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| \\cetus.ece.missouri.edu\users\fischerjd\Desktop\Current Semester\common\logo-clear.png | University of Missouri – Columbia  Department of Electrical Engineering & Computer Science |

Solar Powered Lighting System for Outdoor Unpowered Structures

ECE 4980 Capstone Project Overview

XXX 0, 0000

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# Abstract

The informative abstract must be one paragraph, with a length of 150 – 250 words, having 1.5 line spacing, and must provide this information in the order shown below. Remember that this informative abstract describes the delivered (demonstrated) project and the project’s results/outcome. DO NOT use words like “proposed” in this abstract; you are not writing a descriptive abstract for a project proposal.

* Product Concept. What is the product? What does the product do?
* Problem Domain. What specific problem(s) does this project address and solve?
* Rationale. Why should this problem be solved? Who are the primary beneficiaries/users of this product?
* Background. If your Capstone project serves to continue the development of a product that others worked on before you, briefly summarize the work done by others on the product to this point in time; otherwise, omit this item.
* Approach. Briefly describe the delivered implementation of the entire project. Provide the “10,000 foot view” of the project. DO NOT discuss mundane implementation details—e.g., it uses 555 timers; it uses MOSFETs; it has an Atmel microcontroller, etc. See also NOTE 1 below.
* Innovation. Identify the current state-of-the-art and state explicitly how this project improves upon that art. See also NOTE 1 below.

1. At the beginning of the term describe herein the proposed project implementation. At the end of the term, you must review and adjust the information in the “Approach” and “Innovation” sections to ensure these sections describe the project in its delivered (demonstrated) form.

* Results. Briefly and ACCURATELY discuss the project’s outcome—e.g., successes, shortcomings, measured (not assumed) end-user benefit. Do not lie or provide exaggerated claims that state the project was an awesome success if the reality is otherwise. An unsuccessful result is not uncommon in engineering and should be faithfully reported as such—i.e., you tried a solution and discovered it didn’t work as well as expected, or it did not work at all. See also NOTE 2 below.

1. At the beginning of the semester insert a placeholder statement for this “Results” section—e.g., RESULTS PLACEHOLDER: THIS PLACEHOLDER WILL BE REPLACED WITH A STATEMENT OF THE PROJECT’S ACTUAL OUTCOMES AT THE END OF THE TERM. At the end of the term, you must provide herein one or more statements that describe the project’s actual outcomes.

Index Terms—<DELETEME>A comma-separated list of index terms that serve as search engine keywords. Use the IEEE’s taxonomy[[1]](#footnote-1) of index terms as your primary reference. You may also use index terms of your own inventing/choosing; you are not restricted to using only the IEEE’s taxonomy. The first line is indented ½ inch. The phrase “*Index Terms*” is *bolded and italicized*. The individual index terms are bolded but not italicized. Sort the list of index terms in alphabetical order. The first term in the list is capitalized; index terms that are proper nouns are capitalized; abbreviations are typically formatted with all caps; all remaining terms in the list are lowercase. Place a period ‘.’ at the end of the list. For example:

*Index Terms*—Electric vehicles, global positioning system (GPS), land vehicles, radio telemetry, remotely operated vehicles.

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1. Introduction

## Report Purpose

By: <FirstName> <LastName>[, <FirstName> <LastName>[, …]]

Contributions by: <FirstName> <LastName>[, <FirstName> <LastName>[, …]]

This report establishes the project-level documentation that (1) defines the project concept, requirements, and goals, and (2) explains the project’s theory of operation, and (3) evaluates the project’s outcomes. The engineering 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

State in general terms the problem set your project is expected to solve.

## Project Concept

Clearly summarize the project’s function and purpose.

## Background

If this project is not a continuation of work that was begun by others on this project, then omit this “Background” section from your report. Otherwise, provide brief descriptions of 1) the project’s history, 2) the project’s present state, and 3) your group’s planned contributions to the project—e.g., changes, improvements, feature additions, etc.

## Innovation

Describe the current state-of-the-art and explain how this project improves upon that art.

