ECE 445 SENIOR DESIGN LABORATORY

DESIGN DOCUMENT

Portable Anti-Theft Package Container

Team 44

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1 Introduction

1.1 Problem Overview

Nowadays, ordering products online is a common practice. All sorts of items ranging from entertainment devices to fresh groceries wait at the entrance to people's homes for hours on end. Unfortunately, this leaves unguarded packages vulnerable to theft by opportunistic individuals, also known as porch pirates.In 2021 over 210 million packages were stolen from porches, the majority of which were worth over $50 [1]. This crime is not only a major nuisance, but can have serious consequences when the stolen package contains essential items. This was the case when a porch pirate nonchalantly stole a young boy's chemotherapy medications – worth roughly $40,000 — that he needed to take daily to fight his systemic mastocytosis [2]. The worst part is that this problem is becoming more prevalent as online shopping continues to grow in popularity. There is very little deterrent to stop package thieves, as it is quite simple to do and get away with. Clearly something must be done.

Several potential solutions already exist, but they all have significant flaws. Installing a lockbox is quite expensive and requires a lot of space. Home security systems may serve as some level of deterrent, but are also expensive and can not actually prevent theft. Better delivery practices, like requiring a signature or picking up from a secure location are effective solutions, but they complicate the process more than necessary and can be annoying for both the customer and delivery service. An effective solution must deter theft, not cost too much, and avoid complicating the delivery process.

1.2 Proposed Solution

A portable, package safe container that detects and deters attempted theft would address many of the issues with current solutions. A customer would pay a small additional security fee and the shipping company would deliver the package inside an electronically locked and alarmed crate that can be disarmed via a phone app. While waiting outside someone's residence, the container would be able to detect nearby activity and play a warning noise if anyone gets too close. In case the thief decides to take the entire container and run, a loud alarm noise would play to startle the assailant and alert others nearby. An onboard GPS tracker can be triggered with the app to assist in locating the package. Once the package is retrieved, the customer could simply leave the container on their porch and mark it as ready for retrieval on the app.

1.3 Solution Benefits

- Affordable option for customers that does not require long-term commitment
- Highly modular to packages of all sizes and deliveries in all locations
- Seller greatly increases revenue by eliminating losses and generating a new source
- In worst case scenario GPS can locate circuitry for reuse
- Easy to control system through app
- Utilizes already existing delivery and retrieval routes

