Automated Cat Door with LED Collar

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1.0 Executive Summary

In a study done by Nottingham Trent University on the indoor-outdoor lifestyles of pet cats, indoor-outdoor cats make up almost 59% of the population of pet cats (n = 5129). It is important to allow our pet cats a safe place to return home to even when we are not home. If the owner works a typical 9-5 job, they may not be home for up to eight hours. Or if the owner is forced to stay at work later, then there is no chance they will be home in time to let their furry friend inside. Even worse, if it happens to be raining while the owner is out, then there is no way for the pet to get back inside to stay dry. This is where an automated cat door is a necessity for our indoor-outdoor friends.

There are many products already on the market that allow for microchipped pets to re-enter their home even when their owner is not home or not available to let them in. But that does come with a prerequisite, the cats must be microchipped. And that can cost upwards to $50 per cat without an insurance plan. On top of the price for microchipping, the automated cat doors will cost owners from $100 to $200 alone. Totaling upwards to $250 to have an automated door for an indoor-outdoor cat.

Our design will implement the use of an LED collar weighing no more than 100 grams. This will act as a key for the cat to open the cat door once it has been detected by the passive infrared motion sensor that will turn the system on. An IR receiver diode attached to the cat door will detect the light emitted at 940 nm from the IR LEDs on the cat collar that will notify the system to open the cat door. A set of IR LEDs will shine across the cat door onto some photodiodes that will act as a way to confirm if the cat has passed through the door or not. When the cat passes through the door, the change in voltage across the photodiodes will notify the system to set off a timer to close the cat door after the cat passes. If the cat decides not to enter, the system will default to a timer that will close the cat door after a set amount of time. This prevents the cat door from remaining open due to the unpredictability of cats. Then, the system will return to an idle state where just the motion sensor is supplied with enough power to operate. Now if the cat decides to return later, the automated cat door is ready just as before.

The automated cat door will be easy to install, only requiring the consumer to cut a small rectangular shaped hole in their front or back door, or in some cases the door frame. Due to its size, it will be easier to install than a glass panel on their door.

If households can implement our design into their lives, they will have the peace of mind that their pets can return home safely at any time while giving their pets the freedom they love. Even if the pet owners are home, they will not be forced to stay attentive waiting for their pets to return home. Instead, they can continue working on chores or even stay in their beds. Our design is for cat owners, made by cat owners.

2.0 Project Description

The Automated Cat Door with LED Collar utilizes optics and electronics to automatically let in pet cats without the need of the owner present. Allowing owners, the peace of mind that their furry friends can come home safe whenever the owner is asleep or away from home.
This section includes:

- Background of the design
- Motivation for the design based off the members' previous struggles and complaints.
- Goals and objectives the design will strive to accomplish.
- Existing Products
- List of engineering requirements and specifications with 3 demonstrable specifications
- Prototype illustration
- Functionality of design
- House of quality, block diagram of hardware

2.1 Project Background

Many pet owners are not always home due to work or school; thus, their furry friends are sometimes left bored at home or worse, stuck outside. Our feline friends are forced to unfortunately wait until their owner returns home from work or school after upwards of eight hours. We live in Florida where it happens to rain quite often, which can be a bigger problem for the cats trying to find a safe place to escape from the rain. From experience, cats are forced to hide under nearby parked cars to stay out of the rain, which is not the best option to say the least. Sometimes, our pet cat is stuck outside simply because we fell asleep before our furry friend has returned from their outdoor adventures. This problem can be solved with an automated cat door.

There are some solutions using a microchip and a RFID reader on an automated cat door, but not all owners are able to afford microchipping their pet cat without an insurance plan. Without an insurance plan, microchipping and the cost of a microchip automated door can cost the owner upwards to $250 combined.

Our design will help owners find the solutions to help their pets a chance to return home at any time while keeping the cost of the product down to a minimum. Instead of the need to microchip their pets, our product will utilize optics in the form of a collar equipped with an IR LED that an IR receiver will scan for. Paired with a motion sensor in front of the door, this two-step verification process will act as the cat's key to open the cat door. Then, IR LEDs paired with photodiodes will pass across the entrance of the cat door that will act as a confirmation that their feline friend has re-entered the building. After confirmation, the cat door will automatically close and lock after a certain amount of time has passed. Otherwise, the cat door will still close automatically after a certain amount of time if the cat decides not to pass through the door, whichever comes first.

Although the motion sensor is expected to detect any type of movement, the LED collar is necessary to prevent raccoons, other rodents, and other animals from gaining access into the home. If the cat were to lose said collar, a backup solution will be necessary such as a remote button the owner can press from their computer or phone.

Without the need to get up to open their door, the owner will have the peace of mind that their pet cat has returned home safely while remaining comfortable in their bed. With further development, this design can be accessed through a phone application where the cat door can be opened remotely even when the owner is not home; thus, giving the owner a greater peace of mind if the cat were to lose the collar.

2.2 Motivation

Most of our group members have experienced situations when they are forced to get out of the comfort of their beds to let their pet cats back into the house. We wait around for our feline friend to come home after hours of adventuring outdoors; then, as if they somehow knew we were comfortable in our beds, they come home meowing at our bedroom windows. Our design is meant to help give our pet cats a way inside while simultaneously allowing the owner to stay comfortable in bed. There have also been times after we get home from work on a rainy day to be greeted by our poor friend soaked because they had no way to get back inside.

2.3 Goals

The goal of the Automated Cat Door with LED Collar is to allow owners the capability of staying in their comfortable and warm beds while simultaneously letting their pet cats back into the house. And of course, allow the owners the peace of mind that their feline friends can return home to safety even when the owner is not home due to work or school with the use of optics and electronics as a key for our cats to re-enter their home.

Our design will focus on some basic optics goals and the objectives to accomplish them will be discussed later. Goals are outcomes that we want to achieve with our design. While objectives are tangible actions that we will take to achieve those goals, which will be discussed later. Our goals are categorized into three sections: basic, advance, and stretch goals.
Our goals are:

Basic Goals

- Passive IR motion sensor with 90% accuracy to turn on our system.
- Collar with LED to act as a key
- Combination of LEDs and photodiodes at cat door as confirmation the cat has passed through the door.

Advance Goals

- Active IR motion sensor to increase accuracy to 95% or more.

Stretch Goals

- Camera with about 130° FOV used as a live feed (added security and confirmation)

2.3.1 Basic Goals

The basic goals set are what we expect for our design to accomplish. The goal for the passive IR motion sensor is to ensure that our system will turn on from the motion sensor at least 90% of the time. This function is necessary to save energy so that our system will turn on only when it senses something that radiates some heat in front of the motion sensor.

