figure 6: Microcontroller block diagram

4.2.3 General Validation

This device was specifically chosen for multiple reasons. The ESP32-WROOM microcontroller is a development board, meaning it can be altered at times to specifically fit the needs of the system. In the pinout diagram in figure 2, the ESP microcontroller has many GPIO pins, perfect for digital and analog signal processing. The scope of the project also deals with multiple devices that are SPI oriented. Instead of having to use slave select and speak to devices on one SPI line, the microcontroller's ability to have 2 different SPI lines allows faster communication between both the GPS and MicroSD adapter. This allows for more accurate data logging between the time the GPS signal is received to the moment the data is logged. The usage of 2 SPI lines also allows for more modularity, meaning if another device needs to be needed, one SPI line will not be flooded. Outside the scope of the project, the ESP microcontroller has bluetooth and WiFi capability. This means that

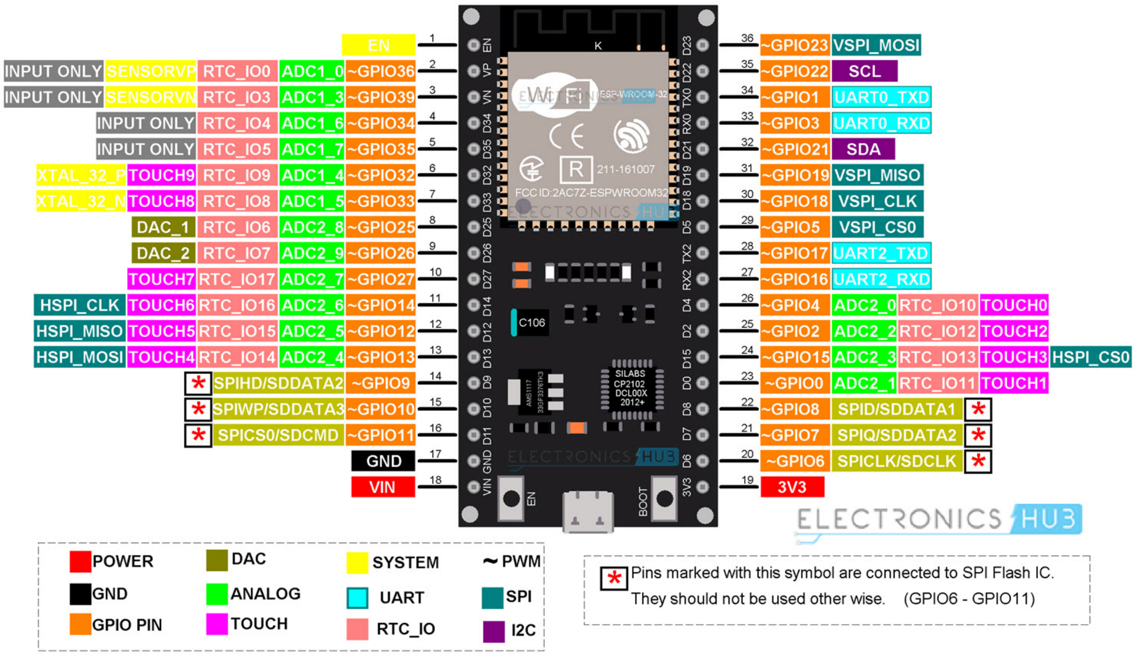

Figure 7: A diagram of the ESP32-WROOM Pinout.

in the future, the microcontroller might be able to communicate directly with a user when the pet arrives from its trip, while having a microSD card adapter as a file storage backup.

4.2.4 Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

gps_mdl_mcrcntrllr_data

Logic Level High: 3V	The ESP32 reads values in binary, which is set by logic level high or low.	Datasheet reads logic levels should be between 0.75 x VDD which is 2.475V and VDD+0.3 which is 3.6V.
Logic Level Low: 0V	The ESP32 reads values in binary, which is set by logic level high or low.	Datasheet reads logic levels should be between -0.3V or 0.25 x VDD which is 0.825V.
$I_{nominal}$: 25nA	The ESP32 reads values in binary, which is set by logic level high or low.	Datasheet reads that maximum current for both high and low level logic should not exceed 50nA. 25nA allows for more than 5% jumps in expected current.

mcrcntrllr_mcr_sd_dptr_data

Logic Level High: 3V	The ESP32 transmits data through binary, which is set by logic level high or low.	Datasheet reads that output logic levels have at least a minimum of: • 0.8 x VDD which is 2.64V.
Logic Level Low: 0V	The ESP32 transmits data through binary, which is set by logic level high or low.	Datasheet reads that the output logic levels have no minimum but a maximum of: • 0.1 x VDD which is 0.33V
$I_{nominal}$: 20nA	The ESP32 transmits data through binary, which is set by logic level high or low.	Datasheet reads that there is no minimum or maximum current but typical applications use between 20-40nA.

pwr_spply_mcrcntrllr_dcpwr

V_{min}: -0.3V	The minimum voltage value was taken from the electrical characteristics section in the ESP32 datasheet.	The datasheet reads: • Absolute minimum voltage is -0.3V
V_{max}: 3.6V	The maximum voltage value was taken from the electrical characteristics section in the ESP32 datasheet.	The datasheet reads: • Absolute maximum voltage is 3.6V
I_{max}: 1A	The peak current was chosen after evaluating characteristics in the ESP32 datasheet. No maximum current rating exists.	The datasheet does not specify a maximum current rating. However, it does specify that the maximum current it can output cumulatively for all output pins is 1200mA. Since the group does not intend to use all pins, 1A maximum is a good in between.
$I_{nominal}$: 700mA	The nominal current was chosen after evaluating the characteristics in the ESP32 datasheet. No nominal current rating exists.	The datasheet does not specify a nominal current rating, only a minimum rating of 500mA. 700mA is a good in between from the minimum 500mA to our chosen 1000mA, allowing for 5% jumps in expected current.

