Campanile-Carillon Model: Phase II

Project Plan v2 - 4/24/19

sddec 19-12

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MCC - Mobile Campanile Carillon Model

SCLC - Student Carillon Leadership Council - responsible for the maintenance and transportation of the future campanile carillon model

MIDI - Musical Instrument Digital Interface - communication protocol, digital interface, and electrical connector standard

Carillon - A musical instrument composed of at least 23 carillon bells, arranged chromatically, and played by a keyboard that allows expression through variation of touch

Baton - The keys of the musical instrument that are played

Carillonneur - A person that plays a Carillon

1. Introductory Material

1.1 Acknowledgement

We would like to thank the previous group for the work done that they did on the model Campanile-Carillon project. We would also like to thank Dr. Tin-Shi Tam and Gary Tuttle for the guidance, support, and for helping us understand what has been completed and what still needs to be improved upon as we continue this project. Another thanks to the ME 415 team who have worked closely with us to provide models, dimensions, and custom hardware solutions to best fit with the electronics that we have chosen. Finally, a thanks to the Stanton Memorial Carillon Foundation and the alumni and friends of Iowa State University that are providing the financial support for this project that makes this all possible.

1.2 Problem Statement

The Iowa State Campanile has been a symbol of ISU pride since the tower's construction in 1897 to memorialize Margaret Stanton. [1] However, alumni and friends of ISU can only admire the tower if they are on campus. Moreover, this audience may not be familiar with the beautiful sound of the 50 bells as the carillon, the instrument inside the campanile, is typically only played at noon.

To remedy this, there has been an enormous effort to create a Mobile Campanile Carillon model. For the past 2-3 years many groups have been involved in the realization of this goal, and great progress has been made in that time. This model will in effect showcase the bells, display history and donor information, and implement a playable carillon at ground level. Our task is to design the electrical components of the model. In addition to the widescreen digital display to showcase a "documentary" slideshow, we will design a Guitar Hero style interface to make the carillon playable by a layperson.

1.3 Operating Environment

As the name suggests, the main intention of the model is to make the carillon mobile so it can be showcased anywhere outside Iowa State's campus. In addition to mobility, the carillon will be displayed both indoors and outdoors, meaning all components must be waterproof and able to withstand the extreme temperatures of the summer and winter months. Since this will be displayed outdoors, there may not always be an easily accessible power outlet, so the model must also be able to operate on battery power for 8-10 hours before having to be recharged.

1.4 Intended Users and Uses

There are two distinct groups who will be interacting with the MCC: curious onlookers who aren't familiar with playing an instrument, and musicians. Since the model will be displayed at many different venues, the client wants anyone to be able to interact with the model and make beautiful music, no matter what their musical background may be. To achieve this, we must design an interface that makes playing the instrument easy, intuitive, and most importantly, fun. We plan on adding features to help make it easier and for non-musicians to pick up the instrument with ease, but we must be cautious that none of our solutions interfere with the expected response from the instrument that the Carillonneur expects.

The other users we must consider are the members of the Student Carillon Leadership Council -- the individuals responsible for upkeep and transportation of the MCC. Any system we implement must maximize reliability, so the model does not require constant maintenance. In addition, any components with reasonable chance of failure must be documented so that individuals with no electrical expertise can diagnose and replace the components in question.

1.5 Assumptions and Limitations

Assumptions

1. Although the MCC will need to withstand outdoor conditions, it will not be left outside during extreme conditions, such as extreme cold, heavy rain/snow, or dangerous winds.
2. We expect the MCC to be fabricated in the Fall, with a test run happening during the Summer of 2019. So we will have a working product after the Spring semester and a final product finished in the Fall of 2019.