1.4 Visual Aid

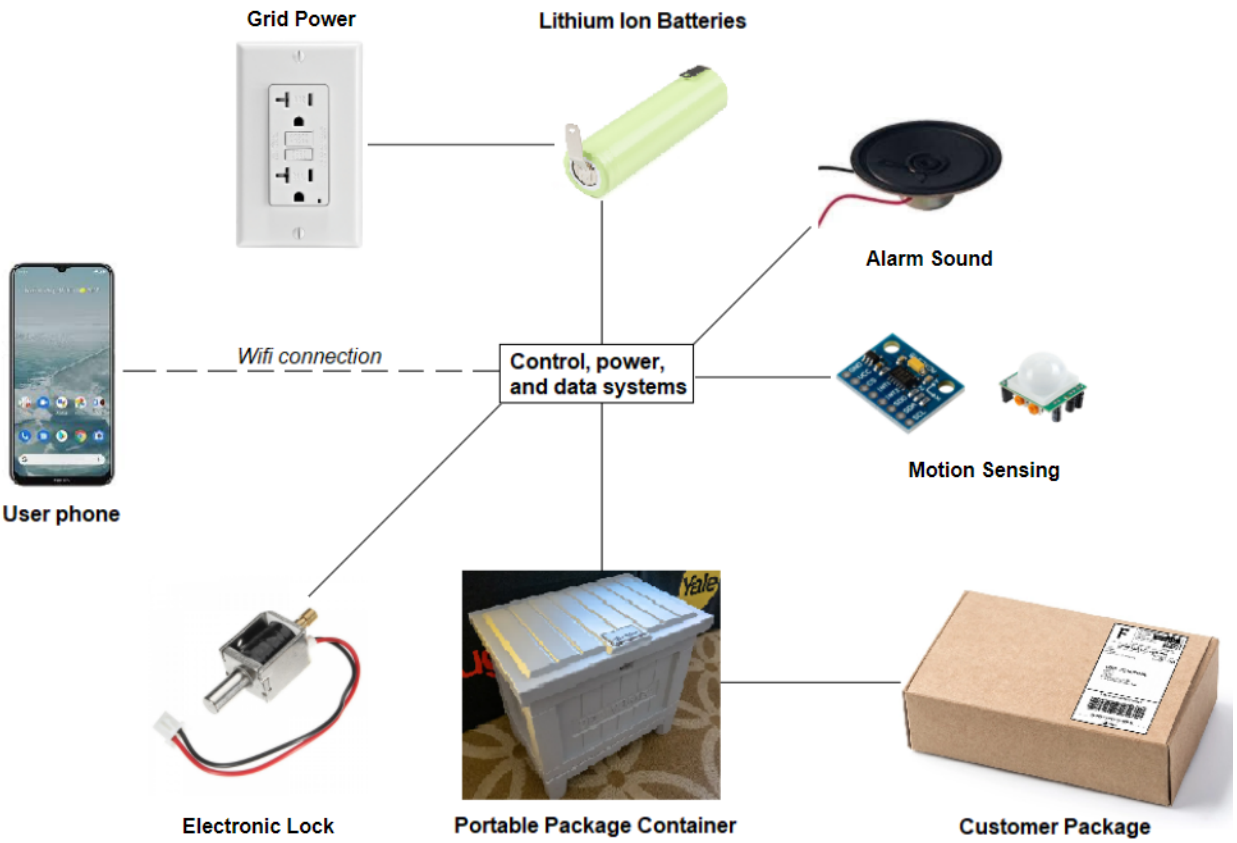


Figure 1.4: Design Visual Aid

1.5 High Level Requirements

- System must be able to communicate with the phone app to operate electronic lock, engage the alarm system, and remotely disable the alarm system in the case of an accidental triggering.
- System must last for at least 12 hours on one set of batteries and enter the active state when initially powered to be fail secure.
- System must only trigger an alarm when the package is actively being moved to prevent unnecessary power drain and avoid false alarms.