## Report Overview

Write a single paragraph that summarizes the report’s organization and the information provided within each chapter and appendix within this report. Mention explicitly each chapter number (or appendix letter)—e.g., chapter 3—and provide a summary of the information provided in that chapter (or appendix). Use simple present tense as the preferred verb tense for the “Report Overview” paragraph. For example:

The remainder of this report is organized as follows. The scope of the Cal Poly intelligent NIC (CiNIC) project is defined in Chapter 2 including a summary of the project’s performance requirements, definitions of the group’s customer-centric SMART goal and objectives, definitions of the group’s ABET “realistic constraints” SMART goals and objectives, the sponsor-driven project constraints, and an explanation of the assumptions our group made at the start of our project. Chapter 3 provides a summary of the possible implementations we considered when we proposed this project, a detailed description of our proposed implementation, our contingency plan information, a detailed description of our actual/delivered implementation, and our individual work assignments. In Chapter 4 we explain our project evaluation plan and discuss our evaluation results. We also provide analyses of our proposed versus actual costs and our proposed versus actual timelines. Chapter 5 provides general concluding remarks and summary discussions of our project’s successes, limitations, deficiencies, and ideas for suggested improvements. Appendix A “Customer Survey” provides a copy of the survey questionnaire we created and used to assess customer satisfaction with the project’s stated purpose of measuring TCP/IP protocol stack latencies for multiple operating system platforms (all running on the same hardware), along with the raw survey data we collected from the respondents who tested our project and completed our survey.

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

In this section describe the various possible implementations, features, etc. your group considered when you proposed the project.

The level of detail provided herein must be limited to the functional block diagram and software architecture level. Do not provide implementation details herein (e.g., circuit schematics, detailed explanations of software functions, etc.). Implementation details are documented in the group members’ individual contributions reports.

## 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 (formatting style: Heading 4)

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

Provide herein one or more product concept diagrams with written prose that describes the theory of operation of the product’s processes for the proposed implementation. An example product concept diagram figure is provided in Figure 1. A product concept diagram should pictorially describes these physical elements: INPUTS, PROCESSES, and OUTPUTS. Information that enters or acts upon the physical system is an INPUT signal. A physical PROCESS accepts this incoming INPUT signal and produces one or more OUTPUTS (the system’s response to the INPUT signal). The idea is to help the reader understand the main wooden physical elements that comprise the physical product and how those elements interrelate.

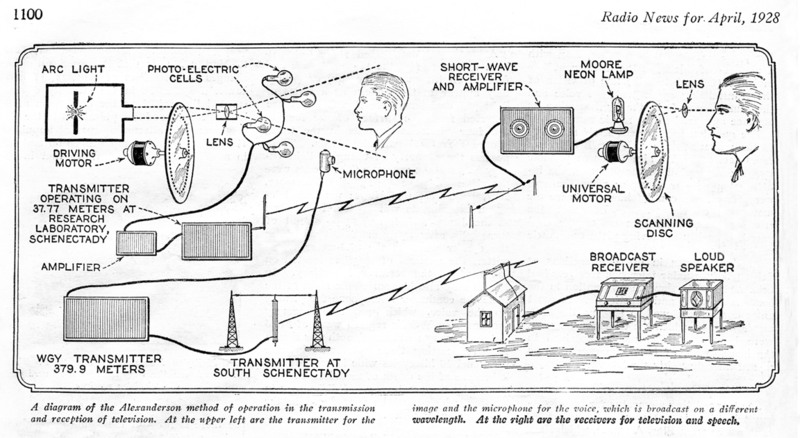


Figure 1. Example of a product concept diagram figure. C. G. B. Rowe, Early Television System Diagram, April, 1928. Available from: Wikimedia Commons, <https://commons.wikimedia.org/wiki/File:Early_Television_System_Diagram.png>.