Figure 8: Microcontroller Interface Validation

4.2.5 Verification Process

1. Connect an LED to a button and wire it to an ADC GPIO pin on the ESP32.
2. Connect the HiLetGo MicroSD Card Adapter to the SPI pins on the ESP32.
3. Connect the MicroUSB to the ESP32, turning it on.
4. Flash the ESP32 with the correct program to test its functionalities.
5. Press the button several times and make sure the LED turns on for the duration of button press.
6. Unplug the USB cable, remove the MicroSD Card from the adapter and plug it into the computer.
7. Verify that the MicroSD Card has data in it, showing that the ESP32 registered the button presses and successfully wrote to the SD Card via SPI

4.2.6 References and File Links

[1] "ESP32 Series - Datasheet," Espressif Systems, Oct-2016. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32-s3-wroom-2_datasheet_en.pdf. [Accessed: 27-Jan-2022].
[2] Mybotic and Instructables, "Micro SD Card tutorial," Instructables, 19-Sep-2017. [Online]. Available: https://www.instructables.com/Micro-SD-Card-Tutorial/. [Accessed: 27-Jan-2022].

4.2.7 Revision Table

Date	Responsible Member	Revision Made
05/06/2022	Aaron Chung	Added images for the microcontroller design.
05/06/2022	Aaron Chung	Added all sections for microcontroller block
05/06/2022	Aaron Chung	Created revision table

Table 12: The revision table for Section 5.

4.3 Block 3 - Code

4.3.1 Description

This is the main code for the GPS Data Logger. It interacts with three devices: the GPS Module, the MicroSD Adapter Module, and the ESP32-WROOM microcontroller. This code is responsible for maintaining connections between the modules and interpreting and logging the specific data coming from the GPS Module. After being powered on and waking, the system will attempt to establish connection with the GPS module and the MicroSD Adapter. If a connection cannot be established between 1 or both modules, the system will send a signal to LEDs to flash red. If it can connect to the modules, the LEDs will flash green. Following successful connection to the modules, the system will immediately begin logging data. The system will continually log data in 1 minute intervals. The system will continue to do so until the battery is depleted or the user presses the stop button located on the device. In the unlikely event the system depletes battery before returning to the user or the battery is somehow damaged, the data logged before system shut off will be saved since the data was already written permanently.

4.3.2 Design

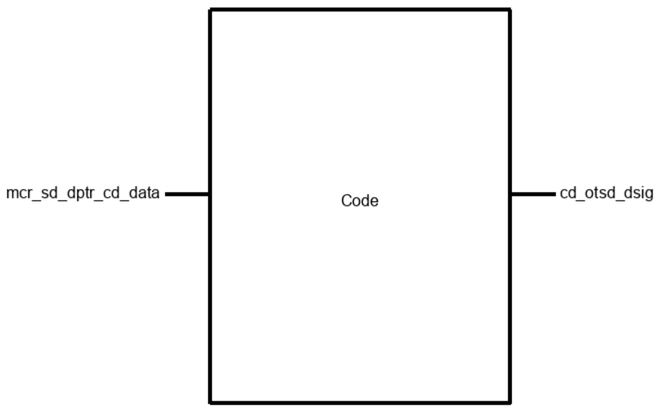

Figure 9: Code block diagram

4.3.3 General Validation

The code block is the main driving force in the system. The choice to implement an LED notification system was purely optional, but we felt it was a necessary addition. Plus, it is highly practical to notify the user in some way about any errors during the operation.

