Department of Electrical and Computer Engineering Technology (ECET)
Division of Engineering, Computer Programming, and Technology (ECPT)

EET 4910

Senior Design Proposal

The Smart Cooler

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Abstract

Coolers are simply used as a portable way to keep things cool, whether it be drinks or food, among other things. Unfortunately, though coolers can prolong the state of ice, the ice will melt over time. Perishables need to be maintained at a certain temperature to prevent mold and bacteria growth. The ideal cooler would be able to maintain a certain temperature for an extended period of time. When going camping, to the beach, or even a party outing, there are no power outlets nearby. There is no access to refrigerators. Coolers are mainly designed to retain ice, but what if it could do more than that.

Given the state of IoT devices that are blooming in this generation, why not a cooler? To keep perishables from going bad, the Smart Cooler has a built-in refrigeration unit to maintain a desired temperature, which in turn keeps the ice from melting. Charging devices can easily be done with wireless or wired charging. A locking mechanism prevents the Smart Cooler from being opened by animals or unexpected visitors. An LED strip activates when it is dark or manually to provide light inside. GPS tracking shows the last known location of the Smart Cooler, allowing someone to find their campsite. Bluetooth speakers are built into the cooler to provide entertainment for any scenario. The cooler will feature an automated lid and retractable cutting board. A touchscreen GUI allows the user to monitor temperature, battery life, and settings. The temperature can also be monitored through an app, which also functions with the GPS system. The Smart Cooler features rechargeable batteries that can be charged from a 120V AC outlet, a 12V car port, or through a solar panel.

Having a cooler with these kinds of capabilities has many advantages, and provides an all-in-one solution for any outdoor event. Though the Smart Cooler is intended for outings, it has implementations in the medical field, where vaccines need to be kept at a certain temperature, or organs and tissues need to be kept in ice. Just as with the medical field, the food industry could benefit from a refrigeration cooler.

Acknowledgements

We would like to thank Professor Notash for his assistance and guidance throughout the proposal process. The weekly meeting following suggestions and improvements to the project really helped to set apart our idea from any other out there.

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Chapter 1

Introduction

Summary

The Smart Cooler is designed to be a multipurpose all-in-one cooler used for any scenario. The cooler features temperature regulation for multiple compartments, Bluetooth and detachable speakers, wireless and USB charging, an RFID locking mechanism, GPS tracking, rechargeable batteries, multiple external charging options, touchscreen interface, mobile app support, interior LED lights, cup and flashlight holder, and bottle opener.

1.1 Introduction

The cooler is a ubiquitous part of society. It solves the problem of being able to keep something cold when taken out and away from a refrigeration unit. The material and insulation used to make a cooler helps to maintain the interior temperature colder than the exterior temperature. Heat transfer causes heat to naturally flow from hot to cold surfaces [1]. The radiation from the sun warms the atmosphere, and the warm air warms the surfaces it touches. The insulation in coolers helps to keep the heat from outside to transfer into the ice inside.

However, ice must be bought and poured into the cooler along with the items meant to be chilled so that the temperature reaches that of the ice. Though the insulation of the cooler helps regulate the temperature inside, the ice will eventually melt. Therefore, either the ice will completely melt and the temperature will reach exterior temperatures, or the ice needs to be replaced to maintain a cold temperature. Having to drain the water and replace the ice, to leave the site to find the nearest store with ice every day, can cause an inconvenience.

1.1.1 Motivation

Given the functionality of a cooler, the ability to maintain temperatures below the outside temperature is vital for any sort of outing. Whether it be at the beach, camping, or at work, food can be preserved and drinks can be kept cold even when away from a power source. However, the utility of a cooler can be improved upon. The motivation to improve upon the design of a simple cooler has many beneficial applications. The majority of cooler utility is to keep food and drinks cold, but the applications expand beyond that. If ice can be prolonged and the temperature inside the cooler maintained, the medical field and food industry can benefit from this.

1.1.2 Objective and Features

The Smart Cooler was planned and designed to have general functionality for any scenario. The main functionality for the cooler will be to maintain the desired temperature. Once power is provided to the cooler to help maintain the temperature, the

possibilities open up for more functionality. When at the beach, ideally drinks would be ice cold and opened with a bottle opener while music plays through waterproof Bluetooth speakers. When camping, perishables need to last multiple days, so ideally, they are kept in coolers. The risk of bears looking for food can be prevented with a locking mechanism for the cooler. If the cooler has GPS functionality and the group becomes lost while exploring, the cooler location can be used to find the campsite. At night, an interior LED could make it easier to find things inside. App connectivity suddenly turns an ordinary cooler into a Smart cooler, where the temperature can be monitored or adjusted. All of this will be powered by rechargeable batteries that can be recharged through an outlet, a 12V car port, or solar panel.

Temperature Regulation for Multiple Compartments

The main functionality for the Smart Cooler is to maintain the desired temperature set by the user. Two separate semiconducting refrigerating units are used, which converts electrical energy into thermal energy using the Peltier effect. This will allow the ice in the cooler to last longer than the typical cooler.

Entertainment

Bluetooth speakers attached to the cooler provide ample entertainment for any outing scenario. The speakers will be waterproof as they will be used for outdoor speakers.

Power Source

Since typically coolers are used in outings, using the cooler power source as a charging bank for portable devices adds another utility to those who will spend extended periods of time from a power source. Wireless charging as well as wired charging will be provided.

RFID Locking Mechanism

Animals have a keen sense of smell and tend to rummage around looking for food. Providing the cooler with a RFID locking mechanism prevents food and drinks from

being scavenged out of the cooler. It also prevents unwanted guests from opening the cooler as well.

GPS Tracking

Since coolers tend to be left at the campsite when camping, providing the user a means to locate the campsite via the cooler provides survival functionality. GPS does not require data or internet, so may be used in the woods.

Rechargeable Batteries

The batteries powering the cooler require an ample amount of amperage. Therefore, the cooler will be given rechargeable batteries as a renewable resource of energy.

Multiple External Charging Options

The rechargeable batteries will be able to be charged through a 120V AC outlet, a 12V car port, or a 12V solar panel.

Touchscreen Interface

A graphical user interface will be designed to be used on a touchscreen interface for intuitive use. The temperature will be displayed for each compartment, along with setting temperatures and accessing settings.

App Support

Temperature monitoring and setting will also be accessible via a mobile app designed for both Android and iPhone support. The mobile app will interact via Bluetooth to communicate with the microcontroller.

Night Light

Given there are no lights in locations like the woods, the cooler will have its own LED light built into the inside. A sensor will sense when it is dark outside and activate the light when the cooler is opened.

Automated Lid

The lid will be controlled by a servo that gives the option to automate the opening and closing of the lid.

Retractable Cutting Board

A retractable cutting board will be attached to a servo to control the extending and retracting of the cutting board.

Structural Utilities

The cooler will have cup holders, as well as a bottle opener. A flashlight holder will also be built into the cooler.

1.2 Similar and Existing Products

Similar products have been produced with tremendous interest and success. Using crowdfunding sites like Kickstarter and Indiegogo, two Smart coolers that stand out are the INFINITE Smart cooler and The Coolest Cooler.

1.2.1 INFINITE

The INFINITE Smart cooler can be found on Indiegogo. The campaign has been closed, raising $136,106 out of its flexible goal of $25,000 [2]. The cooler features a 550W blender, wireless charging, LED light, HD built-in camera, Hi-Fi dual-powerful Bluetooth speakers, digital screen and easy-touch buttons. It has foldable side handles, large sturdy

wheels, side storage, multifunction utensils and cutting board, and 61 quarts capacity. The cooler claims 7 to 12 days of ice retention [2].

This cooler highlights the importance of functionality. Coolers are used for party outings and can function as an all-in-one cooler.

Figure 1.1: The INFINITE Smart Cooler [2]

1.2.2 The Coolest

The Coolest Cooler is considered one of the most successful Kickstarter of 2014, and also considered one of the biggest Kickstarter disasters. The campaign raised $13,285,266 from 62,642 backers [3]. Ultimately, the founder was unable to provide 20,000 backers with coolers, blaming tariffs imposed on products imported to the US from China [4]. However, this Kickstarter highlights the demand for a multifunctional Smart cooler with diverse applications.

This cooler featured an 18V battery powered rechargeable blender, removable waterproof Bluetooth speakers, USB charger, LED lid light, gear tie-down, cooler dividers and cutting board, extra wide easy rolling tires, integrated storage for plates and knife, and bottle opener.

Figure 1.2: The Coolest Cooler [3]

1.2.3 Feature Comparison

The Smart Cooler was designed taking into account the features of several other coolers currently on the market and those that are projected to be released in the near future. When compared to the two most high-profile coolers on the market, INFINITE and The Coolest Cooler, the Smart cooler as designed will offer features comparable to those on offer and features that can't be found anywhere else on the market. Figure 1.3 lists the features on offer by all three coolers. It also must be stated that the version of the INFINITE that is being considered is the highest version offering all features that are on offer.