The collar with IR LEDs will emit light at a wavelength of 940 nm to a receiver at the cat door. Once the receiver recognizes that specific wavelength, the system will recognize when the receiver has reached a certain voltage before continuing onto the next steps of the cat door.

We use a combination of IR LEDs and photodiodes across the cat door as a confirmation that the cat has passed through the door. This is necessary to tell the system to close and lock the door once the cat has passed through. Or to keep the door open if the cat decides to stand in the doorway for some reason. In the event the car has not passed through the door, the voltage of the photodiodes will remain unchanged which the system will recognize and close the door after a set amount of time.

2.3.2 Advance Goals

A passive IR motion sensor relies solely on the naturally emitted radiation to detect an object in front of it. Meanwhile, using an active IR motion sensor can improve the detection accuracy since it will detect the presence of an object from its reflection of radiation from the emitter.

2.3.3 Stretch Goals

In addition to the main goals of the Automated Cat Door, there are a few additional goals that are not strictly required for the core functionalities of the cat door but would provide additional benefits to the user. These goals would incur additional costs and complexity to the project for what they add, so now they are only being considered.

One such stretch goal is the addition of a live camera feed to the door, which could be viewed on the computer. This would add the benefit of the user being able to see exactly what is at the door and allow the Automated Cat Door to also function as a home security camera. Incorporating a live camera feed into the system would however bring several challenges to the project and would incur additional costs. Video processing requires a lot of processing power which our microcontroller alone cannot provide, so we would need to use an additional processor just for video processing. Additionally, to send the video to the computer, we would need a wireless transmitter with enough bandwidth to transmit a live video feed. These additional components would consume additional power, which would then require additional solar panels and batteries to meet energy demands. Achieving this goal would incur additional costs of at least $60, even for a low-quality video feed.

2.4 Objectives

The objective of our design is to allow the owners the ability to purchase an automated cat door for relatively cheap while also not requiring the owner to pay extra for having a microchip implanted in their cat; thus, further reducing the cost of having an automated cat door.

Our main objectives are:

- Keep cost low for our fellow cat moms and dads.
- Allow owners peace of mind that their pet cat has a way inside.
- Recognize our pet cats with an LED collar.
- Keep out raccoons and other rodents.
- Backup method in case cat loses collar.

2.5 Existing Products

As mentioned before there are automated cat doors already on the market, but they require the user's cat to already have a microchip implanted into them. This can cost the owner an additional $50 without an insurance plan. SureFlap is a company with various automated cat door designs that range from $100 to $500, depending on features and accessories.

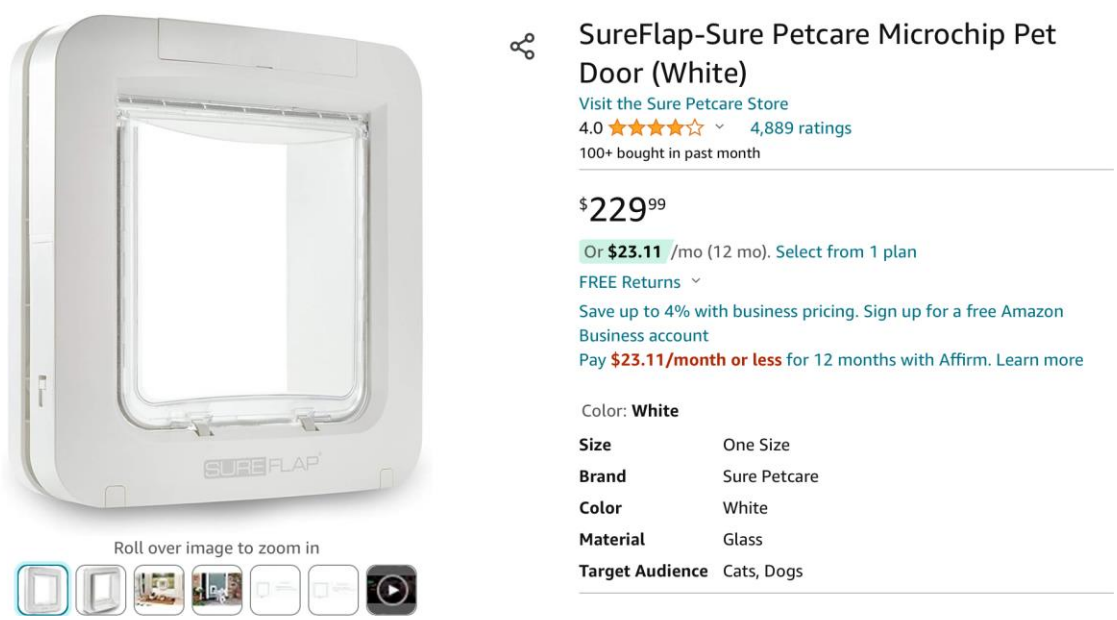

Figure 1 - One of the many SureFlap products already on the market.

With over 4,000 ratings and an average rating of 4.0 stars, we can see that the product is doing very well even at this price point. But not everyone can afford such amenities, or anything automated for their pets. A major con with these products is the necessity of microchipping their pets or buying a collar with an RFID chip separately, ultimately costing the owners even more money they cannot afford to spend. With our product we envision giving the owners the guarantee their purchase will include everything they need to set up their automated cat door, excluding the tools necessary for installation.

Because we cannot include the tools necessary, our design will be compact enough to give the owners the freedom to install the cat door wherever they desire. Whether they install it directly onto their doors or beside the door frame, we will make sure our design will not cause too much of a headache for the owners to install due to its compact size and durable frame at a budget friendly price point.

2.6 Comparisons to Past Projects

When browsing other senior design projects, we saw that a few groups also made a cat door for their project, so we decided to look at the similarities and differences between our project and past senior design projects.

The first project we noticed was like ours was Pet Connect, a project from 2020. This project has a similar goal to ours, to reduce the stress of pet owners who are either not home or not able to monitor the door for their pets which like to go outside. The Pet Connect project uses a system to open a normal sliding glass door, allowing the pet to come inside or outside as they please. It focuses more on dogs, and their need to go outside to relieve themselves, as opposed to our project which focuses on pet owners with indoor/outdoor cats. They also use a camera and audio interface, as well as a mobile app to allow the user to remotely control the door. The advantage of their project is that it is easier for a user to set up, as they can install the system without having to cut a hole in their door, and they have an advanced system which allows the user to monitor what is at the door, and set it to be locked or open, etc. The disadvantages are firstly the cost, as the Pet Connect ended up costing about $370, with an initial budget of $450, while our project budget is $150. This comes from the expenses of the camera system, the advanced sensors they use, as well as the system to automatically open a sliding glass door. This system also requires the user to have a sliding glass door, so it has a more limited customer base. Our project aims to reduce the cost by using a simpler and more cost-effective system, using infrared communication through our collar, and is more accessible as a user can install our system on most front doors.

