ECE 445 SENIOR DESIGN LABORATORY

DESIGN DOCUMENT

Portable Anti-Theft Package Container

Team 44

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1 Introduction

1.1 Problem Overview

Ordering products online is a part of daily life for many people. Everything ranging from entertainment devices to essential medications and tools sit outside peoples front entrances to their homes for hours on end while they're out on business. Unfortunately, this leaves unguarded packages vulnerable to theft by opportunistic individuals, also known as porch pirates. Package thefts have been a common occurrence for many years now, and in one case, thieves stole a package containing a young boy's Ryedapt prescription, a medication he depended on to treat his cancer. What makes package thieves so bold is the lack of risk and difficulty finding the culprits involved in these instances. So a reusable and cost-effective means of deterring or providing information to catch package thieves is necessary.

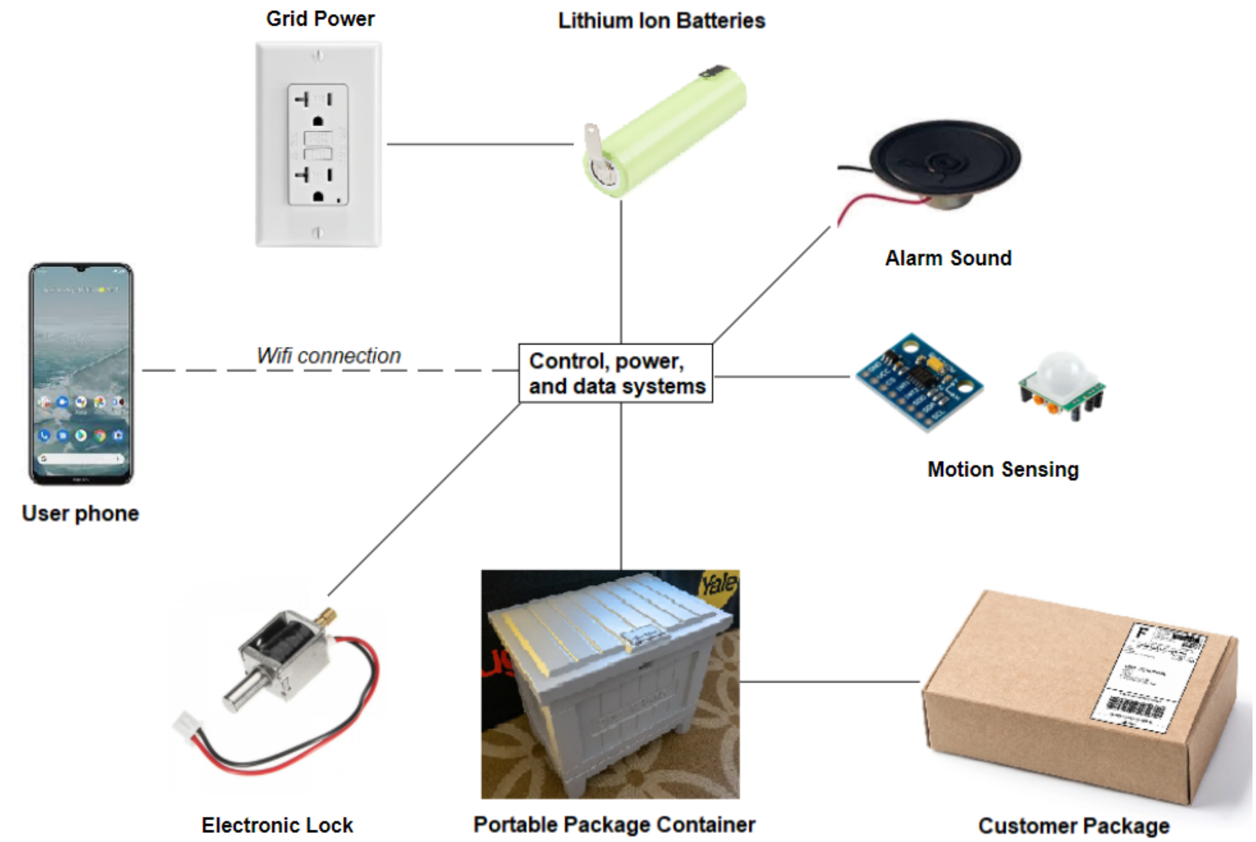
1.2 Proposed Solution

A portable package safe box that detects attempted theft would work to deter thieves. Packages would be placed inside a gated and alarmed crate that could be unlocked and disarmed through a passcode entered on a phone app so the person who ordered the product could access the contents. The container would be able to detect attempts to break inside such as damaging the exterior or by trying to move the container while it is still armed. A camera would be able to see if somebody is approaching the container and emit a warning chirp to deter people from coming any closer. If the tamper detection is triggered, an alarm system inside the box would sound, startling the person trying to steal the contents and drawing attention to them. The person who ordered the package would be immediately notified of the attempted theft over the app and be given the option to call 911. In case the thief decides to take the entire container and run, a GPS tracker would allow the person on the app to know where the package thief is and inform 911 operators of their location. After the person disarms the container and retrieves their package, they could return it to the delivery service and be refunded the money they spent on the package protection service.

1.3 Objective and Background

- Deter package theft in areas where delivery lockers may not be available
- Provide online retailers a means to ensure secure and delivery of goods to customers
- Mobile container for packages can easily be retrieved and redeployed by companies
- A plain and inconspicuous exterior prevent potential thieves from noticing the container
- Preventing theft will cut losses online retailers face due to refunding orders to customers