Features	The Smart Cooler	INFINITE	The Coolest Cooler
Active Refrigeration	☑	☐	☐
Wired Charging	☑	☑	☐
Wireless Charging	☑	☑	☑
Automated Lid	☑	☐	☐
Blender	☐	☑	☑
Lock with keyless Entry (RFID)	☑	☐	☐
LED	☑	☑	☑
Camera	☐	☑	☐
Bluetooth Speakers	☑	☑	☑
Touch Screen Display	☑	☑	☐
Wheels	☑	☑	☑
Handles	☑	☑	☑
Side Storage	☐	☑	☐
Cutting Board	☑	☑	☐
Gear Tie Downs	☐	☐	☑
Cooler Dividers	☑	☐	☑
Bottle opener	☑	☑	☑
GPS	☑	☐	☐
Cup Holders	☑	☐	☐
Flashlight Holder	☑	☐	☐
Solar Panel	☑	☐	☐
Multifunction Utensils	☐	☑	☑

Figure 1.3: Smart Cooler Comparisons

1.3 Smart Cooler Survey

A survey was conducted as a sample size to represent the general population. The survey is shown in Appendix B with each question asked. The survey resulted in 47 responses,

and the responses can be found in Appendix C. The first question of the survey asked what was the feature the participant would be most excited about.

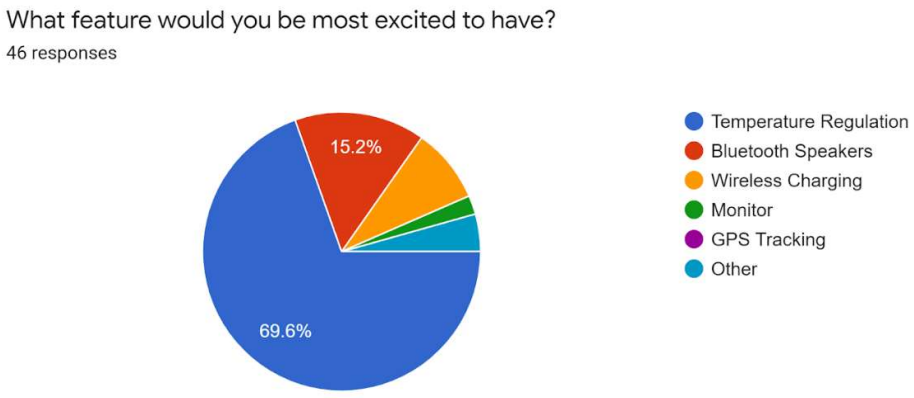

Figure 1.4: Smart Cooler Survey Question 1 Results

The results show that out of the six choices, the most dominant desired feature is temperature regulation, with 69.9% of the votes. Second and third were Bluetooth speakers and wireless charging, respectively. The INFINITE Smart cooler and The Coolest Cooler both do not have any sort of refrigeration system for temperature regulation besides insulation.

The second part of the survey asked what features would be desired for a Smart cooler that wasn't mentioned. The results can be summarized as follows:

- Wheels that work on multiple surfaces
- Temperature monitoring through an app or digital screen
- Removable freezer blocks that can create dividers, shelves, and integrate into the lid
- Notification when the ice melts
- Maintain different temperatures for different compartments
- GPS tracking and a way to contact emergency services
- Screen to play games
- LED light inside

Though there were already plans to implement some of these features such as temperature monitoring through an app or different temperatures for different compartments, the other suggestions were nice additions that were considered for the project. Several of these proposed ideas were not implemented in the two most successful

crowdfunded campaigns that were found. Therefore, valuable data was obtained from the survey.

Finally, to have a general idea of what the cooler would most often be used for, the survey asks where the participant would use the cooler most often.

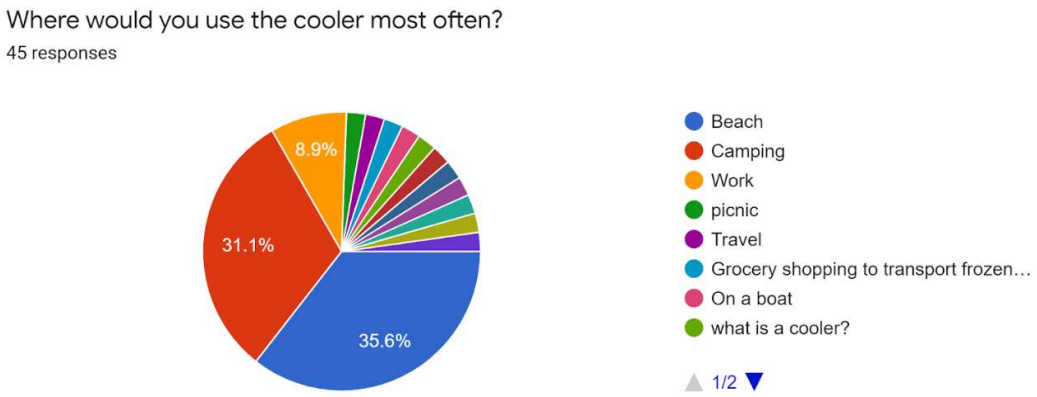

Figure 1.5 Smart Cooler Survey Question 3 Results

The majority of the results were split between camping and the beach as the places the cooler would be used most often. With these results, the focus of the project was to obtain features that would be most beneficial to people mainly to those kinds of outings. The question was also open for suggestions, which show other uses such as for picnicking, travel, grocery shopping, etc.

Chapter 2

Proposed Work

Summary

Planning of the Smart Cooler was done by starting with a block diagram. Engineering specifications and power budget show the justifications for the parts selected for the modules. Each part is described in detail to highlight their contribution to the overall functionality of the project. These parts will be thoroughly tested with success criteria to make sure the modules work as expected every time.

2.1 Introduction

The Smart Cooler will provide mobile active refrigeration for multiple compartments with the capability of controlling the temperature of each compartment independently. With this active refrigeration system, we expect to have the capability to maintain solid ice for seven days. The user will have two methods to control the temperature in the cooler, a mobile app and a touchscreen mounted on the lid. Additional features to improve the operation of the cooler will be a battery system that will support wireless and wired charging options as well as supply power to the cooler's main systems, the ability to charge the batteries from a number of exterior inputs, a solar panel installed to help with power needs and charging, a locking system with mechanism and sensor to track if the lid is open or not, and a GPS module to track location.

For entertainment and convenience, the Smart cooler will also have Bluetooth speakers, cup holders, an automated mechanism to open and close the lid, as well as a retractable cutting board, an internal led light in the cooler that turns on when it is dark outside, an app that can report in real time the status of the cooler temp and alert the user if there is a problem, and wheels for ease of transport.

2.2 Proposed Systems

This section contains the Design Engineering Requirements, Design Engineering Specifications, and Block Diagram. The features that the cooler will have, along with what components each feature will have and how the features will function as modules are gone into detail.

2.2.1 Design Engineering Requirements

The Smart Cooler has been designed around several systems and functions. Table 2.1 lists the required functions that were chosen for the Smart Cooler based on the description of the proposed project.

Table 2.1

Design Engineering Requirements

High-Level Requirements	• Temperature Regulation in both compartments • Ice retention for a minimum of 7 days • Minimum active operation of all systems 12 hours • Multiple Exterior input Charging options • Mobile App functionality • RFID Keyless entry
Mid-Level Requirements	• Wireless/Wired Charging options • GPS Tracking • Locking Mechanism • Bluetooth Speakers • Mechanized lid opening and closing • Solar Panel integration for battery charging
Low-Level Requirements	• Cup Holders * • Wheels * • Storage Space * • Interior LED • Retractable Cutting board • Flashlight holder *Denotes features that will be covered in the Shell of the cooler

2.2.2 Block Diagram

The block diagram shows each module that the cooler will have. There are nine modules in total, as shown in Figure 2.1, represented by the colored blocks. Figure 2.1 is a block diagram which details how the different modules will work together to create the entire system.

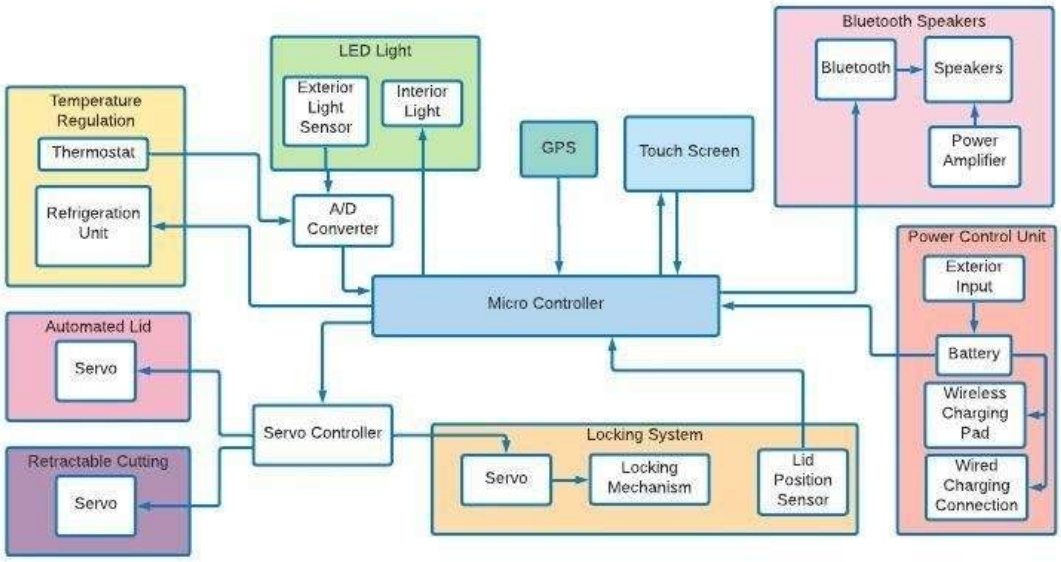

Figure 2.1 Block Diagram

All the modules will be communicating with the microcontroller, as that will be the “brain” of the system. The microcontroller will be a Raspberry Pi, that contains 40 pins which can be used as GPIO pins and other communication protocols. At least 20 pins have been mapped out for all modules. The Raspberry Pi will either be acting as a switching device for larger power sources or will be used with the communication protocols to send and receive information.