Limitations

1. Each component of the design shall be reliable and minimize failure rate.
2. Although no discrete financial limitations were specified, the project should minimize unnecessary costs while maximizing reliability and durability.
3. The design should be simple enough so that it can be repaired and operated by a layperson. To assist in this, we will create relevant documentation.
4. The design should be in compliance with the goal to remain portable, and modular.
5. There will be limited software support from the team after we graduate

1.6 Expected End Product and Other Deliverables

1. Operating manual: (S 2019), this document will specify the exact details of operation. This document should be concise to promote usability. This will likely be a short document as the idea is to make operation as simple as possible. All extraneous features will be highlighted in this document such as how to add MIDI files to the system. These extraneous features will be features not used by the average user. The SCLC will be able to use this in order to use the program.
2. Diagnostic manual: (S 2019), this will be an in-depth document that can efficiently guide the members of the SCLC through replacement and diagnoses of all electrical components. This document will be much longer than the operating manual. It will outline LED replacement and any graver repairs that one may encounter.

3. Polished interface: (S 2019), this will include updating the current interface so that the user experience is intuitive to how an average user expects the menus to work. Also includes updating the interface so the program is nicer and will fit on the new monitor.
4. Design Power Supply: (S 2019), design a power supply so that the MCC will be able to travel without having a generator or other external power source necessary for the model to work properly. This also needs to fit within the limited space of the MCC.
5. Design “Infostation” (F 2019), this is a standalone project that will travel with the MCC to show a slideshow about the campanile and include an interactive model of the interior of the campanile

2. Proposed Approach

2.1 Objective of Task

By the end of Spring 2019, we will be able to demonstrate software that can read MIDI files and play them in real time in the form of falling notes on a monitor. This is achieved by using a Windows PC, which will power the program and control the LED bar that will light up when the notes should be played. This system will be fully powered by a battery-operated power supply, which will be able to power the system for up to 8 hours of use.

In Fall 2019 we plan on finalizing our software for the MCC and creating an Infostation that will be a standalone object which will display information about the Campanile and the Carillon. This will include a way to view a model of the campanile and view interesting facts on a screen that will travel with the MCC.

2.2 Alternative Solutions

Throughout our work on the project, we have had new use cases and information regarding the model arise that have forced us to routinely change course on our design. The first of these is the hardware used to run the program. While we originally planned on using a Raspberry Pi, the hardware proved to be insufficient to run the program at an acceptable speed and responsiveness. As such, we have switched to using a laptop, and may upgrade to a more embedded solution further down the road.

Additionally, by request of our client, we decided to begin porting the program to Windows to allow for more ease of use when the group is no longer available for troubleshooting. Luckily, our Windows port is finished and we are able to add a few small features before getting the program ready for the summer test run. We also still have our stable LInux version on-hand, and can switch back to that if need be.

The battery solution might also change from our original plan due to the lack of internal space in the Campanile model. We will not make final decision before the next meeting with our client.

Our alternative solution is to put all the electronics in a portable box outside the Campanile model. This also the restrictions of physical space the electronics are allowed to take up less constraining which choosing parts. The voltage inverter, the battery charger, and the battery voltage indicator will be the same as the ones we originally selectioned, but now with the new mounting place.

