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Solar Powered Lighting System for Outdoor Unpowered Structures

ECE 4980 Capstone Project Overview

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# Abstract

By Sterling LaBarbera

This report documents the creation of a lighting system for unpowered outdoor structures. Structures too far from any electrical power line require special equipment for power generation. We also designed this with the ideas of durability and ease of setup, while also being easy to move if needed. Since the parts are generally modular, assembly only requires fixing the enclosures to parts of the structure, the solar panel being the most difficult. This project uses a high-capacity battery and solar panel to generate, store, and provide power to the electronics. Other problems with such outdoor structures include weather exposure and lack of pest control. We have all electronics in IP65 or better rated weatherproof enclosures and have added an ultrasound frequency generator circuit that repels certain types of pests. Since this project is intended for use in small gatherings or parties, it uses multi-color light emitting diodes. The lights are both color and brightness controllable through an Android phone application and feature a flow mode with gradual color changing, as well as music mode, which pulses along with the volume of nearby music. This project successfully performs all the intended tasks above. However, while we attempted to design the power supply units ourselves, we were unsuccessful and replaced it with two purchased power supplies.

*Index Terms*—Addressable LED, Bluetooth, feedback circuit, feedback communications, graphical user interface (GUI), microcontroller, pest deterrence, power generation, solar power, switched mode power supplies, ultrasound, voltage control.

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1. Introduction

## Report Purpose

By Matt Soehngen

The contents of this report cover documentation which describes first the project concept, engineering goals, and requirements. Next, an analysis of the projects theory of operation is given. Lastly, an evaluation of the outcome of the project will be inspected. Each team members’ *Individual Contributions* reports, which are separate from this report, establish and document the implementation details for the project elements described herein.

## Problem Statement

By Matt Soehgnen

Running power to a distant pavilion or gazebo with no nearby power line access would ordinarily mean that the gazebo owner would not be able to use the gazebo for parties after dark. Venues such as wineries which host live musicians to play on outdoor stages on their premises often have a distant gazebo or pavilion which could be used a dancing area. A gazebo such as this could use an exciting illumination system which could be controlled by guests to fit the mood for their enjoyment of the evening. Still, one downside with using bright yellow lights at night is the tendency to attract pesky insects toward the glow.

## Project Concept

By Matt Soehngen

This project includes a solar cell which is used to harvest solar energy that is stored into a battery which provides power to the assemblies. An individually addressable LED strip is connected to a microcontroller which regulates the color and brightness of each LED in programed flashing patterns which can be selected by the user through a smartphone app paired to the microcontroller through Bluetooth. One of the settings of the user control is “music mode” in which the microcontroller uses an audio sensor to detect the intensity of surrounding audio and pulses in response to beats in the music. In order to address the issue of pests swarming the vicinity of the lighting strip, an ultrasonic tone generating device is connected to the system and directed at the lighting strip to deter insects which have a higher frequency hearing range than humans.

## Innovation

By Matt Soehngen

There are existing lighting devices which include multicolor LED strips and the capability to have smartphone control through wifi or Bluetooth to select between various colors and flashing patterns. Some products in the market include an audio sensing mode to pulse on with the detection of sound. This project improves on the music pulsing by including dynamic flashing patterns which completely change based on thresholds of intensity of the audio signal. The project also includes a renewable energy source used to provide power to the system.

## Report Overview

By Matt Soehngen

The contents of the following report are given here. Chapter 2 covers the implementation process for designing and creating the project, featuring breakdowns of each assembly and component. Chapter 3 details the scope of the project, including the performance requirements of the system, descriptions of the customer centric SMART goal and objectives, descriptions of the engineering SMART goals and related objectives, and constraints placed on the design process of the system. Chapter 4 discusses the management of presumed risks for the success of the project. Chapter 5 evaluates the outcomes of the project in perspective of the general outcome, the customer and engineering goal achievement, as well as timeline and budget evaluations. Chapter 6 analyses the successes, failures, limitations, and suggested future improvements of the project. Finally the References section is at the end of the report.

1. Implementation

In this chapter we describe the possible implementations we considered for this project, our proposed implementation for this project, our contingency plan for the proposed implementation, and the actual “delivered” implemen­ta­tion of our project. At the end of the chapter, we identify each group member’s work assignments and responsibilities for the project.

## Implementations Considered

By: Nicholas Erickson

Other implementations our group considered when choosing our project included on the grid power supply and off-site solar cell charging. Our group decided to choose a solar rechargeable power supply to allow our product to be an environmentally conscious product. During project consideration, we contemplated the idea of remotely charging the battery cell to improve aesthetics of the gazebo. Our consensus decision was that the convenience of having a stationary product that can remain in one place would be the optimal solution for potential customers.

## Proposed Implementation

Inform the reader that this section of the report describes the proposed implementation of your group’s Capstone project—i.e., the implementation your group proposed to build at the start of the ECE 4980 semester. This section is for the proposed implementation only—i.e., the implementation the group proposed at the start of the semester. A separate section titled “Delivered Implementation” follows this section; this is where you will document the actual, delivered, demonstrated implementation of your Capstone project.

#### Theory of Operation

The proposed project’s theory of operation is described herein via system diagram figures, functional block diagram figures, and software architecture figures.

### Product Concept Diagrams

By Sterling LaBarbera

Figure 1 shows our intended usage, with a solar panel installed on the roof of a gazebo, and the lighting mounted as the user wants. The battery and power supplies will be placed on the floor with wiring running up the maximum power point tracker (MPPT) and the Arduino. The user will be able to control the lighting with a smart phone app using a Bluetooth connection.

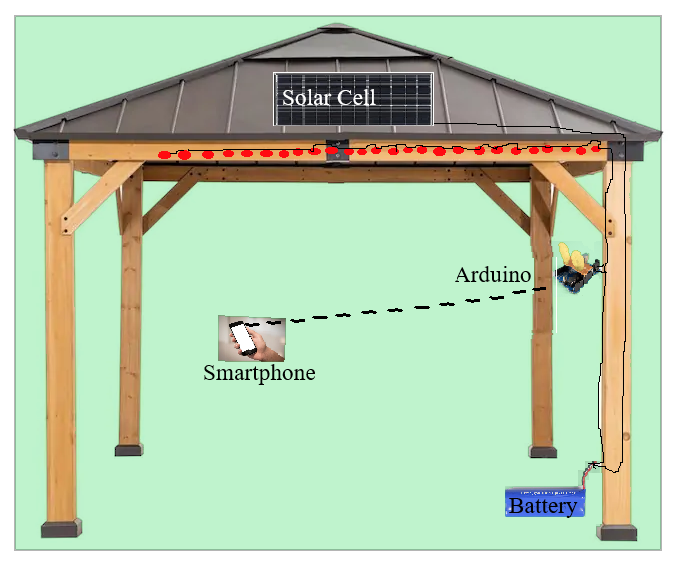


Figure 1. Product concept diagram

### Functional Block Diagram

By Sterling LaBarbera

Figure 2 is the basic functional block diagram for this lighting system. The solar power unit is separable but will be designed specifically for this lighting system. The lighting system uses LED strips for the actual lighting and a controller. User interface is through an app, and the user’s device connects using Bluetooth. There is also an audio sensor for visualization options and an insect repellent circuit.