<u>**1.4 Visual Aid**</u>

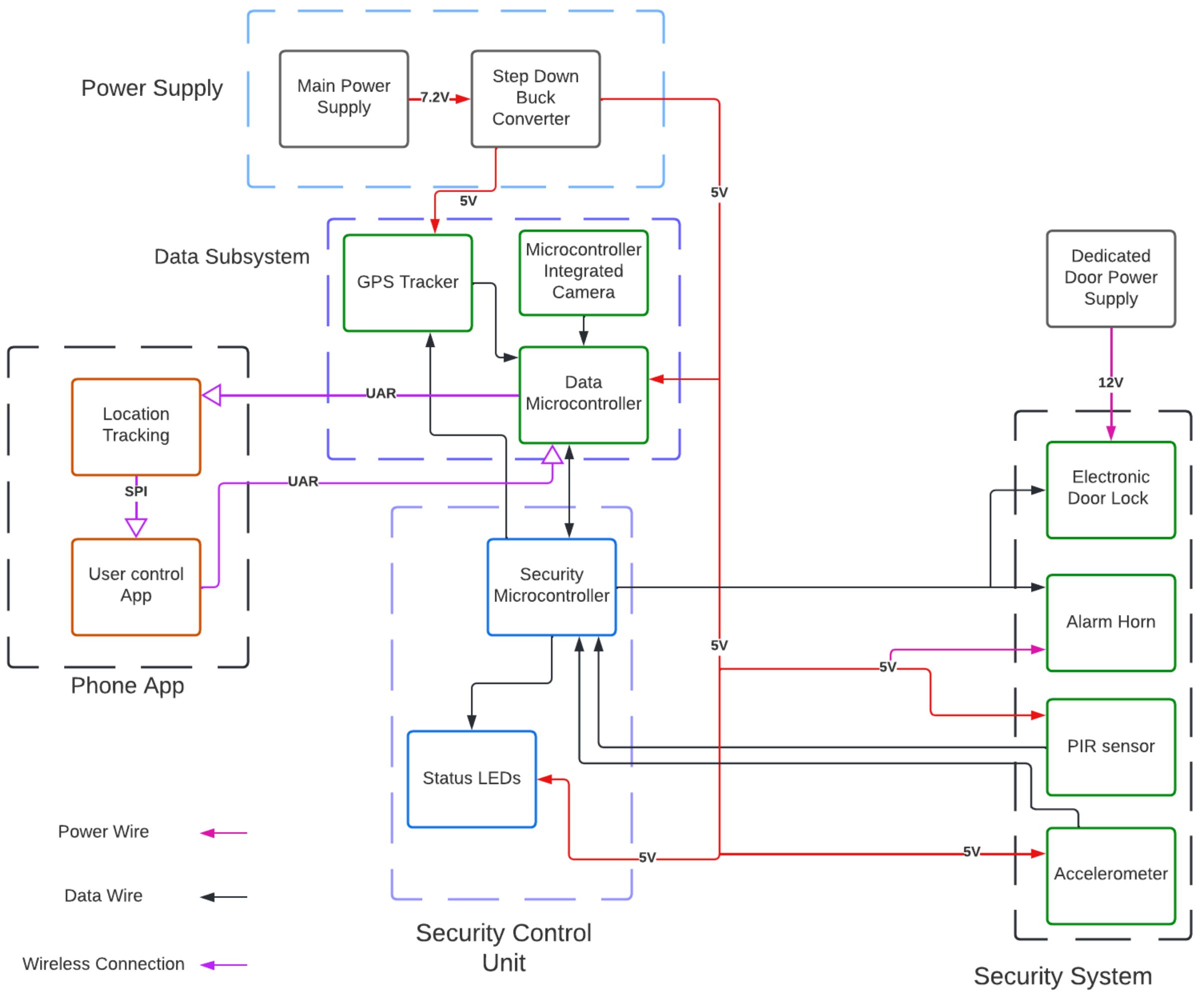


1.5 High Level Requirements

- Container must be able to communicate with a phone app that locks and unlocks the door to the package inside. The app must also be able to manually shut the alarm off in case of an accidental activation by delivery personnel or customers.
- The container's security measures must not become a nuisance for people who are minding their own business or be susceptible to frequent false positives. Maximum volume for the alarm must not exceed the threshold at which hearing can be damaged.
- Systems must be able to operate on battery life for up to 12 hours and be removed from the device to recharge when out of power. A low power mode that the system remains in until a possible threat exists will help to keep devices from being powered at unnecessary times.

2 Design

2.1 Block Diagram



2.2 Design & Subsystem Requirements

2.2.1 Main System Power Input

The power to operate the device will come from a network of lithium ion batteries. There will be two pairs of parallel-connected batteries. These two pairs will be connected in series, and a step down buck converter will be implemented in order to give our batteries the desired output voltage to our devices. Recharging will be done by removing the batteries from the container and charging them separately. This also allows the power supply to be quickly swapped out for charged batteries, allowing for an easy and cost-effective means of redeploying a drained unit. Power will be delivered to devices through transistors that allow for current supply to be toggled on and off by our microcontroller.