2.3 Use-Case Diagram

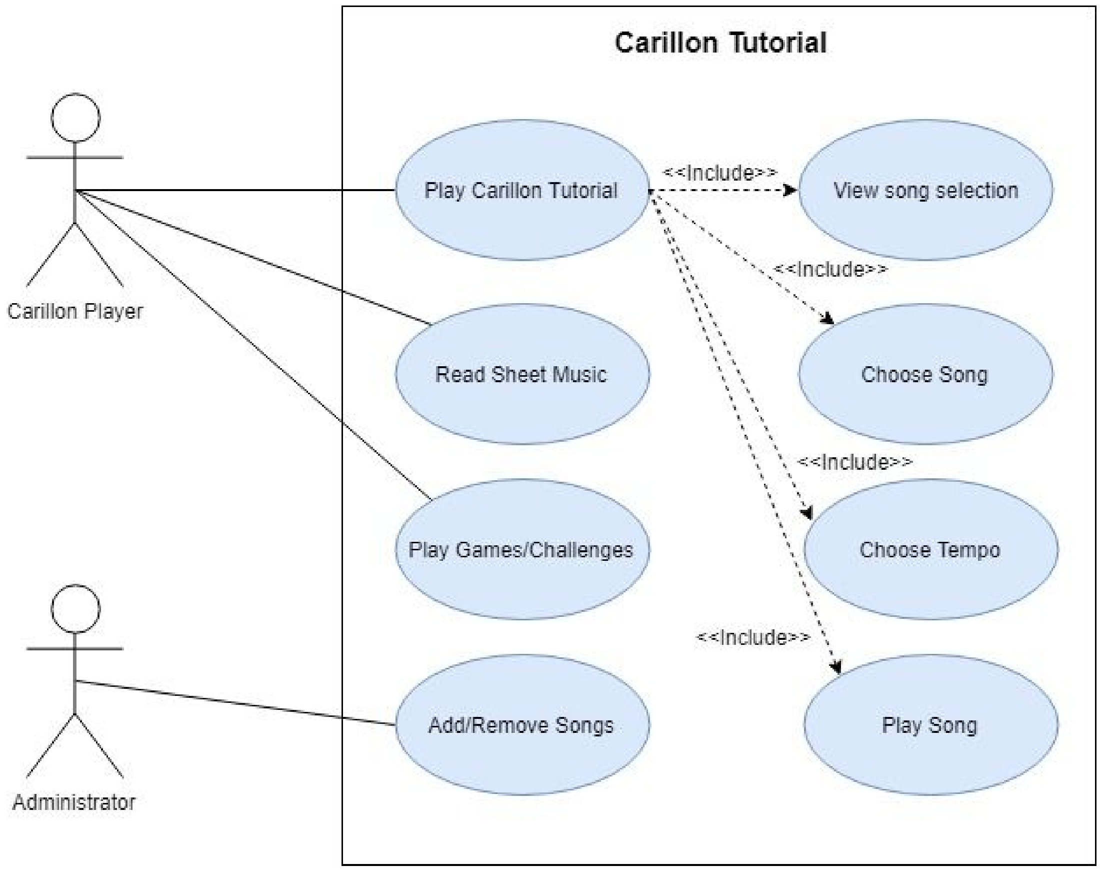

Figure 1 - Use Case Diagram of the System

2.4 Block Diagram

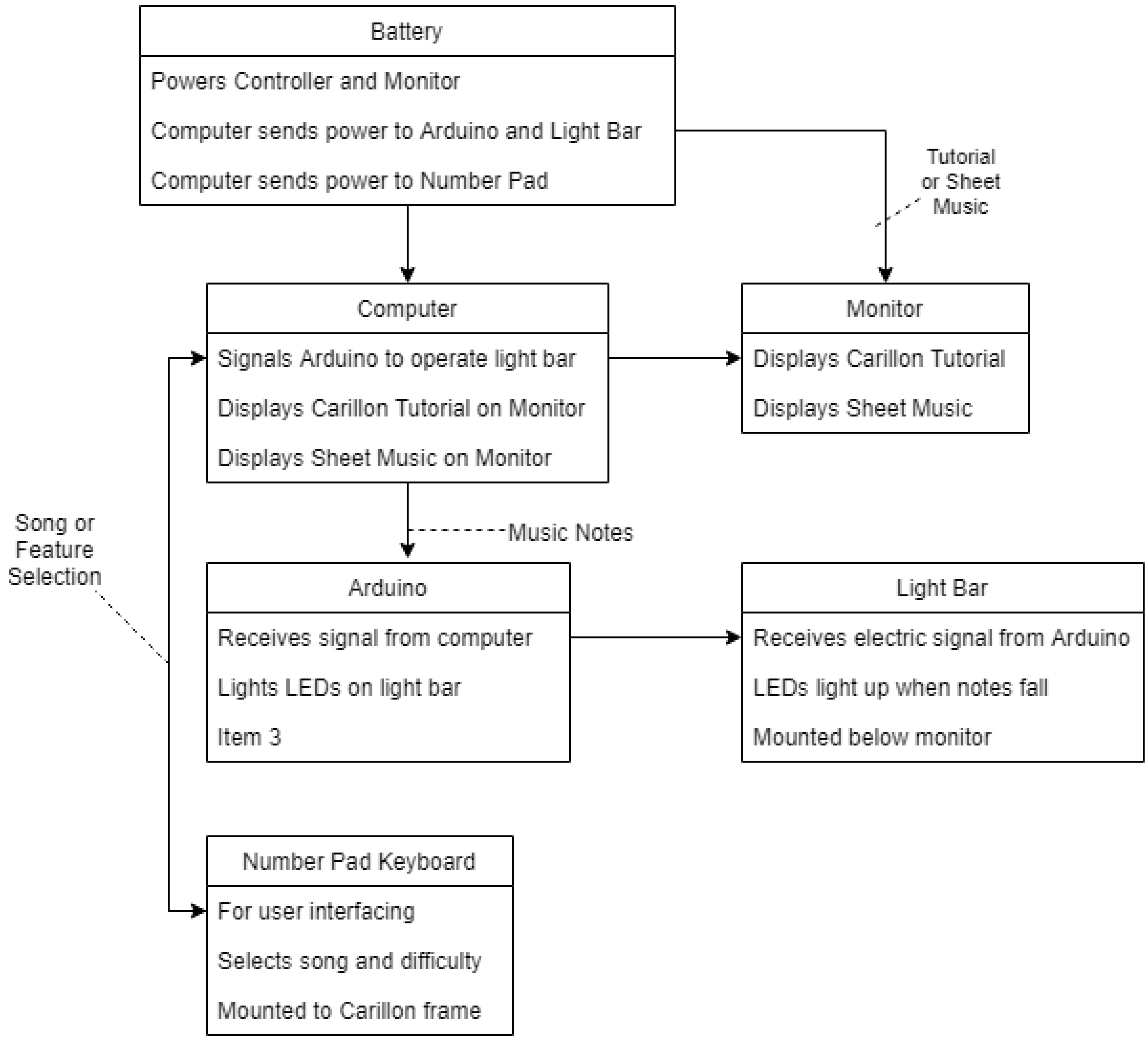

Figure 2 - Block Diagram of the System

2.5 Functional Requirements

The system requested by our client, Dr. Tin-Shi Tam, must meet the following functional requirements:

- Must display musical notes in a falling fashion to allow users to play a song with little to no prior musical experience
- Must be able to display sheet music directly for more seasoned musicians
- Must have a set of LEDs corresponding to the specific key to be played for a note
- Must be able to operate on battery alone for at least 8 hours
- Must have an intuitive user interface
- Must have tempo control options to make it easier/harder for players

2.6 Constraints Considerations

- The MCC will have to be water-resistant and be able to withstand both extremes in temperature
- Display will have to visible in bright sunlit areas and darker indoor settings
- The components need to be visually pleasing as this will be used publicly
- Components need to fit within the small space that we are given

2.7 Technology Considerations

- Battery life may vary greatly between indoor, cool scenarios and outdoor, warm scenarios
- Space constraints of physical structure require custom display hardware
- Monitor must fit within the current design of the system

2.8 Testing Requirements Considerations

- Ensure the program doesn't crash on normal use
- Ensure battery won't run out of power too early
- Ensure the cable management of the electrical parts are proper and are safety compliant

2.9 Safety Considerations

- Battery temperature check to prevent overheat.