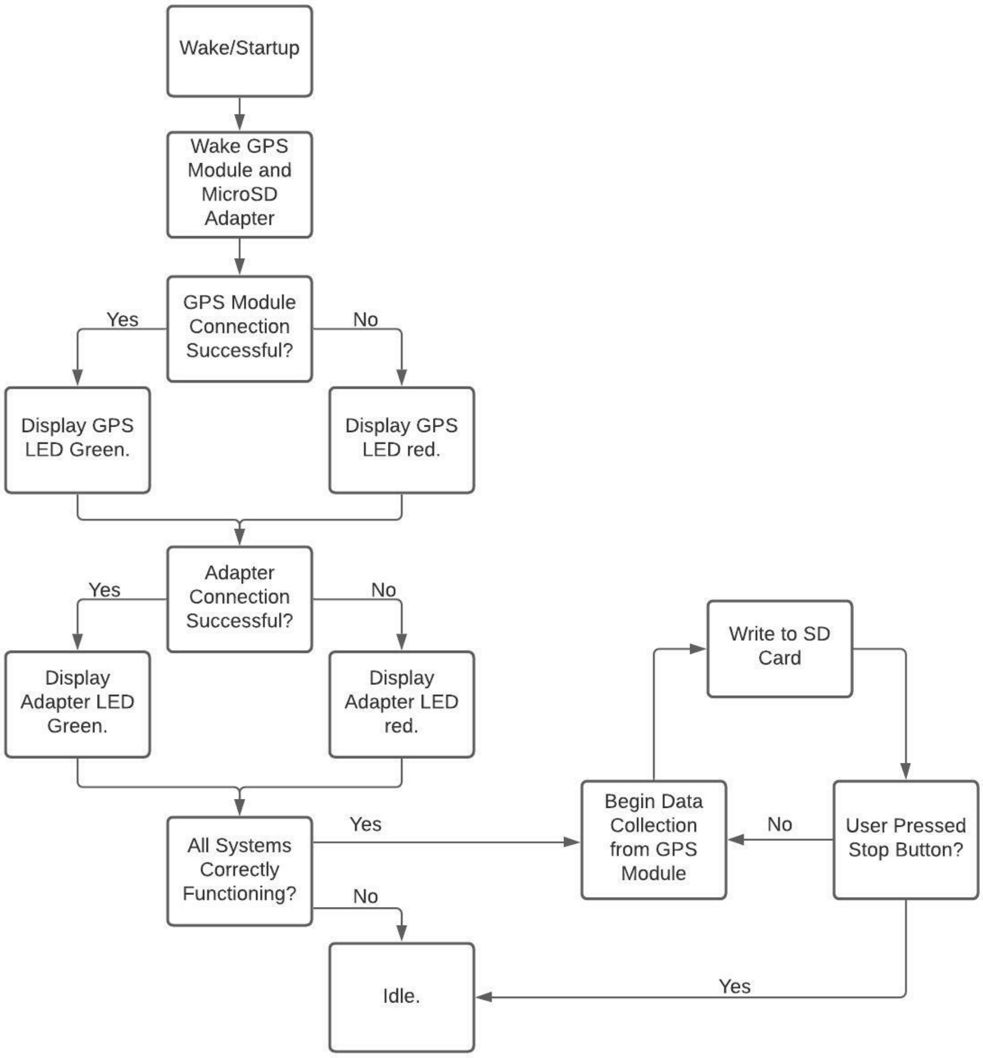

Figure 10: A diagram depicting the flowchart of the code.

4.3.4 Interface Validation

gps_mdl_cd_data

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
GPS_send_data()	The GPS module will continually send data to the microcontroller. Having an intuitive function name makes debugging easier.	This function is used when the ESP32 begins gathering data from the GPS module.
GPS_get_data()	The GPS module will continually receive data from satellites about its location.	This function is when the ESP32 begins gathering data from the GPS module.
GPS_begin()	The GPS module will begin starting up and will notify the ESP32 if it is not working.	This function is during startup.

mcr_sd_dptr_cd_data

SD.write()	The microcontroller will continually write data to the MicroSD card.	This function is used by the ESP32 when it begins logging data.
SD.ready()	The microcontroller is only able to write data to the MicroSD card when the adapter is ready.	This function is used by the ESP32 when it begins logging data continually.
SD.begin()	The microcontroller will begin to establish connection with the SD card.	This function is used by the ESP32 during startup.

cd_otsd_data

Code needs to sleep whenever the system is not gathering information.	To save battery, the microcontroller will sleep when it is not being used.	Information.
Code will configure GPS module.	The system must verify that the GPS module is correctly connected before beginning program.	Information.
Code will configure MicroSD Adapter.	The system must verify that it can log data in the MicroSD card before beginning program.	Information.

Figure 11: The interface validation of the code block.

4.3.5 Verification Process

1. Connect the power cable to the ESP32 microcontroller.
2. Flash the microcontroller and verify that it has successfully uploaded.
3. Verify that the red LED pin is set high twice to show that it successfully reads that no devices are connected.
4. Disconnect the device and attach the MicroSD card adapter for testing purposes.
5. Reconnect the power cable and reflash the ESP32.
6. Verify that the green LED pin is set high when trying to connect to the adapter, but red for anything else.

4.3.6 References and File Links

[1] "ESP32 Series - Datasheet," Espressif Systems, Oct-2016. [Online]. Available: https://www.espressif.com/sites/default/file s3-wroom-2_datasheet_en.pdf. [Accessed: 27-Jan-2022].

[2] Mybotic and Instructables, "Micro SD Card tutorial," Instructables, 19-Sep-2017. [Online]. Available: https://www.instructables.com/Micro-SD-Card-Tutorial/. [Accessed: 27-Jan-2022].

4.3.7 Revision Table

Date	Responsible Member	Revision Made
05/06/2022	Aaron Chung	Added images
05/06/2022	Aaron Chung	Added all sections of the code block
05/06/2022	Aaron Chung	Edited processes and file links
05/06/2022	Aaron Chung	Created revision table

Table 13: The revision table for Section 5.

4.4 Block 4 - Power supply

4.4.1 Description

This power supply module will power the GPS dog collar. Since this project is a portable device, there will be a 9V battery to provide power input. The battery will be enclosed in a battery clip that has a 5.5*2.1mm plug to mate with the power supply board jack. Since the micro SD card adapter in the project requires a 5V input, and the other modules (ESP32 wroom) require a 3.3V input. So, this power supply module is a dual output. It has two regulators, AMS1117-3.3 and AMS1117-5, which allow it to provide 3.3V and 5V output voltages separately.

4.4.2 Design

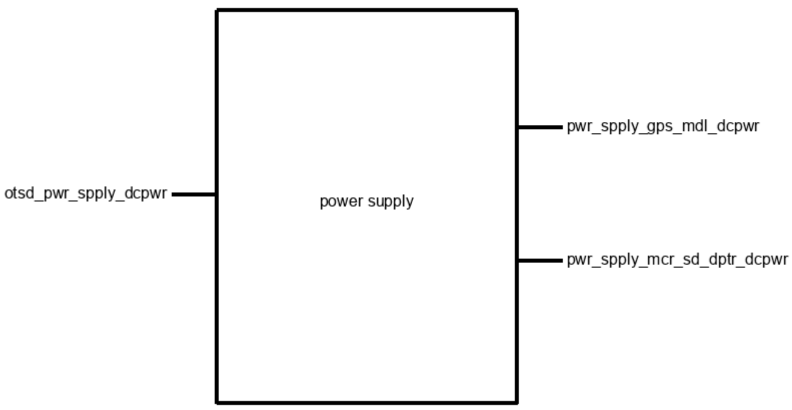

Figure 12: Block diagram

4.4.3 General Validation

This design will meet the system requirements power supplies capable of providing 3.3V power to the ESP32 and 5V power to the SD card adapter. For the 3.3V part, it has a AMS1117-3.3 voltage regulator, it can let the power supply board has a 3.3V output, it is similar to LC1117 that used in ECE 341. while the AMS1117-5 used for the 5V output. The main function of this power supply board is power the components that require different input voltage. The module has an LED indicator to show whether work is currently being performed, and the module is cheap and can provide good help for the block.

