Christmas Village Light Display

Group 17

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1 Design Impact Statement

1.1 Public Health, Safety, and Welfare Impacts

The safety of the product we are building was one of the biggest areas that we considered. According to One Medical, there were 15,000 injuries caused by holiday decorations in the Holiday season of 2012 alone [1]. Decorations, including Christmas lights, share a bulk of those hazards from fires and burns. Unsafe connections and exposed wires lead to most safety hazards [1]. For these reasons, our team included a safety requirement in our design. We specifically ensured no exposed wires were in our design, since they are the most significant safety hazard in our project.

1.2 Cultural and Social Impacts

Each year, the client adds a new Department 56 Christmas village building to his family's collection. The specific village our client has is from a company called department 56. Department 56 became famous with their hand painted ceramic Christmas village buildings with lights in them. According to Department 56'swebsite, they have been in business since 1976 [2]. One thing they have not changed is the incandescent light bulbs used in lighting the village buildings. This is a major change our team was tasked in making. Our team is disrupting over 40 years of tradition. Changes to the traditional lighting can become more socially acceptable if we impress the client's family and friends and keep in mind the cultural significance these buildings represent.

1.3 Environmental Impacts

Environmental impacts are the main area of concern for this project. Due to the client's desire for wireless fixtures without rechargeable batteries, our project uses 2 AA batteries per fixture.

According to the United States Environmental Protection Agencyepa.gov, energy efficiency is a resource that reduces the need to generate excess electricity and therefore reduces environmental impacts [3].To power 1 fixture for the Christmas season (31 days, 2.5 hrs./day), each fixture requires 2 AA batteries. Assuming full capacity with 30 buildings, each Christmas season would consume 60 AA batteries. Compounding the environmental effect, the energy consumption from wireless communication and powering bright LEDs means users need to replace the batteries every season. To combat this, rechargeable batteries are the best option, as they are substantially for the environment [4]. Rechargeable batteries also reduce the yearly cost for the user, further incentivizing their use. Another potential remedy would be to combine the wireless fixtures with the Department 56 incandescent lights, an application the client has expressed interest in.

1.4 Economic Impacts

Following the environment, the economic impacts from this project have the second-most significant concerns.At the time this document is being written, the average price of AA batteries on Amazon ranges from $0.24 - $1.24 [5]. At the aforementioned 60 AA batteries per Christmas season, this results in prices ranging from $14.40 to $74.40. While the client has been made aware of and accepts these prices, other people could be unwilling or unable to handle the recurring cost if this project was more widely used. Additionally, AA alkaline batteries are a nonrenewable resource, and could rise in price in the future [6].

1.5 Conclusion

Multiple areas of impact have been reviewed. For each, our team has given our best effort to reduce or eliminate the negative impact brought forth by our project.

2 Project Timeline

Christmas Village Light Display

PROJECT TITLE	Christmas Village Display	**UNIVERSITY**	Oregon State University
PROJECT MANAGER	Calvin Hughes	**DATE**	5/19/21

Desgin Phase: WEEK 1-2 · WEEK 3-4 · WEEK 5-6 · Week 7-8 · Week 9-10 · WEEK 11 · Week 12 · WEEK 13
Build Phase: WEEK 14-17 · WEEK 18-23 · WEEK 24-26
Presnenting Phase: WEEK 27-28 · WEEK 29-30

WBS NUMBER	TASK TITLE	TASK OWNER	PCT OF TASK COMPLETE
1	**Project Conception and Initiation**		
1.1	Project Executive Summary	Michael B	100%
1.1.1	Team Protocols and Standards	Zachary W	100%
1.2	Communication Evaluation	All Members	100%
1.3	Projections	Jesus A	100%
1.4	Project Charter	Michael B	100%
1.5	Risk Register	Jesus A	100%
1.6	Research Topics	Zachary W	100%
2	**Block Definition**		
2.1	Bill of Materials / Budget	Zachary W	100%
2.2	Engineering Requirements	Michael B	100%
2.3	Project Implications Report	Michael B	100%
2.4	Block Validations	All Members	100%
3	**System Integration**		
3.1	Implications Report	All Members	100%
3.2	Ordering Parts	All Members	100%
3.2.1	Block 1 Check-Off	All Members	100%
3.2.2	Technical Cohort Collabortaiton	All Members	100%
3.3	Block 2 Check-Off	All Members	100%
3.3.1	Block 3 Check-Off	All Members	100%
4	**Project Presentation**		
4.1	Final System Check-Off	All Members	100%
4.2	Project Close Out	All Members	100%
4.3	Project Showcase	All Members	100%
4.4	Profesional Development	All Members	100%