- Cover all the expose pins in the circuit and create an auto shut down system to prevent short circuit.
- Polish hard edges for end product.

2.10 Previous Work / Literature Review

There are currently two mobile Carillons in the United States. [3] One is called the Mobile Millennium Carillon, the other is called Cast in Bronze.

The Mobile Millennium Carillon [2] is rather large and fits neatly on the back of a 21 ft trailer. The obvious disadvantage of this instrument is that it would be very difficult to bring indoors, making it difficult to play in concert halls. The Cast in Bronze carillon [4] has 35 bells in total which is 8 more than the MCC, but it also does not have automated tutorials like the MCC will eventually have.

The MCC is unique because there are no carillons that also provide an interactive learning environment. Our client's intended use for this instrument is very different from any other carillon in the United States. According to the World Carillon Federation, there are only 14 other mobile carillons in the world. [5] Additionally the following groups have contributed to the current design and plan of the MCC.

- Spring 2016 ME 415

- Fall 2016 ME 466
- Spring 2017 ME 415 & ME 490H
- Fall 2017 ME 415
- Spring 2018 ME 415
- Fall 2018 ME 415

The previous ECpE 491 group at Iowa State was able to get a functioning program that was able to turn a MIDI file into a form that allows notes to fall down in a nice fashion. They also completed an LED bar that lights up when the falling notes reach the bottom of the screen providing another visual indicator to the user. This will give us a nice baseline to finish this project in the Fall of 2019, when the final MCC is fully assembled and used by the public.