4.4.4 Interface Validation

Interface Property	why is this interface this value	Why do you know that your design details for this block above meet or exceed each property?
Inominal: 80mA	In the features of micro SD card adapter [1].	It is in the range of operating current of micro SD card adapter.
Ipeak: 200mA	In the features of micro SD card adapter [1].	It is in the range of operating current of micro SD card adapter.
Vmax: 5.5V	In the features of micro SD card adapter [1].	It is in the range of operating voltage of micro SD card adapter.
Vmin: 4.5V	In the features of micro SD card adapter [1].	It is in the range of operating voltage of micro SD card adapter.

Table 14: pwr-supply-mcr-sd-dptr-dcpwr (output)

Interface Property	why is this interface this value	Why do you know that your design details for this block above meet or exceed each property?
Inominal: 1A	Measured value.	It is in the range of current in a battery.
Ipeak: 2A	Measured value.	It is in the range of current in a battery.
Vmax: 9.6V	Measured value.	9.6V voltage input is fully sufficient to support normal operation of the device
Vmin: 7V	Measured value.	A voltage input of 7V is the minimum required to support normal operation of the device.

Table 15: otsd-pwr-spply-dcpwr (input)

Interface Property	why is this interface this value	Why do you know that your design details for this block above meet or exceed each property?
Inominal: 47mA	The values were chosen based on the datasheet for the GPS module [2].	The datasheet for the GPS module states this value.
Ipeak: 67mA	The values were chosen based on the datasheet for the GPS module.	The datasheet for the GPS module states this value.
Vmax: 3.6V	The values were chosen based on the datasheet for the GPS module.	The datasheet for the GPS module states this value.
Vmin: 2.7V	The values were chosen based on the datasheet for the GPS module.	The datasheet for the GPS module states this value.

Table 16: pwr-spply-gps-mdl-dcpwr (output)

4.4.5 Verification Process

1. Connect the power supply board to the battery clip and test the jack and plug to see if they match.
2. Check the input voltage from the battery in the range 9-15V .
3. Press the switch on the power supply board, if the LED is on, it means that this power supply board is working.
4. Use a multimeter to test that the output at 3.3V and 5V is accurate or close to that value
5. Test the value of current by adding other components to check if the values close or equal to corresponding current values .

4.4.6 References and File Links

[1] “Micro SD Card Adapter Module” [Online]. Available: https://components101.com/modules/micro-sd-card-module-pinout-features- datasheet-alternatives Accessed on: Feb 16, 2022

[2] u-blox Systems, “NEO-6 u-blox 6 GPS Module Datasheet,” NEO-6 Datasheet Revision E, May 2011. Available: “https://www.u-blox.com/sites/default/files/products/documents/NEO-6$_{D}ataSheet_{(}GPS.G6-HW-$ $09005).pdf_{J}.[Accessed : Feb.2022]$.

4.4.7 Revision Table

Date	Responsible Member	Revision Made
05/06/2022	Wang Xiang	Integrating content into project documentation.
02/18/2022	Wang Xiang	Added and modified some properties of interfaces and corrected some obvious grammar errors.
02/16/2022	Wang Xiang	Added features of micro SD card adapter as a reference.
02/01/2022	WangXiang	Created the original Document and wrote the first draft.

Table 17: The revision table for Section 5.

4.5 Block 5 - GPS Module

4.5.1 Description

The NEO-6M Global Positioning System (GPS) Module will receive latitude and longitude coordinates and process it in the Degrees/Minutes/Seconds (DMS) format to be read by the ESP-32 WROOM microcontroller (μC), which will operating on 3.0V from a power supply. It will use the Serial Peripheral Interface (SPI) protocol to communicate with the μC, sending the received latitude, longitude, date, and time in the form of Degrees/Minutes/Seconds (DMS). The GPS Module will be operated in a low power consumption mode to improve battery life, as the system must be able to operate for 8-12 hours. In this mode, the acquisition engine is powered off once sufficient satellite tracking is reached, resulting in a significant reduction in power consumption, while maintaining a good performance [1]. With the consideration of the importance of limiting power consumption, between the available protocols of SPI and UART, SPI is utilized, as well as due to a SPI solution on average being significantly faster than a UART solution, respectively.

4.5.2 Design

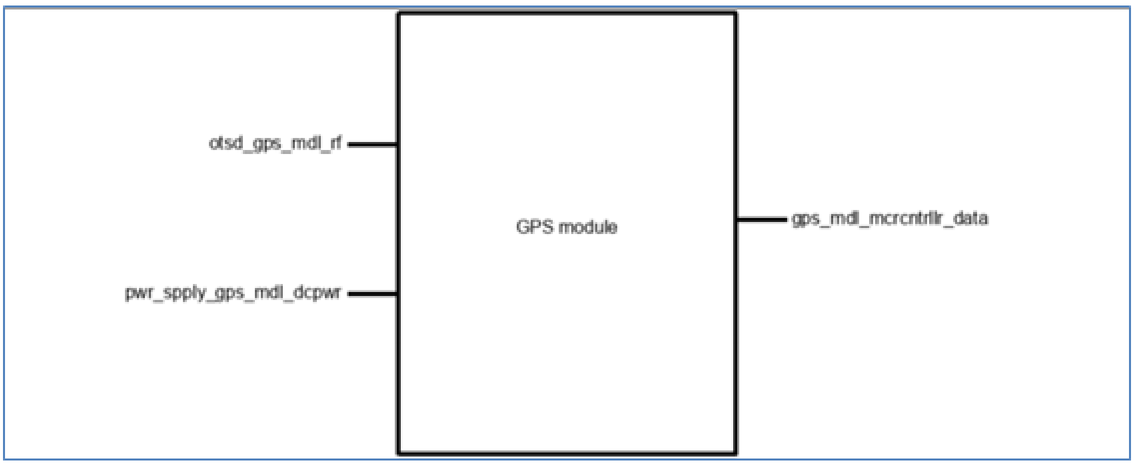

Figure 13: Block diagram

4.5.3 General Validation

This block will be able to function with the power supply which is able to output 3.3V, as well as communicate with the ESP-32 WROOM microcontroller through SPI. Both the GPS Module and μC include the required pins to support SPI. The GPS Module according to the data sheet can acquiesce satellites and provide position data with error of 2.5m, accurate for the application of tracking a pet.