2 Design

2.1 Block Diagram

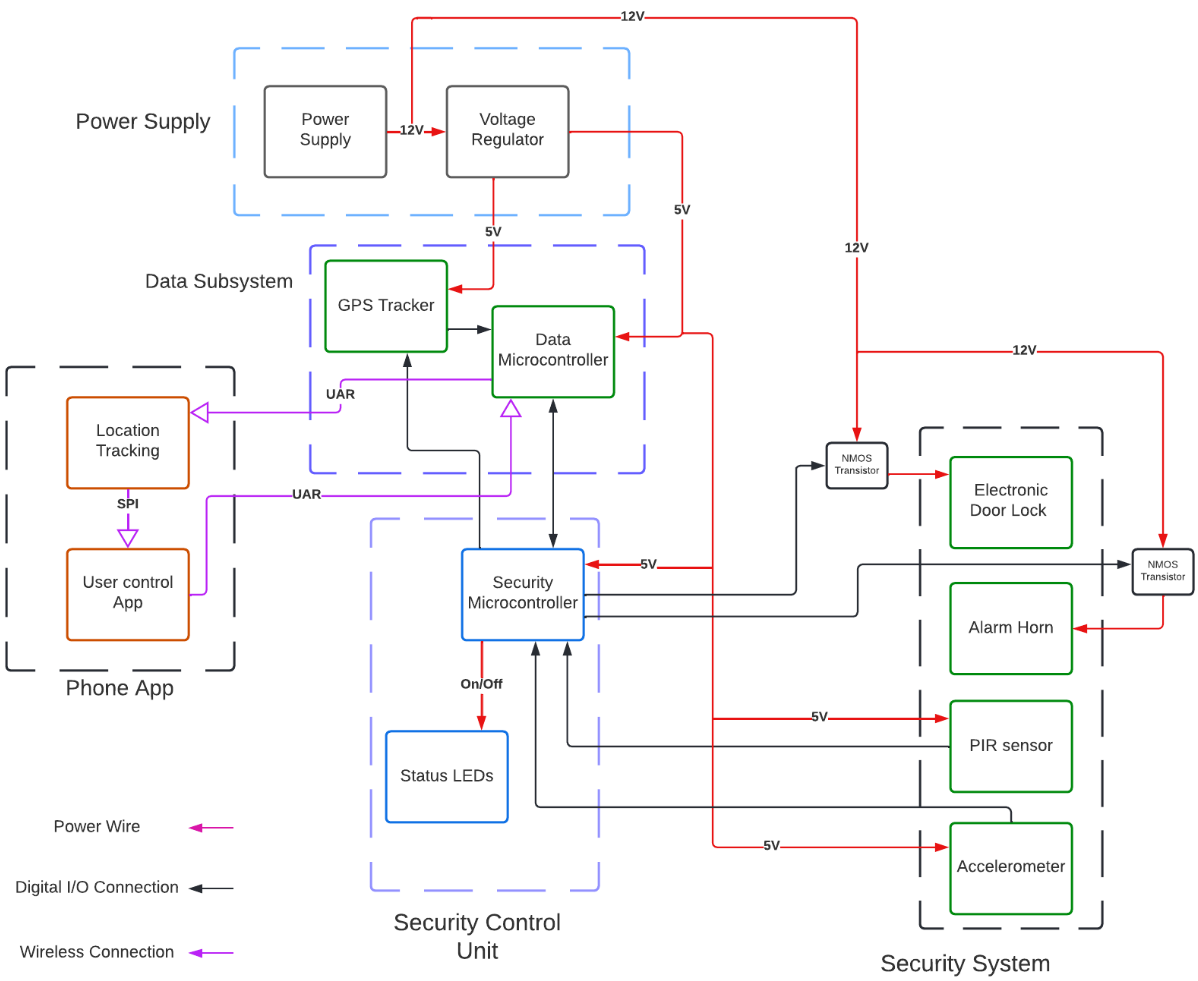


Figure 2.1: System Block Diagram

2.2 State Diagram

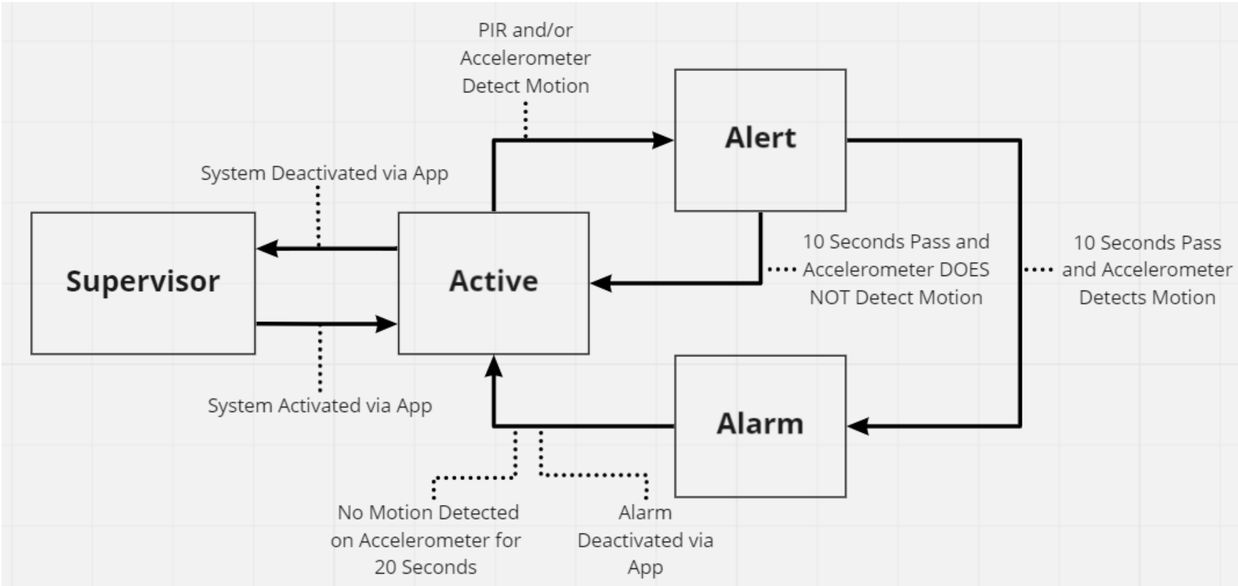


Figure 2.2: State Flow Diagram

Table 2.2: State Functions

State	Function
Supervisor	Security system is disarmed Status LED = Green
Active	Security system is armed Sensing devices are powered Status LED = Solid Red
Alert	Potential thief is detected Warning sound is played Status LED = Flashing Red
Alarm	Container is in motion Blaring alarm is played User is notified Status LED = Flashing Red