2.11 Possible Risks and Risk Management

At this point in our project we have a few concerns that might become problems further down the road. One of them is that we have just ordered a monitor to be used in the final product which is in an awkward resolution. This will cause potential problems in the program and since the monitor won't be arriving for about 9 weeks, we won't get much time to prototype with it to ensure that it works. We plan on testing our software at this weird resolution before the monitor arrives so that we know the program will work at this resolution for the monitor. This will help us reduce the problems the new monitor might cause.

Another concern that we have is the space available for the battery that will power our monitor and windows PC. With the amount of space that we have available, we will have to figure out a power supply option with a small form-factor that won't take up too much space in the model. Our plan for this is to research exactly how much power draw our system will have and find the most rugged solution give our design constraints.

2.12 Project Proposed Milestones and Evaluation Criteria

1. Initial Design
2. Final Design Plan
3. Start Debugging Software
    a. Work with new resolution
    b. Fix problems in past code
    c. Redesign input
4. Design Power Supply
    a. Calculate energy costs
    b. Create design that fits in space constraints
5. Test the Software with the Hardware
    a. Beta tests in the team
6. Port to Windows
    a. Get the program to work on Windows OS to make it easier for our client to use

    b. Implement a full installer/uninstaller, further providing ease-of-use for the client
7. Finalize Software
    a. Add required features
    b. Polish tutorial
    c. Create new graphical assets
    d. Put final touches into program
8. Assemble Hardware
    a. All lights and monitors work properly
9. Build Infostation
    a. Standalone with slideshow
10. Instructions for Operation
    a. SCLC can easily use the carillon after reading the instructions
11. Troubleshooting guide
    a. Third party is able to understand how to fix the hardware
12. Finished product

2.13 Project Tracking Procedures

To track our progress, we will reference our timeline below and we will have weekly meetings with our team and client to discuss our project and get feedback. We also have a Trello board to help with progress tracking and to set goals for ourselves.

2.14 Task Approach

1. Discuss design with client and faculty advisor
2. Redesign software to work with new monitor
3. Order hardware for final product
4. Test the light bar
5. Write code to display sheet music
6. Integrate the software and hardware
7. Test the full MCC
8. Construct the MCC
9. Design plan for Infostation
10. Work on Infostation models
11. Work on Infostation slideshow
12. Present full system with MCC and Infostation

2.15 Expected Results and Validation

- Will display musical notes in a falling fashion to allow users to play a song with little to no prior musical experience
    - Validated by users with no musical experience attempting to play the song using the falling musical notes. The song should be recognizable to others, indicating that the user is playing the song correctly
- Will display sheet music directly for more seasoned musicians

    - Validated by displaying sheet music to seasoned musicians and confirming that the display is correct
- Will have a set of LEDs corresponding to the specific key to be played for a note
    - Validated by ensuring that LEDs light up with synchronization with falling notes
- Will be able to operate on battery alone for at least 8 hours
    - Validated by testing battery life at typical workload for at least 8 hours
- Will have an intuitive user interface
    - Validated by taking feedback from users who have not used the program before. If the users can access and use all features of the program correctly without help, the user interface can be considered intuitive
- Will have options for tempo control
    - Validated by seeing if changing the tempo on the main menu will make the song play slower or faster

2.16 Test Plan

Testing LED bar

1. Brightness
    a. Ensure LEDs are visible under the current power input from the usual sitting position in from of the carillon
2. Strength & Durability
    a. Replacing beam in MCC so has to be strong
    b. LED connections
    c. Longevity
3. Accuracy
    a. Ensure LEDs light up as the notes fall, with no misses or false positives

Testing Battery Voltage Monitor

1. Power assumption
    a. Low power assumption during over all day usage
2. Voltage indication range for each LED
    a. The detected voltage range should include highest and lowest battery output voltage
    b. The detected voltage range can adjust for batteries with different voltage decay rate