The temperature regulation module will have a thermostat that communicates with an analog to digital converter, so that the Raspberry Pi can read analog data as it does not have any analog pins. The microcontroller will then determine whether to turn on or off the refrigeration unit based on the temperature readings.

The LED light module also has a sensor that detects the amount of light outside. The analog to digital converter is used so that the Raspberry Pi can read the sensor values. If the value is determined to indicate a dark environment, the LED light strip will be turned on by the microcontroller.

The GPS module will be sending its location to the microcontroller. That information will be relayed to the Bluetooth app so that the location can be recorded on the map. With the last known location recorded, if someone were to wander off, they would be able to use the GPS position along with a compass to find the location.

The touch screen will not only display a GUI to the user but will also provide feedback to the microcontroller. Through the touch screen, the temperature will be able to

be adjusted, the LED light can be turned on or off manually, the automated lid can open and close, the locking mechanism can be activated, the cutting board can be extended, the speakers can be turned on or off, and low-power mode can be activated. All of this is configurable through a GUI menu.

The Bluetooth speakers will connect with the Raspberry Pi, so that when the user connects to the Raspberry Pi through Bluetooth, any sound playing from the phone will play through the speakers. A power amplifier is required for the speakers as they are 100W speakers.

A servo controller is used so that the microcontroller can communicate with the three servos required. One servo is for the automated opening and closing of the lid. A second is required to extend the retractable cutting board. And finally, one is required for the locking mechanism. The locking mechanism will use a switch to check if the lid has been closed all the way and will lock if properly closed.

All of this will be powered by two 12V batteries. The power control unit provides charging to the batteries by external sources such as an AC outlet, carport, or solar panel. The batteries will provide power to all the modules, as well as power for any device connected to the USB charging ports or wireless charger.

To see the program logic of how the microcontroller will be communicating with all these modules, the flowchart can be found in Appendix D.

2.2.3 Design Engineering Specifications

Table 2.2 outlines the engineering specifications of the system's modules and individual components.

Table 2.2

Engineering Specifications

Cooler				
Module	**Specific Components**	**Engineering Specification**	**Justification and Verification**	**Responsibility**

Shell	Coleman 100qt	Should have cup holders, wheels, and be large enough to support multiple compartments. Exterior walls should be at least 2’ thick.	**Justification:** Anyone should be able to move or load the Smart Cooler. **Verification:** Smart Cooler should be lightweight, have large carrying capacity, and wheels to help with transportation and loading.	Clarence
Control	Microcontroller: Raspberry Pi 4	Controller will provide SPI (Serial Peripheral Interface) used for communicating with other boards or modules. Bluetooth will connect with app at a range of 15m, and microcontroller will operate between 3.5-5.5V.	**Justification:** The Pi 4 can handle the input and output traffic, and communicate with the other modules. While connecting to the HDMI touch screen. **Verification:** The microcontroller will be able to handle the six primary inputs, and four primary outputs, and communicate with the other modules. Testing will ensure the microcontroller is communicating	Team

			with the application.	
Mobile Application	Apple or Android Smartphone	Bluetooth will communicate with microcontroller at a range of 15m. Application will monitor temperature of each compartment, ability to set temperature for each compartment, ability to change settings (GPS enable, locking mechanism enable, LED light enable, low-power mode enable), and able to save profile.	**Justification:** Providing Android and iPhone support allows for the majority of users to use the app. The app communicating with the microcontroller allows for remote monitoring and setting of the cooler. **Verification:** Testing will ensure the microcontroller is communicating with the mobile application using an Apple Smartphone.	Reuben
Refrigeration	Thermoelectric Cooler: ESUMIC 12V	Regulate refrigeration in both compartments. Refrigeration unit will be able to lower the temperature in a compartment to	**Justification:** Use active refrigeration to extend the ice retention of the cooler. **Verification:** Monitor the temperature with a separate	Team

		a minimum of -2.0°C.	thermometer in the compartments, and verify that it can be cooled to -2.0°C.	
Entertainment	Pyle Marine Speakers	Speakers should be no deeper than 2’ Speakers should operate between 50-200W	**Justification:** Narrow footprint so that they can be placed in the walls of the Smart Cooler. **Verification:** Speakers should be able to be heard at least 5 meters away.	Clarence
	Amp: TPA3116 DAMGOO	Provide at least 200W for Speaker operation.	**Justification:** Exceed minimum Wattage needs for both Speakers. **Verification:** Speakers should properly operate with the wattage provided from the AMP.	Clarence
Sensors	Temperature: DHT11 Temp. and Humidity Sensor	Monitor Temperature in compartments to an accuracy of ± 1.0°C in real time	**Justification:** The Temperature of the compartments is used to govern when the refrigeration units are turned on.	Reuben

			Verification: Monitor the temperature with a separate thermometer in the compartments.	
	Exterior Light: Photo-sensitve Sensor	Exterior light sensor will change output voltage in low light conditions in real time.	**Justification:** Interior lights are needed for operation after dark. **Verification:** Will test and confirm that output voltage changes when ambient light is low.	Reuben
Lid Opening Mechanism	Servo: BETU 25Kg Gusodor Led Strip Lights	Allow the user to remotely open and close the lid. Track lid status and change output voltage based on lid position in real time.	**Justification:** The opening mechanism will open and close the lid quickly. **Verification:** Mechanism shall correctly trigger interior LED during opening tests.	Clarence
	Servo Controller: SunFounder PCA9685	Shall drive the servos for the lid opening, cutting board, and lock in less than 3 seconds.	**Justification:** Provide the input and outputs required for the servos. **Verification:** Servo operation will be tested and cycled no less than 25 times.	Team

Power Input Control Module	Voltage Regulator 12V input power socket	Shall provide the cooler multiple charging options to accept 120V AC and 12VDC.	**Justification:** Allow for battery charging from Solar Panel, outlet plug, or automobile barrel jack. **Verification:** A digital multimeter will be used to confirm that the module is supplying the correct voltages when both inputs are used to pass.	Team
Battery	Battery: LiFePO4	Provide 12V to the Smart Cooler modules. Battery shall maintain active operation for at least 12 hours	**Justification:** Needed to power active cooling systems when outside power is not available. **Verification:** A digital multimeter will be used to confirm that the battery is supplying the correct voltages to pass.	Team
	Solar Panel: Eco-Worthy 12V 10W	12-20V output voltage, at least 1.5A current output, at least 14.4W power output, at least 9.6Ah output	**Justification:** The solar panel will provide power to the battery during daylight hours and assist with charging for night time operation.	Clarence

			Verification: A digital multimeter will be used to confirm that the module is supplying the correct voltages when both inputs are used to pass.	
Power Output Control Module	Voltage Regulator	Convert stored energy in the battery into voltages required for operation, 5V and 12V.	**Justification:** The Voltage Regulator will ensure that the voltages supplied by the batteries are the correct voltages to ensure the modules of the Smart Cooler operate properly without damaging components. **Verification:** A digital multimeter will be used to confirm that the voltage regulator is allowing the correct voltages to pass.	Team
	Exterior USB Charger: Damavo YM1218 USB C and USB A Charger socket	Should operate using either 5V or 12V input voltage. Will output 5V 2.1A for USB A & 5V 3A for USB C	**Justification:** The charger will allow wired charging of devices. **Verification:** Plug will be tested with several USB devices	Clarence

LID				
Module	**Specific Component**	**Engineering Spec**	**Justification**	**Responsibility**
GPS Module	BN-880 GPS Module	Module will accurately track location to within 3 meters.	**Justification:** Allow the user to mark the Smart Cooler and possible camp site. **Verification:** Google Maps will be used to confirm the accuracy of the GPS location.	Team
Charging Module	Qi Wireless Charging Transmitter	Output at 5W at a minimum of 100 KHz	**Justification:** Allows the user to charge other mobile devices in a timely manner. **Verification:** Capable of charging modern Smart devices especially cell phones.	Clarence
Lock	Locking Mechanism	Close and lock the Smart Cooler using the APP touch screen or RFID Keyless entry.	**Justification:** Secure the lid so that it cannot be opened on accident, unauthorized people, or animals. **Verification:** The lock should engage and disengage when signaled by the Touch screen,	Team

			Mobile app, and RFID keyless entry.	
Touch Screen	Sunfounder 7 inch	Shall support touchscreen functions and at least Wide SVGA resolution.	**Justification:** Allows the user to interact with the Micro controller and control the operation of the cooler. **Verification:** Should respond to the inputs of up to 5 fingers at once.	Clarence
Cutting Board	BETU 25Kg Servo 3D printed parts	Supply the user with a retractable cutting board that is in the lid.	**Justification:** In camping settings a cutting board could be very useful. **Verification:** Should extend and retract cutting board no less than 25 times without fouling.	Team

2.3 Systems Components

Given the specifications of the project, these parts were found to accomplish the tasks for each module. A lot of fabrication will be involved with the automated systems, so general hardware and any 3D printed components are not included.