2.3 Security Subsystem

2.3.1 Exterior Casing

A robust metal casing will house the circuitry and package contents. The casing will be split into three distinct sections shown below (Figure 2.3.1). The casing can be of any size so long as it fits the package to be delivered. That being said, it must be large enough to sufficiently fit all of the circuitry, so while theoretically there is no maximum size, there is a limit on how small the casing can be. The cut zone serves as a last resort way of opening the casing in case of an unexpected failure, but it would require high powered tools and significant effort which prevents common thieves from cutting the casing and stealing the contents. The exterior will be resilient to blunt attacks and reinforced to prevent thieves from tampering with circuitry. The inside of the casing will be lined with a soft foam to dampen any motion of the contents inside the casing. For demo purposes this semester we do not plan on constructing a metal casing, but it is a crucial component of the design as it is the main barrier of defense from porch pirates.

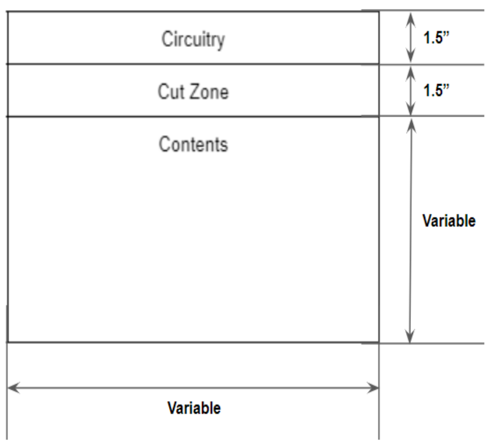


Figure 2.3.1: Casing Design

Table 2.3.1: Casing R&V

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

2.3.2 System Power *[YXY-ICR18650-A-0001]*

The power to operate the device will come from a network of rechargeable lithium ion batteries. The network will have an output voltage of 12VDC, but a step down buck converter will be implemented to power the 5V devices. New batteries can be swapped in if the box loses power and the system will start in the active state. Power will be delivered to devices through transistors that can be toggled on and off by our microcontroller.

Table 2.3.2: System Power R&V

Requirement	Verification
Li ion battery network needs to deliver a voltage of 12v ± 5%	Measure output of battery pack with multimeter and make sure it is in acceptable range
Step down buck convertor must deliver voltage of 5v ± 5%	Measure output of regulator with multimeter and make sure it is in acceptable range
Transistor must regulate power to devices	Test each transistor and ensure proper operation

2.3.3 Passive Infrared Sensor *[NCS36000]*

Our design will utilize three PIRs to serve as motion sensors. One PIR will be placed on each side of the box, leaving the fourth side to be placed against a wall by the delivery person. The PIRs will produce an output voltage proportional to the temperature they sense, which we will use to determine if someone or something is too close to the box.

Table 2.3.3: PIR R&V

Requirement	Verification
PIR must send signal to microprocessor when triggered	Measure output of PIR when tested under different coverages
PIR must be regulated to only trigger microprocessor when certain threshold is reached	Measure output above and below threshold using potentiometer and ensure proper delivery

2.3.4 Accelerometer *[ADXL345]*

The accelerometer is the main sensory element of the system. It is responsible for detecting if the container is in motion and is required to trigger the alarm state. This prevents unnecessary alarm triggers and ensures that an actual attempt to steal the package is being made before sounding the alarm.

Table 2.3.4: Accelerometer R&V

Requirements	Verification
Must communicate with the microprocessor to ensure proper data collection for state flow	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	Test varying rates of acceleration and record the accelerometer outputs to determine an appropriate threshold

2.3.5 Electromechanical Door Latch *[CABINETLOCK11]*

The container door will be secured with an electromechanical latch. Lock operation will be controlled through the phone app and will only be available when the box is in the Supervisor state. The latch is normally closed and will remain closed in the absence of power. The latch must secure the door well enough to prevent break-ins, and it must be inaccessible from the outside so that it can not be cut.

Table 2.3.5: Latch R&V

Requirement	Verification
Latch must open when prompted	Apply test signal and ensure latch opens
Latch must remain locked when not powered	Remove power to the system and verify that latch remains locked
Latch must be robust enough to prevent break-in attempts	Make a reasonable attempt to break into latch door and ensure that it is impossible

2.3.6 Alarm Speaker *[CED-ME516AQSW]*

This alarm speaker will be the biggest theft deterrent. The alarm will play a warning tone when in the alert state and a blaring alarm in the alarm state. The applied voltage determines the volume output, ranging from 75dB at 3V to 100dB at 18V.