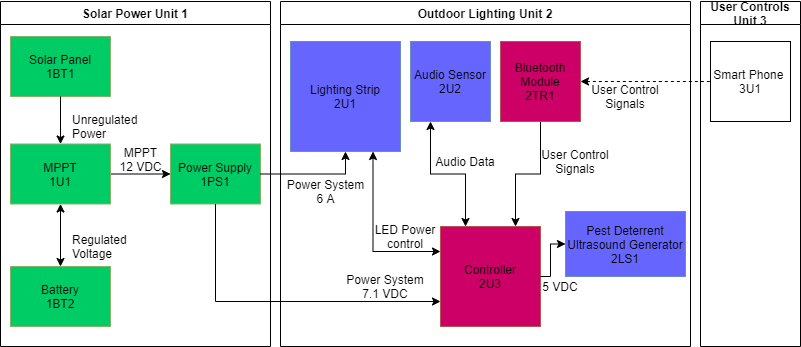


Figure 2. Functional block diagram for the proposed project

#### Unit 1 Solar Power

The Solar power system is composed of a solar panel to generate power, a maximum power point tracker to regulate the output signal, and battery to store the electrical energy. Unit 1 will provide power to Unit 2. The battery will charge during the day via solar panels mounted to the roof of the structure.

#### Assembly 1BT1 Solar Panel

This will be a purchased solar panel, attached to 1U3 via provided wiring.

#### Assembly 1U1 MPPT

The maximum power point tracker (MPPT) will also be purchased due to complexity. It provides regulated output from the unregulated Solar panel. It also functions with the battery as a charger.

#### Assembly 1BT2 Battery

The battery will be purchased. It provides electrical energy for nighttime operation.

#### Assembly 1PS1 Power Supply

The power supply is a dual output DC to DC power supply that will receive a 12 V variable power input from 1U1 and supply 10 VDC up to 63 W peak power to the lighting strip 2U1 and 7.1 VDC up to 1 A to the controller 2U3.

#### Unit 2 Outdoor Lighting

The Lighting installation will run for up to 4 hours from Unit 1’s fully charged battery.  There will be app control for different light settings and intensities, and any Bluetooth capable smart device will be able to use the app. This unit will also feature a pest deterrent circuit that produces a high frequency audio tone.

#### Assembly 2U1 Lighting Strip

We will be purchasing LED strip lighting with color/intensity control to allow our software features to function.

#### Assembly 2TR1 Bluetooth Module

This will be a purchased Bluetooth radio attachment for the Arduino controller. It will provide wireless communications with user smart devices.

#### Assembly 2U3 Controller

The controller will consist of an Arduino running custom software that can modify the lighting with various audio from the environment via the sensors.

#### Assembly 2LS1 Pest Deterrent Ultrasound Generator

We will build and attach a circuit that emits a high-pitched tone known to repel various pests. It will be controlled via the app software as well but is only an on/off element.

#### Unit 3 User Controls

This unit is a user provided device to run the Android compatible control app.

#### Assembly 3U1 Smart Phone

The user will provide a Bluetooth capable smart device to use the app controls.

### Software Architecture

By: Nicholas Erickson

Figure 3 shows the proposed software architecture for the mobile app that sends user input signals to the control assembly (Figure 2). Our control assembly is connected to an audio sensor (Figure 3) that receives input audio signals and pulses with varying intensity based on the magnitude of the audio signal. Figure 4 shows the proposed software architecture for the app. The mobile interface provides options to change the color of the LEDs, adjust the LED brightness, connect and disconnect to Bluetooth, and turn on and off the music mode to pulse the LEDs.

|  |  |  |
| --- | --- | --- |
| Control Assembly – 2U3 | | |
| LED Output Management | | Remote Connection |
| LED Power Control | Audio Data | User Control Signals |

Figure 3.   Software architecture for the CONTROL assembly 2U5 (see also Figure 2).

|  |  |  |
| --- | --- | --- |
| Smartphone – 3U1 | | |
| Mobile Interface | | |
| LED Output Control | Bluetooth Connection Manager | Music Mode |

Figure 4. Software architecture for the Smartphone 3U1 (see also Figure 2).

#### 2U3LPC1 – LED Power Control

The LED power control will control the brightness and LED color output by sending digital signals to the LED strip from the controller. Additionally, the power control will offer the features of both music mode and flow mode. Music mode will pulse with varying intensity based on the intensity of the audio input if the music mode feature is turned on. Flow mode will continuously change the output color of the LED strip.

#### 2U3AUD1 – Audio data

The audio sensor will detect the input of the surrounding audio and send a signal to the controller to pulse the LED strip based on the input audio data.

#### 3U1MIF1 – Mobile Interface

The mobile interface will send signals to the controller based on user input on the mobile app. The signal sent by the user on the mobile interface will be interpreted and displayed by the control assembly.

#### 2U3MIF1 – User Control Signals

User control signals are the input signals to the controller sent by the smartphone through the mobile interface. The controller will interpret these signals and display the result with the LED power control.

#### 3U1BCM1 – Bluetooth Connection Manager

The Bluetooth Connection Manager will determine if the mobile device is connected to the controller where the mobile app will be able to communicate with the controller. This will allow the user the option to connect and disconnect to the Bluetooth module using the mobile interface.

#### 3U1LOC1 – LED Output Control

LED output control is a feature in the mobile interface that allows the user to signal to the controller. The user will have options for varying output colors, led fading patterns, and brightness adjustments.

#### 3U1MM1 – Music Mode

Music mode is a feature in the mobile interface that allows the user to signal to turn on and off the music mode feature on the controller.

## Delivered Implementation

This section is written at the end of the term, after the project is completed.

This section describes the differences between the proposed project implementation from the previous section written at the beginning of the development and the delivered project implementation. Changes will be described from the perspectives of the system diagram, block diagram, and software architecture diagram.

### System Diagram

By: Sterling LaBarbera

For the delivered implementation of this project, there were no changes to the system diagram shown in the proposed implementation in Figure 1.