2.3.1 Cooler

The cooler needs to have a structure that allows for ice retention and for all the electronics to go into. The walls need to be built with plastic with some kind of insulation to allow better temperature regulation. The dimensions of the cooler will be 17” x 36.4” x 17.9”, shown in Figure 2.2.

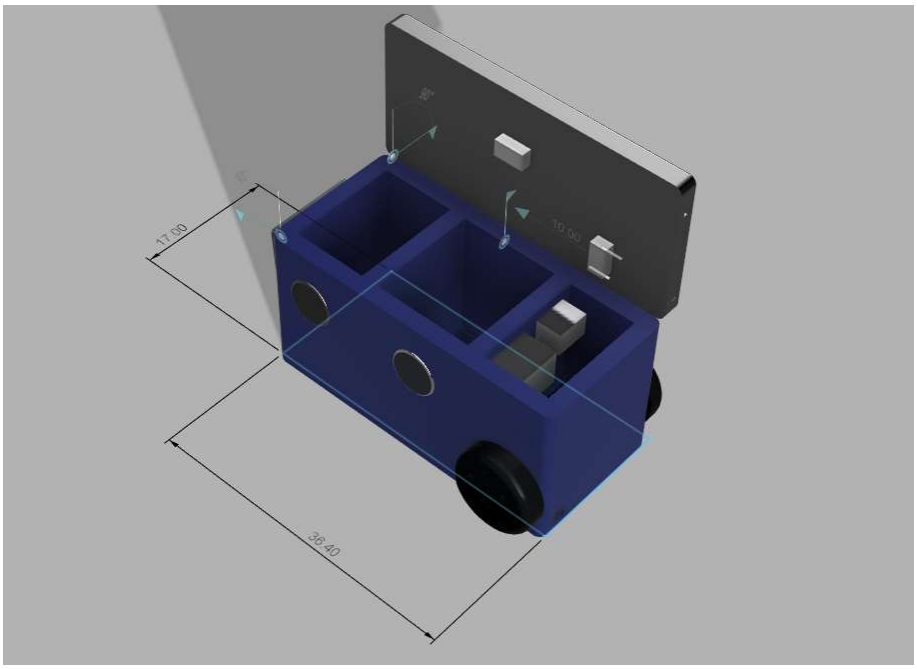

Figure 2.2 Smart Cooler Dimensions

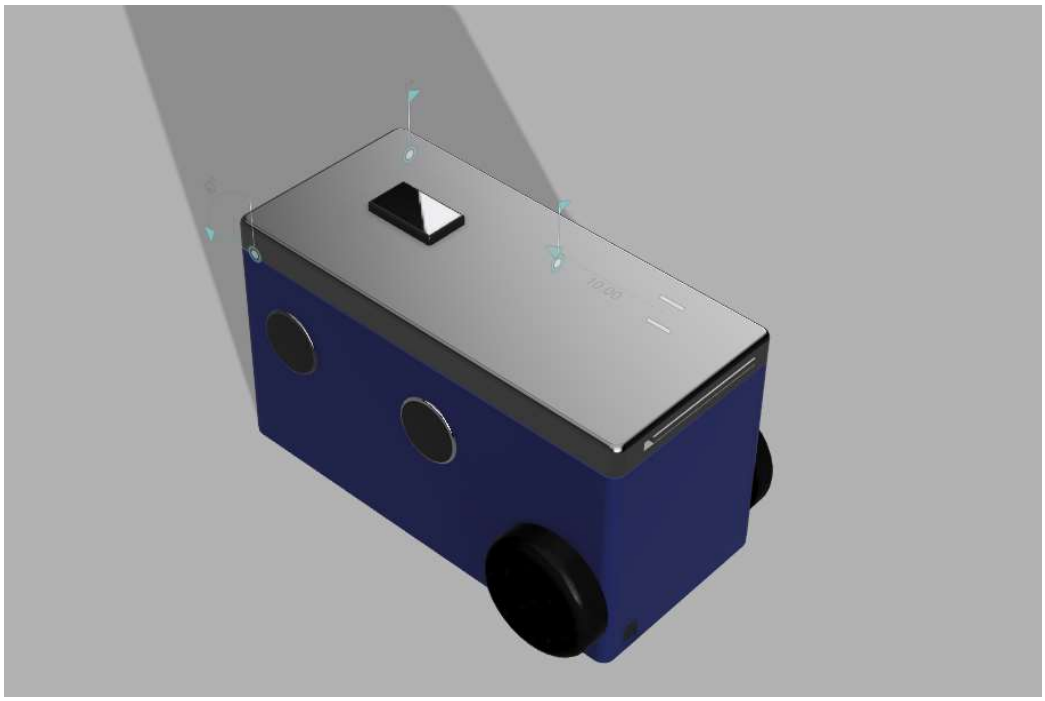

Figure 2.3 Smart Cooler Top View

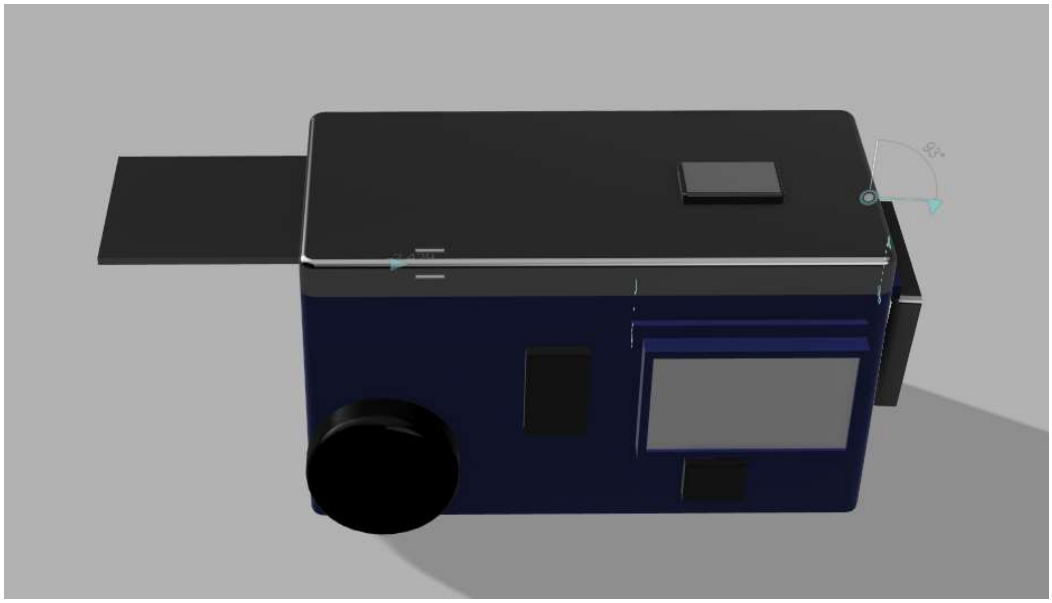

Figure 2.4 Smart Cooler Back View Cutting Board Extended

The Shell

The shell is going to be the platform that everything will be constructed around and on. With our standards requiring a handle and wheels we decided to go with the Coleman 100qt XTREME 5 Day Cooler. It has the required wheels and is advertised as retaining ice for 5 days so there is a very good opportunity to increase that through integrating the Smart Cooler system.

Figure 2.5 Coleman 100qt Cooler [5]

The Microcontroller

The microcontroller is the brain for this system. It must provide SPI (Serial Peripheral Interface) used for communicating with other boards or peripherals. Also, because we need Bluetooth and Wi-Fi connectivity to support the use of a mobile application we decided to go with the Raspberry Pi 4 for our microcontroller.

Figure 2.6 Raspberry Pi 4 [6]

Thermoelectric Refrigeration

The refrigeration unit is the main focal point of the entire design. The Thermoelectric cooler works by drawing the heat out of a small space by induction and without using any refrigerant. We believe that this offers new options for mobility, and we decided to go with the ESUMIC 12V cooler. It operates at 12V and 6A which opens up the possibility to power a refrigeration system with a battery.

Figure 2.7 ESUMIC 12V Thermoelectric Refrigeration Unit [7]

Speakers

Given that the speakers will be built into the wall of the cooler the speakers that we will be using must be narrow. Also given that there will undoubtedly be dealing with water and moisture around the cooler and compartments we wanted to make sure that our speakers were waterproof or at least water resistant. We selected the Pyle indoor outdoor speaker because they meet all our requirements.

Figure 2.8 Pyle Low Profile Marine Speakers [8]

Temperature Sensors

The temperature sensor first and foremost must be able to reliably track the temperature in the compartments. Sensors like these are instrumental in telling the microcontroller the status of the compartments and environment so that it can correctly control the activation of the refrigeration unit. Given that we need these readings fast and in real time we require accuracy of ± 1.0°C. The DHT22 has a rated accuracy of ± 0.5°C with a range of - 40°C -± 80°C.

Figure 2.9 DHT22 Temperature Sensor [9]

Light Sensor

The Smart Cooler is going to use a photosensitive sensor to track the level of light in the outside environment, because this will be what triggers the activation of the internal LEDS. We are doing this to lower the battery draw which is very important since we are going to try and save every bit of power in the battery to extend the time that the refrigeration system can be run. Using the CdS photoresistor with an analog to digital converter will give the desired light readings.