The next project we noticed was similar was the IoT Smart Doggy Door. This project also focuses on dogs like Pet Connect but works in a completely different way. This project uses collars like ours does, except they use RFID instead of infrared communication. The IoT Smart Doggy Door focuses on incorporating IoT into the project, as the name says. The features this allows is that the user can be sent pictures of the outside of the door when something is there, and they can set custom permissions for each pet based on the collars which are registered to the system. Being an IoT project, it allows much more remote control than our project. Another advantage of their project is that the collar they use does not require a battery, since it uses a passive RFID tag instead of an infrared communication system like ours, which requires a battery. However, all this customization and remote control comes at a cost, as their project ended up costing them around $600. A large part of this cost comes from the RFID technology, as the reader and antenna cost them around $350. Our project is different in that we aim to provide a solution for pet owners that is lower cost, around $150 if possible. Still, the IoT Smart Doggy Door is a good project for us to draw inspiration from.

2.7 Engineering Requirements and Specifications

Component	**Parameter**	**Specification**
IR Motion Sensor	**Maximum Response Time**	< 3 Seconds
	Range	≥ 3 meters
	Detection Reliability	~ 90%
Power Supply	**Maximum power usage while offline**	< 100 milliwatts
	Maximum power usage while online	< 50 watts
Microcontroller	**Time Before Door Closes (Cat Enters)**	10 Seconds
	Time Before Door Closes (Cat Leaves)	60 seconds
IR LEDs	**Collar Weight**	< 100 grams
Collar Battery	**Battery Life**	~ 8 hours

2.8 Prototype Illustration

A motion sensor will be the initial step to turn on the entire system, rather than using a RFID reader that will require more power to operate than a simple motion sensor. Without the need of a RFID tag and reader, the cat's collar will be lighter, and our design will require less electronics; thus, lowering the cost.
In our design, an LED is attached to a cat's collar along with a Fresnel lens. An IR LED at 940 nm is used because it will prevent misbehaving neighbors from tampering with the cat door. A simple IR receiver is used to detect the IR LED, as shown in Figure 2.

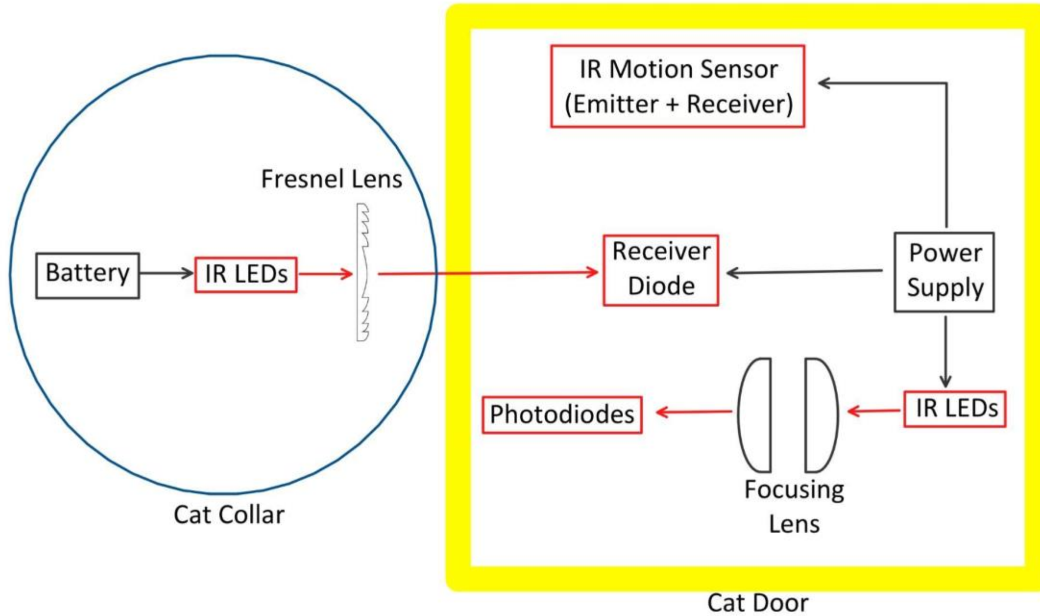

Figure 2 - Prototype Illustration of optical components.

A camera with a live feed will be a stretch goal to provide the owner safety and clarity in case it is not their cat setting off the motion sensor. With the live feed, the owner can see if their pet cat has lost its collar so the owner can manually activate the system's backup to open the door with a press of a button.

At the cat door, IR LEDs along with photodiodes will be used as a confirmation step that the cat has passed through the door, as shown in Figure 2.

2.9 Functionality of Design

Initially, most of the system is off, and the only component powered will be the motion sensor. Once something has passed the motion sensor, the system will turn on and a shutter will open, revealing the IR receiver to detect the light coming from the IR LED on the cat's collar. When the IR receiver has reached a certain threshold voltage, the cat door will open, and the IR LEDs will turn on and another shutter will open to reveal the photodiodes used to detect the IR LEDs to begin the verification step of the cat passing through the cat door.

If the cat enters through the cat door, all the photodiodes will be blocked and the voltage will drop; thus, indicating to the system that the cat has passed through the door. After the cat has passed through the cat door, the photodiodes will not be blocked anymore and will detect a certain voltage again, indicating that there is no cat blocking the doorway. This will then set off a timer in the system to close and lock the cat door after the time has expired.

Or if there is no voltage drop from the photodiodes because the cat decides not to pass through the cat door, then a predetermined timer will notify the system to close and lock the cat door. To ensure the cat door does not remain open forever, the cat door will close whichever event occurs first.