Requirement	Verification
Power system needs to deliver a voltage of 5V +/- 5% during operation	1. Measure the voltage drop starting from the output of our step down buck converter to ground

2.2.2 Security Microprocessor (ATMEGA48A-PU)

In order to control the operation of the security devices, we will utilize the I/O functionality of an ATMEGA48A-PU microcontroller. The microcontroller will monitor the readings from sensory devices such as our motion sensors and accelerometers and send activation signals to our front camera and alarm depending on the level of intrusion. In addition to monitoring the signals of sensory devices, the security microcontroller will also take input from our phone app through UAR delivered to our wifi module. This signal will be used to open our electromechanic door latch.

Requirement	Verification
Microcontroller needs to power on an alarm whenever the container is being stolen	1. Move the accelerometer connected to the microcontroller and observe if there is current flowing into the alarm speaker
Microcontroller needs to enter an alert state and sound an alarm chirp when the PIR sensor or Accelerometer detects motion	2. Trigger PIR and Accelerometer and measure if expected microprocessor output signals occur

2.2.3 Exterior Casing

A plastic box will house the circuitry that the device requires. Most of the volume will be a hollow chamber where a package to be delivered will be stored. A hinged door will allow the box to be opened and closed to allow for safe storage. For the purposes of this project we do not plan to construct a full casing, just the housing for the circuitry.