Figure 2.10 CdS Photoresistor [10]

Servos

Servos will be needed to control the automated opening and closing of the lid, as well as the locking mechanism. The servos selected are high torque metal gear servos, which have a stall torque of 21kg/cm, which should provide plenty of torque. Parts will need to be fabricated to provide the automated lid mechanism and locking mechanism functionality.

Figure 2.11 Betu DS3225 High Torque Servos [11]

Servo Controller

Given the numbers of servos that we will be employing with the Smart Cooler's system we have decided to go with the PCA9685 LED driver. As the controller provides 12-bit PWM for 12 channels, this will provide the required control signal to be sent to the servos. Servos need control signals with a certain duty cycle to set the angle of the servo arm. Using a PWM controller will allow us to send signals with a desired duty cycle.

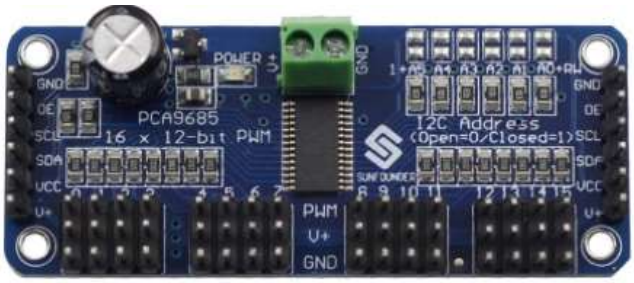

Figure 2.12 PCA9685 Servo Controller [12]

Battery Charger

Given that the system will be running on two 12V batteries wired in parallel, the correct battery charger needed to be found for the specific batteries selected. Looking at the datasheet for the Miady batteries that were selected, it was specified a charging current of

10 amps. Therefore, the NOCO Genius 10 battery charger was found. It provides charging for lithium batteries, as lithium batteries need a certain algorithm to charge fully. Lithium chargers are designed to use constant current constant voltage charging (CCCV) to fully charge a battery, where initially it uses a constant current to charge it up to 70%, then switches to constant voltage, where the current decreases as it fully charges [13]. The NOCO Genius 10 provides 10 amps of charging current for 12V lithium batteries.

Figure 2.13 NOCO Genius 10 [14]

Solar Panel

To improve the time that the active systems can be on we are using a solar panel to trickle charge the battery for the Smart Cooler. Because the batteries that will be in parallel have very specific charting requirements, so we need a solar panel with circuitry that is compatible. The Eco-Worthy 12V 10W solar panel is small enough to use the space on the back of the shell that we weren't actively using, applies a 12V input, and is waterproof which meets all of our requirements.

Figure 2.14 Eco-Worthy 12V 10W Solar Panel [15]

Batteries

The Smart Cooler will be powered by two rechargeable lithium batteries that are going to be set up in parallel. This will functionally create one battery with twice the capacity. We decided to go with the LiFePO4 because it is a rechargeable battery that supports having its terminals connected in parallel. Connecting two batteries with identical specifications will allow us to double the Ah rating of the battery, while keeping it rated for the same voltage. The batteries are rated for a maximum discharge current of 42A, and a charging current of 10A.

Figure 2.15 Miady LFP16AH 12V 20Ah LiFePO4 Rechargeable Battery [16]

GPS

The GPS module will communicate with the microcontroller to record the last known location of the cooler. The GPS module chosen was the BN-880 GPS module, which also has a built-in compass. The Raspberry Pi will need software installed for it to communicate with the GPS module.

Figure 2.16 BN-880 GPS Module [17]

USB Charger

One of the requirements of the Smart Cooler was to incorporate a wired charging option for Smart mobile devices. The plug will support both popular USB charging options USB A and USB C.

Figure 2.17 Car Port USB Charger [18]

2.3.2 The Lid

The lid will feature the touch screen for user interaction, wireless charging and retractable cutting board. The lid must provide ample room for the 7” touch screen, as well as cup holders. The interior of the lid will be modified to accommodate the retractable cutting board.

Wireless Charging

Another very important requirement of the Smart Cooler is the wireless charging pad. The wireless charging pad will be recessed in the lid. We selected a Qi wireless charging board made by Adafruit. It has a charging distance of 2-8mm which should easily be able to transmit through the plastic of the lid. Between this and the Wired USB Charger we will provide the user with charging options that should cover most mobile devices.

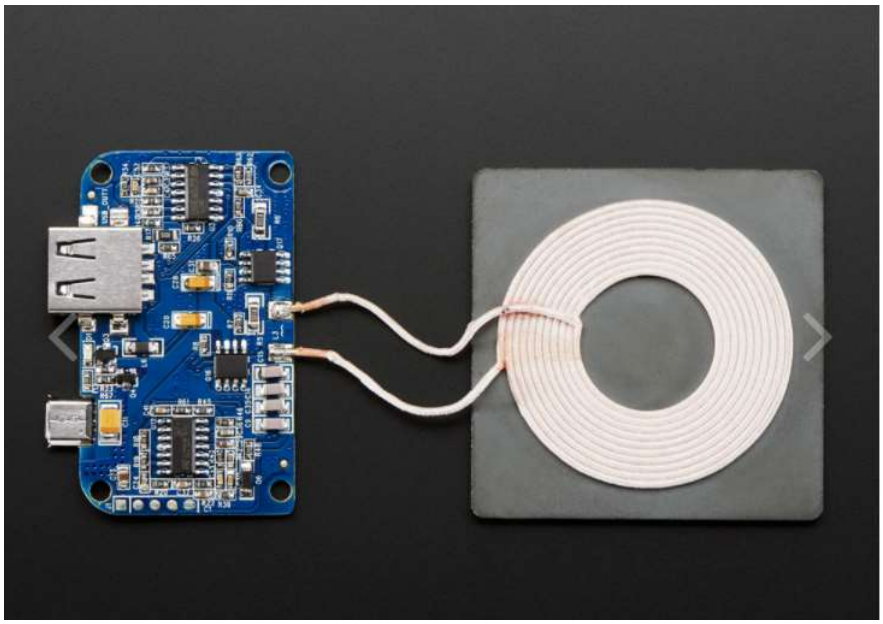

Figure 2.18 Qi Wireless Charging Transmitter [19]

Touch Screen

The touch screen is very important as it is designed to be the primary means of interfacing with the Smart Cooler's systems. We had to make sure that the size and depth of the touch screen didn't interfere with the mechanisms that we are building into the lid of the Smart Cooler. Given these considerations we decided to go with a 7-inch screen and decided on the Sunfounder 7-inch touch screen. This touch screen also supports inputs for up to 5 fingers at once, making it ideal as the main user interface for the Smart Cooler.

Figure 2.19 SunFounder 7" Touch Screen [20]

Cutting Board

The cutting board was selected completely on the grounds that it's dimensions and rigid nature should allow us to easily recess it in the lid of the cooler. This is a standard plastic cutting board that is 14 inches long by 11 inches wide, and .5 inches tall. The cutting board will be extended and retracted using the servos from section 2.4.1.7.

Figure 2.20 FarberWare Plastic Cutting Board [21]

2.4 Power Budget

The power budget shows how much power will be required from the batteries at any given time. The wattage was derived using the power equation.

$$P=IV$$

Table 2.3 shows the power budget, with a total required amp of 30.81A. The batteries selected have a maximum discharge current of 42A.

Table 2.3

Power Budget

Component	**Model**	**Voltage**	**Amp**	**Watts**
Microcontroller	Raspberry Pi 4	5V	3A	15W
Temperature Sensor	DHT11	5V	0.3mA	1.5mW
Refrigeration Unit	Thermoelectric Refrigerator x2	12V	6A x 2 = 12A	144W
Wireless Charging	Qi Wireless Charging Transmitter	5V	1A	5W
Wired USB Charging	YM1236 Dual USB Charger	5V	2.1A x 2 = 4.2A	21W
Solar Panel	Eco-Worthy	12V	0.833A	10W
Servo	Betu DS3225	5V	1.9A x 3 = 5.7A	28.5W
RFID	RC522	3.3V	26mA	85.8mW
GPS Module	BN-880	5V	50mA	250mW
Touch Screen	Sunfounder 7”	5V	480mA	2.4W
Amp Board	DAMGOO	5-27V	>3A	Up to 200W

Analog to Digital Converter	MCP3008	5V	500uA	2.5mW
Servo Controller	PCA9685	5V	25mA	125mW
Total			30.81A	426.13W

2.5 Success Criteria

Based on Table 2.2 Engineering Specifications, we have created a second table, Table 2.4, that plainly states the testing methods that we will use, and the criteria of success. Because our project will involve lithium-ion batteries safety is our first and primary concern during testing, we have decided that anything less than a 90% success rate will be acceptable, and anything below that will trigger a retest.

We have decided that our trial plan will involve between 10-30 attempts depending on the component or system being tested. This range of attempts was chosen because of the time constraint, our projected timeline, and milestone development trails. This will ensure that at every stage the system should be able to make its overall success rate.

Table 2.4

Success Criteria

Subject	**Success Criteria**
Shell	1) Does the Cooler retain Ice for a minimum of 7 days?
Refrigeration	1) With the refrigeration engaged -2.0°C.
Touch Screen	1) Does the touch screen respond to touch inputs correctly 9/10 times?
Controller	1) Does the microcontroller properly control the system without errors 19/20 times?
App integration	1) Does the App take full control of the system without interference 9/10 times?
Power System	1) Does the system properly power on and off 95% of the time 19/20?