3 Scope and Engineering Requirements Summary

3.1 Universal Requirements

The universal requirements for our project are zero-tolerance policy constraints that every project must meet in order to build a quality system. These constraints also keep the system professional and original, allowing for our own work to do the heavy lifting of the project using non-drafted material when needed. The Universal Requirements are the following:

1) *All wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors.*
2) *The final system must contain one of the following: a student designed PCB, a custom Android/PC/Cloud application, significant utilization of a specialized software required by the project.*
3) *The project must meet the required 'Work-level' of 56.*
4) *The system may be no more than 50% built from purchased 'modules.'*
5) *The system may not include a breadboard*

3.2 Engineering Requirements

Name	**Customer Requirement**	**Engineering Requirement**
Accessibility	The system must be easy to use and set up.	9 out of 10 people must read the documentation and set up and operate the system.
Battery Life	The system's light fixtures must have enough battery life to last the whole Christmas season.	The system must have enough battery life to last at least 1 month (31 days) on a full charge, used an average of 2.5 hours per day.
Energy Efficiency	The system must be energy efficient.	The system should consume at least 30% less power than the equivalent of a 6-10 Watt incandescent bulb for each Dept. 65 Christmas building the client uses.
Light Colors	The system must have different colored lights, excluding bright white.	The system's light fixtures must show at least 4 different colors, including red, green, blue, and warm white.
Music	The system must react to music.	The system must have at least 1 pre-programmed Christmas song, and the light fixtures must have at least 1 accompanying light pattern representing each Christmas song's waveform.
Safety	The system must be safe and hazard-free.	The system does not have any exposed wires or components and is made out of solid, non-drafted materials.

Size	The system's light fixtures must fit into the client's Department 56 Christmas houses.	The system must control 3 modules with dimensions no larger than 1.06’’ (27mm) wide by 2.76" (70mm) tall (except for the retaining edge for the module)."
Wireless Communication	The system must control the light fixtures wirelessly.	The system's remote light fixtures must communicate with the central box within 5m indoors and 10m outdoors.

3.3 Summary

Our team’s primary objective with this project was to improve upon our client’s current Department 56 Christmas village light display. We focused on 8 areas of improvement with our project. First was the accessibility of the system. The system should be easy enough to use such that nearly everyone could operate the system with basic instructions. To avoid changing the batteries in the fixtures once they are set up, the battery life of each light fixture was required to last a month, used an average of 2.5 hours per day. To increase battery life, the system needed to be more energy efficient than the incandescent bulbs currently used by the client in the buildings. To improve the aesthetics of the buildings, the system’s fixtures were required to have multiple light colors to choose from, including the soft white color from incandescent bulbs. To build on the aesthetic changes to the lights, the system was required to output Christmas music and light patterns to bounce to it.

The next area focused on was the safety of the system. We defined our system as safe if there were no exposed wires or components and the system had to be made out of solid, “non-drafted materials,” or enclosures specifically designed for the system. A size requirement was included since the space inside the buildings are miniscule. The module measurements were restricted to be no larger than 1.06’’ (27mm) wide by 2.76" (70mm) tall to ensure proper fitting inside the village buildings. The last aspect our team focused on was wireless communication. The system was required to take user input from a central box, and send instructions to all modules in the buildings.