Requirement	Verification
Casing must protect circuits and components from damage	1. Apply stress to the casing and ensure that it is capable of protecting circuitry

2.2.4 Electromechanical Door Latch

The door to open the container will be secured by a spring loaded electronic latch. Its locking/unlocking operation will be controlled by our phone app, which will send a signal to our Wi-Fi module, which will then be delivered to the security microcontroller and finally to the powered latch. The latch is closed when in a “power off” state and pulled back to allow the door to be opened when in the “power on” state.

Requirement	Verification
Latch must open when prompted	1. Deliver a test input signal to the microcontroller and measure the current being sent to the latch
Latch must remain locked when not powered	1. Remove power to the system and verify that latch remains locked
Latch must be robust enough to not be broken into	1. Make a reasonable attempt to break into latch door and ensure that it is impossible

2.2.4 Passive Infrared (PIR) Sensor

These will serve as our motion sensors. Three of them will be used to cover the front and peripherals of the container. The main function these will serve will be to put the microcontroller into the alert state when motion is detected within a certain distance from the container.

Requirement	Verification
The detection range for the motion sensors needs to be a reasonable amount to prevent frequent and even annoying activations	1. Test varying ranges and coverages to determine an appropriate response level to trigger the system to move to an alert state
Sensors need to send a signal to put the microcontroller into alert mode when motion is detected	1. Read the current to our other devices when the container is in low power mode to ensure they are inactive 2. Activate the motion sensors and measure the current to devices again to see if they're being powered now

2.2.5 Alarm Speaker

This device will be our means to defend against thefts. When the container is moved while in the alert state, a loud alarm will sound, drawing attention to the package thief. The speaker will be activated through an output signal from the microcontroller. Its volume is controlled by the amount of voltage delivered to the device, ranging from 75dB at 3V to 100dB at 18V.

Requirement	Verification
The alarm horn must operate in a range of 3.3V-5.5V so as to be loud be also to not damage hearing	1. Measure the voltage drop across the speaker and ensure it remains within the desired range

2.2.6 Accelerometer

This system will toggle the microcontroller to the alarm mode when the container is being carried off by the thief by monitoring for changes in acceleration.

Requirements	Verification
Must communicate with the microprocessor to ensure proper data collection for state flow	1. Read the output of the accelerometer through the microprocessor to ensure proper data communication
Must be calibrated to ignore accelerations below a certain threshold to avoid unnecessary alarm triggers	1. Test varying rates of acceleration and record the accelerometer outputs to determine an appropriate threshold

2.2.7 Status LEDs

Two LEDs, one green and one red, will be located near the latch of the box. The LEDs will serve as a way to signal what state the system is currently in as well as a way to see if the box is currently charged or not.

Requirements	Verification
In each state the coordinating LEDs must be operating as expected Supervisor = Green Active = Solid Red Alert = Flashing Red Alarm = Flashing Red	1. When moving the system through all states the LEDs must receive updated signals and function as expected

2.3 Mobile User App

2.3.1 Language, framework, and systems for the App

There will be a mobile phone App for the device. The App will be Coded in Javascript and based on React Native. Since utilizing React Native framework, the App will be available on both Android and IOS.