2.10 Marketing and Engineering Requirements (House of Quality)

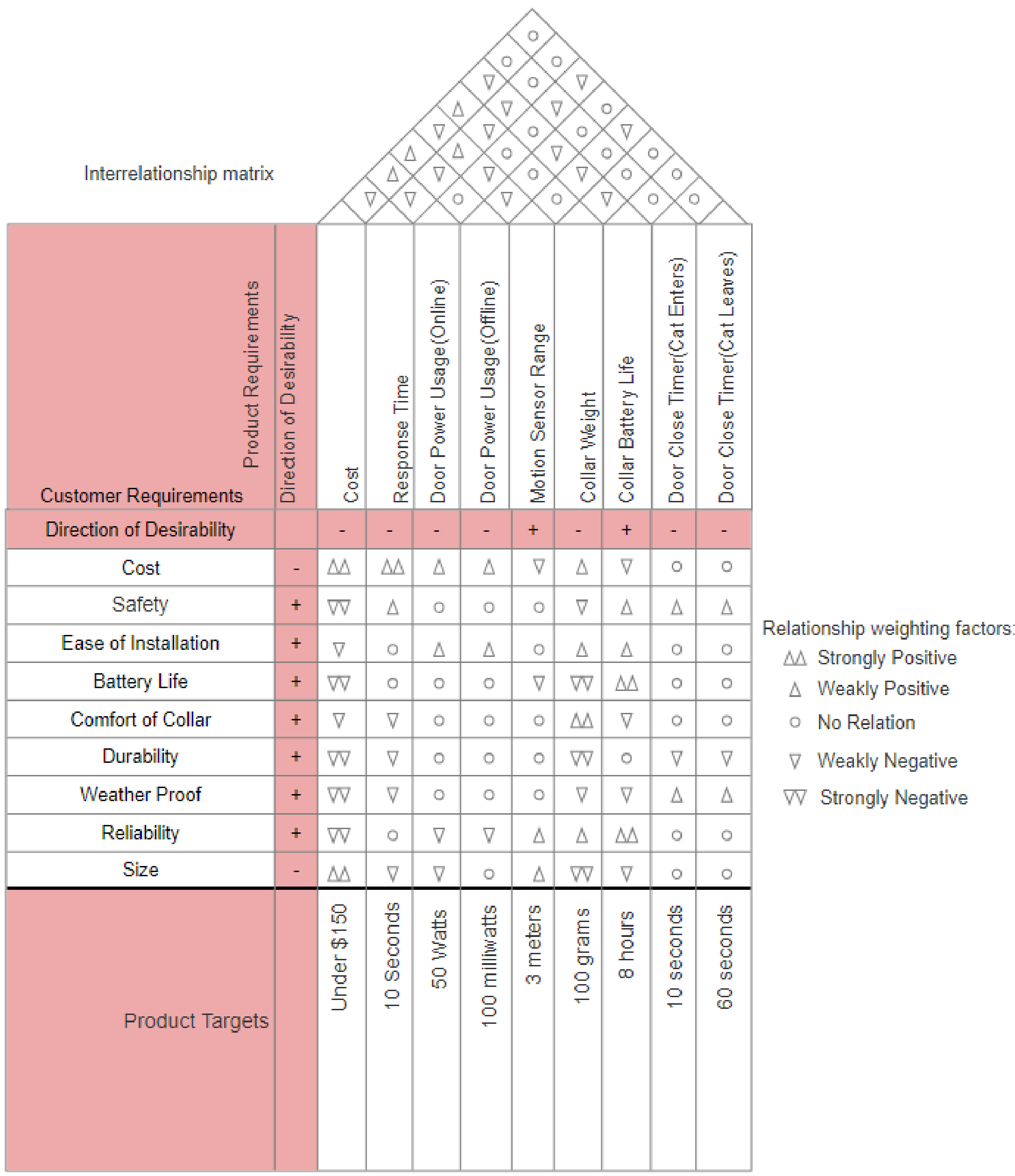

Figure 3 - House of Quality diagram.

2.11 Hardware Block Diagram

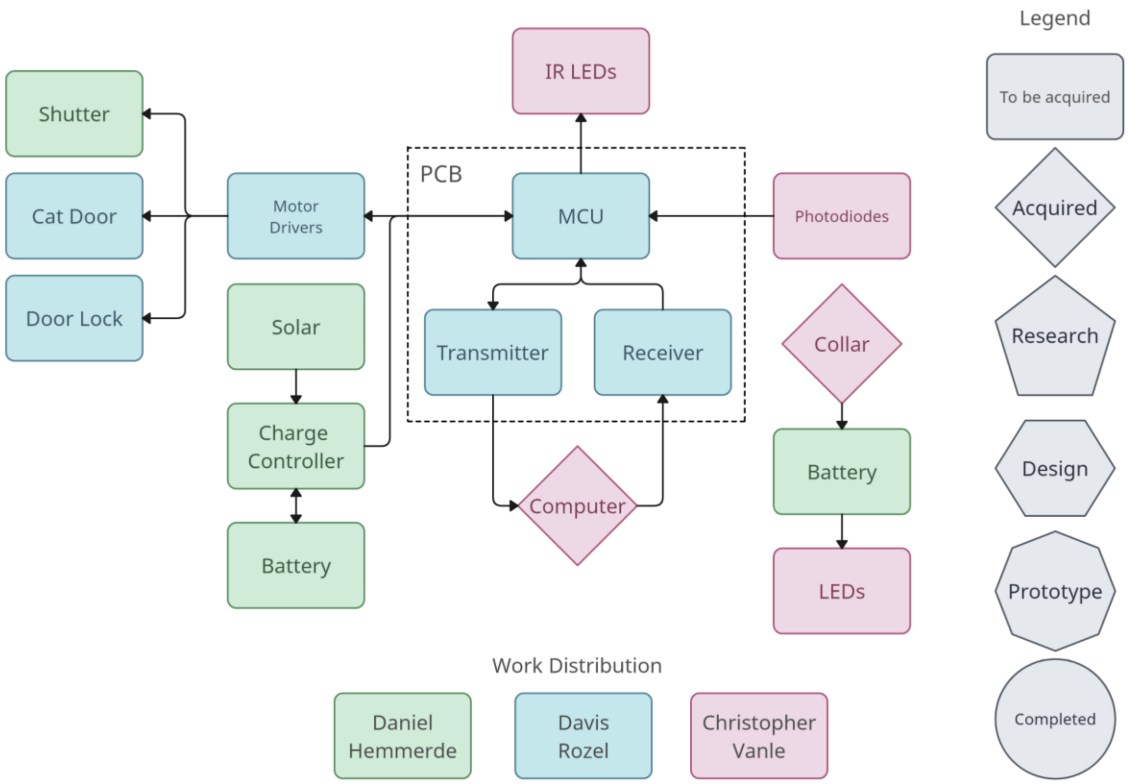

Figure 4 - Hardware block diagram with work distributions and progress.