For additional examples of product concept diagrams, see these pages on Pinterest.com:

* [Garden hose handle](https://i.pinimg.com/originals/1f/b1/cf/1fb1cf6926512c3b6f409fb4ab450255.jpg)
* <https://www.pinterest.com/pin/837599230666289528>
* <https://www.pinterest.com/pin/519532506987464957/>

### Functional Block Diagrams

Provide herein one or more functional block diagram figures with written prose that describes the theory of operation at a functional level for the proposed implementation. Recall that a functional block diagram pictorially describes the functional structure of the proposed system via these visual elements: SYSTEM, SET, UNIT GROUP, UNIT, ASSEMBLY, SUBASSEMBLY, BASIC PART.[[2]](#footnote-2) As a general rule, do not describe BASIC PARTs in this section. The idea is to help the reader understand the main functional elements that comprise the project, and how those elements interrelate. An example of a system diagram figure is provided in Figure 2.

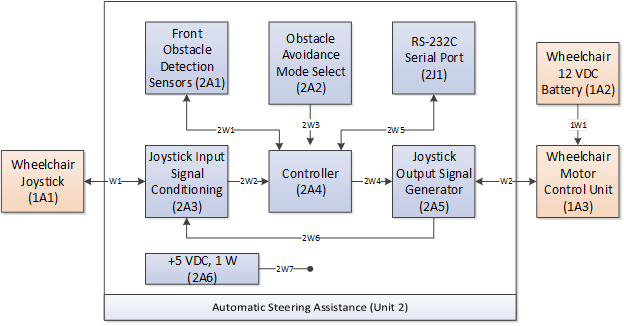


Figure 2. Example of a functional block diagram figure.

The best way to organize your discussion in this section is a “top down” hierarchical structure—i.e., first describe the system overall; next describe the SETs that make up the system (if any); next describe the unit GROUPs units (if any); next describe the UNITs, and finally, describe the ASSEMBLIES and SUBASSEMBLIES. As a general rule, do not describe BASIC PARTS in this section. For example:

#### System “<system\_name>” (Heading 4)

- If your project does not meet the definition of a *system* [[1](#_ENREF_1)], delete this subsection.

- Opening commentary that briefly summarizes the system’s purpose and operation.

- Functional block diagram showing the set’s composition (unit groups, units, assemblies, subassemblies) with discussion of the system’s theory of operation.

#### Set “<set\_name>” (Heading 4)

- If your project does not provide one or more sets as defined in [[1](#_ENREF_1)], delete this subsection.

- Opening commentary that briefly summarizes the set’s purpose and operation.

- Functional block diagram showing the set’s composition (unit groups, units, assemblies, subassemblies) with discussion of the system’s theory of operation.

#### Unit 1 “<unit1\_name>” Operation (formatting style: Heading 4)

- Opening commentary that briefly summarizes the unit’s purpose and operation.

- Functional block diagram showing the unit’s composition (assemblies, subassemblies) with discussion of the system’s theory of operation.

#### Assembly 1A1 “<assy\_1a1\_name>” Operation (Heading 4)

- Briefly describe using written prose, and possibly generic figures, the function of assembly 1A1 and its theory of operation. DO NOT describe herein assembly 1A1’s implementation details; implementation information is provided in the *Individual Contributions* reports.

#### Assembly 1A2 “<assy\_1a2\_name>” Operation (Heading 4)

- Briefly describe using written prose, and possibly generic figures, the function of assembly 1A2 and its theory of operation. DO NOT describe herein assembly 1A2’s implementation details; implementation information is provided in the *Individual Contributions* reports.

#### Subassembly 1A2A1 “<assy\_1a2a1\_name>” Operation (Heading 4)

- Briefly describe using written prose, and possibly generic figures, the function of subassembly 1A2A1 and its theory of operation. DO NOT describe herein assembly 1A2A1’s implementation details; implementation information is provided in the *Individual Contributions* reports.

Etc...

### Software Architecture

Provide herein one or more software architecture figures, one figure per CPU, and summary discussion thereof that explains the structure of the **proposed** software architecture. The caption under each software architecture figure must contain the label (e.g., CONTROL) and the reference designation (e.g., 2U3) of the functional block that executes the software that’s modeled in the software architecture figure. It is a “best practice” to also reference the figure number (e.g., Figure 8) of the functional block diagram figure that displays the functional element (e.g., CONTROL assembly 2U3) that executes this software. An example technology stack diagram figure and caption are provided in Figure 3.