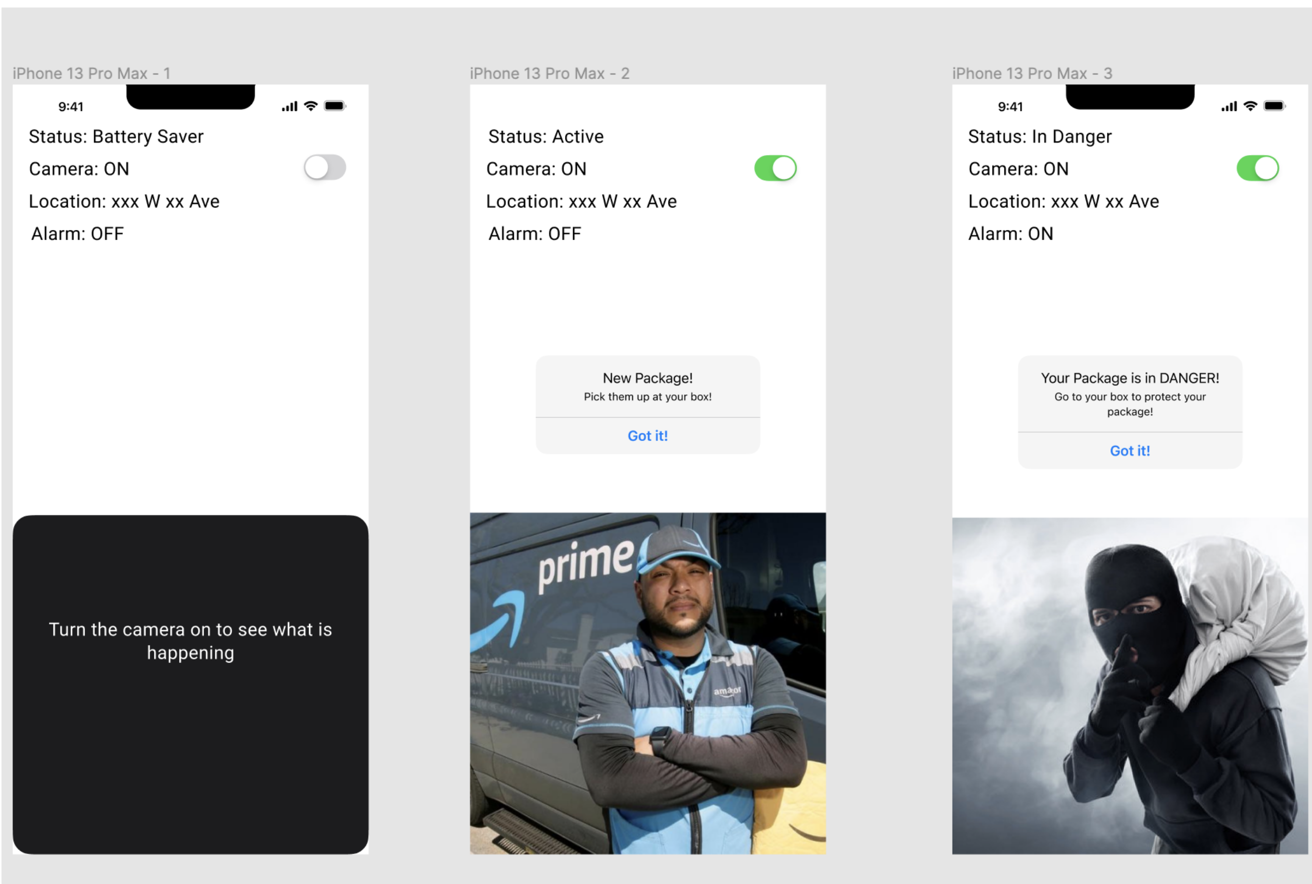
2.3.1 Notification & Alert

After the delivery crew drops the packages off, the alarm system will be activated and the app will notify users. After the alarm system is activated, the app will notify users when an attempted theft occurs.

2.3.3 User interface

The user interface will display some information and status of the device. The app will tell the user the mode of the device, location of the device, status of the camera, and whether the alarm is on. In addition,the device will be able to receive the photo/video the camera takes and uploads over the Wi-Fi module to the app for users to see what is in front of the device. An example of the user interface on an iOS device is below. In the case of an accidental activation of the alarm, the user interface will have a manual deactivation for the alarm.