2.12 Software Block Diagram

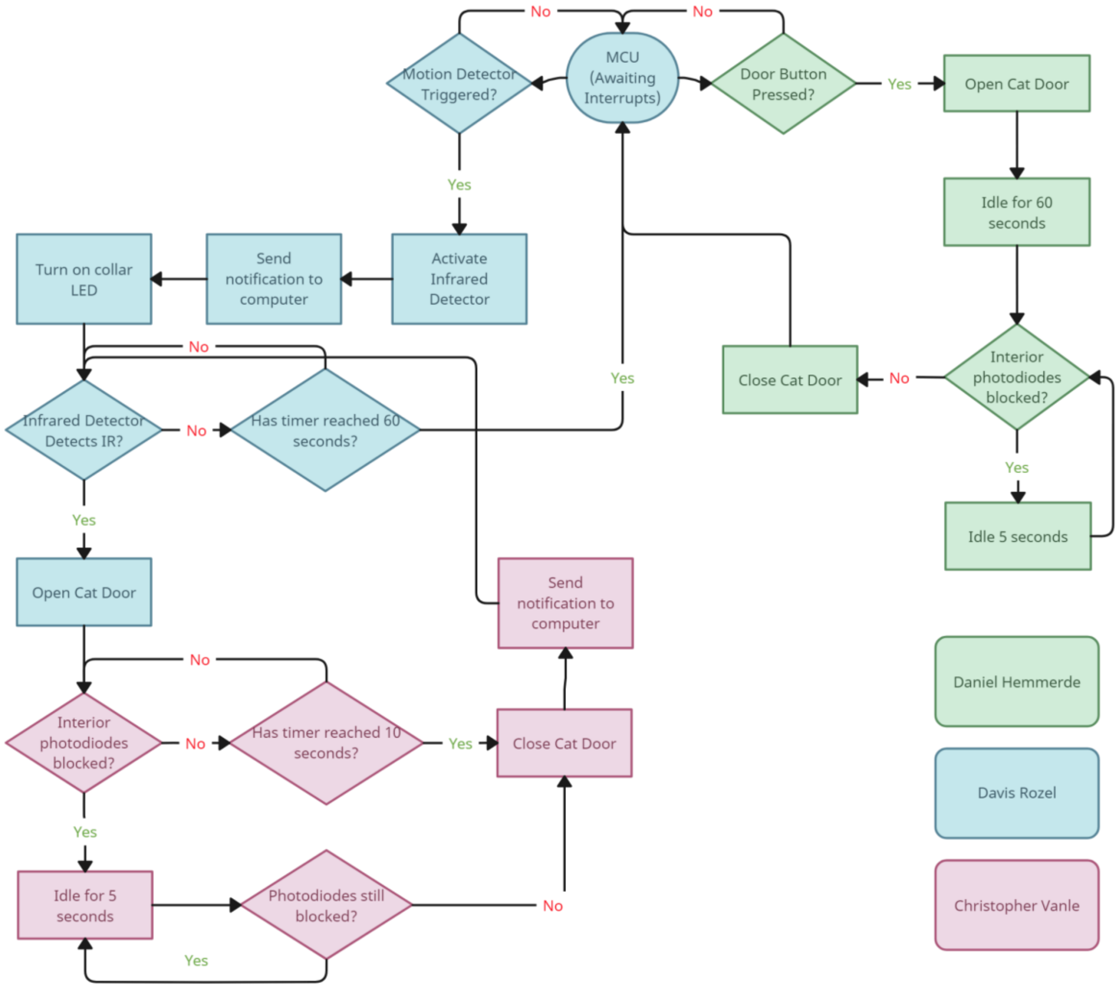

Figure 5 - Software block diagram with work distributions.

3.0 Research and Investigation

3.1 Technology Comparison and Selection

3.1.1 Communication Technology

Our project will require wireless communication to and from a computer as well as transmitting data to the collar. Therefore, it is important that we choose the right wireless communication technology to meet these needs.

3.1.2 Power Source Technology

Our project will include several electronic components that will need a consistent power source to keep everything running properly.

3.2 Part Comparison and Selection

3.2.1 Microcontrollers

The microcontroller (aka MCU) is one of the most important components of this project. It will be responsible for the logical operation of the system, controlling when and what actions are taken by the system. The microcontroller will be interfaced with all of the sensors and actuators of the system and will be reading sensor data to determine when to open the cat door, what to communicate to the collar and the computer, as well as all of the other control elements of the system. Therefore, it is vitally important that we choose a microcontroller that can meet all the specifications and requirements of the components of the system. There are many factors to consider when choosing a microcontroller, including clock speed, memory, pin count, supported software, programming languages, power consumption/efficiency, and more. For our project, we will need at least two microcontrollers, one for the main system on the cat door which will control the main system operations, as well as a smaller one for the collar which will control the functionalities of the collar.

The pin count is very important, since pins are needed to connect the microcontroller to external elements like sensors. The microcontroller needs to at least have enough pins to connect all the components needed for the project, plus having some extra would allow us flexibility in the implementation of our project. Having more pins is useful, but we also do not want an excess of pins, as this comes with disadvantages such as increased space usage, an increase in power consumption as well as an increase in cost.

Clock speed is another essential aspect of the microcontroller to consider, as a faster clock speed generally means faster processing. Having a higher clock speed allows the microcontroller to execute instructions faster, which would lead to a faster response time. A faster clock speed also increases power consumption, which is important to consider.

Storage is also an important part of the microcontroller. Storage comes in multiple forms, including flash, which is a nonvolatile memory used to store and load programs, RAM which is volatile memory that is used for temporary storage during operation, ROM which is nonvolatile memory used to store instructions, and EEPROM, which is also nonvolatile memory and usually used to store configuration settings. Both the size of storage and rate of data transfer must be considered as we need enough storage space to handle the size of our code, and the data must be transferred as quickly as possible to improve response time.

The microcontroller we choose should also support the communication protocols we decide to use. Most MCUs available support the common communication protocols like UART, I2C, and SPI, but if we want to use a different communication protocol, we need to make sure the MCU supports it. The architecture and programming languages that the MCU supports is also important, ideally, we would want one that supports the Arduino IDE, or the Code Composer Studio (CCS) IDE, as these IDEs are familiar to us, but other MCUs are still worth considering if they provide worthwhile benefits.