Figure 3. Software architecture for the CONTROL assembly 2U3 (see also Figure 8).

## Delivered Implementation

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

The delivered (demonstrated) implementation of the project is often different from the proposed implementation of the project. **Describe herein the differences between the “proposed implementation” and the “delivered implementation” of the project**, where the “delivered implementation” is the final, delivered version of the project (at the end of the term). Limit the level of detail provided herein to the system diagram, one or more functional block diagrams, and one or more software architecture figures, and superficial discussions of each.

1. DO NOT describe herein implementation details for the various project elements. Implementation details are provided in the INDIVIDUAL CONTRIBUTIONS reports.

### System Diagram

If a system diagram figure for the delivered implementation is **identical** to its corresponding system diagram figure for the proposed implementation, then simply refer the reader to the system diagram figure provided in the proposed implementation section of the report. Otherwise, provide herein one or more system diagram figures with written prose that describes the theory of operation of the system’s processes for the **delivered implementation**. Describe in the written prose only the differences between the proposed and delivered system diagrams. For example:

The system diagram for the delivered implementation is identical to the system diagram shown in Figure 13 for the proposed implementation.

### Functional Block Diagram

If a functional block diagram figure for the delivered implementation is **identical** to its corresponding functional block diagram figure for the proposed implementation, then simply refer the reader to the functional block diagram figure provided in the “Proposed Implementa­tion” section of the report. Otherwise, provide herein one or more functional block diagram figures and describe the theory of operation at a functional level for the **delivered implementation**. Do not include herein any functional block diagram figures or descriptions that are identical to those provided in the “Proposed Implementation” section above. Only describe herein the differences between the delivered and proposed functional block diagram figures. As a general rule, do not describe BASIC PARTs in this section. For example:

Except for Power Supply Unit 5, the functional block diagrams for the delivered project are identical to the functional block diagrams for the proposed implementation. During the project we made significant changes to Power Supply Unit 5’s design to correct an overheating problem. The functional block diagram shown in Figure 22 shows the functional elements that comprise the redesigned and delivered version of Power Supply Unit 5. The only noteworthy change in Figure 22 is the 12 VDC POWER assembly. In our proposed implementation we intended to design and build the 12 VDC POWER assembly ourselves; see assembly 5A3 in Figure 12. However, we ended up purchasing a commercial off-the-shelf power module for the 12 VDC POWER assembly, and therefore this item’s reference designation changed from 5A3 to 5U7.

### Software Architecture

If a software architecture figure for the delivered implementation is **identical** to its corresponding software architecture figure for the proposed implementation, then simply refer the reader to the software architecture figure in the proposed implementation section of the report. Otherwise, provide herein one or more software architecture figures, one figure per CPU, and summary discussion thereof that explains the structure of the **delivered software architecture**. Describe in the written prose any differences between the proposed and delivered software architectures.

## Work Assignments

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

A given hardware or software element must be assigned to one, and only one group member who is ultimately responsible for specifying, designing, building, and delivering that item fully functional on or before its delivery deadline. Note that assemblies are not limited to circuit assemblies; they may be any type of assembly (e.g., a robot’s mechanical chassis) that is part of the project.

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. In Table 2.1 be sure to indicate whether each line item is commercial off-the-shelf (COTS)—i.e., purchased already assembled as a unit of supply—or is not COTS (i.e., designed by and created from individual basic parts by someone in the group).

Table 2.1 – Group member assignments: unit assemblies.

|  |  |  |  |
| --- | --- | --- | --- |
| Assembly Reference Designation | Assembly Name | COTS? | Assigned To |
| 1A1 | +12 VDC, 1 Watt DC power supply | N | John Smith |
| 1A2 | -12 VDC, 1 Watt DC power supply | N | John Smith |
| 1U1 | Control Assembly | Y | Allison Norris |
| 1U2 | Control Assembly DC-DC Converter/Regulator | Y | Allison Norris |
| … | … |  | … |

Table 2.2 – Group member assignments: software elements.