Requirement	Verification
The App should notify users in less than 60 seconds when packages are dropped off or suspicious activities happen.	1. Manually trigger package drop and alarm signals repeatedly. Record how long it takes on average and make sure it is less than 60 seconds.
The device will be able to receive the photo/video the front camera takes and uploads over the Wi-Fi module	1. Make sure photos received by the the App is the same as what it is under stable WiFi connection



2.4 Data Subsystem

2.4.1 Data Microcontroller (ESP32-CAM)

Since processing and uploading images is beyond the computing power of the security system microcontroller, a separate microcontroller will be dedicated towards managing the Wi-Fi, GPS tracking, and imaging data that our system needs to process. Due to this device's rate of power consumption, it must only operate when told to do so by the security microcontroller (in alert or alarm state). This device has the added benefit of being outfitted with a Wi-Fi/Bluetooth module. This will allow us to seamlessly integrate wireless user control to the security and data systems.

Requirement	Verification
Data microprocessor must remain in a quick boot state when not in alert/alarm mode	1. Measure the current to the microcontroller when in the low power state to ensure it is running on minimal power draw
Microprocessor must receive signals from the user app through the Wi-Fi router.	1. Use a test button on the phone app to remotely turn on an LED through the microprocessor

2.4.2 Microcontroller Integrated Camera

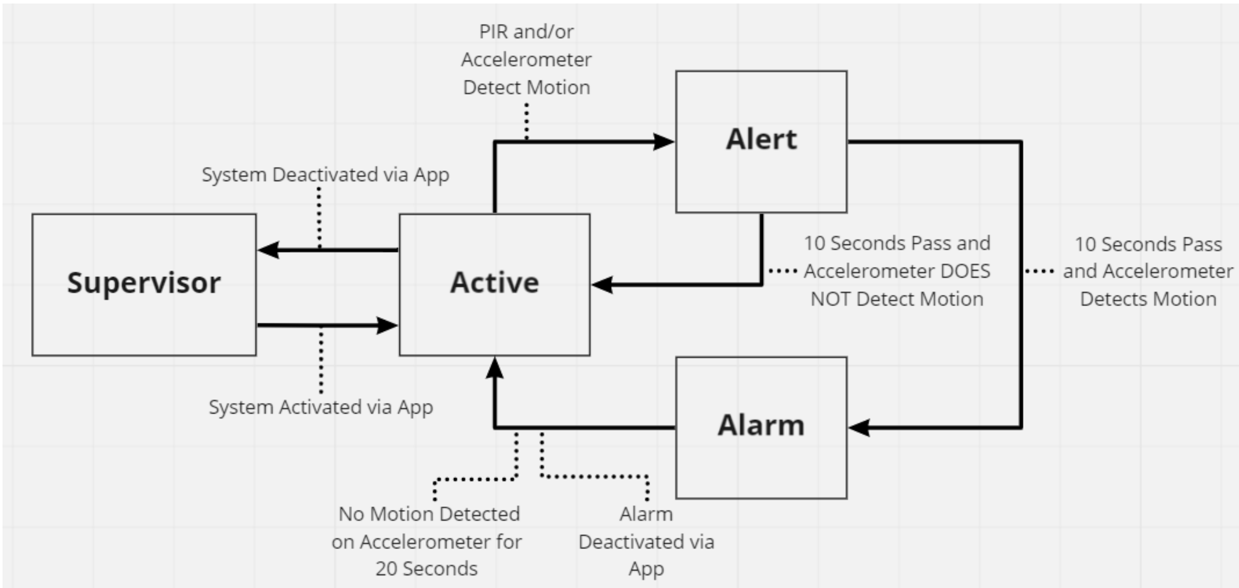
The ESP32-CAM comes with a compatible 720p camera. It's capabilities range from taking single photographs to recording video. This comes at the downside of requiring large amounts of power to run the camera. The datasheet estimates the power draw to this device during operation to be 2A -/+5%. It's operation must be limited only to taking snapshot photographs when the security system enters the alert/alarm state.

Requirement	Verification
The camera must remain inactive when the device is in the low-power/all clear state	1. Measure the current to the ESP32-CAM when in low power mode to ensure the camera is not drawing additional power

2.4.3 GPS Tracker

This system will allow companies to recover lost/stolen containers. As long as the container remains within range of Wi-Fi, the GPS data can be transmitted through the Wi-Fi module on the ESP32-CAM and delivered to the phone app.