### Functional Block Diagram

By Sterling LaBarbera

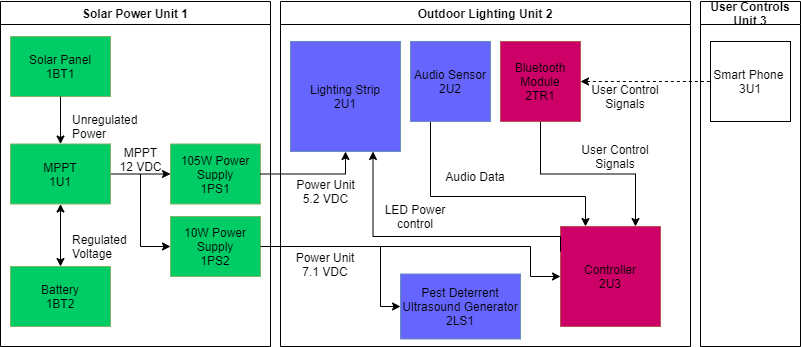
The functional block diagram of the delivered project differs in two places from the functional block diagram from the proposed implementation. Power Supply 1PS1 is replaced by 105W Power Supply 1PS1 and 5W Power Supply 1PS2. 1PS1 now only provides a 5.2 VDC peak 105 W output for the Lighting Strip 2U1, and 1PS2 provides a 7.1 VDC 10 W peak power output for the Pest Deterrent Ultrasound Generator 2LS1 and Controller 2U3. below shows these differences.

Figure . Functional block diagram for the delivered project

### Software Architecture

By: Nicholas Erickson

The software architecture for the delivered implementation is identical to the proposed implementation for the controller described in Figure 3. Additionally, the software architecture for the smartphone is identical to the proposed implementation.

## Work Assignments

By Sterling LaBarbera

The tables below list the group member assignments for each assembly in the revised functional block diagram and the software architecture diagrams. Table 2.1 lists the unit assemblies with their individual group member assignments, and Table 2.2 lists the software elements with their individual group member assignments.

Table – Group member assignments: unit assemblies.

|  |  |  |  |
| --- | --- | --- | --- |
| Assembly Reference Designation | Assembly Name | COTS? | Assigned To |
| 1BT1 | Solar Panel | Y | Sterling LaBarbera |
| 1U1 | Maximum Power Point Tracker | Y | Sterling LaBarbera |
| 1BT2 | Battery | Y | Sterling LaBarbera |
| 1PS1 | 105 W Power Supply | Y | Sterling LaBarbera |
| 1PS2 | 5 W Power Supply | Y | Sterling LaBarbera |
| 2U1 | Lighting Strip | Y | Matt Soehngen |
| 2U2 | Audio Sensor | Y | Matt Soehngen |
| 2TR1 | Bluetooth Module | Y | Nicholas Erickson |
| 2LS1 | Pest-Deterrent Ultrasound Generator | N | Matt Soehngen |
| 2U3 | Controller | Y | Nicholas Erickson |

Table – Group member assignments: software elements.

|  |  |  |
| --- | --- | --- |
| Software Element | Software Element | Assigned To |
| 2U3LPC1 | LED Power Controls | Nicholas Erickson |
| 2U3AUD1 | Audio Data | Nicholas Erickson |
| 2U3MIF1 | User Control Signals | Nicholas Erickson |
| 3U1MIF1 | Mobile Interface | Sterling LaBarbera |
| 3U1BCM1 | Bluetooth Connection Manager | Nicholas Erickson |
| 3U1LOC1 | LED Output Control | Sterling LaBarbera |
| 3U1MM1 | Music Mode | Sterling LaBarbera |

1. Project Scope

This chapter identifies the project’s key performance requirements, engineering and design constraints, our customer goals, our engineering goals, and our assumptions that collectively define our project’s scope.

## Requirements

By: Nicholas Erickson

The requirements for this project include a dual output power supply, remote LED control, music driven LED output, and an environmentally friendly footprint. The LED strip must be powered by a renewable energy source by our dual output supply. The LED output is required to be remotely user-controlled through a mobile smartphone. Additionally, the LED output must provide an audio feedback loop to pulse to input audio signals based on the varying intensity of the input.

### Functional and Performance Requirements

#### Dual Output DC Power Supply

By Sterling LaBarbera

The solar power system (Unit 1) provides voltage regulated output power from the battery to the Arduino Controller (2U5) and separately to the LED strip (2U1) due to the 20 Amp current requirements to run a 5-meter strip of LEDs. The Arduino cannot support the maximum current for full brightness since its maximum current draw is 1 Amp. The 12 VDC output signal from the maximum power point controller (MPPT) will be split to provide 5 VDC to the LEDs and 7.1 VDC to the Arduino with variable currents. Maximum output power based on device specifications will be 112.1 Watts. The range for the LED output voltage of (5.0 ± 0.25) V is to limit unwanted variance in the light intensity when not being modified by the controller. The Arduino output voltage range of (7.1 ± 0.1) VDC is based on a website [ref#] stating that going below 7 VDC can result in the actual voltage to the board being too low after passing through the internal voltage regulator. Using the lowest optimal voltage will help reduce power usage from the battery. Maximum Power is calculated as maximum current in LEDs times the output voltage to the LEDs, plus maximum current draw from the Arduino times output voltage to the Arduino. Table 1 lists the performance requirements for the power supply.

Table . Performance requirements for the power supply regulation to assemblies

|  |  |  |  |
| --- | --- | --- | --- |
| Description | Symbol | Value | Units |
| DC input voltage | Vin | 12 ± 1 | VDC |
| Regulated output voltage to LEDs | VLED | 5.0 ± 0.25 | VDC |
| Output current range for LEDs | ILED | 0.0-20.0 | A |
| Regulated output voltage to Arduino | Vmc | 7.1 ± 0.1 | VDC |
| Output current range for Arduino | Imc | 0.0-1.0 | A |
| Maximum total output power | PO,max | 112.1 | W |

#### LED Control

By: Nicholas Erickson

Our mobile app will be programmed and connected to the controller with Bluetooth remote control functionality to change the light-emitting diodes (LEDs) signal output. The functional requirements include the ability to turn on and off the LEDs, turn on and off music mode, change the LEDs output color, and turn on and off LED flashing mode.

##### Bluetooth Connectivity Range

Bluetooth connection will be used to communicate between the mobile device and the receiving controlling device. The Bluetooth connection must be able to successfully signal to the controller when within 20 feet of the receiving controller.

##### LED Output Requirements

LED output requirements include the ability to change the output color to at least five different colors through remote control Bluetooth connection. Additionally, the output requirements include the ability to output a LED flashing mode to cycle between changing LED colors every two seconds.