GPS	1) Does the GPS module accurately track the cooler's location 95% of the time?
Locking mechanism	1) Does the lock engage and disengage when signaled by the Touch screen, Mobile app, and RFID keyless entry 9/10 times?
Servos	1) Does the lid properly open 95% of the time? 2) Does the cutting board extend and retract properly 95% of the time?

Chapter 3

Non-Technical issues

Summary

The budget for the project is outlined with the price of each item, how many is needed, and total. The timeline gives the project deadlines for completion of each phase. The project is looked at as a whole of the impact it would have on society, including the effect on the environment, the health and safety impact, ethical and social aspects, and the sustainability of the project.

3.1 Budget

One of the requirements for the project was to adhere to a $700 budget, approximately. With the approval of the professor, the budget can go over if requested, but the goal of this project is to stay to the initial budget. Given that the Smart Cooler has so many components to it, the cost budget is going to have a lot of parts. This budget table covers the main parts.

Table 3.1

Project Budget

Module	Part	Unit Cost	Quantity	Cost
Cooler	Coleman 100qt	$69.97	1	$69.97
Microcontroller	Raspberry Pi 4	$79.99	1	$79.99
Temperature Sensor	DHT11	$5.99	2	$11.98
Refrigeration Unit	Thermoelectric Refrigerator	$23.99	2	$47.98
Charging Application	Qi Wireless Charging Transmitter	$26.95	1	$26.95
Solar Panel	ECO-Worthy	$33.00	1	$33.00
Battery	Miadi LFP20AH	$69.99	2	$139.98
Wired USB Charging	YM1236 Dual USB Charger	$9.59	1	$9.59
AC Battery Charger	NOCO Genius10	$64.96	1	$64.96
RFID	RC522	$5.49	1	$5.49
Servo	Beta 25kg	18.50	3	$55.50
LED Light Strip	Flexible LED Strip Light	$8.79	1	$8.79
Photoresistor	Photocell	$0.95	1	$0.95
Cutting Board	FarberWare Plastic Cutting Board	$6.62	1	$6.62
GPS Module	BN-880	$18.99	1	$18.99

Touchscreen	Sunfounder 7 inch	$65.99	1	$65.99
Speakers	Low Profile Marine Speakers	$29.99	1	$29.99
Amp Board	DAMGOO	$22.99	1	$22.99
ADC	MCP3008	$3.75	1	$3.75
Servo Controller	Sunfounder PCA9685	$9.99	1	$9.99
Total				$713.45

3.2 Timeline

The timeline gives start dates and deadlines for each phase of the project. The majority of the project will be spent researching parts, designing, fabricating, programming, and testing.

Table 3.2

Senior Design Proposal Timeline

Task	Length (Days)	Start Date	End Date
Research Ideas	17	05/12	05/28
Research Components	51	05/18	07/09
Proposal Report	26	06/07	07/02
Proposal Presentation	7	07/02	07/09
Proposal Website	59	05/12	07/09

Table 3.3

Senior Design Project Timeline

Task	Length (Days)	Start Date	End Date
Buy Parts	20	07/12	07/31

Fabricate Parts and Electronics	111	08/01	11/19
Mobile App Development	111	08/01	11/19
Software Development	111	08/01	11/19
Testing Software and Hardware	44	10/11	11/23
Project Report	40	10/25	12/03
Project Presentation	17	11/24	12/10
Project Website	132	08/01	12/10

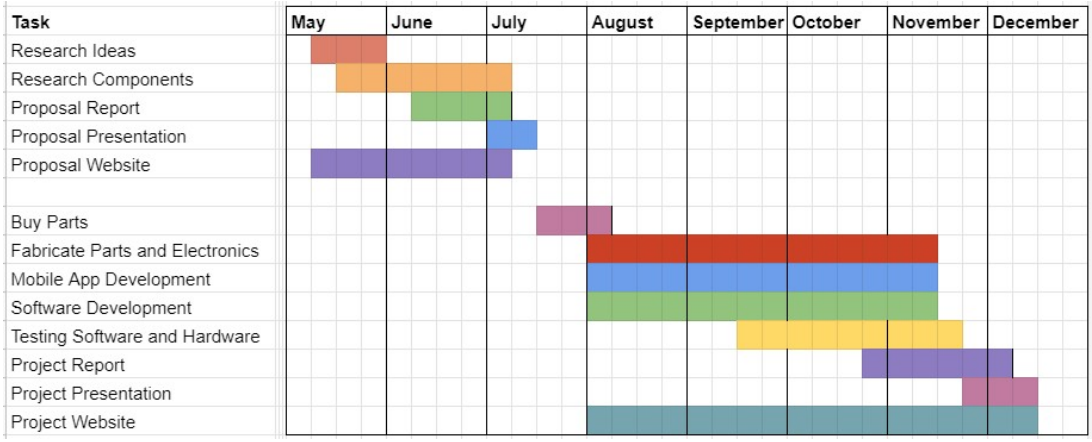

Figure 3.1 Graphical Representation of Proposed Timeline

3.3 Environmental Aspects

In order to keep the system environmentally friendly and for convenience of the user, the cooler will have 12V rechargeable LiFePO4 batteries. Lithium batteries have more cycles than SLA batteries, which means it will last longer. Having rechargeable batteries reduces the waste of disposable batteries and has renewable energy benefits. Since the Smart Cooler has a 12V solar panel attached to it, the batteries will be able to be recharged from the sun. This can also be extended to the AC input as well. If the user's house has solar panels, then the cooler can be recharged through the limitless power of the sun, leaving no carbon footprint.

3.4 Health and Safety

The health and safety of the user is the most important aspect for this project. That is why extensive research is being conducted into the power source. Making sure the batteries are worked within their safety specifications, as well as proper charging and discharging, making the cooler waterproof so components don't get damaged, proper ventilation to maintain a safe operating temperature for all the components, and extensive testing of components individually and assembled together will ensure a safe a reliable product that can be distributed without worry.

3.5 Ethical Aspects

Holding to the IEEE Code of Ethics, the "safety, health, and welfare of the public" is the top priority [22]. The Smart Cooler attempts to use technology to improve the functionality of an item that has been used for decades with minimal improvements and advancements. Given that the health and safety of the user is the top priority, testing of the product along with the success criteria specified will ensure that everything is working properly and should the system fail, it will not do so in a way that endangers the user or surroundings.

All references and materials used in this project have been cited and proper credit given to the original sources.

3.6 Social Aspects

Party engagements are the ideal scenario for the Smart Cooler.

The benefits of having a cooler that can regulate temperature makes sure food won't grow bacteria, making sure food is safe to eat. But this also extends to the medical field. The Pfizer-BioNTech COVID-19 vaccines needed to be "stored in the refrigerator at 2°C to 8°C (35°F to 46°F) for up to 1 month" [23]. To have a cooler that can regulate its temperature for mobile transportation of vaccines, blood, and organs among other things will have a strong impact on the benefit of society.

Having GPS to find the location of the cooler will prevent people from getting lost in the woods. “Around 2,000 people get lost in the woods every year” [24]. Not everyone in the woods knows wilderness survival skills necessary to find their campsite.

3.7 Sustainability

The batteries used will be 2000 deep cycle LiFePO4 batteries. Lithium batteries have the advantage of having more cycles, faster charge time, and are lightweight compared to SLA batteries. Lithium batteries last longer, so therefore the sustainability of the product was taken into consideration. If the batteries were to be charged every day, they would last 5 and a half years.

Chapter 4

Conclusion

Summary

The long list of features that the Smart Cooler has went through a lot of research and analysis. With this list of wanted features, components were researched, specifications were developed, and success criteria were specified. The cooler has a lot of possible implementations, and can only be improved upon in the near future.

4.1 Summary and Conclusion

The Smart Cooler is bound to be a successful product. The success of the INFINITE cooler and The Coolest Cooler shows that demand for a multipurpose cooler. Each cooler product had its own set of features that allowed convenience for all sorts of possibilities. There are many different situations that a cooler can be used for, so to cater for all possibilities is the goal. However, the main feature that these coolers lack is the option of regulated cooling. To add a thermoelectric refrigeration unit to a cooler enhances it from just a cooler to a portable refrigeration unit. With the help of a microcontroller, the cooler will be able to regulate the desired temperatures by controlling the thermoelectric units. Figure 1.3 shows that the primary feature that users would like to have in a cooler is temperature regulation. Ice will need to be added, but with the help of refrigeration, the temperature will be able to be controlled in a more precise manner. This opens up the possibilities of different profiles for different foods and other miscellaneous items that need refrigeration. All of the other features just complement and enhance your typical cooler.

Given that the Smart Cooler will have a battery source for power, this allows the addition of features that are more than just ice retention. The power budget shows how resources will be allocated. The Smart Cooler will demand a lot of amperage given that the cooler will have two thermoelectric refrigeration units that take 6A each. The rest of the components are not as power intensive. All the modules have certain criteria that need to be met, and testing will ensure that every module is working as intended.

Having a cooler with smart capabilities has many positive implications in society. It can be the object of the party, the storage to preserve food, or even used in other scenarios besides just parties. Having a cooler that can maintain its temperature can positively impact the medical field, as COVID vaccines need to be kept within a certain temperature. It can be an instrument to save lives, or it can be a multifunctional party tool. Whatever the use case, the aim of the project is to improve upon the typical cooler, giving more functionality that turns something simple to an advanced, smart item.