4.5.4 Interface Validation

otsd_gps_mdl_rf

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
Timing: will receive and send DMS and coordinates every minute	1-minute intervals were chosen to balance the requisites of providing accurate information and limiting power consumption.	The dog collar must track and function for 8-12 hours, so retrieving satellite data once every minute is a balance between reliability of position and power consumption

gps_mdl_mcrcntrllr_data

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
Bandwidth: 100kbit/s	To allow quick transfer of information from the GPS Module to the microcontroller, when GPS information is logged.	There is compatibility between the NEO-6M GPS Module and ESP-32 WROOM μC, respectively as both support SPI, and the maximum bandwidth for SPI is 100kbit/s [2], which falls within the requirement of sending the received GPS information every minute to the μC.
GPS Module mode: input	SPI is used for speed over the option of UART, and as a requisite, the GPS must be set as an input to send received GPS data to the microcontroller.	According to SPI protocol specifications, the two communicating devices must be set as input or output, respectively.
Microcontroller mode: output	the bandwidth chosen allows the GPS Module to send coordinates in 1-minute intervals.	According to SPI protocol specifications, the two communicating devices must be set as input or output, respectively.

pwr_supply_gps_mdl_dcpwr

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
V_{min}: 2.7V	The values were chosen based on the datasheet for the GPS Module.	The datasheet for the GPS Module states that V_{min} is 2.7[2].
V_{max}: 3.6V	The values were chosen based on the datasheet for the GPS Module.	The datasheet for the GPS Module states that V_{max} is 3.6[2].
I_{peak}: 67 mA	The values were chosen based on the datasheet for the GPS Module.	The datasheet for the GPS Module states that I_{peak} is 67 mA[2].
$I_{nominal}$: 47 mA	The values were chosen based on the datasheet for the GPS Module.	The datasheet for the GPS Module states that $I_{nominal}$ is 47 mA[2].

Figure 14: Block diagram of the GPS Module.

4.5.5 Verification Process

1. Connect the GPS Module to the μC through the respective SPI pins.
2. Configure the GPS Module as MOSI (output), and the μC as MISO (input), respectively.
3. Configure SCLK to transmit GPS information to the μC every minute.
4. Move the system more than 2.5m to account for horizontal position accuracy every minute.
5. Connect the μC to a computer and output the SPI data to the screen.
6. Verify that the coordinates are accurate with consideration of the horizontal position accuracy specification of 2.5m [2].

4.5.6 References and File Links

[1] Espressif Systems, “ESP32-WROOM-32D ESP32-WROOM-32U Datasheet,” ESP32 Datasheet Version 2.4, Mar. 2018. Available: “https://www.mouser.com/datasheet/2/891/esp-wroom-32_datasheet_en-1223836.pdf”. [Accessed: Feb. 2022].

[2] u-blox Systems, “NEO-6 u-blox 6 GPS Module Datasheet,” NEO-6 Datasheet Revision E, May 2011. Available: “https://www.u-blox.com/sites/default/files/products/documents/NEO-6_DataSheet_(GPS.G6-HW-09005).pdf”. [Accessed: Feb. 2022].

4.5.7 Revision Table

Date	Responsible Member	Revision Made
02/04/2022	Andre Zhu	Added block overview.
02/04/2022	Andre Zhu	Added block design diagram.
02/12/2022	Andre Zhu	Revised interface properties values and explanations in 4.2.4.
02/12/2022	Andre Zhu	Added more project details in 4.2.1 overview and clarified abbreviations.
02/17/2022	Andre Zhu	Added section describing the interfaces and the design in 4.2.2

Table 18: The revision table for the GPS Block Validation.

4.6 Block 6 - Enclosure

4.6.1 Description

The enclosure will allow the components of the system, including the PCB, power supply, GPS Module, microcontroller, status LEDs, to be secured in place, allowing ease of access to the various ports required to use the device, including clear visual of the status LEDs.

4.6.2 Design

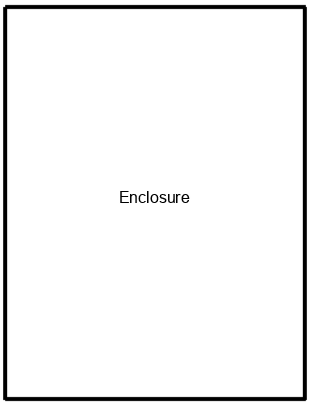

Figure 15: Block diagram of the enclosure.

4.6.3 General Validation

The enclosure must be designed ergonomically, with ease of access to the micro-USB port, readability of the status LEDs, and screws that hold that secure the enclosure, for access into the electronics. It must also be able to fasten the PCB and GPS Module antenna securely and prevent unnecessary movement, and protect the electronics from a level of dust and water.

4.6.4 Verification Process

1. User will place and fasten PCB into the enclosure, and close it.

2. User will spray water from a spray bottle, and sprinkle sand across the enclosure in an even distribution.
3. User will open enclosure and check that the enclosure has protected the contents, and achieved an IP54 rating[1].

4.6.5 References and File Links

4.6.6 Revision Table

[1] “IP Ratings Explained: IP Rating Chart.” Rainford Solutions, 2 Nov. 2021, Availab;e: https://rainfordsolutions.com/pr protection-ip-rated-enclosures/ip-enclosure-ratings-standards-explained/. [Accessed: Feb.2022].