Table . Performance specifications for the LED control functionality

|  |  |  |  |
| --- | --- | --- | --- |
| Description | Symbol | Value | Unit |
| Bluetooth Connectivity Range | R | R <= 20 | Feet |
| LED Output Colors | O | O >= 5 | N/A |

#### Music-Driven LED Brightness Control

By Matt Soehngen

In order to match the LED strip brightness to the intensity of music playing around the gazebo, an audio sensor 2U2 will provide a control signal to the microcontroller 2U5 for brightness control. The performance requirements for this audio feedback control are listed in Table 3. Given that the music mode is most likely to be used in the setting of a party, the minimum audio threshold for turning on the LED strip to the lowest brightness will be above the background noise level of around 50 dB at which usual outdoor conversations occur; the noise level to turn on the LED strip *Vth*is chosen as 60 dB to avoid activation due to background noise. In addition to the lighting strip, the system includes a high-frequency noise generator 2A2 as pest deterrent device. Considering this, the audio sensor used for brightness control must have a selective detection range of frequencies in order not to detect this high frequency noise as a constant source of audio signal. The frequency range *fmax* for the audio feedback control is chosen near the upper range of human hearing at 8 kHz. Third, given that most upbeat party music has a tempo of up to 150 bpm (beats per minute), the audio sensor will need to detect changes in audio levels at a rate of at least four times this rate in order to flash in time with sixteenth notes in the music. Therefore, the maximum permissible feedback control delay through the audio sensor and microcontroller, *Δtmax* must be less than 100 milliseconds for this audio feedback control to pulse in time with notes at a rate of four times the tempo of 150 bpm, as shown in the calculation in Equation 1.

Equation 1. Maximum feedback delay calculation

Table . Performance requirements for music-driven brightness control function

|  |  |  |  |
| --- | --- | --- | --- |
| Description | Symbol | Value | Units |
| Threshold Volume | *Vth* | 60 | dB |
| Frequency Range | *fmax* | 10 | kHz |
| Maximum Feedback Delay | *Δtmax* | 100 | ms |

## Goals and Objectives

### Customer Benefit Goal Statement: Usability

By: Nicholas Erickson

By March 26th, 2021, develop a smartphone app for customers to remotely control the LED (light-emitting diode) outputs by having at least 80% of new customers successfully demonstrate all functional controls in under one minute of app usage.

#### Plan of Action to Complete Goal Statement

1. Create a smartphone app that includes the following functional requirements: turn on and off the LED strip, change the color of the LED output, and turn on and off music mode. Record a demonstration of successfully using all the functional requirements on the LEDs by March 12th, 2021.
2. Research and gather feedback from a focus group of three people to help create a more intuitive interface to increase consumer usability by March 19th, 2021. Review consumer input and work on the following non-functional requirements: organized controls interface, and user settings interface.
3. No later than March 26th, 2021, identify at least thirty potential customers and test them to complete all functional controls on the app in under one minute.

#### Metric Measurand

Measure the amount of time it takes a customer to turn on and off the LED strip, change the color of the LED output, turn on and off the app’s music mode, and turn off the LED strip.

#### Goal Achievement Threshold

Achievement of our goal entails that customers successfully complete the test of all functional controls sequence in one minute or less. At least 80% of customers tested need to complete our test in one minute or less on their first attempt to achieve the goal threshold.

#### Measurand Measurement Method

The method to test the usability of our smartphone is app is to time how long it takes the customer to use all our functional controls on their first attempt. Our testing will include the following: turn on the LED lights, change the color of the LED lights, turn on the Music Mode for the LED Lights, turn off the Music Mode for the LED lights, turn off the LED lights.

### Engineering Team Goal – Environmental Impact

By Sterling LaBarbera

By March 22, 2021, in order to be completely powered by renewable sources, connect a solar power unit that charges fast enough to be fully charged at least every 3 days in mostly clear weather conditions, in spring, summer, and fall in central Missouri.

#### Plan of Action to Achieve This Goal

1. Research possible battery options that can hold the estimated power consumption of 4+ hours usage and choose the one that has the longest lifetime with reasonable price by March 1, 2021.
2. To achieve a full charge over 3 days in good weather conditions, select a solar panel with enough energy production to generate that power in 24 hours of direct sunlight by March 1, 2021.
3. Acquire or construct a maximum power point controller to optimize battery charge time based on our battery and solar panel statistics by March 1, 2021.
4. Test the prototype in various conditions from March 8-20, 2021.
5. On March 21, 2020, using the results from step 4, determine if our system charges fast enough to be available after 3 days.

#### Goal Metrics

The goal metrics below will determine project achievement for this goal.

##### Metric Measurand

The elapsed time to completely recharge the battery from a fully discharged state using only solar power will be the measurand.

##### Goal Achievement Threshold

The goal is achieved if the charge rate is at least 80 minutes operating power, or at least 33% total battery capacity, per day, charging in partly cloudy to clear conditions during spring, summer, and fall months in Columbia, Missouri.

##### Measurand Measurement Method

From full discharge, measure the percentage increase in state-of-charge per hour and per day under various weather conditions during March 2021 in Columbia, Missouri. These values will be determined using the coulomb counting method.

Engineering Team Goal: Weatherproofing

By Matt Soehngen

Upon the final construction of our lighting system, our team wishes to ensure that every electrical component and connection in the system is weatherproof so that the system will be safe to operate outdoors and will be considered safe to use during rainfall.

#### Plan of Action to Complete Weatherproofing Goal

1. Proper waterproofing methods for outdoor electronics projects will be researched and an optimal method will be selected by March 10th.

2. During assembly of the system, care will be taken to ensure that the connections may be easily weatherproofed using selected method. This will be complete by the end of the individual contributions phase on March 12th.

3. Weatherproofing materials will be ordered for delivery by March 15th.

4. Weatherproof connections of electrical components will be constructed upon the completion of the system integration on March 26th.

#### Metric Measurand

Upon final construction of the integrated system, electrical assemblies will be contained in IP-67 rating weatherproof casings, and each connection between assemblies will likewise be insulated from water.

#### Achievement Threshold

The achievement threshold for the weatherproofing goal is that the connections between microcontroller to each connected assembly are insulated using chosen weatherproofing technique, and the microcontroller is contained within an IP-67 rated weatherproof case.

#### Measurement Method

The weatherproofing can be assessed following completion of system integration through inspection of proper implementation of connection insulation and weatherproof casing.