Testing Software

1. Test usability by random users
    a. Is it comprehensible what keys to hit?
2. Expand to test more of the campus
3. Test tempo controls on multiple different songs and ensure that the song speeds up or slows down without any new issues appearing
4. Ensure monitor brightness settings can adequately display graphics under bright and dark scenarios

Testing Power System

1. Test battery life, while powering the computer running the program, and the monitor connected
2. Ensure that the battery charge charges the battery to full capacity with a safe voltage

Weatherproof testing

1. Temperature tests over 90 degrees
2. Simple waterproofing tests
    a. Is it resistant to small amounts of water (simulating rain)

Final Test

1. Appearance
2. LEDS
    a. Brightness
3. Weatherproof testing
    a. Temperature tests
    b. Waterproofing
4. Testing Software
    a. Usability
5. Instruction/troubleshoot guide
    a. Easy to understand and follow

2.17 Standards

- IEEE 1625-2004: *IEEE Standard for Rechargeable Batteries for Portable Computing*
    - Guidelines to design, test, and evaluate different battery components to create well-rounded solution
    - Will use when designing battery solution for electrical components
- IEEE 14764-2006: *Standard for Software Engineering – Software Life Cycle Processes – Maintenance*
    - Guidelines for testing and maintaining software in the long term
    - Will use as we implement the software, ensuring that any team that follows us has an easy time of maintaining the software
- IEEE 2003-1997: *Requirements and Guidelines for Test Method Specifications and Test Method Implementations*
    - Best practices for software test-cases, including types, readability, complexity, etc.
    - Will use while writing test cases concurrently with designing the program

2.18 Assessment of Proposed Solution

When looking back on our proposed solution, we believe that we have created a solid plan that isn't trying to achieve too much within the time constraints that we have this semester. We have made solid progress and are keeping up with the ME team on the work being done. We have achieved as much if not more work than we were planning on having when starting out with this project. We have worked through many of the bugs, and have a battery solution designed ready to be built in the Spring semester.

Many of the weaknesses of our plan stem from inheriting questionable design decisions from the previous group. For example, while developing the Tutorial via Unity or another high-level game engine would undoubtedly be preferable, due to tight time constraints we were forced to build upon the previous group’s inferior SFML implementation. In addition, the last group’s decision to run the solution on a Linux-powered Raspberry Pi proved insufficient, thus delaying new feature additions until we could get the program running on better hardware. Despite this, we believe we can overcome these weaknesses and deliver a polished final product that Iowa State will be proud to display for years to come.

For the battery solution, our original plan is using acid or lithium ion battery with a voltage inverter as a power supply. After weeks of research, we went for the same path as the previous group with the rechargeable lead acid battery due to its high power rate output. Because we switched the main hardware from Raspberry Pi to the laptop, the power supply needs to re-evaluate for our new workflow. A bigger volume battery is required to power the new equipment. We also found out a battery level indicator, and a charger with full charge auto cutoff function is missing. We will continue researching increasing power efficiency and other accessories for possible needs.

3. Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

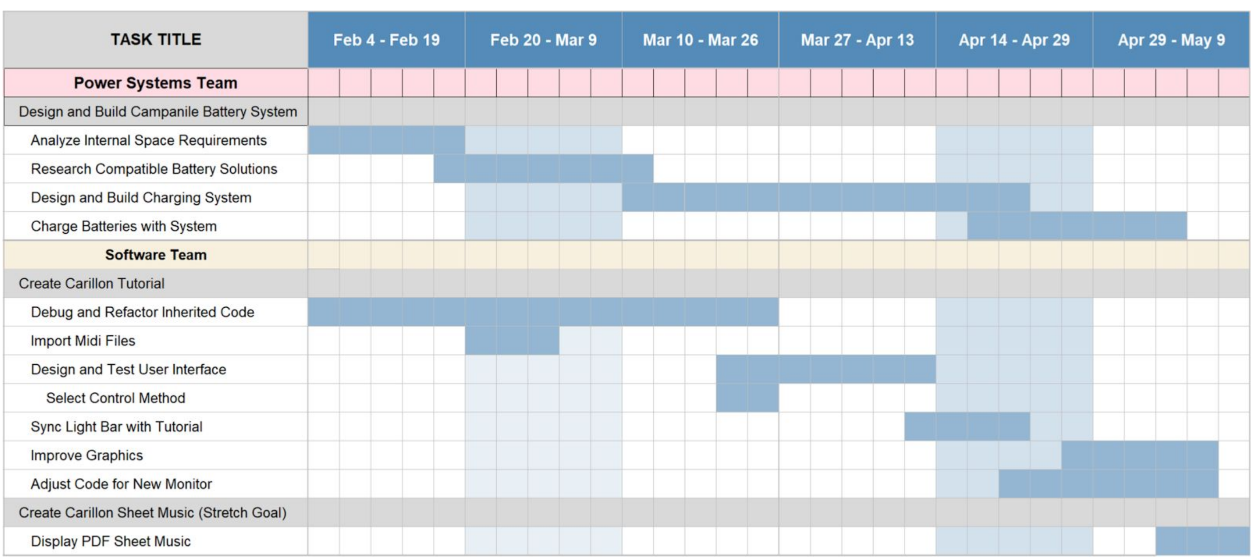

Figure 3 - Spring Gantt Chart

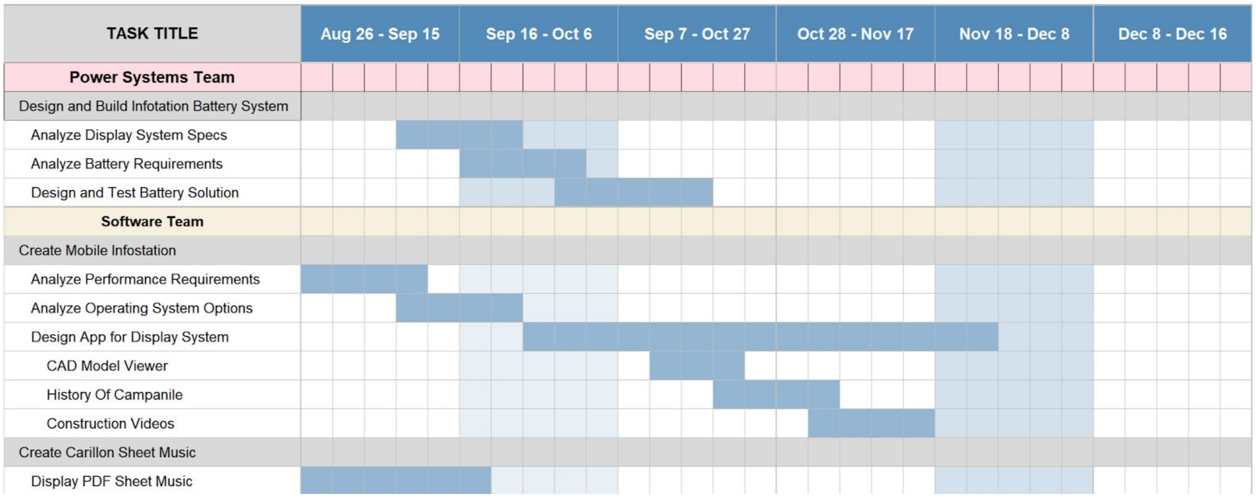

Figure 4 - Fall Gantt Chart

Due to our project already existing and being worked on for the previous year, there is a significant portion of work already laid out for this semester. As you can see in Fig. 2, we have two teams working on separate tasks under multiple milestones. A few tasks also have their own subtasks to complete before the main task can be completed. Within the first semester we have been given other use cases to add to the software program such as porting the program to Windows to have easier usability, and adding tempo control to make songs easier or harder to play depending on the user’s skill level. These were given the status of sub task because we anticipate an above-average amount of work will be required to complete these.

This semester (Fig. 3), we are working to complete the system that will sit onboard the campanile structure. The previous group left a program which was fairly-functional but lacked multiple requested features. Therefore, we are spending time debugging their code and adding in these features. Bonus software features for the structure are listed as stretch goals for this semester and hard goals for next semester. Along with the software, we also are building the battery and charging system that will allow the structure to sit somewhere without access to a hardlined power supply for multiple hours.