Date	**Responsible Member**	**Revision Made**
02/04/2022	Andre Zhu	Added block overview.
02/04/2022	Andre Zhu	Added block design diagram.
02/12/2022	Andre Zhu	Revised interface properties values and explanations in 4.2.4.
02/12/2022	Andre Zhu	Added more project details in 4.2.1 overview and clarified abbreviations.
02/17/2022	Andre Zhu	Added section describing the design in 4.2.2

Table 19: The revision table for the Enclosure Block Validation.

5 System Verification Evidence

5.1 Universal Constraints

5.1.1 The system may not include a breadboard

The final system includes a custom designed PCB, with direct connections to the microcontroller, Micro SD Card Adapter, NEO-6M GPS Module and status LEDs, such that the system can be powered and used without a breadboard.

5.1.2 The final system must contain both of the following: a custom designed PCB

A student designed PCB will be used to connect the microcontroller, SD Card Adapter, GPS Module, power supply, and status LEDs..

5.1.3 If an enclosure is present, the contents must be ruggedly enclosed/mounted as evaluated by the course instructor

The enclosure will allow the PCB to be fastened and mounted securely, and status LEDs will have a thoroughly designed space to allow clear visibility and be secured to the enclosure. A space for the charging port and Micro SD Card is also present to allow ease of access, and will include a cover to allow an IP54 rating.

5.1.4 If present, all wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors

The PCB has no internal or external wire connections, and does not require connectors.

5.1.5 All power supplies in the system must be at least 65% efficient

The power supply, which contains both a 3.3V and 5V rail, will be at least 65% efficient.

5.1.6 The system may be no more than 50% built from purchased modules

Of the six system components, there are three purchased modules, including the ESP-32 WROOM microcontroller, Micro SD Card Adapter and NEO-6M GPS Module. The enclosure, code, and PCB will be created specifically for usage in the system.

5.2 All data to be logged on a MicroSD Card

5.2.1 Requirement

The system will log all GPS location data into a MicroSD Card.

5.2.2 Testing Processes

1. User will plug micro SD card into micro SD card adapter correctly.
2. User will start the system for few minutes.
3. User removes the micro SD card from the adapter and inserts the micro SD card into the computer to read the data.

5.2.3 Testing Evidence

1. User can see the information from micro SD card on their computer

5.3 Monitor Device Connections

5.3.1 Requirement

The unit's successful device connections must be displayed to the user.

5.3.2 Testing Processes

1. User will power on the unit.
2. User will make sure the MicroSD Card is correctly in place.
3. User will verify the result based on the color of the LEDs.

5.3.3 Testing Evidence

1. User will verify that the LEDs are displaying green.

5.4 Frequency of Updating Location

5.4.1 Requirement

The system will gather the pet's location data at a minimum of every minute.

5.4.2 Testing Processes

1. User will power on the device.
2. User will wait at least 3 minutes to gather 3 points of data.
3. User will power off the device and insert MicroSD card into a computer to read data.

5.4.3 Testing Evidence

1. User will get 3 points of data after 3 minutes.

5.5 System life duration

5.5.1 Requirement

The system will operate normally for at least 8 hours on one full charge.

5.5.2 Testing Processes

1. User will use a new 9V battery and measure the voltage of the battery.
2. User will set up timer for 8 hours.
3. User will power on the device and run for 8 hours.
4. If processes 1-3 are not possible, user will measure the voltage of battery after 20 minutes, and use the data to calculate whether the battery can support 8 hours.

5.5.3 Testing Evidence

1. User can see that the power supply is still active at the end of the 8 hour timer.
2. User can verify that the battery has 5 percent battery capacity above 8 hour estimated run consumption.

5.6 Weatherproof design with a rugged enclosure that protects the device from environmental damage

5.6.1 Requirement

The inner circuitry of the board is fully enclosed and there are no exposed connections.

5.6.2 Testing Processes

1. User will open enclosure to verify prevention of sufficient quantity of water and dust entering the enclosure, such that a rating of IP54 is able to be given.

5.6.3 Testing Evidence

1. User will verify that GPS data is still being transmitted and received by reception unit.
2. User will open enclosure to verify prevention of sufficient quantity of water and dust entering the enclosure.

5.7 Accuracy of GPS acquisition of location

5.7.1 Requirement

The module will maintain an accuracy within 2.5m.

5.7.2 Testing Processes

1. User will power on GPS Data Logger and place outside for a period of time.
2. Users are able to properly remove the SD card from the GPS Data Logger and insert it into the computer for information reading.

5.7.3 Testing Evidence

1. Users are able to verify that the location information read by GPS does not differ by more than 2.5m from the current position of the data logger.

5.8 References and File Links

[1] "IP Rating Chart." Rainford Solutions, International Electrotechnical Commission, 2 Nov. 2021, https://rainfordsolutio
protection-ip-rated-enclosures/ip-enclosure-ratings-standards-explained/.

5.9 Revision Table

Date	Responsible Member	Revision Made
03/06/2022	Wang Xiang	Created section 5 framework
03/06/2022	Andre Zhu	Entered Universal Constraint descriptions
03/06/2022	Andre Zhu	Entered enclosure requirements and processes
03/06/2022	Aaron Chung	Edited processes and file links
04/20/2022	All team members	Added revision table

Table 20: The revision table for Section 5.

6 Project Closing

6.1 Future Recommendations

6.1.1 Technical recommendations

PCB Recommendations:

The PCB should be a key item in the project. In this current project, a 2 dimensional 3" x 4" square was used to ensure that the devices could be millimeters apart from each other to save space. However, the width of the devices altogether was not considered, and even though a 3" x 4" square is small, it is not small when compared to the size of most animals. To ensure an even smaller device, future builders may instead expand into 3 dimensions, where each device is essentially "stacked" on each other. Wires or metal rods carrying power or data can transcend through the boards and connect to devices.