## Constraints

One constraint for this project regarding the gazebo design require that the gazebo onto which the system is installed may have a structurally stable enough roof to bear the weight of the entire system including the solar cell, as well as the battery, microcontroller box, and the LED strip. The weight of weatherproofing materials may be considered as a selection factor as a method of mitigating this concern. Another constraint of this project is the consideration of testing the audio sensitivity of the music mode while in the capstone lab. Play music at full volume to emulate the expected noise levels for realistic use cases could be disturbing to other groups in the lab if others are working nearby during the same hours as we are testing. Asking other groups for permission or waiting until they leave may be a considerate option during the testing of the music mode function.

1. Risk Management

## Project Planning Phase Assumptions

By Sterling LaBarbera

There are a few assumptions we made about usage of our product. Since it is designed for outdoor use, we assumed there will be users who leave it attached to a structure indefinitely, therefore the product must be weatherproof. We also assumed that the structures this will be installed on are not powered or near any power outlets.

## Health and Safety Considerations

By Sterling LaBarbera

We considered the users and location to be the main Safety concerns. This product will be weatherproofed to prevent water related short circuits or other failures which could cause electrical fires. The weatherproofing will also serve to keep users from accidentally touching or spilling something into the electronics. This includes children who may be around the product.

## Proposed Implementation Contingency Plan

The contingency plans below are for three elements we have Identified as high-risk either because they are necessary to the functioning of our project, or difficult to implement.

### Risk Management for Power Supply 1A1

By: Sterling LaBarbera

This is a contingency plan for power supply 1A1 in figure 1 that provides regulated power for both the controller 2U5 and the lighting strip 2U1. The maximum power point tracker (MPPT) 1U1 converts energy from the solar panel 1BT1 and battery 1BT2 into voltage-regulated 12 VDC output power. However, a separate power supply will be required to produce a voltage-regulated 7.1 VDC 7.1 W power source for controller assembly 2U5, and a 5 VDC 100 W power source for lighting strip assembly 2U1. We determined this to be a primary risk element since it is required for powering all of Unit 2 and is a dual output power supply.

Since the numbers above are specific to the project and are mainly to minimize power consumption from the battery, if we cannot construct a working power supply by March 5, 2021, we plan to purchase a two power supplies as a replacement. Our goal is to have the purchased supply arrive by March 10, 2021 for the last week of development. Unit 1 can function without the power supply, and Unit 2 is testable using DC power supplies in the lab until we get this one working. Purchasing a DC-to-DC dual output power supply that supports the appropriate currents and voltages would be outside the $500.00 budget for our group. Purchasing two buck/boost converters would cost between $40.00 and $60.00 plus $5.00 shipping and connecting them to the MPPT output will require one week at most. Our goal to complete this is March 12, 2021.

### User Control Signals Contingency Plan

By: Nicholas Erickson

The user control signal (Figure 3) is identified as a risk element in our capstone project because it provides input to the controller to test the software and circuit design associated with the controller. The user control signals are the software elements associated with the mobile application that will be signaled to controller through a Bluetooth module. Without user control signal functionality, our project would need a way to test our light-emitting diodes (LEDs) resulting outputs to test our circuit and controller. My proposed contingency plan for user control signals is to use physical circuits with buttons and switches connected to our controller to change the input mode and LED output colors. Our controller would have conditional switch programming associated with the signal associated with physical inputs instead of receiving signals remotely through Bluetooth. This contingency plan would replace the software element of the mobile app and the Bluetooth connection module connecting to the phone. The cost of these electrical components would be $30 including potential shipping costs. This contingency plan would allow us to test the other components of our project very easily while still trying to debug our mobile interface. We will begin implementing the backup contingency plan if the user control signals are not successfully working by March 5th. Our contingency plan will be delivered no later than March 15th to successfully integrate the other aspects of our capstone project.

### Lighting Strip 2U1

By Matt Soehngen

In order ensure sufficient time to test the function of the controller, the lighting strip will need to be acquired early in the semester. The desired LED strip for this project will be ordered online from a lighting manufacturer called BTF Lighting. Placing the order at the start of the semester should allow plenty of time for the processing and delivery of the order. If the lighting strip does not function properly when delivered or the strip becomes damaged accidentally through overvoltage during testing, a replacement LED strip must be ordered from Amazon which could be delivered in a short time frame of a week or less. The deadline for the delivery of the BTF LED strip will be two weeks after the start of the spring semester, February 9th. The contingency plan for ordering an LED strip from Amazon will take at most one week to carry out assuming expedited shipping is selected. Carrying out the contingency plan of purchasing a replacement LED strip from Amazon would likely cost an additional $35 with tax and shipping included.

### Repellant Tone Circuit 2A2

By: Matt Soehngen

The gazebo lighting system will feature a pest-repellant high-frequency tone generating circuit 2A2. This is a low-risk element for the gazebo lighting system. Incorporation of the tone generating circuit will increase the overall functionality and complexity of the lighting system, providing a unique feature for the outdoor product. However, the development of the tone generating circuit assembly may require time and efforts beyond the hours required to complete more essential components of the system during the product development phase. In order to solve this issue if it arises, the tone generating circuit assembly 2A2 may be omitted from the final project. The deadline to make the decision for omitting the repellant circuit will be Friday, March 12th and the cost to carry out this contingency will be $0.

## Managed Contingencies

By: Nicholas Erickson

Our project team had to call our risk managements contingency for our power supply 1PS1 and 1PS2 due to the inability for it to successfully output to the LED strip. In response, we followed our contingency plan and purchased a commercial off the shelf power supply. The purchased power supply was able to successfully power our LED strip with a 5V output with current capacity up to 20 amps. With the backup power supply our LED strip was able to work as intended. We also purchased a 10W power supply that successfully powered our controller and repellant tone circuit.

1. Evaluation

## Project Outcome

by Matt Soehngen

*This section discussed the project’s outcomes. Successes, partial successes, deficiencies are described.*

## Requirement Evaluations

In this section, the adherence to specified requirements will be assessed through the requirement measurement metrics for each requirement. The determination for requirement achievement is through the requirement achievement threshold for each requirement.

### LED Control

By: Nicholas Erickson

Our mobile app will be programmed and connected to the controller with Bluetooth remote control functionality to change the light-emitting diodes (LEDs) signal output. The functional requirements include the ability to turn on and off the LEDs, turn on and off music mode, change the LEDs output color, and turn on and off LED flashing mode.

#### Bluetooth Connectivity Range

Bluetooth connection will be used to communicate between the mobile device and the receiving controlling device. The Bluetooth connection must be able to successfully signal to the controller when within 20 feet of the receiving controller.