4.2 Suggestions for Future Work

The main suggested improvement for this type of project is to prolong the temperature regulation. By adding more batteries, or batteries with more Ah ratings, allowing temperature regulation and ice retention for longer than seven days would be a tremendous improvement. However, adding more batteries, and more powerful batteries at that, will increase the price of the product. Of course, additional features can be included as there will always be something that can be added. One important feature that can be added is for the cooler to have a way to contact emergency services. For the cooler to have that feature, it would need a SIM card, unfortunately.

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Appendix A

Equations

Power Equation

$$P = V \cdot I \qquad (2.1)$$

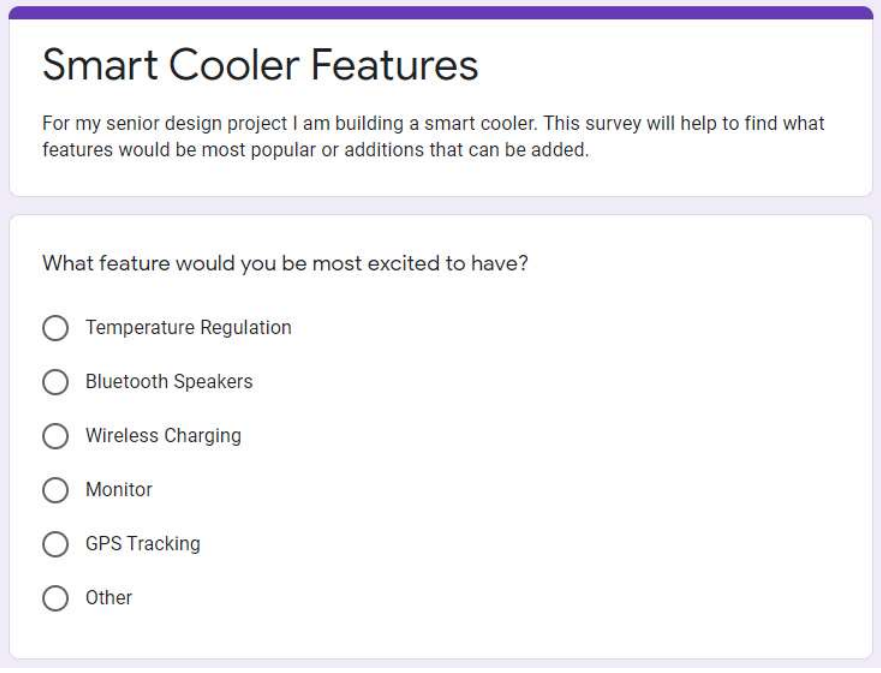
Appendix B

Smart Cooler Survey

Summary

This survey was posted online to get feedback on the proposed features, as well as additional features that would like to be added and where the Smart Cooler would be used. The survey was kept short to encourage more responses.

Question 1: What features would you be most excited about?



Question 2: What features would you like in a smart cooler?

Question 3: Where would you use the cooler most often?

Appendix C

Smart Cooler Survey Results

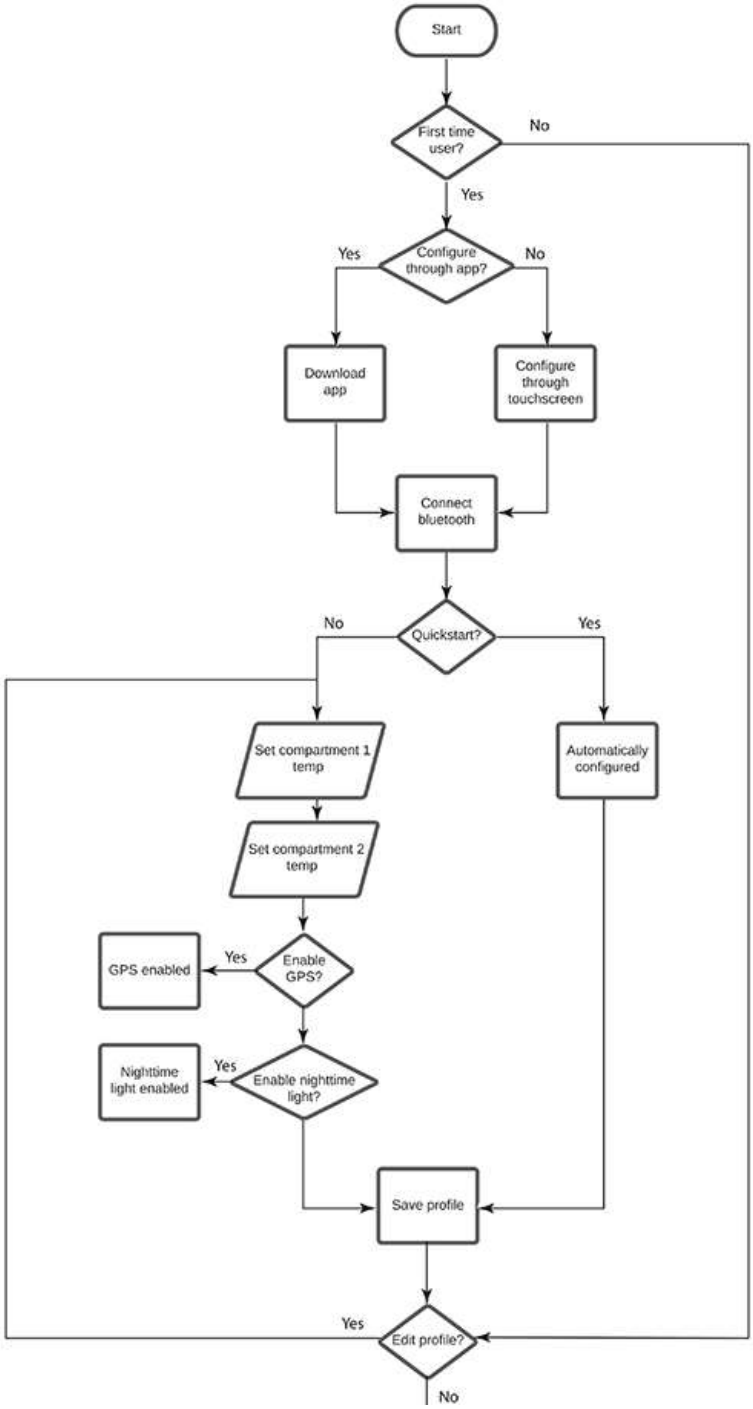
Timestamp	What feature would you be most excited to have?	What features would you like in a smart cooler?	Where would you use the cooler most often?
6/5/2021 15:22:25	Bluetooth Speakers	The ability to stay cold for a really long time	Beach
6/5/2021 15:45:24	Temperature Regulation	Separate small freezer compartment(in conjunction with temperature regulation)	Beach
6/5/2021 15:45:49	Bluetooth Speakers	App support	Beach
6/5/2021 16:04:03	Temperature Regulation		what is a cooler?
6/5/2021 16:12:27	Temperature Regulation	The most important features for me when buying a smart cooler would be a long-lasting battery and a way to regulate/monitor the temperature. It would also need other basic features like being waterproof and having adequate storage room.	Camping
6/5/2021 16:42:19	Wireless Charging		Camping
6/5/2021 17:02:02	Temperature Regulation	Lightweight, easily mobilised, good temperature regulation, reasonably priced, low maintenance	Camping
6/5/2021 17:11:24	Temperature Regulation	Probably most useful would be ability to control temperature inside cooler from an app and check what's inside the cooler	Beach
6/5/2021 17:34:01	Temperature Regulation	Cooling	
6/5/2021 17:43:40	Other	None at all	Beach
6/5/2021 17:50:42	Bluetooth Speakers		Camping
6/5/2021 17:54:37	Temperature Regulation		Camping
6/5/2021 18:04:12	Temperature Regulation	Charging would also be nice	Beach
6/5/2021 18:10:22	Temperature Regulation	wheels that work well on multiple types of surfaces, for example asphalt and sand	picnic
6/5/2021 18:30:02	Wireless Charging	Durable	Beach
6/5/2021 18:39:00	Temperature Regulation	less bulky, when i have to pack up my cooler and take it out for work it's a giant pain something slimmer that fits better in a laptop bag	Work
6/5/2021 18:39:46	Temperature Regulation	Price	Camping