2.5 State Diagram



State	Function
Supervisor	This is the disarmed state of the device. There is no security functionality other than the door being unlocked. Intended for use by the delivery person delivering a package or the customer picking it up
Active	Security system is armed and in low power. The only operating devices are sensory devices that will move to the alert state if they detect something.
Alert	A possible intrusion has been detected. Activated either by the motion sensors detecting movement too close to the container, or the container being moved slightly. A quick alarm chirp will sound to draw attention to the box and hopefully dissuade any possible thieves. If no acceleration to the container is detected within ten seconds, the container will revert to active mode.
Alarm	The container is currently being tampered with or being stolen. The speaker will emit an alarm approximately 85 dB in volume to draw attention to the thief. Once activated, a message will be sent to the user app informing them that a theft has been attempted. If the container experiences no acceleration for 20 seconds, it will revert back to active mode.

2.6 Tolerance Analysis

Our main issue of concern is that the container might turn out to be extremely annoying if its activation threshold is too sensitive. A gust of wind being enough to sound a blaring alarm in a quiet neighborhood isn't tolerable. We will need to properly calibrate our motion sensors and accelerometer to trigger at distances or accelerations that likely coincide with a theft. Since packages can be delivered in narrow hallways at apartments, an activation distance of the motion sensor should be somewhere within the range of 3-5 feet. More importantly, the alarm chirp does not need to play at the same volume as when a theft occurs. We aim to scale down the voltage to the speaker when the chirp is activated to 3.0-3.3V from the actual alarm's 4.5V-5.0V. This will drop the chirp volume from 85dB-90dB down to a much more appropriate 70dB-75dB.

Power consumption will be another hurdle for us to overcome since this is a portable device. With 5600mAh of power, we want our power draw during the low power mode to be within the range of 200-400mA. While in alert mode, the camera is our main power draw at 1.8-2.0A and will result in a total alert mode runtime of only 2.8-3.1 hours. Successfully implementing a low power mode to our circuit will be an essential task in this project.

3 Costs and Schedule

3.1 Costs

Labor

MAJOR	Employed Graduates	Graduates Reporting Salary	Average Salary	25th Percentile	50th Percentile	75th Percentile	Graduates Reporting Signing Bonus	Median Signing Bonus
Aerospace Engineering	22	17	$70,697	$66,500	$73,000	$79,000	9	$5,000
Agricultural & Biological Engineering*	27	19	$65,519	$56,000	$65,000	$72,500	--	--
Bioengineering	12	9	$62,411	$62,000	$65,000	$71,000	5	$5,000
Civil Engineering	58	45	$65,035	$62,000	$65,000	$67,600	22	$2,500
Computer Engineering	138	113	$99,145	$80,000	$100,000	$112,000	89	$15,000
Computer Science	94	69	$110,978	$93,000	$112,000	$126,000	58	$15,000
Electrical Engineering	65	52	$76,129	$71,000	$76,000	$82,000	37	$5,000

Our team is composed of two electrical engineers and one computer engineer. From the above chart in the 2019-2020 Illini Success Report, we can convert the salaries to hourly pay by assuming an engineer works 52 weeks for 40 hours per week. Giving us a total of 2080 hours. We are currently in the sixth week of the school year, leaving us with nine more full weeks until the conclusion of this class. Assuming we each work 12 hours a week, our cost estimate is as follows.

Member	Conor Mueller	Ethan Fransen	Yufei Zhu
Pay Rate	$36.60	$36.60	$47.67
Hours	108	108	108
Cost	$3952.85	$3952.85	$5147.91

Exterior Casing

It is important to consider the size of the exterior casing as that would be variable based on the size of the products wanting to be delivered. This would be the most expensive part of the product, as building a robust metal box would demand a high volume of expensive material. We do not plan on actually building this casing for our demo, but will assume we are creating a 12” x 12” x 12” box with ¼” thick walls. This would lead to a total volume of 207.125 cubic inches. Below are the costs of a few different types of metal at this volume.