We could also consider using a microprocessor like the Raspberry Pi instead of a microcontroller or using both for different tasks. A microprocessor would provide us with much more processing power than a microcontroller and allow us to compute more complex tasks than a microcontroller, but there are also many downsides to this approach. A microprocessor uses more power than a microcontroller, and often lacks a low power mode, where most microcontrollers have multiple low power modes which can be switched between for different applications. A microprocessor requires more additional components like external RAM/ROM, I/O ports, etc., which adds to the size and cost, and would require a larger and therefore more expensive PCB. For our application, the benefits of a microprocessor are not really needed, and the drawbacks are too great, so we will most likely not be using one.

3.2.1.1 Main Microcontroller

The main microcontroller for this project will be installed on the cat door itself, and it will be responsible for most of the major operations of the system. Therefore, the microcontroller we select must be capable of handling multiple peripherals and tasks, so we must make sure it has good enough specs for this. Additionally, the microcontroller we choose should not have many more pins than is necessary, as this will increase its footprint on the PCB and therefore increase costs.

Atmel ATmega328

Atmel is a very popular microcontroller manufacturer, whose chips have been used for many projects. The ATmega328 is one of their most common chips, being used in Arduino development boards like the Arduino UNO. It is an 8-bit RISC based microcontroller, featuring a clock speed of 20 MHz, as well as 32 KB of ISP Flash memory, 1 KB of EEPROM memory, and 2 KB of SRAM memory. It has 23 GPIO ports, a 6 channel 10-bit A/D converter, and supports UART, I2C, and SPI communication protocols. The ATmega328 is quite power efficient and offers a low power consumption, with 5 different low power modes. It is also inexpensive considering what it offers, and is overall a decent microcontroller, and it has extensive documentation available given its popularity, so it is easier to work with. For our application this MCU could be enough, but being a beginner chip, it may not be able to provide all the capabilities we need. The pin count is especially an issue, with all the components of our system this MCU may not have enough pins.

Microchip ATxmega64A4U

The ATxmega64A4U is an 8/16-bit AVR microcontroller, with 64 KB self-programming flash memory, a 4 KB boot code section, 4 KB of SRAM, 2 KB of EEPROM, and has a 32 MIPS throughput at 32 MHz. This MCU has 44 GPIO ports, a 12 channel 12-bit A/D converter, a two-channel, 12-bit D/A converter, and supports common protocols like I2C and SPI. The capabilities of this MCU are enough to support all the needs of our project, and the pin count is high enough to support all of the peripherals we plan to use in our system. The active mode power consumption is higher than other chips like the ATmega328, which is a drawback to consider.

Microchip ATxmega128A4U

The ATxmega128A4U is in the same family as the ATxmega64A4U, but it is a slightly more powerful chip. It features 128 KB of self-programming flash memory, as well as 8 KB of SRAM. Therefore, this chip has higher capabilities than the ATxmega64A4U, but it also comes at the cost of slightly increased power consumption. For this application, we likely do not need the extra performance that this chip offers, but it is worth considering.

Microchip PIC24FJ128GA006

Another MCU by Microchip, the PIC24FJ128GA006 has a key difference from the rest of the microcontrollers considered so far, being that it is a purely 16-bit MCU instead of 8-bit or 8/16-bit. It has a 16 MHz clock speed, 128 KB flash memory, and 64 GPIO ports. This MCU has a 16 channel 10-bit A/D converter, and supports common communication protocols like UART, I2C, and SPI. This chip has good specs at a fairly low cost; however it consumes quite a bit more power than the other options. It also has the most pins out of all the other options here, and its specs make it worth considering, however the extra power consumption may not be worth it.

Table of Options

MCU	**ATmega328**	**ATxmega64A4U**	**ATxmega128A4U**	**PIC24FJ128GA006**
Max Clock Speed	20 MHz	32 MHz	32 MHz	16 MHz
Flash Memory	32 KB	64 KB	128 KB	128 KB
RAM	2 KB	4 KB	8 KB	8 KB
EEPROM	1 KB	2 KB	2 KB	N/A
Pin Count	23	44	44	64
Bit Size	8-bit	8/16-bit	8/16-bit	16-bit
Recommended				

Operation Voltage	1.8V - 5.5V	1.6V - 3.6V	1.6V - 3.6V	2.5V - 3.6V
Low Power Mode Current	0.9 μA @ 3V	1.4 μA @ 3V	1.4 μA @ 3V	27 μA @ 3.3V
Active Mode Power Consumption	5.2 mA @ 8 MHz	8.2 mA @ 32 MHz	9.5 mA @ 32 MHz	32 mA @ 16 MHz & 3.3V
Cost	$2.63	$5.13	$6.18	$4.80

3.2.1.2 Collar Microcontroller

An additional microcontroller is required to be mounted on the cat collar, to control the few operations on the collar. It must be capable of communicating to and from the cat door, by using an infrared LED and detector. It just must receive the code from the door, and then flash the LED to communicate that code back to the door. Since it will be mounted on the collar, we want to minimize the size and weight it takes up, so we want a microcontroller that is just able to handle these simple requirements, while being as small and having as little power consumption as possible.

Microchip ATtiny84A

The ATtiny84A is our first choice for the collar microcontroller, being that it has a small pin count at 12 pins. It features an 8 KB flash memory, 512 B EEPROM, 512 B SRAM, two timers, one 8-channel 10-bit A/D converter and operates on 8-bits. This chip has more than enough to support the few peripherals we need it to, and the specs are more than enough to complete all the processes we need this microcontroller to do. This microcontroller may be too powerful for our application however and draw more power than we would like.

Microchip ATtiny212

The ATtiny212 is another microcontroller by Microchip, and it uses an 8-bit AVR processor. It can run up to 16 MHz, though for our application we do not need it to run anywhere near that fast. This microcontroller can run at 32.768 kHz on an ultra-low power oscillator, which we would use to consume as little power as possible. It is equipped with 2 KB of flash memory, 128 B of SRAM, and 64 B of EEPROM. It has 8 pins, and a 6-channel, 10-bit A/D converter. This microcontroller has very small memory sizes, but this is okay given that the functionality we require it to have been very limited. Given its low power consumption and size, this microcontroller is a good option to consider.

Microchip ATtiny402

The ATtiny402 is yet another microcontroller by Microchip and features slightly better specs than the ATtiny212. It uses an 8-bit AVR processor, able to run at speeds of up to 20 MHz. It has 4 KB of flash memory, 256 B of SRAM, and 128 B of EEPROM. This microcontroller also has an 8-pin package like the ATtiny212 and has a 12-channel 10-bit A/D converter. This microcontroller like the ATtiny212 can also be run at 32.768 kHz on an ultra-low power oscillator, which will be very useful for saving power. Considering that this microcontroller is essentially an upgraded ATtiny212, we may consider using the ATtiny402 if the ATtiny212 is not enough to meet our needs.