Table 2.3.6: Alarm R&V

Requirement	Verification
Alarm must operate in 3v-18v range to prevent hearing damage	Measure alarm voltage under all possible circuit voltages and ensure limited output
Alarm must be able to chirp for alert state and blare for alarm state	Apply test signals and listen to alarm noise

2.3.7 Status LEDs *[YSL-R531K3D-D2 & YSL-R531R3D-D2]*

Two LEDs, one green and one red, will be located near the latch of the box. The LEDs will signal what state the system is currently and if the box is currently charged.

Table 2.3.7: LED R&V

Requirements	Verification
In each state the coordinating LEDs must be operating as expected	When moving the system through all states the LEDs must receive updated signals and function as expected

2.3.8 Security Microprocessor *[ATMEGA48A-PU]*

The security microprocessor will oversee the operation of all other security components. The microcontroller will receive calibrated inputs from the PIR motion sensors and accelerometer and provide appropriate output signals to the alarm and status LEDs. The security microcontroller will also take input from our phone app through UAR delivered to our wifi module that will trigger the release of the electromechanical door latch.

Table 2.3.8: Security Microprocessor R&V

Requirement	Verification
Microcontroller needs to move the system through the correct sequence of states when different input signals are met.	Use buttons to simulate input from accelerometer and PIR and use LEDs to make sure appropriate outputs are activated.

2.4 Data Subsystem

2.4.1 Data Microcontroller *[ESP32-CAM]*

In order to enable GPS tracking and app control our design must have Wi-Fi capabilities. The data microcontroller will be responsible for communications between the circuitry and app.

Table 2.4.1: Data Microcontroller R&V

Requirement	Verification
Data microprocessor must remain in a quick boot state when not in alert or alarm state	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.	Use a test button on the phone app to remotely turn on an LED through the microprocessor

2.4.2 GPS Tracker *[SAM-M8Q]*

This system will allow for the recovery of lost or stolen containers. The user can request the location of the package through the app, at which point the GPS tracker will receive power and send its location to the app. Afterwards the GPS tracker will stop receiving power to increase overall battery life.

Table 2.4.2: GPS R&V

Requirement	Verification
GPS tracker must send current location to app when it is pinged	Send test signal to GPS tracker and ensure that it sends location to smartphone within 30 seconds

2.5 Mobile User App

2.5.1 App Framework

Both other subsystems will be controlled through a smartphone app. The app will be coded in Javascript and based on React Native. As it will utilize the React Native framework, the app will be available on both Android and IOS operating systems. As stated above, the app will communicate with the circuitry through the data microcontroller.

2.5.2 Notifications & Alerts

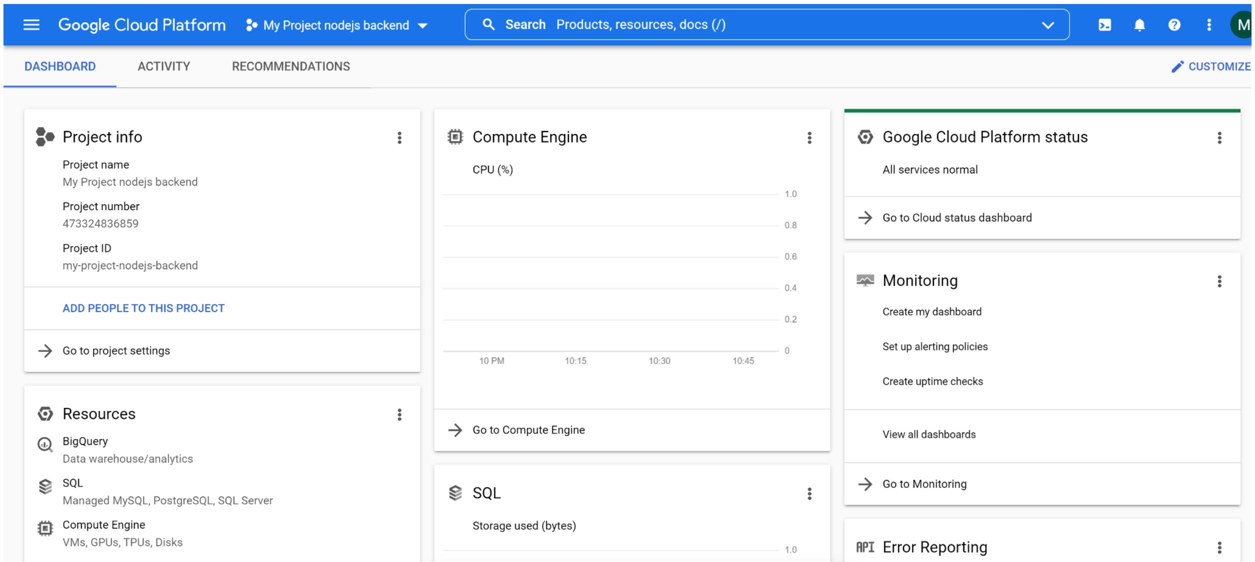
The app will update the user on the system status through the use of notifications and alerts. After the delivery crew drops the container off and activates the alarm system, the app will notify users that their package has been delivered. If the container ever enters the alarm state, the app will notify the user that an attempted theft has occurred. Once the container power supply is running low the app will alert the user and tell them to grab their package soon.