Hot Rolled Steel (Grade A36)	$155.23	58.7 lbs
Aluminum (Grade 5052)	$224.90	20.2 lbs
Stainless Steel (Grade 304)	$524.95	59.86 lbs

Circuit Parts and Components

In order to build our circuit we must purchase the following parts. These will be used to make the security system functional.

Part	Part Number	Retail Cost
Accelerometer	ADXL345	$10.95
Electromechanical Latch	CABINETLOCK11	$10.95
GPS Module	SAM-M8Q	$42.95
Alarm Speaker	CE-C75	$3.98
Lithium Ion Battery x8	YXY-ICR18650-A-0001	$55.60
PIR sensor	NCS36000	$17.50

Security Microcontroller	ATMEGA48A-PU	$2.56
Data Microcontroller	B07S5PVZKV	$18.99
Status LED Red	YSL-R531R3D-D2	$0.45
Status LED Green	YSL-R531K3D-D2	$0.45
	Total Cost	$164.08

3.2 Schedule

Week	Dates	Goals
6	**2/21 - 2/27**	**Begin development of PCB board. Have rough idea finished by 2/27. Design the external housing of the container. Design UI for phone app.**
7	**2/28 - 3/6**	**Finalize the parts to order by 3/1. Make necessary changes to PCB board to integrate the parts. Buy parts for the container. Prototype security system circuit on a breadboard and code microcontroller. Get the ESP microcontroller to connect to our phone.**
8	**3/7 - 3/13**	**Finish rough assembly of circuit with microcontroller. Want the alert and alarm stages of the security system working by then. Develop code for the ESP microcontroller.**
9	**3/14 - 3/20**	**SPRING BREAK. Integrate phone app control to turn alarm system on and off. Assemble container.**
10	**3/21 - 3/27**	**Alter PCB board for security circuit if necessary. Buy new parts if it turns out some of ours won't actually work with our design. Update app to receive photos from camera on a manual signal.**
11	**3/28 - 4/3**	**Test security system while mounted on container and test the door lock. Continue testing camera/GPS with app.**
12	**4/4 - 4/10**	**Refine GPS/phone app code. Assemble final version of security circuit inside container.**
13	**4/11 - 4/17**	**Integrate GPS tracking and photo sending to the user app. Hopefully the app works by now and there are no issues in our security system.**
14	**4/18 - 4/24**	**Mock demo with TA. Note any flaws or shortcomings of our system and correct.**
15	**4/25 - 5/1**	**Pray and hope any changes we need to make are minor. Demo project and begin writing final paper.**
16	**5/2 - 5/9**	**Presentation and final paper due.**

4 Ethics & Safety

4.1 Ethical Concerns

The IEEE code of ethics states that we are obliged to "uphold the safety, health, and welfare of the public." From this guideline, we have identified a major risk our project could pose. Our lithium ion batteries are major fire hazards, and placing them at the doorstep of online customers places their lives at risk if we do not take the proper precautions when executing our design. We need to take proper precautions to ensure our device is not susceptible to overheating, and we need to ensure that our batteries will always be connected to the device in the correct orientation.

For safety concerns, we intend to ensure our voltage controller keeps our batteries operating at a voltage within the range of 3.6-5.0V per cell at all times. Otherwise, our development should be put on pause until we can acquire safer cells to use. Also, re-reading the handbook on proper procedure for handling batteries will be a must to ensure no mistakes are made.

5 Citations

[1] Rober, Mark. "EXPLODING Glitter Bomb 4.0 vs. Package Thieves". *YouTube* video, 18:27. December 13, 2021. https://www.youtube.com/watch?v=3c584TGG7jQ

[2] "Annual Reports." *Illini Success*, University of Illinois at Urbana-Champaign, https://illinisuccess.illinois.edu/annual-reports/.

[3] "How Many Work Hours in a Year." *Indeed Career Guide*, Indeed, 22 Feb. 2021, https://www.indeed.com/career-advice/career-development/how-many-work-hours-in-a-year.