#### LED Output Requirements

LED output requirements include the ability to change the output color to at least five different colors through remote control Bluetooth connection. Additionally, the output requirements include the ability to output a LED flashing mode to cycle between changing LED colors every two seconds.

#### Performance

Our project was able to successfully maintain Bluetooth connectivity and send signals to the Bluetooth module at all distances up to 25 feet. This signifies successful completion of the Bluetooth connectivity range requirement. Additionally, our project was able to create 16,777,216 different output colors by allowing the user to control the red, green, and blue intensity on the lighting strip. Our project was able to successfully meet our output color requirement.

### Dual Output DC Power Supply

By Sterling LaBarbera

The solar power system (Unit 1) provides voltage regulated output power from the battery to the Arduino Controller (2U5) and separately to the LED strip (2U1) due to the 20 Amp current requirements to run a 5-meter strip of LEDs. The Arduino cannot support the maximum current for full brightness since its maximum current draw is 1 Amp. The 12 VDC output signal from the maximum power point controller (MPPT) will be split to provide 5 VDC to the LEDs and 7.1 VDC to the Arduino with variable currents. Maximum output power based on device specifications will be 112.1 Watts. The range for the LED output voltage of (5.0 ± 0.25) V is to limit unwanted variance in the light intensity when not being modified by the controller. The Arduino output voltage range of (7.1 ± 0.1) VDC is based on a website [ref#] stating that going below 7 VDC can result in the actual voltage to the board being too low after passing through the internal voltage regulator. Using the lowest optimal voltage will help reduce power usage from the battery. Maximum Power is calculated as maximum current in LEDs times the output voltage to the LEDs, plus maximum current draw from the Arduino times output voltage to the Arduino. Table 1 lists the performance requirements for the power supply.

#### Performance

The power supply we designed did not manage to meet the specifications above. It did provide a 5 V output when connected to a bench power supply, but not when we integrated it with the other components. The contingency power supplies meet our goals as are adjustable allowing for the 1PS2 in the actual functional block diagram to be exactly 7.1 V and 1PS1 to be exactly 5.2 V when measured with the bench power supply, both with the 12.7 V battery input. 1PS1 also specifies a maximum output of 105 W which is just above the needed power for the 20 A maximum current of the light strip.

## Goal Evaluations

In this section, the adherence to specified goal statements is assessed through the goal measurement metrics defined for each goal. The determination of goal achievement is given in the goal achievement threshold for each goal statement.

## Customer Goal – Usability

By: Nicholas Erickson

By March 26th, 2021, develop a smartphone app for customers to remotely control the LED (light-emitting diode) outputs by having at least 80% of new customers successfully demonstrate all functional controls in under one minute of app usage.

### Goal Evaluation

The following sections describe the intended evaluation plan, and the actual evaluation.

#### Metric Measurand

Measure the amount of time it takes a customer to turn on and off the LED strip, change the color of the LED output, turn on and off the app’s music mode, and turn off the LED strip.

#### Goal Achievement Threshold

Achievement of our goal entails that customers successfully complete the test of all functional controls sequence in one minute or less. At least 80% of customers tested need to complete our test in one minute or less on their first attempt to achieve the goal threshold.

#### Measurand Measurement Method

The method to test the usability of our smartphone is app is to time how long it takes the customer to use all our functional controls on their first attempt. Our testing will include the following: turn on the LED lights, change the color of the LED lights, turn on the Music Mode for the LED Lights, turn off the Music Mode for the LED lights, turn off the LED lights.

#### Measurand Measured Value

There was a total of 30 random customers that took the test and 29 were successful in completing all functional controls within one minute. The success rate of the users was 96.7%.

#### Goal Outcome

The 96.7% success rate of the thirty users completing all functional controls under a minute is a successful completion of the goal. The success rate was greater than the goal percentage of 80%.

## Engineering Team Goal – Environmental Impact

By Sterling LaBarbera

By March 22, 2021, in order to be completely powered by renewable sources, connect a solar power unit that charges fast enough to be fully charged at least every 3 days in mostly clear weather conditions, in spring, summer, and fall in central Missouri.

### Goal Evaluation

The sections below have the intended goal evaluation plan, followed by the actual plan.

#### Metric Measurand

The elapsed time to completely recharge the battery from a fully discharged state using only solar power will be the measurand.

#### Goal Achievement Threshold

The goal is achieved if the charge rate is at least 80 minutes operating power, or at least 33% total battery capacity, per day, charging in partly cloudy to clear conditions during spring, summer, and fall months in Columbia, Missouri.

#### Measurand Measurement Method

From full discharge, measure the percentage increase in state-of-charge per hour and per day under various weather conditions during March 2021 in Columbia, Missouri. These values will be determined using the coulomb counting method.

#### Measurand Measured Value

The measured value is the state of charge (SOC) of the battery. The Coulomb counting method is defined by Equation 2, where It is the current discharge current, and is the change in time between measurements.

Equation . State of charge estimation for lead acid batteries.

#### Goal Outcome

Over 1 hour of charging in clear weather from 5:30pm to 6:30pm, the battery discharge current increased by 0.3 A from 7.1 A to 7.4 A, and the terminal voltage increased from 12.75 V to 12.8 V. Based on this data, the SOC increased by about 7 percent in one hour. Charge rate goal was 100% in 24 hours, making this goal successful. These values were measured with a DC current clamp meter for currents and a digital multimeter for the voltages.

## Engineering Team Goal: Weatherproofing

By Matt Soehngen

Upon the final construction of our lighting system, our team wishes to ensure that every electrical component and connection in the system is weatherproof so that the system will be safe to operate outdoors and will be considered safe to use during rainfall.

### Goal Evaluation

The following sections detail the intended goal measurement plan, followed by the actual goal evaluation.

#### Metric Measurand

Upon final construction of the integrated system, electrical assemblies will be contained in IP-67 rating weatherproof casings, and each connection between assemblies will likewise be insulated from water.

#### Achievement Threshold

The achievement threshold for the weatherproofing goal is that the connections between microcontroller to each connected assembly are insulated using chosen weatherproofing technique, and the microcontroller is contained within an IP-65 rated weatherproof case, which is considered protected from water jets for up to 3 continuous minutes.

#### Measurement Method

The weatherproofing can be assessed following completion of system integration through inspection of proper implementation of connection insulation and weatherproof casing.

#### Goal Outcome

Having an IP-65 weatherproof box for the controller and battery satisfy the weatherproofing goal for the assemblies contained within those enclosures. Another enclosure with a rating of IP-65 contains the power supply, and the MPPT and solar panel are already rated for IP-65. According to the achievement threshold for this goal, the result can be qualified as a success.