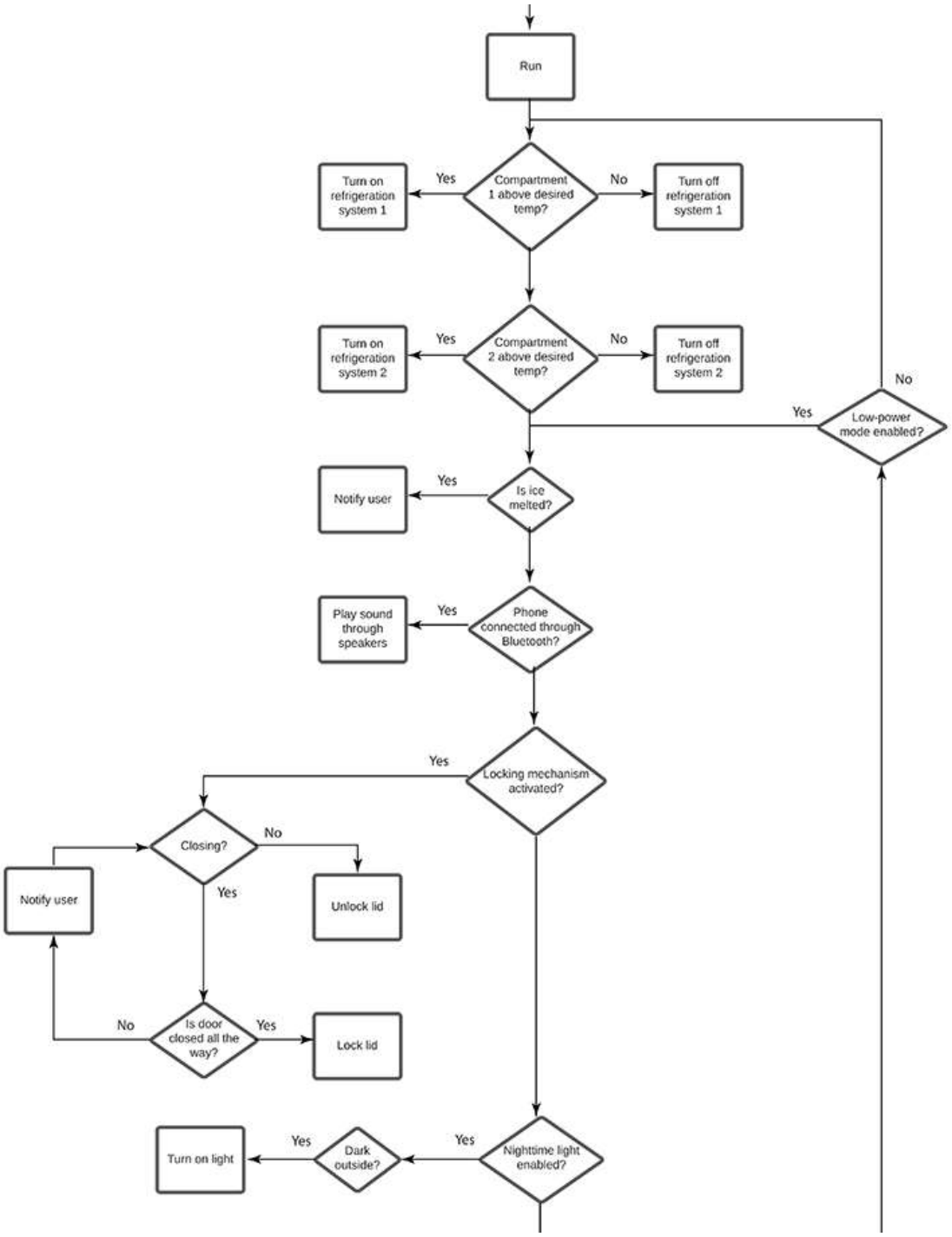
6/5/2021 19:13:25	Temperature Regulation	Temp monitoring through app. Alarm if it drops under a programmable temp. Removable freezer blocks that can create dividers, shelves, and can intigrate into the lid to have cold come down from top.	Camping
6/5/2021 19:16:47	Temperature Regulation		Beach
6/5/2021 19:19:12	Temperature Regulation	maintain different temperatures for different items	Work
6/5/2021 19:46:37	Temperature Regulation	On screen thermometer.	Work
6/5/2021 20:24:01	Wireless Charging		Camping
6/5/2021 20:37:51	Temperature Regulation	I want it to be as waterproof and sandproof as possible, sturdy enough to sit on, spacious enough for all the beers I'm going to drink, bluetooth speakers would be nice, solar chargeable with attachable panel, plug in capability, but it's not necessary to have it plugged in all the time to keep things cool, lightweight for carrying, made of recycled materials if possible, heck, maybe even a cute little screen that you can play games on to occupy the kids in the back seat.	Camping
6/5/2021 20:39:52	Temperature Regulation		Camping
6/5/2021 20:44:57		keep my drinks cold. don't leak	house party
6/5/2021 20:46:43	Temperature Regulation		car
6/5/2021 21:05:22	Temperature Regulation		Beach
6/5/2021 21:11:33	Temperature Regulation	Intelligent temperature control; swappable inserts for different types of items like holding drinks upright or shelves for more varied items	Work
6/5/2021 21:20:42	Monitor		Camping
6/5/2021 21:31:42	Temperature Regulation		Beach
6/5/2021 23:47:06	Temperature Regulation	Temperature sensor, readout that gives a warning and timestamp of when the cooler has exceeded the allowable internal temp (so you know when to buy more ice or if foods are safe to eat while camping)	Grocery shopping to transport frozen goods
6/6/2021 1:41:29	Temperature Regulation	Thermometer reading of the inside temperature. Perhaps even a way to set the cooler to a specific temperature. GPS tracking and a way to contact emergency services. In the event that something goes wrong while camping and for some reason the people camping do not have access to their phones or any other emergency device. Perhaps make it animal-proof so that animals can't easily get inside and maybe a way to repel wild animals.	Outdoor work and activities
6/6/2021 1:52:29	Temperature Regulation		Travel

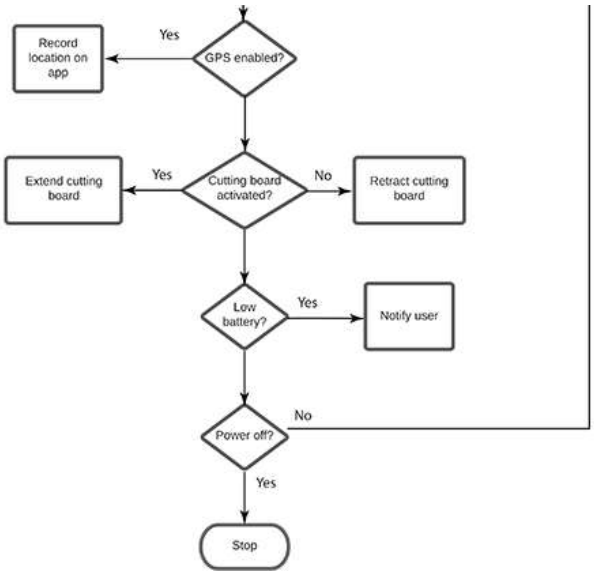
6/6/2021 2:44:40	Wireless Charging	Notification when ice is melted	On a boat
6/6/2021 3:38:19	Temperature Regulation		Beach
6/6/2021 7:35:28	Temperature Regulation	Digital temp controls and easy portability	Road trips and days at the park
6/6/2021 14:46:04	Temperature Regulation		Camping
6/6/2021 19:04:56	Temperature Regulation	Temperature regulation, wheels, cup holder	Beach
6/6/2021 22:12:36	Temperature Regulation	An app or some thing that lets you control the temperature. Also cool LED lights inside of it	Beach
6/6/2021 22:26:29	Bluetooth Speakers	Bluetooth speaker & wireless charging	Everywhere: home, picnic, etc.
6/6/2021 22:31:04	Temperature Regulation		Beach
6/6/2021 23:44:57	Temperature Regulation	Wireless charging and Bluetooth speakers	Family gatherings
6/7/2021 9:27:46	Temperature Regulation	Monitor for Perishable items	Camping
6/8/2021 0:17:12	Bluetooth Speakers		Beach
6/8/2021 15:54:14	Bluetooth Speakers	Mobility, BT, water proof	Beach
6/8/2021 17:04:15	Bluetooth Speakers	Flashlight	Camping
6/9/2021 17:02:10	Other	Must cost less and use less power then non-smart cooler. Must work without additional app/smartphone/internet	
6/30/2021 8:31:26	Temperature Regulation	Keeping track of the optimum temperature for the drinks. Like if we put stuff in it, if it can tell when drinks are cooled down to its most chill temperature to enjoy.	Beach

Appendix D

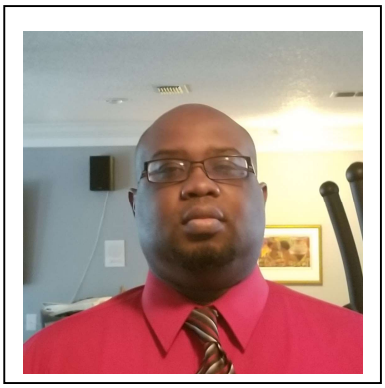
Flowchart




Run
Compartment 1 above desired temp?
Yes
Turn on refrigeration system 1
No
Turn off refrigeration system 1
Compartment 2 above desired temp?
Yes
Turn on refrigeration system 2
No
Turn off refrigeration system 2
Low-power mode enabled?
Yes
No
Is ice melted?
Yes
Notify user
Phone connected through Bluetooth?
Yes
Play sound through speakers
Locking mechanism activated?
Yes
Closing?
No
Yes
Notify user
Unlock lid
Is door closed all the way?
No
Yes
Lock lid
Nighttime light enabled?
Yes
Dark outside?
Yes
Turn on light


GPS enabled?
Yes
Record location on app
Cutting board activated?
Yes
Extend cutting board
No
Retract cutting board
Low battery?
Yes
Notify user
Power off?
No
Yes
Stop

Biography



Clarence Scott

I am currently working full-time as an LRU Repair Technician while in pursuit of my Bachelors in Electrical and Computer Engineering Technology with a concentration in Electrical/Electronic Systems. I am expected to graduate in the spring of 2022.

Reuben Taveras

I am currently a student on his final year of school pursuing a Bachelors in Electrical and Computer Engineering Technology with a concentration in Electrical/Electronic. My interests include science, technology, web development, and art.