Table 2.5.2: App Notifications R&V

Requirement	Verification
App must notify users within 60 second of alarm trigger	Intentionally trigger security system and see how long it takes for a notification to appear

2.5.3 User Interface

The user interface will display the system information and allow for user control. An example of the user interface is below. The user interface will display the system state, estimated battery life, and the most recent location data received. There will also be options for the user to deactivate the security system, request a location update, and mark the box as ready for pickup.


Google Cloud Platform
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ACTIVITY
RECOMMENDATIONS
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Go to project settings
Resources
BigQuery
Data warehouse/analytics
SQL
Managed MySQL, PostgreSQL, SQL Server
Compute Engine
VMs, GPUs, TPUs, Disks
Compute Engine
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0.8
0.6
0.4
0.2
0
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10:15
10:30
10:45
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SQL
Storage used (bytes)
1.0
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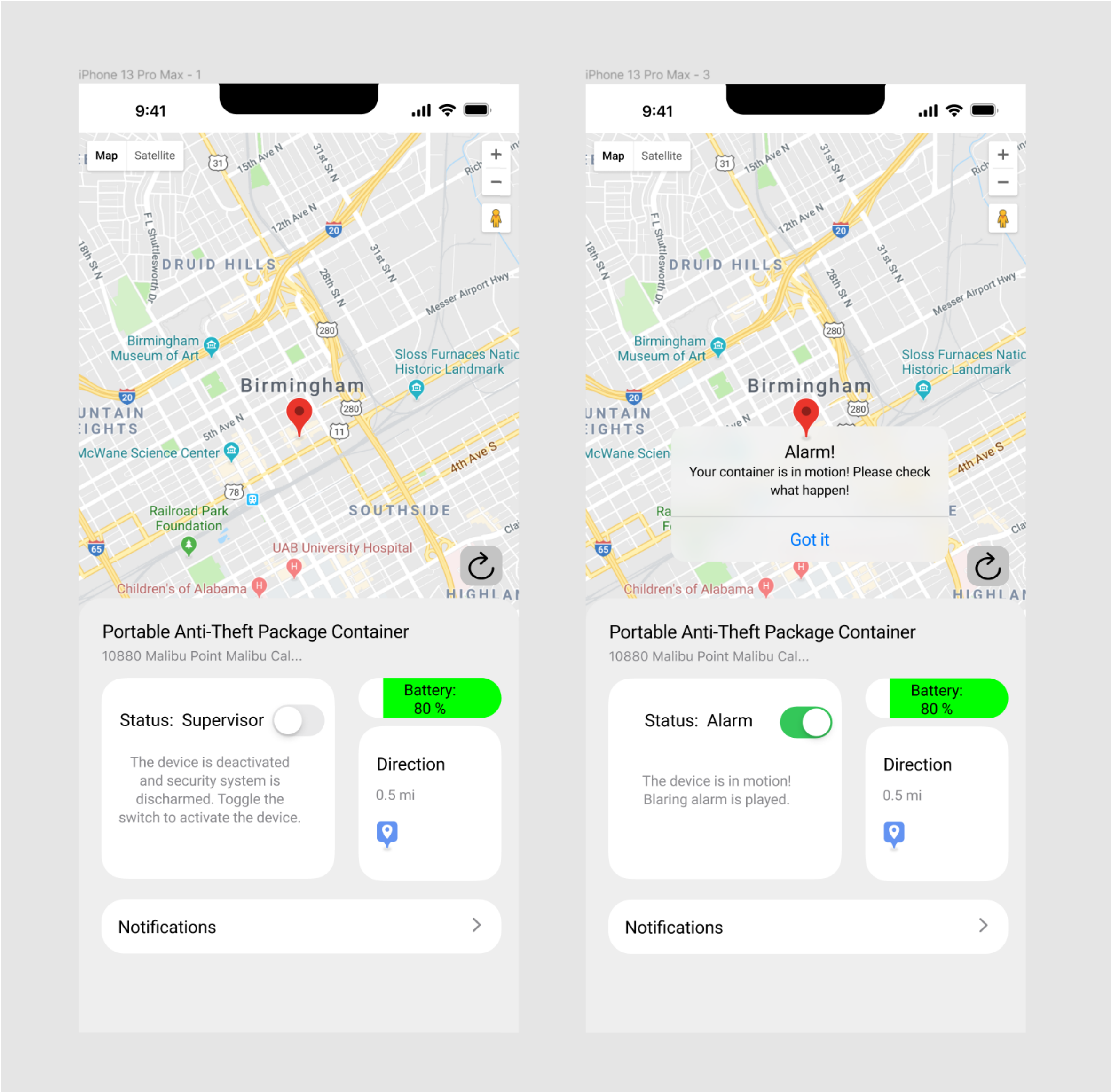
All services normal
Go to Cloud status dashboard
Monitoring
Create my dashboard
Set up alerting policies
Create uptime checks
View all dashboards
Go to Monitoring
API Error Reporting