Texas Instruments MSP430G2230-EP

The MSP430G2230 is an ultra-low power microcontroller by Texas Instruments, using a 16-bit RISC processor. Its max clock speed is 16 MHz, and it has 2 KB of flash memory, and 128 B of RAM. This microcontroller is also equipped with a 4 channel, 10-bit SAR A/D converter and has 4 GPIO pins. The pin count of this microcontroller is smaller than the other microcontrollers in this list, and the cost is greater than the ATtiny212 and ATtiny402 which have similar specs, but the MSP430G2230-EP has advanced features that make up for this. Firstly, this microcontroller has multiple clocks including the master clock, a 32 kHz crystal, and a very-low-power low-frequency oscillator. It also has four low power modes, which the other microcontrollers lack, which allows it to consume much less power when not in use than the others in this list.

MCU	**ATtiny84A**	**ATtiny212**	**ATtiny402**	**MSP430G2230-EP**
Max Clock Speed	20 MHz	16 MHz	20 MHz	16 MHz
Flash Memory	8 KB	2 KB	4 KB	2 KB
RAM	512 B	128 B	256 B	128 B
EEPROM	512 B	64 B	128 B	N/A
Pin Count	12	8	8	4
Bit Size	8-bit	8-bit	8-bit	16-bit
Recommended Operation Voltage	1.8V - 5.5V	2.7V - 5.5V	1.8V - 5.5V	2.2V - 3.6V
Idle Current	40 µA @ 1 MHz	4 µA @ 32.768 kHz & 3V	4 µA @ 32.768 kHz	0.5 µA in LPM3 (only ACLK clock enabled) & 2.2V

Active Mode Power Consumption	250 µA @ 1 MHz & 2V	11 µA @ 32.768 kHz & 3V	10 µA @ 32.768 kHz & 3V	300 µA @ 1 MHz & 3V
Cost	$1.62	$0.55	$0.54	$1.95

3.2.3 LEDs

Light Source	**Power Consumption**	**Weight**	**Cost**	**Example**
IR LED	70 mW	9 grams	< $1	Gikfun 5mm 940nm LEDs IR Emitter and Receiver EK844
Laser Diode	100 mW	14 grams	< $1	HiLetgo 10pcs 5V 650nm 5mW Red Dot Laser Head

We chose LEDs instead of other components that can produce more light due to its cost and small size. Although laser diodes are just as small, laser diodes consume more power and are more expensive, especially infrared. LEDs are cheap and can be purchased in a pack, which will help if any LEDs go bad or break; making it easier to maintain the design as well as reduce stress if a replacement is needed. Since LEDs do not require a lot of power to operate, the battery and power supply requirements are not as taxing. This keeps the cost of the design to a minimum while also accomplishing our basic goals of using a cat collar as a key for the cat door.

For the sake of the cat collar, LEDs weigh less than laser diodes and consume less power. This is important because we will need to install multiple sources of light onto the collar just in case the cat has somehow twisted or flipped the collar around. Laser diodes can consume upwards to 100 mW per diode. Laser diodes also weigh upwards of 14 grams compared to the 9 grams of a single IR LED. Also, more photodiodes are necessary to pair with the laser diodes if we want to accomplish the same goal as the IR LED emitter and receivers.

3.2.4 Photodiodes

Photodiodes were chosen because they are relatively cheap and do not require a large output light to operate. Like LEDs, photodiodes can be purchased in packs and are easy to replace if they were to go bad or break. For that reason, phototransistors are not an option. Photoresistors are a viable option in place of photodiodes, but further testing must be done to see which of the two are a better option. Although, using either photoresistors or photodiodes should be capable of accomplishing our goal of having a confirmation step across the cat door.

3.2.5 Motion Sensor

Sensor	Detection Method	Distance	Cost	Example
Infrared	Light Waves	< 8 m	< $1	Gikfun 5mm 940nm LEDs IR Emitter and Receiver EK8443
LiDAR	Light Waves	< 8 m	$25	MakerFocus LiDar Range Finder Sensor
Ultrasonic	Ultrasonic Waves	< 5 m	< $2	Smraza Ultrasonic Module HC-SR04
Radar	Radio Waves	< 7 m	$3.50	Radar Sensor RCWL-9196

Like the cat collar and cat door, we decided to use infrared for our choice of motion sensor. As shown above there were quite a few options, including LiDAR, ultrasonic, and radar. For our design, infrared LEDs will be the cheapest option because we are capable of buying a pack of 20 emitter and receiver pairs for about 62 cents each pair. There is also an advantage in terms of power consumption, as IR LEDs take less than 70 mW to power. Weight and size are a huge factor for our design, as each LED weighs less than 9 grams and about two inches in length; thus, there will be no issue when installing onto the cat door. Infrared motion sensors are commonly used in automated lights and doors, so there are other products and designs we can reference with our design. LiDAR options are available to satisfy the optics portion of the design, but a single LiDAR kit costs at least $25; thus, replacements if it were to break will quickly add to the overall cost of the design. LiDAR kits also consume upwards to 350 mW of power. Although not a lot, keeping our power consumption at a minimum is a necessity.

3.2.6 Fresnel Lens

For the cat collar, a Fresnel lens was chosen due to its illumination capabilities. Like lighthouses, the Fresnel lens will help illuminate the IR LEDs on the collar to make it easier for the receiver on the cat door to detect. If the point source, in this case the IR LED, is at the focal point of the Fresnel lens can collimate the light. We are not worried about doing that because we want the light to diffuse so that our cone of light will stretch wider to take in account the collar rotating around; thus, more than one IR LED and Fresnel lens will be attached around the cat collar.

Also, Fresnel lenses can be made from plastic rather than glass. This will aid in our weight restriction for the cat collar as well as the cost of buying multiple Fresnel lenses. With further testing, a Fresnel lens can also be used in place of the focusing lenses at the cat door. Just like the cat collar, this will greatly reduce the cost for the design, maintaining the goal of designing a product that will compete with microchip cat doors.

Although finding a perfect circular Fresnel lens can be costly or require ordering from online shops from China, which can require 30 days to ship, small credit card sized Fresnel magnifying cards can be cut to the desired shape and size needed to fit onto the cat collar. For example, FUCAS' credit card sized Fresnel magnifiers can be purchased in a lot of 12 for about $0.40 each. This will give us plenty of leeway to test multiple sizes to test fit onto the cat collar. In addition to having enough supply to be able to fit all around the collar if necessary.