Bluetooth Capabilities:

The chosen microcontroller, the ESP32-WROOM, has both bluetooth and WiFi capabilites. The ability to use bluetooth expands the capabilities of the system significantly. While the capabilities of the bluetooth itself was not researched much by the team, it is known that simple words or letters can be sent through bluetooth. 2 things a future team could implement are communication through bluetooth and signal processing through bluetooth. When a pet returns to its owner, the owner could communicate with the device by having it send data to a phone (or other capable BT device) without the owner even having to open the device and take out the MicroSD Card. The system could also return other vital information such as battery life. Similarly, the owner could send simple signals (disguised as "buttons") where the system could start/stop recording data.

Different Choices for a Microcontroller:

The microcontroller used is the ESP32-WROOM. While its capabilities are large, its size is too. Other microcontrollers such as the Arduino Nano or Arduino Nano Every are smaller and can deliver the same main capabilities. One must consider the bluetooth application of the ESP32-WROOM vs. its size when choosing microcontrollers. One very important thing to note is the compile time. The ESP32-WROOM has a compile time in the minutes. The code that was run on the ESP32 was less than 200 lines. If more intricate and user-friendly code (upwards of 1000 lines) was used, it would take several minutes to simply compile and upload, making testing and troubleshooting extremely cumbersome and wasteful.

Alternative Power Sources:

The power supply utilized had multiple 3.3V and 5V rails, respectively, and there was an excess that the system did not need. Although the power supply was effective in providing connections for the other modules, it is possible to find a smaller alternative that would have been more effective in this project. In addition, different power supplies, such as a lithium-ion battery could have been used, if all selected modules were able to operate on 3.3V, saving space and being able to be recharged [1].

6.1.2 Global impact recommendations

Recommendation 1: The Capstone project should push the development of positive paths in real-world fields. The goal of conducting Capstone projects is to increase the real-life accessibility of these finished projects and to foster an interest in hands-on learning. These points need to be kept in mind for future Capstone courses.

Recommendation 2: During the project development process, mistakes will inevitably occur, and some of these mistakes will result in some electronic parts being damaged and no longer usable. Secondly, when we purchase these components, we should try to buy them from sustainable sources. These parts may include some circuit components, PCBs, etc. The advice on this problem is to look for some recycling solution, as much as possible in the area where we are located [2].

6.1.3 Teamwork recommendations

Recommendation 1: As a project team, it is important to communicate effectively and in a timely manner. Not only us, but also many other groups will use Discord to communicate. The software allows you to set up many channels for text chat and voice chat, as well as a channel for file sharing. When communicating, group members can make voice or video calls and also be able to share files in the text channel at the same time. Such effective communication is almost the same as face-to-face communication.

Recommendation 2: It is recommended in cases where blocks are dependent each other, to communicate and update status on these respective blocks frequently between teammates, as optimal ergonomic and design decisions for these blocks will be dependent on communication, such as the microcontroller and code blocks, or the PCB and enclosure blocks.

[1] “Lithium-Ion Battery.” Clean Energy Institute, 25 Sept. 2020, [Online]. Available: https://www.cei.washington.edu/education/science-of-solar/battery-technology/. [Accessed: 6-May-2022].
[2] "Electronics Donation and Recycling," EPA, 03, 3-March-2022. [Online]. Available: https://www.epa.gov/recycle/electronics-donation-and-recycling. [Accessed: 6-May-2022].

6.2 Project Artifact Summary with Links

```
// Group 17
// GPS acquisition and request code

#include <TinyGPS++.h>
#include <SoftwareSerial.h>

static const int RXPin = 16;
static const int TXPin = 17;
static const uint32_t GPSBaud = 9600;

// The TinyGPS++ object
TinyGPSPlus gps;

// The serial connection to the GPS device
SoftwareSerial ss(RXPin, TXPin);

void setup(){
  Serial.begin(9600);
  ss.begin(GPSBaud);
}

void loop(){
  // This sketch displays information every time a new sentence is correctly encoded.
  while (ss.available() > 0){
    gps.encode(ss.read());
    if (gps.location.isUpdated()){
      // Latitude in degrees (double)
      Serial.print("Latitude= ");
      Serial.print(gps.location.lat(), 6);
      // Longitude in degrees (double)
      Serial.print(" Longitude= ");
      Serial.println(gps.location.lng(), 6);

      // Raw latitude in whole degrees
      Serial.print("Raw latitude = ");
      Serial.print(gps.location.rawLat().negative ? "-" : "+");
      Serial.println(gps.location.rawLat().deg);
      // ... and billionths (u16/u32)
      Serial.println(gps.location.rawLat().billionths);

      // Raw longitude in whole degrees
      Serial.print("Raw longitude = ");
      Serial.print(gps.location.rawLng().negative ? "-" : "+");
      Serial.println(gps.location.rawLng().deg);
      // ... and billionths (u16/u32)
      Serial.println(gps.location.rawLng().billionths);

      // Raw date in DDMMYY format (u32)
      Serial.print("Raw date DDMMYY = ");
```

```
Serial.println(gps.date.value());

// Year (2000+) (u16)
Serial.print("Year = ");
Serial.println(gps.date.year());
// Month (1-12) (u8)
Serial.print("Month = ");
Serial.println(gps.date.month());
// Day (1-31) (u8)
Serial.print("Day = ");
Serial.println(gps.date.day());

// Raw time in HHMMSSCC format (u32)
Serial.print("Raw time in HHMMSSCC = ");
Serial.println(gps.time.value());

// Hour (0-23) (u8)
Serial.print("Hour = ");
Serial.println(gps.time.hour());
// Minute (0-59) (u8)
Serial.print("Minute = ");
Serial.println(gps.time.minute());
// Second (0-59) (u8)
Serial.print("Second = ");
Serial.println(gps.time.second());
// 100ths of a second (0-99) (u8)
Serial.print("Centisecond = ");
Serial.println(gps.time.centisecond());

// Raw speed in 100ths of a knot (i32)
Serial.print("Raw speed in 100ths/knot = ");
Serial.println(gps.speed.value());
// Speed in knots (double)
Serial.print("Speed in knots/h = ");
Serial.println(gps.speed.knots());
// Speed in miles per hour (double)
Serial.print("Speed in miles/h = ");
Serial.println(gps.speed.mph());
// Speed in meters per second (double)
Serial.print("Speed in m/s = ");
Serial.println(gps.speed.mps());
// Speed in kilometers per hour (double)
Serial.print("Speed in km/h = ");
Serial.println(gps.speed.kmph());

// Raw course in 100ths of a degree (i32)
Serial.print("Raw course in degrees = ");
Serial.println(gps.course.value());
// Course in degrees (double)
Serial.print("Course in degrees = ");
Serial.println(gps.course.deg());

// Raw altitude in centimeters (i32)
Serial.print("Raw altitude in centimeters = ");
Serial.println(gps.altitude.value());
// Altitude in meters (double)
Serial.print("Altitude in meters = ");
Serial.println(gps.altitude.meters());
// Altitude in miles (double)
Serial.print("Altitude in miles = ");
```

```
      Serial.println(gps.altitude.miles());
      // Altitude in kilometers (double)
      Serial.print("Altitude in kilometers = ");
      Serial.println(gps.altitude.kilometers());
      // Altitude in feet (double)
      Serial.print("Altitude in feet = ");
      Serial.println(gps.altitude.feet());

      // Number of satellites in use (u32)
      Serial.print("Number os satellites in use = ");
      Serial.println(gps.satellites.value());

      // Horizontal Dim. of Precision (100ths-i32)
      Serial.print("HDOP = ");
      Serial.println(gps.hdop.value());
    }
  }
}
```