iPhone 13 Pro Max - 1
9:41
Map
Satellite
DRUID HILLS
Birmingham
Birmingham Museum of Art
Sloss Furnaces Natic Historic Landmark
McWane Science Center
Railroad Park Foundation
SOUTHSIDE
UAB University Hospital
Children's of Alabama
Portable Anti-Theft Package Container
10880 Malibu Point Malibu Cal...
Status: Supervisor
The device is deactivated and security system is discharmed. Toggle the switch to activate the device.
Battery: 80 %
Direction
0.5 mi
Notifications
iPhone 13 Pro Max - 3
9:41
Map
Satellite
DRUID HILLS
Birmingham
Alarm!
Your container is in motion! Please check what happen!
Got it
Children's of Alabama
Portable Anti-Theft Package Container
10880 Malibu Point Malibu Cal...
Status: Alarm
The device is in motion! Blaring alarm is played.
Battery: 80 %
Direction
0.5 mi
Notifications

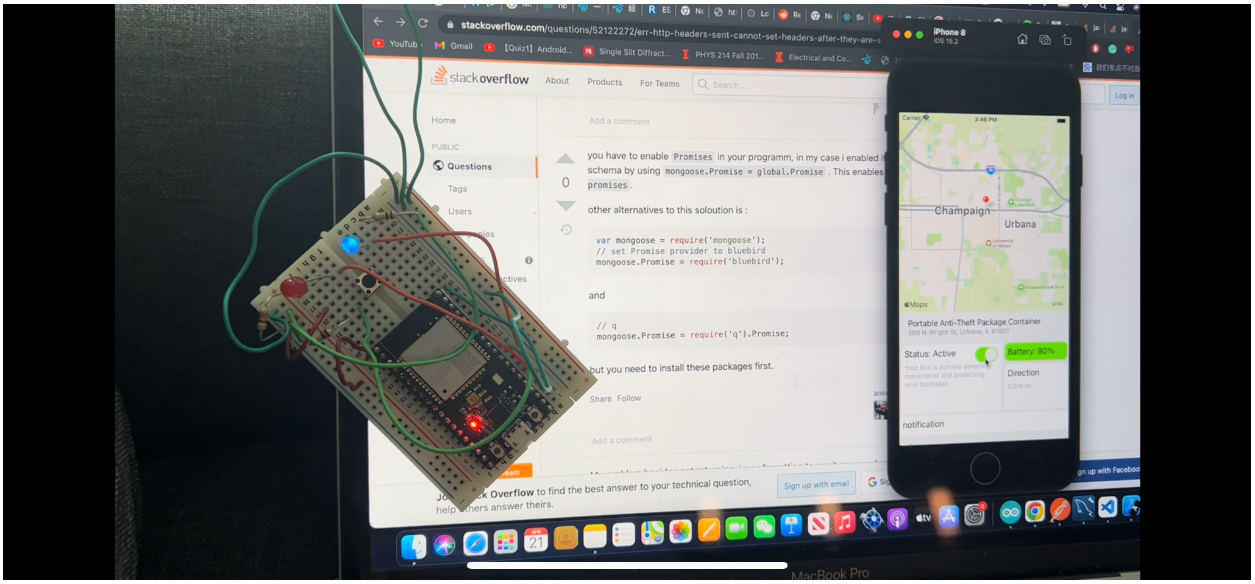


Figure 2.5.3

Table 2.5.3: App UI R&V

Requirement	Verification
App must be able to enable and disable security system (+ update status display)	Measure output of data microcontroller after sending activation signal from app
App must be able to request GPS location data and location display must update when new GPS data is received	Measure output of data microcontroller after sending data request and verify that display updates accordingly