## Timeline Evaluation

By: Nicholas Erickson

The timelines describe our proposed timelines for the four phases of our project: phase 1 – Development, phase 2 – System Integration, phase 3 – Demonstration, and phase 4 – Evaluation.

### Proposed Timeline

The timeline below describes our proposed timelines including our phase timelines, individual contribution timelines, and our evaluation phase of our SMART goals. Contributions by Nicholas are indicated in dark blue, contributions by Sterling are indicated in orange, and contributions by Matt are indicated in purple.



Figure . Project Proposal Timeline

### Actual Timeline

The timeline below describes our actual timelines including our phase timelines, individual contribution timelines, and our evaluation phase of our SMART goals. Contributions by Nicholas are indicated in dark blue, contributions by Sterling are indicated in orange, and contributions by Matt are indicated in purple.



Figure . Actual Project Timeline

### Late Deliverables

During the semester, Nicholas had to switch the deadlines of the music mode software and Bluetooth software and wiring due to delays in the lighting strip shipment. He needed the physical lighting strip to develop and test the music mode software and the system response to various patterns and intensities. He decided to do the Bluetooth software and hardware first since he already had the Bluetooth module. Matt needed a few extra weeks for the high-frequency tone circuit due to added complexity requested by the project adviser.

## Budget Evaluation

By Sterling LaBarbera

Below are a set of charts for the proposed and actual budgets for this product. The proposed budgets were made in December 2020. The actual budget reflects the costs to fully complete this product.

### Proposed Budget

The four charts below indicate the overall budget, and breakdowns for unit 1, unit 2, and contingency plans for high-risk elements.

Figure 8. Overall proposed budget.

Figure 9. Unit 1 proposed budget.

Figure 10. Unit 2 proposed budget.

Figure 11. Contingency proposed budget.

### Actual Budget

Table 6 below shows the Comparisons of our actual budget for the entire project with the proposed budgets. It also provides a comparison for Unit 1, Unit 2, and the contingency plans. The tables after break down the costs of each unit with the same comparisons.

Table . Actual vs proposed budgets overall and each unit.

Table 7 shows the breakdown for each assembly of Unit 1 with proposed vs actual costs. The solar panel and battery ended up being more expensive than proposed. However, since there was a compatible MPPT from previous projects, we saved the full price on that Assembly. The discrepancy in cost was partly because we found the MPPT before purchasing and knew we had spare budget, and partly due to the proposed cost only being an estimate based on current Amazon products. The PSU parts came out about even considering shipping costs, which are only estimated here.

Table . Actual Budget breakdown for assemblies in Unit 1.

Table 8 shows the cost breakdown and comparison for Unit 2. We already had an Arduino for the controller allowing for a full savings, and the lighting strip ended up being much cheaper than anticipated. The Bluetooth module and audio sensor ended up being well above our estimates since we purchased multiple of each to reduce risk. We also knew we still had good savings from the MPPT and lighting strip, allowing for slightly more expenditure here.

Table . Proposed vs actual budget for Unit 2.

Finally, for the contingencies shown in Table 9, the replacement power supplies from amazon ended up being much cheaper than our estimates, and we did not have to resort to any of the other contingency purchasing we planned.

Table . Proposed vs actual budget for contingencies.

1. Conclusions

This section describes the overall outcome of the project, its successes, failures, limitations, and suggested future improvements for the system.

## Successes

By Matt Soehngen

Numerous assemblies of this project perform as expected according to the design at the beginning of the project development. The audio feedback control for the music pulsing mode operates with 3 separate patterns based on the intensity of signal, and was programmed to respond to input signal changes with no more delay than 0.03 seconds. The pest deterrent ultrasound generator operates in the intended frequency range and produces an output at a volume of about 55dB when tuned to the human hearing range. The app control includes a continuous color selection slider set, music mode and flow mode buttons, and a Bluetooth connection menu and settings menu. The solar panel and MPPT are sufficient to charge the battery of the system at a rate above the desired threshold for expected in-season use rate.

## Limitations

Some parts of this project were limited in complexity and functionality for a few different reasons. The sensitivity of the audio sensor can be manually changed in the code of the microcontroller by editing a global variable for the music mode program. Ideally, this could be controlled in the app through a selection in the settings for music mode. For the pest deterrent ultrasound generator, restricted breadboard space and insufficient resources for design reference limited the complexity of the signal modulation to a simple two-tone frequency alternation. The limitations for the project were the inability to add a frequency response element to the music mode response of the lighting strip. We would have liked to implement this feature and would have had to have an aux input instead of a surrounding sound audio response. The response of the lighting strip from the signal sent to the controller is 100ms due to noise from the serial connection with the mobile phone. The project would send 0 values for the red, green, blue stored value to display the output without a sufficient delay in the controller software.

## Failures

Parts of this project development that did not work out as intended include an initial attempt at weatherproofing the audio feedback sensor by covering the entire front of the sensor with a caulk. This method detrimentally decreased the sensitivity of the sensor rendering it unusable. Another failure for the project is the designing of a low-side switch mode power supply. The execution was more difficult than anticipated and a COTS power supply was required in order to power the project in the end.

## Suggested Improvements

One improvement for this project is the design of a high-side switch mode power supply possibly being a more straightforward approach for an in-house switch mode power supply. Another improvement would be to modulate the frequency of the ultrasound tone in the pest deterrent ultrasound generator through the use of sinusoidal signal generation components which could better emulate changing motion of a high frequency audio source. As mentioned above, the inclusion of additional settings in the app control for audio sensitivity adjustment and other settings like flow mode color switching speed control and an on/off button for the lights in the standard illumination mode could improve the user experience when controlling the system. Adding a frequency response element to the music mode response of the lighting strip could be achieved by either using an aux input instead of a ambient audio response, or through accessing the media output signal from the user’s device through the app if their device is the source of the music being played.

Software

<DELETEME> It is recommended that you use an Excel (or similar) spreadsheet to document your detailed software requirements. If you use a spreadsheet, use the following format to name the spreadsheet file:

ece4980-s<#>-<year>-{spring|fall}-G<NN>-SoftwareSpecs.{xlsx|ods}

where <#> is the course section number (1, 2, 3, …), <year> is the four-digit year (e.g., 2015), either the “spring” or “fall” term, and <NN> is your group number (two digits, padded with a leading zero as needed). For example:

ece4980-s1-2015-spring-g02-SoftwareSpecs.xlsx

ece4980-s2-2015-fall-g13-SoftwareSpecs.ods

Then, in this appendix, inform the reader that the software requirements are provided in a separate spreadsheet file named “<give the file name>”, which accompanies this GROUP report. </DELETEME>

Replaceable Parts

**HINT:** Use the Excel spreadsheet “Group Report – Parts List” to compile the information in this parts list appendix. You are not required to use the spreadsheet, but systems like the one demonstrated herein are commonly used in industry to identify a) the original equipment manufacturers (the companies that make the parts you used), and b) the distributors from whom you purchased the parts you used, and c) the set of top-level “units” that comprise the system, and d) the assemblies and subassemblies that comprise each unit.