6.3 Presentation Materials

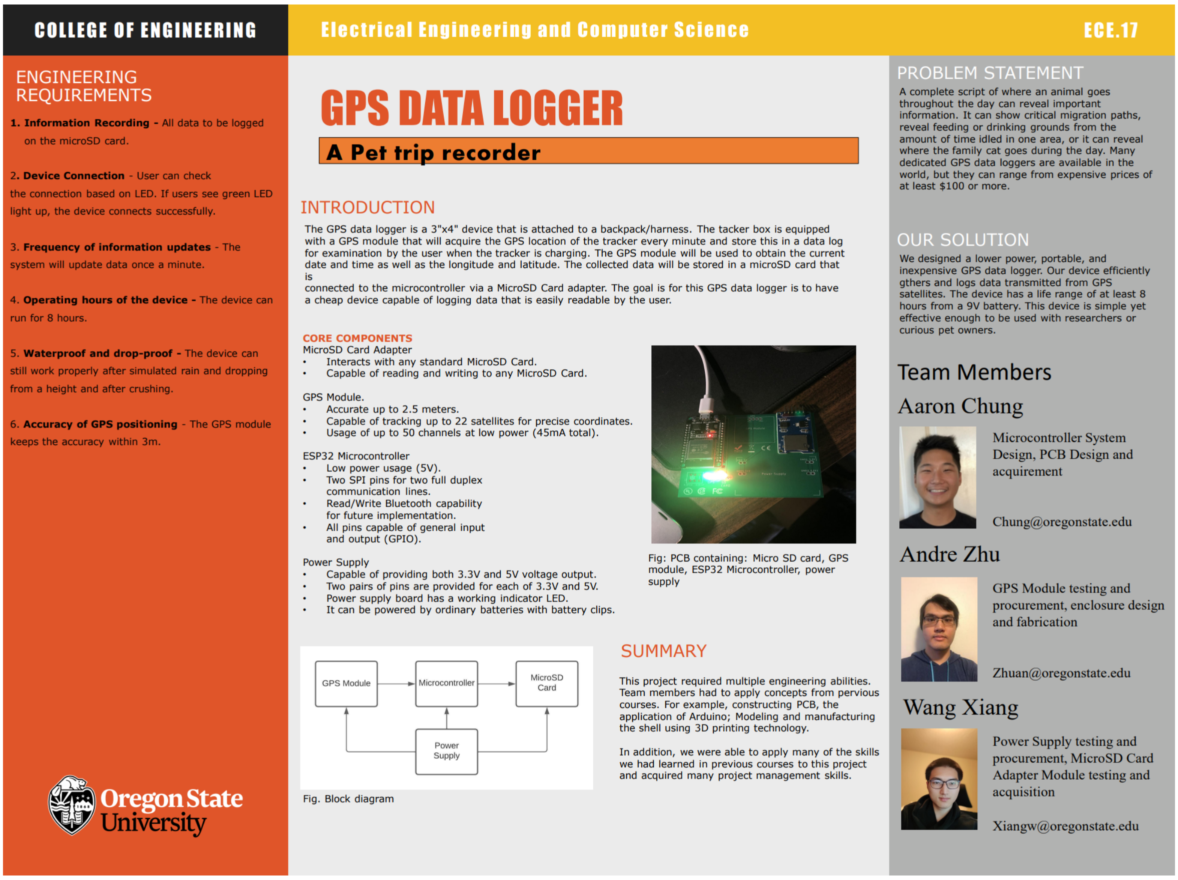

Figure 16: Poster for the Engineering Expo.

Date	Responsible Member	Revision Made
05/06/2022	Wang Xiang	Created Global impact recommendations
05/06/2022	Andre Zhu	Created teamwork recommendations
05/06/2022	Aaron Chung	Created technical recommendations
04/20/2022	All team members	Added Revision table

Table 21: The revision table for Section 6.