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 is not 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 4.5-5.0v. 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

3.1.1 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

Figure 3.1.1: Salary by Major of UIUC Graduates

Our team is composed of two electrical engineers and one computer engineer. From the above chart (Figure 3.1.1) in the 2019-2020 Illini Success Report [3], 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 [4]. 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.

Table 3.1.1: Labor Costs

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

3.1.2 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.

Table 3.1.2: Exterior Casing Costs

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

3.1.3 Circuit Parts and Components

The table below (Table 3.1.3) contains the list of all the parts necessary for our project and their costs. The batteries and GPS module each make up roughly ⅓ of the cost.

Table 3.1.3: Component Costs

Part	Part Number	Retail Cost
Accelerometer	ADXL345	$20.50
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	$173.53

3.2 Schedule

Week	Date	Conor	Yufei	Ethan
6	2/21 - 2/27	Begin development of PCB board.	Design the functionality and UI for the phone app.	Design the external casing of the system.
7	2/28 - 3/6	Make necessary changes to PCB board to place order on time.	Purchase Wi-Fi microcontroller. Finalize app design.	Finalize parts to order and prepare for circuit assembly.
8	3/7 - 3/13	Finish rough assembly of circuit with microcontroller.	Complete the coding of the UI part of the app	Finish rough assembly of circuit with microcontroller.
9	3/14 - 3/20	SPRING BREAK Update PCB with revisions	SPRING BREAK Integrate app control with the alarm system	SPRING BREAK Assemble exterior casing
10	3/21 - 3/27	Finalize PCB board and begin integrating circuitry.	Make the app be able to communicate with the device via Wi-Fi	Purchase any components that we may need for final PCB
11	3/28 - 4/3	Wire components and make sure state flow moves as designed	Ensure functionality of app communications	Perform tests on all components and set sensor thresholds
12	4/4 - 4/10	Assemble final version of security circuit inside container.	Set up GPS data sharing between module and phone app.	Integrate everything into single unit and prepare demo tests

13	4/11 - 4/17	Make any last minute corrections and prepare for mock demo	Make any last minute corrections and prepare for mock demo	Make any last minute corrections and prepare for mock demo
14	4/18 - 4/24	Mock demo with TA. Make any necessary changes to demo and presentation.	Mock demo with TA. Make any necessary changes to demo and presentation.	Mock demo with TA. Make any necessary changes to demo and presentation.
15	4/25 - 5/1	Work on writing the final paper and finalizing our presentation.	Work on writing the final paper and finalizing our presentation.	Work on writing the final paper and finalizing our presentation.
16	5/2 - 5/9	Presentation and final paper due.	Presentation and final paper due.	Presentation and final paper due.

4 Ethics & Safety

4.1 Ethics

In our design of this product we pledge to uphold the IEEE code of ethics to the best of our ability. This includes holding the highest standards of integrity, responsibility, and conduct. Part of this is “upholding the safety, health and welfare of the public”, which is important to consider in our design. Our device must perform its function of protecting packages from thieves while also not being disruptive to the public peace.

4.2 Safety

The largest concern for our project in this regard is ensuring the safety of its use. We must consider the volume output of our device and ensure that it is not high enough to cause permanent hearing damage. We must ensure that the package does not trigger unnecessarily so as to not disturb the welfare of the public. Additionally, we must take care to prevent the risk of fire that is associated with using lithium ion batteries.

Specifically, we must regulate the decibel output of the alarm to prevent it from exceeding 120 decibels [5]. The alarm system will not trigger unless the package experiences an acceleration to prevent causing a disturbance for no reason. While we do not yet have a good threshold for a warning signal, it must not be going off too frequently or cause too large of a disturbance. We will regulate the voltage output of the batteries and house them in a fire-proof container away from the package and other circuitry.

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