In the fall (Fig. 4), our work on the campanile should be mostly complete and we will move onto a new project. Our client has requested a standalone information station which will follow the campanile model to various events but will be entirely independent. This will require the development of a second power system. We anticipate this will be a simpler system to design and implement and so our power team will become integrated into software team while we fine tune our work.

3.2 Personnel Resource Requirements

Table 1

Task	Requirements	Estimated man hours
Debug and Refactor existing codebase	Change user interface, update resolution, bug testing	50
Import MIDI files	Fix any problems with importing MIDI files and test	10
Research Battery Options	Analyze internal space and research possible battery solutions	10
Create Battery Solution	Use knowledge gained to construct power supply	50
Improve Graphics	Make the program more presentable and professional	10
Sync Light Bar with Tutorial	Ensure the lights work properly and are in-sync with the falling notes on the monitor	15
Port to Windows	Port Linux version to Windows for easier use for setup and running the program	25
Build final prototype	Combine the software and hardware aspects together into a final cohesive product	40
Design Infostation Plan	Plan how the Infostation will be created and developed	20
Create Infostation	Develop the Infostation according to our plan	60

3.3 Other Resource Requirements

- Monitor mounting hardware
  - Needed to attach monitor to MCC
  - Swings open to allow access behind the monitor
- Monitor

    - Displays falling notes and sheet music
- LED board
    - Displays what notes should be played
    - Provided by previous phase
- Windows Computer (tbd)
    - Interfaces with the screen to show visuals
    - Communicate with Arduino
- Arduino Uno
    - Controls LEDs to indicate what notes should be played
    - Accepts data from the Windows PC
- 5V Power Supplies
    - Power for Windows PC, monitor, Arduino, and LEDs
- 120V outlets
    - Needed to charge power supply
- Power Supply
    - Used to power monitor and 5V power supplies
- 12V to 120V Inverter
    - Needed to charge power supply where 120V cannot be found
- Infostation Monitor
    - Displays 3D model and information about the MCC
- Infostation power supply
    - Powers infostation monitor for at least 8 hours of use
- Infostation Frame
    - Developed by other senior design group
    - Houses infostation monitor and power supply

3.4 Financial Requirements

The client has confirmed that financial restrictions should not be overly impactful to design decisions. However, there are items of significant price that need to be considered. The client requires a monitor for the MCC that can be seen clearly in full daylight and is a custom resolution. The price of the chosen monitor before tax is $1099. At the time of writing this project plan, this is the final choice for the monitor. The power supply for the MCC will also need to be purchased, which our early research suggests could cost $50-$200.

The info station requires a touchscreen monitor that can be seen clearly in daylight. Based on our early research, this monitor could cost anywhere from $300-$1200 depending on the solution chosen. The frame for the info station will be completed by a different senior design group, which will handle the costs. The primary goal is to create a working system that meets all requirements, and keeping cost low can be considered a secondary goal.

4. Closure Materials

4.1 Conclusion

This Mobile Campanile Carillon project is an ideal way to spread Iowa State University pride. Any reader familiar with the university is sure to understand that the Campanile is held in considerably high esteem. This model is a method of spreading the admiration that friends of the university have for the Campanile beyond the reach of central campus. There has already been considerable effort put forward to create the MCC, and our project will extend the use of this model to become an educational tool. Through creating an interactive carillon tutorial similar to many music-based games on the market, we will allow anyone to create beautiful music, no matter what their musical background may be. The software will also educate onlookers about the inner workings of a carillon, an instrument of which most people know very little. Finally, we will also provide documentation on every solution implemented so that non-engineer personnel can repair and replace components or software as needed. With these contributions, the authors believe that we will make a significant improvement to the current state of the mobile carillon model.

4.2 References

[1] “Campanile | Iowa State University Admissions.” Admissions, www.admissions.iastate.edu/traditions/campanile.php.

[2] “About the Mobile Millennium Carillon.” Chime Master, www.chimemaster.com/mobilemillennium-technical/

[3] World Carillon Federation, www.carillon.org/eng/fs_reizende.htm.

[4] “About.” Cast in Bronze, www.castinbronze.net/about-cast-in-bronze/

4.3 Appendices

We do not currently have any content for the appendix. We expect to add relevant documentation in the next iteration.