|  |  |  |
| --- | --- | --- |
| Software Element | Software Element | Assigned To |
| 1A3SDD1 | Device driver, TEST MODE ENABLE input signal | Frank Cedars |
| 1A3SDD2 | Device driver, DOOR LOCK ACTUATOR output signal | Frank Cedars |
| 1A3SDD3 | Device driver, USART0 serial port | Frank Cedars |
| 1A3SLB1 | Standard C Library, STDIO | Frank Cedars |

NOTE: I recommend you devise a reference designation system that allows you to uniquely identify each software element shown in your software architecture diagram(s). Display each reference designation code, along with a unique descriptive name, on each software element on the software architecture figure(s). For example: Assume unit 1, separable assembly is the “Control” assembly that has the microcontroller, microcontroller power supplies, etc. For example, assume that within Unit 1, separable assembly A3 is a controller assembly that executes software:

* 1A3SDD1 := Unit 1, separable assembly 3, Software Device Driver 1
* 1A3SDD2 := Unit 1, separable assembly 3, Software Device Driver 2
* 1A3SLB1 := Unit 1, separable assembly 3, Software LiBrary 1
* 1A3SPC1 := Unit1, separable assembly 3, Software Process Control 1

|  |  |  |
| --- | --- | --- |
| Main Program (SPC1) | |  |
| STDIO (SLB1) |
| Test Mode Enable (SDD1) | Door Lock Actuator (SDD2) | USART0 (SDD3) |

**DO NOT** place the software architecture figure at this location in the report. The technology stack diagram figure shown above is provided only for convenience, to supplement the discussion above.

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

<DELETEME> In this section of the report, **use written prose to identify and discuss** the project’s most critical requirements (functional requirements, performance requirements, interface requirements, software requirements) and engineering / design constraints. The goal is to document herein the group’s decision-making process when defining the critical requirements described herein.

**NOTE: Detailed requirements tables are NOT provided herein; they are provided in Appendices A, B, C, and D.** </DELETEME>

### 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 1. 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 |

## Goals and Objectives

This section defines the project’s SMART goals and objectives. Each group must have (a) at least one customer-centric goal that focuses on customer benefit (how should the customer benefit from using this project?), and (b) at least four “engineering” goals whose focus is four of the eight ABET realistic design considerations and constraints. Each SMART goal must have its own set of SMART objectives that outline the group’s plan-of-action for accomplishing that particular goal.

### Customer-centric Goal and Objectives

Provide the SMART goal statement.

#### Goal Objectives

Provide the SMART objective statement(s) that define the plan of action—i.e., the set of tasks your group must successfully accomplish—to realize the stated goal.

#### Goal Metrics

Provide the Goal Metrics, to include a description of the measurand (what will you measure to determine goal achievement?); the measured value or value range that indicates goal achievement; the procedure to be used to measure the measurand.

### <ENGINEERING\_GOAL1> Goal and Objectives

Replace “<ENGINEERING\_GOAL1>” with the proposed ABET realistic design constraint category. Choose one of “Constraints” or “Considerations”, as appropriate (see the EXAMPLES below).

EXAMPLE: Economic Goal and Objectives

EXAMPLE: Sustainability Goal and Objectives

Provide the SMART goal statement.

#### Goal Objectives

Provide the SMART objective statement(s) that define the plan of action—i.e., the set of tasks your group must successfully accomplish—to realize the stated goal.

#### Goal Metrics

Provide the Goal Metrics, to include a description of the measurand (what will you measure to determine goal achievement?); the measured value or value range that indicates goal achievement; the procedure to be used to measure the measurand.

### Engineering Team Goal – Environmental Impact

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

##### 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\_GOAL3> Goal and Objectives

### <ENGINEERING\_GOAL4> Goal and Objectives

## Constraints

In this section, describe any other constraints the project group must contend with while designing and implementing the project. Project constraints are commonly classified as *technical*, *resource*, or *physical* [[6](#_ENREF_6)], or as *scope*, *time*, and *cost* which together comprise the so-called project management triangle [[7](#_ENREF_7)]. (Sometimes a fourth constraint *quality* is considered, and so the project management triangle changes into a square.)

An example constraint might be availability of a flight simulator resource; multiple engineering teams must use/share a single flight simulator, and consequently your group will be constrained by simulator time (1) are beyond your control, and (2) must be considered and managed.