4 Risk Register

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance Indicator	Responsible Party	Action Plan
R1	Vendor delay	Timeline	M	H	Shipment Delays	Jesus	Avoid
R2	House unit breaks	Cost	L	H	House is dropped	Michael	Avoid
R3	Team member contracts COVID-19	Health	M	H	Symptoms of Covid	Zachary	Avoid
R4	Power consumption exceeds battery capabilities	Technical	M	M	Battery life is too short	Zachary	Reduce
R5	Client not approving of product	Communications	M	M	Client lets us know in client meeting	Jesus	Avoid
R6	Project cannot be assembled	Communications	M	H	Covid-19 keeps us from assembling together	Michael	Avoid
R7	Limiting space	Technical	M	H	Module does not fit in all homes	Michael	Reduce

4.1 Summary of High Impact Risks

Prior to beginning to build our project, our team compiled a list of possible risks that could occur while working on the project. Since then some of these risks have occurred while others did not. From the list of risks, there were five risks that we deemed to have a high impact on our project if they occurred. Fortunately for us, vendor delays were the only risk that actually affected the project. One distributor of components our team used had a freak snow storm halt all shipments. Another high impact risk was having one of the client's village buildings getting destroyed by dropping it. This would have not only set us back from not having one for reference, but also would have substantially eaten into our budget since each village house roughly costs $100.

The COVID-19 pandemic impacted most of our day to day lives throughout the entire project. One risk associated with the pandemic was a member of our team contracting COVID-19, which could have delayed progress due to symptoms of the virus. Another risk associated with the pandemic is social distance guidelines preventing or restricting our team from meeting in person to build the project. The availability of vaccines and loosening of these restrictions during spring term allowed Zachary and Michael to meet in person to build the system.

5 Future Recommendations

Recommendation	Reason	Solution
Avoid using the Nordic Semiconductor Software Development Kit (nRF SDK)	The nRF SDK was too low-level for this project and had contradicting, limited documentation.	Use an Arduino or other higher-level microcontroller or SoC, or learn the nRF SDK prior to project start.
Increase Light Fixture Battery Pack Voltage to at Least 3.5V	LEDs were too dim, needed more voltage	Use a larger battery pack with a voltage step-down converter
Earlier Requirement Communication with Client	Started engineering requirement tradeoff discussions late	Understand that engineering intuition will help coming to the conclusions quicker
Improve Detach Method on Light Fixture Enclosures	The enclosures have to be pushed through, and then taken out	Cutouts in the CAD design to allow through holes so connectors can be attached
Begin Construction in Fall	Pressed against time to complete the project.	Allocate less time to planning upfront and more to build time
Start PCB Design Early	Unable to get a correct design in time	Start earlier to allow for more iterations to perfect design over time
Customer Satisfaction vs Engineering Requirements	If the project is losing time and passing the class becomes in question, having priorities in line will help move the team forward	Having all team members on the same page of what will be prioritized will keep the engineering requirements and the project as a whole moving forward
Have a Detailed Timeline with Extra Time	Timeline was somewhat ignored throughout the project development	Make a point to continuously update the timeline with details of delays and how that will impact completion time

5.1 Avoid using the Nordic Semiconductor Software Development Kit (nRF SDK)

The nRF SDK and the nRF52840 SoC initially seemed to be the best choice for the project due to the support for many concurrent peripherals and the cheaper price compared to hobbyist kits. However, to take advantage of these powerful advantages, we not only had to learn Bluetooth Low Energy (BLE) programming, but also the intimidating nRF SDK. Researching online for documentation, examples, or support yielded answers which (1) did not apply to the version of the SDK we were using, (2) were not compatible with all products utilizing the nRF52840, or (3) contradicted what other tutorials or datasheets stated. As a result, development of the Fixture Code and Central Code blocks consumed far more project time than anticipated, putting the team behind schedule for deadlines.

Recommendation: Instead of using the nRF SDK and chipset, use a higher-level or hobbyist system, such as an Arduino or Espressif microcontroller. While this could reduce the number of concurrent BLE connections and increase monetary project costs, the tight timeline of the project would have been better served by a system and tools our team was familiar with. If there cannot be a compromise on the number of BLE connections and project costs, the team should be willing to invest 2-3 months learning the nRF SDK prior to the start of software development.

5.2 Increase Light Fixture Battery Pack Voltage to at Least 3.5V

For the current system setup, the battery pack is only able to achieve a maximum output voltage of around 3V to 3.2V due to variations in the duracell batteries. Our original goal of the LED lights shining as bright as the incandescent bulbs was not achieved because there wasn't enough forward voltage on the LEDs, which are rated for 3.4V. This was a result of the client valuing the use of widely-available, disposable, non-rechargeable batteries. The client seemed to be more open on the number of batteries used.