3.2.7 Door Battery

The door will contain most of the electronic devices used in our project, resulting in the largest power usage. The door will consistently consume a low amount of power while offline, but when active, it will consume a much larger quantity. Due to our decision to charge the battery with solar power, there will be long periods of time where it will not receive charge. The battery we choose must be able to survive these long periods, while remaining safe and cost effective. In this section we will discuss the pros and cons of four battery chemistries and decide which is best for our project.

Lithium-ion batteries are the most energy dense of the chemistries we considered and for that reason they are popular. They also require little to no maintenance and will last for a long time. These batteries also have the highest storage to cost ratio of all the batteries we researched. However, despite all the benefits of this chemistry, lithium-ion batteries also come with the greatest safety risk. If these batteries are not properly charged or discharged, or if they are physically damaged, there is a chance that they will explode. The fire created by this explosion is extremely hot and could cause immense damage to the surrounding area. For this reason, several safety measures would need to be made, increasing the overall effective price of the battery. This alongside the unpredictable nature of pets, leads us to believe that this battery is not the best choice.

Lithium Iron Phosphate batteries are another option that we considered. They have a high energy density, albeit lower than lithium-ion batteries. $LiFePO_4$ batteries also have a negligible maintenance requirement and have the second highest storage to cost ratio. Although they fall decently below Li ion batteries in these aspects, $LiFePO_4$ batteries stand much higher in the aspect of safety. Just like lithium-ion batteries, they are weak to being overcharged. However, when this happens, they do not explode and will instead expand and release fumes. Similar protective measures will still need to be made to ensure this doesn't happen, but in the case that it does, it is much safer than Li ion batteries.

Nickel Metal Hydride is another battery chemistry that we considered using for our project. NiMH batteries are much different from the lithium batteries as their cell voltages are much lower, but their rated currents are much higher proportionally. This means that in order to achieve the desired voltage for our project, we would need to purchase multiple and use them in series. Unlike the lithium batteries, NiMH carry none of the safety risks, while having only slightly lower energy density. The main downside to these batteries is their need for maintenance. These batteries require an occasional full discharge or crystals will begin to form within them, severely decreasing their storage.

Battery Chemistry	**Lithium Ion**	**LiFePO4**	**NiMH**	**NiCd**
Voltage	3.6V	3.2V	1.2V	1.2V
Amp-Hours	1650mAH	1200mAH	900mAH	1000mAH
Length	65mm	65mm	44.5mm	50mm
Diameter	18mm	18mm	10.5mm	14.2mm
Price	$8.99	$8.99	$2.79	$3.49
Maintenance required	No	No	Yes	Yes
Brand	Toshiba	Power Portable	Power Portable	Power Portable

3.2.8 Collar Battery

10.0 Administrative Content

10.1 Budget Estimates and Financing

Component	Quantity	Estimated Cost	Total Cost
Microcontroller	1	$15	$15
Infrared Photodiodes	3	$1	$3
Infrared LED	6	$0.60	$3.60
Infrared Detector	1	$1	$1

Infrared Motion Detector	1	$5	$5
Wireless Receiver	2	$3	$6
Wireless Transmitter	1	$3	$3
PCB	1	$25	$25
Motors	3	$5	$15
Motor Drivers	3	$5	$15
Solar Panel	1	$20	$20
Rechargeable Battery (collar)	1	$3	$3
Rechargeable Battery (door)	1	$20	$20
Cat Collar	1	$1	$1
Power Supply Unit (PSU)	1	$15	$15
Total Cost			$150.6

- Note - PCB and PSU costs include miscellaneous electronics like resistors, voltage regulators, etc.

10.2 Table of Work Distributions

Photonics Engineering	Responsibilities
Chirstopher Vanle	Optical Design and Implementation
	Computer Integration
	Mechanical Design
	Software Design and Implementation
	Administrative Content
Electrical Engineering	Responsibilities
	MCU Selection and Implementation

Davis Rozel	PCB Design
	Wireless Communications
	Software Design and Implementation
	Website Design and Management
Electrical Engineering	Responsibilities
Daniel Hemmerde	PSU Design and Implementation
	PCB Design
	Motor Control and Implementation
	Solar Power and Power Storage
	Software Design

10.3 Project Milestones

Task	**Who**	**Duration**	**Status**
Team Formed	Group C	January 4th, 2024	Completed
Design Brainstorming	Group C	January 16th, 2024	Completed
Design Final Selection	Group C	January 23rd, 2024	Completed
Role Selection	Group C	January 25th, 2024	Completed
Research Components	Group C	February 2nd, 2024	In Progress
Initial Project Document - D&C	Group C	February 2nd, 2024	Completed
Design Schematic	Group C	March 14th, 2024	In Progress
Bill of Materials	Group C	March 25th, 2024	In Progress

Table of Contents	Group C	March 28th, 2024	In Progress
Half-way (45-page) Draft	Group C	March 29th, 2024	In Progress
¾ Way (65-page) Draft	Group C	April 9th, 2024	In Progress
Final Document (90-page)	Group C	April 23rd, 2024	In Progress
Order Components	Group C	Summer Semester	
Senior Design 2	Group C	Fall Semester	
PCB	D.R. and D.H.	Fall Semester	
PSU	D.H.	Fall Semester	
MCU	D.R.	Fall Semester	
Motors	D.H.	Fall Semester	
Sensors	C.V.	Fall Semester	
Diodes/LEDs	C.V.	Fall Semester	
Camera	D.R. and C.V.	Fall Semester	
Computer Software	D.R. and C.V.	Fall Semester	
Collar	D.H. and C.V.	Fall Semester	
Design Testing	Group C	Fall Semester	
Demo Presentation	Group C	Fall Semester	
Redesign and Testing	Group C	Fall Semester	
Final Testing	Group C	Fall Semester	
Final Presentation	Group C	Fall Semester	

Declaration

We hereby declare that we have not copied more than 7 pages from the Large Language Model (LLM). We have not utilized LLM for drafting, outlining, comparing, summarizing, nor proofreading purposes.

Works Cited

Foreman-Worsley R, Finka LR, Ward SJ, Farnworth MJ. Indoors or Outdoors? An International Exploration of Owner Demographics and Decision Making Associated with Lifestyle of Pet Cats. Animals (Basel). 2021 Jan 20;11(2):253. doi: 10.3390/ani11020253. PMID: 33498511; PMCID: PMC7909512.