Original Equipment Manufacturers

Table – Original Equipment Manufacturer (OEM) codes.

| **Code** | **OEM Name** | **Website URL** |
| --- | --- | --- |
| 1 | Atmel | <http://www.atmel.com> |
| 2 | Yageo | <http://www.yageo.com> |
| 3 | Nichicon | <http://www.nichicon.co.jp> |
| 4 | Kemet | [http://www.kemet.com](http://www.kemet.com/) |
| 5 | Microchip Technology | [http://www.microchip.com](http://www.microchip.com/) |
| 6 | ON Semiconductor | [http://www.onsemi.com](http://www.onsemi.com/) |
| 7 | Aavid Thermalloy | [http://www.aavid.com](http://www.aavid.com/) |

Distributors

Table – Distributor codes.

| **Code** | **Distributor Name** | **Website URL** |
| --- | --- | --- |
| 1 | Digi-Key | [http://www.digikey.com](http://www.digikey.com/) |
| 2 | Newark | [http://www.newark.com](http://www.newark.com/) |

Project Units

Table – Project units.

| **Identifier** | **Description** |
| --- | --- |
| 1 | Remote-controlled Vehicle |
| 2 | Base Station |

Unit 1: Remote-controlled Vehicle

Table – Remote-controlled vehicle assemblies.

| **Reference Designation** | **Description** |
| --- | --- |
| 1A1 | Linear amplifier, 20 dBV |
| 1A2 | Butterworth 5 Hz low pass filter |
| 1A3 | Controller |
| 1A4 | Controller Power Supply, +3.3 VDC, 0.5 W |
| 1U1 | IEEE 802.15.4 LR-WPAN transceiver |

Table – Remote-controlled vehicle parts list (example only; this list is not complete).

| **Reference Designation** | **OEM Code** | **OEM P/N** | **Description** | **Dist. Code** | **Distributor P/N** |
| --- | --- | --- | --- | --- | --- |
| 1A3U1 | 1 | ATmega644PA-PU | 8-bit MCU, 64kb Flash, 2k EEPROM, 4k SRAM, 20 MHz, 1.8~5.5V, 40-DIP | 1 | ATMEGA644PA-PU-ND |
| 1A4C1 | 3 | UES1V100MEM | CAP ALUM 10UF 35V 20% RADIAL | 1 | UES1V100MEM-ND |
| 1A4R1 | 2 | CFR-50JB-5210K | RES CARBON FILM 10K 5% 1/2W AXIAL | 1 | 10KH-ND |
| 1A4U1 | 6 | LM317BTG | ADJ LDO REG 1.2-36 VDC 1.5A TO220 | 2 | 18M8206 |

Unit 2: Base Station

Table – Base station assemblies.

| **Reference Designation** | **Description** |
| --- | --- |
| 2A1 | Power supply, +15 VDC, 1 W |
| 2A2 | Power supply, -15 VDC, 1 W |
| 2A3 | Li-Ion Battery Charger Assembly |
| 2A3A1 | Li-Ion Battery Overcurrent Protection Subassembly |
| 2A3A2 | Li-Ion Battery Charge Level Monitor Subassembly |

Table – Base station parts list (example only; this list is not complete).

| **Reference Designation** | **OEM Code** | **OEM P/N** | **Description** | **Dist. Code** | **Distributor P/N** |
| --- | --- | --- | --- | --- | --- |
| 2A1C1 | 3 | UES1V100MEM | CAP ALUM 10UF 35V 20% RADIAL | 1 | UES1V100MEM-ND |
| 2A1MP1 | 7 | 6021BG | HEAT SINK 12.5°C/W TO220 | 2 | 18M8206 |
| 2A1MP2 | 7 | 4880SG | HEAT SINK INSULATOR/MOUNTING  KIT TO220 | 2 | 10M7230 |
| 2A1U1 | 6 | LM317BTG | ADJ LDO REG 1.2-37 VDC 1.5A TO220 | 2 | 45J0735 |

# References

[1] *IEEE Standard Reference Designations for Electrical and Electronics Parts and Equipments*, IEEE Std 200-1975, ANSI Y32.16-1975, 1975.

[2] MySafetySign.com. *Definitions for Danger, Warning, Caution Signs that follow ANSI Z535 Standards and OSHA 1910.145 Rules* [Online]. Available: <http://www.mysafetysign.com/danger-caution-warning-safety-sign-headers>. [Accessed: February 18, 2015].

[3] Stranco, Inc. *Safety Labels: Information on ANSI Z535.4-2007* [Online]. Available: <http://www.strancoinc.com/pdf/warning/ANSI.pdf>. [Accessed: February 18, 2015].

[4] S. M. Hall *et al.* *Update on ANSI Z535.6: A New Standard for Safety Information in Product Manuals, Instructions, and Other Collateral Materials* [Online]. Available: <http://www.ussafetysign.com/ansi.html>. [Accessed: February 18, 2015].

[5] M. Ibrahim. (2009, May 20). *'Do Not Trash' clip art* [Online]. Available: <http://www.clker.com/clipart-28635.html>. [Accessed: Jan. 10, 2014].

[6] The Pennsylvania State University. (2005). *MANGT 520: Planning and Resource Management, 8.1 Project Constraints* [Online]. Available: <https://courses.worldcampus.psu.edu/welcome/pmangt/samplecontent/520lesson08/lesson08_02.html>

[7] Wikipedia Contributors. (2014, Nov. 10). *Project management triangle* [Online]. Available: <http://en.wikipedia.org/wiki/Project_management_triangle>. [Accessed: January 20, 2015].

[8] Washington State, Office of the Chief Information Officer. "Assumptions & Constraints," *Project Management Framework* [Online]. Available: <https://ocio.wa.gov/pmframework/initiation/organization/assumptions>. [Accessed: August 24, 2016].

[9] R. Halligan. *Q. What is the significance of different types of requirements such as states and modes, functional, performance, external interface, environmental, resource, physical, other qualities and design?* [Online]. Available: <https://www.ppi-int.com/resources/systems-engineering-faq/q-significance-different-types-requirements-states-modes-functional-performance-external-interface-environmental-resource-physical-qualities-design/>. [Accessed: February 12, 2018].