Recommendation: Start early on researching different inexpensive battery voltage options. Using a 4 battery pack holder instead of 2 will double the battery pricing options for the system, but it would allow for 6V at the output by having an extra set of batteries in series with the previous two. Then, a buck converter could be used to step the voltage from 6V to 3.4 before sending it to the transistor for the LED and SoC. Using a transistor (2N2222A) [7] on the custom light fixture PCB to act as a switch would allow the LEDs to draw power from the battery directly, allowing for the nRF outputs to just act as the signal. This would allow for the LEDs to have the needed 3.4V and 25 mA for the rated lumens. The issue with this method was where to put the buck converter and compensating 5 SMT 2N2222 transistors on the light fixture PCB, which could be solved given sufficient time.

5.3 Earlier Requirement Communication With Client

Our team ended up having tradeoff discussions with the client for multiple engineering requirements late into the first term and early into the second. For example, our team was faced with the client wanting the light fixtures to last 31 days with 8 hours of usage per day equating to 248 hours of total battery charge with at least 25 mAh of drain from one LED. Without breaking the bank on high capacity batteries, this is difficult to achieve with the clients given budget. Ensuring the team and client are on the same page is a major step in moving forward with building the system.

Recommendation: Since the team is composed of the engineers for the project, an engineer knows what is possible within the constraints that the client gives. Voicing this with the client as early as possible will keep the project moving forward. For the aforementioned example, voicing this early on would benefit the team in the long-run.

5.4 Improve Detach Method on Light Fixture Enclosures

The current iterations of the CAD enclosures that house the nRF SoC and custom PCB for the lights do not have an easy way of being detached from the house once they are set into place. The reason for this was because the enclosure required a one-fits-all approach due the the numerous different types of housing units the client uses, so having material protruding from the enclosure did not suffice.

Recommendation: The enclosure has room underneath the bed that the SoC lies on. Creating a cut-out that allows a through hole to be made could be used for a metal string or connector that would allow the user to pull the enclosures from the house instead of pushing the enclosure through, then wiggilging it out. Another option would be to have the retaining edge come out slightly more to be able pull the enclosure out.

5.5 Begin Construction in Fall Term

There have been some unexpected delays on gathering materials and overall progress. Our team was pressed on time to finish the project. We did not fully understand how our time would be stretched between assignments in the senior design class and the actual project itself. Including each team member's respective course load, this resulted in project construction being a stressful ordeal.

Recommendation: The course is generally designed to dedicate the first term to planning and research for the project. While this planning phase is vital, given the time constraints, allocating less time for planning and more time for development would have been helpful in hindsight. Begin development in fall term since the team may not know what to research until system development begins.

5.6 Start PCB DesignEarly

Our team's original design called for the creation of a Power Distribution Board (PDB) for the central box of the system. We struggled to provide the correct power measurements for every device that needed to be powered in the central box. Ultimately our team was able to power the devices in the central box (excluding the LCD) without the need for a PDB.

Recommendation: When making a design for the PDB, try a simple design at first. This will take less time to create versus more complicated designs, which will allow extra time to make several iterations of the PDB if the first design is not working or not ideal. Also, make the PDB the first block to check-off as opposed to the last to give more time to get the best iteration.

5.7 Customer Satisfaction vs Engineering Requirements

There are two groups who have stewardship over the project, the course instructors who enforce the engineering and universal requirements, and the client who the project is intended for. The project can pass, but the product being handed to the client can be underwhelming or fall short of the original idea or goal set out by the project proposal. Satisfying both is the clear goal, but time, budget and resources can become conflicting.

Recommendation: Having teammates on the same page early as to which case will be prioritized early will prevent team conflict later in the project. There is a balance in each group as to how much is prioritized in getting a good grade versus how good the craftsmanship and final product comes out to be.

5.8 Have a Detailed Timeline with Extra Time

Timelines for the project progress are required in fall term and our team did not stick to the timeline due to unforeseen circumstances and delays. One thing that would have been helpful was to continuously update the timeline as unexpected delays occurred. Updating would restore confidence that we would have time to finish the project.

Recommendation: When designing a timeline, plan for potential unexpected delays by dedicating free time at the end of the timeline. This free time would serve as a safety net in case the project could not be completed in the predicted time frame. Having a detailed timeline will make it easy to know when progress is falling behind as opposed to always feeling behind without actually knowing if there will be time for completion.

References

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