1. Risk Management

## Health and Safety Information

This section is written at the end of the term, after the project is completed. Describe any pertinent Safety Information for the completed, demonstrated project (not the proposed project).

Provide herein all relevant precautionary statements (danger, warning, caution, notice, and safety instructions) [[2](#_ENREF_2)], [[3](#_ENREF_3)], [[4](#_ENREF_4)] that alert the user to known hazards when working with or working around the project. Notices must conform to ANSI Z535.1 *American National Standard for Safety Colors*, as shown in Figure 4.4:



Figure 4.4 – Examples of safety icons from ANSI Z535.1.

If the project contains components that should not be thrown into the trash, inform the user as such and display the “Do Not Trash” icon with that message (Figure 4.5) [[5](#_ENREF_5)].

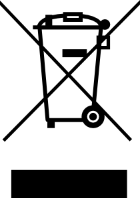


Figure 4.5 – Example “Do Not Trash” icon.

## Proposed Implementation Contingency Plan

In this section describe the contingency plan for the proposed implementation of the project. The level of detail provided herein should be limited to the functional block diagram / software architecture level. (Do not provide implementation details herein.)

For each high risk element, provide the following information in the order shown here

a) Identify and describe the “plan A” high risk element

b) Explain why this element is a high risk element

c) State the completion deadline date for the high risk element

c) Identify the lower risk “plan B” alternative element the group will switch to and implement if the high risk element is not completed on or before its specified deadline date

d) State the completion deadline date for the lower risk “plan B” element.

Repeat this sequence for each remaining high risk element.

## Managed Contingencies

In this section describe the contingencies, if any, the group had to manage. For example, which, if any, of the contingency plans did you actually use? Were there unplanned contingencies the group had to manage—e.g., a team member became severely ill and had to drop the course midway through the semester, and consequently the team had to compensate for the loss of that team member).

1. Evaluation

## Project Outcome

Discussion of the project’s outcomes. Successes, partial successes, deficiencies, etc. Use objective language and avoid subjective statements/opinions, and dDo not exaggerate your results.

## Goals Evaluation

<DELETEME>

INSTRUCTIONS. For each customer and/or engineering goal, provide/discuss the following:

* Subheading. Create a subheading with descriptive keywords that identify the goal—e.g., Customer Goal, or Engineering Goal – Sustainability. Format this subheading with the report template’s format style ‘Heading 2’. *[[3]](#footnote-3)*
* Goal Statement. Provide the SMART goal statement, verbatim.
  + DO NOT provide herein the SMART objective statements for this SMART goal.
* Subheading. Provide a subheading titled “Goal Evaluation”. Format this subheading with the report template’s format style ‘Heading 3’.*[[4]](#footnote-4)* Under this heading discuss the following topics in the same order as shown here:
  + Goal Measurand. Identify the quantity you measured to evaluate this goal.
    - Ensure the measurand is definable as a numeric range with well-defined units; see the next section “Goal achievement threshold”.
    - Examples: knowledge transfer via didactic delivery; RoHS compliance; capstone project budget, circuit board compliance with IPC-9252B. *[[5]](#footnote-5)*
  + Goal achievement threshold. For the specified metric measurand, identify the numeric range with well-defined units that indicates goal achievement. If measurement of the measurand during the Project Evaluation phase yields a result that is outside the range of values of values that indicate goal achievement, the goal is unachieved.
    - Examples: 95 % of students who take the exam must score 75 % or higher; the project’s basic parts, subassemblies, assemblies, and units shall all be RoHS compliant; money spent on parts purchases for the project must not exceed $200 USD; our circuit board shall be compliant with IPC-9252B’s guidelines for testing circuit boards during manufacturing.*[[6]](#footnote-6)*
  + Measurand measurement method.  Describe the method that shall be used next semester in ECE 4980 to measure the measurand—e.g., accounting; user survey; direct observation; statistical analysis, etc. Your description must provide sufficient detail of the measurement methodology to be used; it cannot be a suggestion of the measurement methodology to be used.
    - Examples: Use a spreadsheet to record the students’ exam scores and determine the percentage of students who scored 75 % or higher on the exam; Use a spreadsheet to document and tally RoHS compliance data for each basic part, subassembly, assembly, and unit; Use a spreadsheet to record and tally all funds spent on parts purchases; Use a spreadsheet to itemize the guidelines in IPC-9252 that are relevant to our circuit board, and document whether our board is compliant with these guidelines.
  + Measurand measured value. Show the numeric value (with well-defined units) that you obtained when you measured the specified measurand using the measurement methods(s) described above.
    - Example: 38 students scored 75 % or higher on the quiz. The enrollment is 43 students. .
  + Goal outcome. Using the goal achievement threshold and measured value, declare whether the goal was achieved or unachieved. There is no partial credit; the goal is either 100 % achieved or it is unachieved.
    - Example: The percentage of students who took the quiz and scored 75 % or higher was measured as 88.4 %. This outcome fails to meet the requirement that 95 % of the students who take the exam score 75 % or higher; therefore, the goal is unachieved.

</DELETEME>

### Customer-centric SMART Goal and Objectives

### <ENGINEERING\_GOAL1> SMART Goal and Objectives

### <ENGINEERING\_GOAL2> SMART Goal and Objectives

### <ENGINEERING\_GOAL3> SMART Goal and Objectives

### <ENGINEERING\_GOAL4> SMART Goal and Objectives

## Timeline Evaluation

### Proposed Timeline

### Actual Timeline

## Budget Evaluation

### Proposed Budget

Pie chart

### Actual Budget

Vertical bar chart (side-by-side comparison of proposed vs. actual expenditures)

Compare and discuss herein your group’s proposed and actual budgets. This should be a macro analysis, not a micro analysis, of your group’s expenditures on this project.

If the actual expenditures for an element exceeded the group’s budgeted expenditures for that element, explain this cost overrun; why did the group go over budget on this element?

The granularity of your budget analysis should the functional block (assembly) level or higher (e.g., units, sets, etc.). DO NOT describe herein the costs of individual basic parts (components). DO NOT provide herein tables that itemize the cost of every basic (component) in your project. (Itemized parts listings belong in the “Bill of Materials” appendix within the INDIVIDUAL CONTRIBUTIONS reports.)

For example, your written prose might reference a vertical bar chart figure that compares your budgeted (proposed) expenditures versus your actual expenditures for a) Plan A expenses, and b) Plan B expenses, and c) ancillary expenses, etc.

For example, you could provide a series of vertical bar chart graphs that compare the proposed and actual expenditures for the sets, units, and assemblies that comprise your project.

1. Conclusions

Add your summary remarks here…

## Successes

## Limitations

## Failures

## Suggested Improvements

Evaluation Methods (or custom)

<DELETEME> Your content here … </DELETEME>

Evaluation Methods (or custom)

<DELETEME> Your content here … </DELETEME>

Evaluation Methods (or custom)

<DELETEME> Your content here … </DELETEME>

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 E.1 – 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 E.2 – 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 E.3 – Project units.

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

Unit 1: Remote-controlled Vehicle

Table E.4 – 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 E.5 – 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 E.6 – 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 E.7 – 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].

1. 2013 IEEE Taxonomy Version 1.0 <http://www.ieee.org/documents/taxonomy_v101.pdf> [↑](#footnote-ref-1)
2. See IEEE Std 200-1975 *IEEE Standard Reference Designations for Electrical and Electronics Parts and Equipments*. [↑](#footnote-ref-2)
3. Microsoft Word’s RIBBON BAR > HOME tab > STYLES gallery > Heading 2 [↑](#footnote-ref-3)
4. Microsoft Word’s RIBBON BAR > HOME tab > STYLES gallery > Heading 3 [↑](#footnote-ref-4)
5. IPC-9252B Requirements for Electrical Testing of Unpopulated Printed Boards defines industry-standard practices for facilitating circuit board testing during manufacturing processes. [↑](#footnote-ref-5)
6. <https://bayareacircuits.com/bare-printed-circuit-board-electrical-test/> [↑](#footnote-ref-6)