***Aqua Strings*: Interactive Waterfall Display**

Initial Divide and Conquer Document

EEL4914 – Senior Design I

Group 13

Department of Electrical Engineering and Computer Science

University of Central Florida

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Chapter 1: Project Description

1.1 Motivation & Background

Through the years, the availability and concept of modern technology is constantly evolving which allows individuals, such as engineers, to improve existing ways of life. One of these areas of life that is constantly evolving is the entertainment and music industry through how content is created, distributed, and experienced. These advancements allow for vast audiences to immerse themselves within a given culture and/or gain a sense of enjoyment in their day-to-day lives. More specifically, these technical advancements consist of new sensors, Digital Audio Workstations (DAWs), software instruments, and even AI in music composition. Through these advancements we can do a multitude of projects, one of them involves creating a water harp/ interactive waterfall display. The concept of a “water harp” combines the practical use of a traditional harp with the new visual water element which elevates the user and audience's experience.

Water harps, also referred to as water-based instruments, allow for a multisensory experience employing different modes and tones since the sounds are now electronically generated compared to the vibrations from a traditional harp. Whether people like to acknowledge it or not our society revolves around music whether it's listening to music in the car, while doing work or eating in a restaurant. Music is an experience that we all subject ourselves to daily, so why wouldn’t we look to evolve and immerse ourselves further in the experience? Since a water harp would consist of electronically generated sounds, it makes the machine more accessible to younger children of any person who doesn’t have the musical knowledge needed to tune and play a traditional string harp.

Besides the artistic value of the project, it also stands for an innovation of technological integration and a sense of sustainability. While water is used both as the working medium and as an aesthetic component, the integration of natural elements in a technologically heavy project such as this joins two groups together. The water harp combines modern engineering with creativity while focusing on a user-friendly experience.

1.2 Goals and Objectives

Our Interactive Waterfall Display project aims to integrate interactive technology into an artistic experience to further develop an existing instrument into a multisensory machine by integrating sound, visuals, and user interaction. By achieving our primary goals, we hope to create a more enjoyable musical experience.

The primary (basic) goals of our project are as follows:

- Design and construct a technologically advanced interactive instrument using a multitude of different sensors that will read user input and translate this information into a musical sound/note.
- Create 3 fully functioning strings of water that deal with only three notes and demonstrate how the other components of the project work
- Implement an efficient real-time signal processing system to achieve responsive reactions with minimal latency, ensuring the expected result from the user's inputs (such as breaking a water string) in correspondence with the desired audio output.
- Maintain a constant, continuous water flow so there is no undesired break in the water (water pump calibration). This will also require additional water level sensors to be installed in each reservoir to make sure there is a constant flow of water through each string.
- Provide a multisensory user experience involving the necessary audio tones/ notes, visuals (the colors of the laser sensors projected through the water string), and the actual tactile water element creating a laminar flow.

The advanced goals of our project are as follows:

- Complete 8 (5 additional) fully functioning strings of water, so that each note in a musical scale can be accounted for.
- Create different modes consisting of OFF, FOUNTAIN, and HARP. OFF halts all components of the project, FOUNTAIN allows the water to flow without an interactive component, and HARP adds the interactive component to the flowing water.
- Using either solenoid values or a sliding component to cut off the streams of water when needed/ desired.

The stretch goals for our project are as follows:

- Create different modes (possibly three) for different electronic sounds to be played when a string is broken. Modes could include musical, synthesized, etc. If not, we could instead have three different octaves of notes, low, middle, and high.
- Integrate small water turbines at the bottom of the water strings involving a DC motor and a 3D-printed curved cup rotating component (Pelton Turbine).
- Using the values mentioned in the advanced goals, we could have motorized sequences that would create breaks in the water at specific times to have a water display without human interaction.
- Install a laser horizontally across the strings of water that would detect hand movement and play different notes for the same string of water depending on if the stream is broken higher or lower.

The overall objectives consist of fulfilling the listed goals from above and then some. The process and techniques we plan to use are subject to change as we research, and new information is discovered.

Our listed objectives are as follows:

- Correct implementation of our hardware design:
    - Incorporate accurate sensors such as laser diodes with photodetectors for interruption detection in water streams to provide steady and accurate input signals
    - Design a water pump system capable of generating a uniform, laminar flow for the water strings whose flow rate will vary for dynamic interaction
- Development of firmware and microcontroller interface
    - Program microcontroller (MSP430 or ESP 32, not decided yet) to process the inputs from the different sensors and map the user interactions to the necessary MIDI or audio files
    - Utilize precise timing components, interrupt-driven processing, and other efficient aspects offered by the microcontroller
- Audio sequence development and implementation
    - Implement a module of sound generation that is capable of producing customizable tones as desired
    - Employ DSP techniques to control the audio output to manipulate pitch, amplitude, and waveform shaping depending on the specific audio device chosen (utilizing a speaker).
- Closed loop, recycling water system
    - Design a water management system that recirculates the water through the machine efficiently, reducing waste and the need for added resources.
    - Use flow sensors/ water level sensors so the system knows whether a specific reservoir is low or filled with water.
- Rigorous testing of the prototype and final project
    - Ensure all components are acting as intended with little to no errors or mishaps.
        - Ex: sensor accuracy, response time, signal mapping, audio quality, overall latency between different systems
- Hardware safety/ waterproofing
    - Waterproof will include, but not limited to, silicone casing for specific components to ensure separation of electrical systems from the water recirculation system.
    - Housing all possible electrical components of the machine above the upper water reservoir to ensure the crucial electrical components do not interact with the flowing water.

From this breakdown of our goals and objects we now have a check list of checkpoints we want/ need to complete for a functioning interactive waterfall display. The expected outcome of this project is to provide our team with actual design experience while also being able to produce a product that is innovative and efficient with a friendly user interface.

1.3 Project Features and Functionalities

The Aqua Strings: Interactive Waterfall Display project brings together the best of modern technology with sensitive designs for an interactive and captivating experience. The machine simply serves as a water harp and is able to read user inputs in the form of movement, as the user's fingers or hand pass through the flowing strings of water, causing a note or sound to play out of a speaker embedded in the machine. There is also a dial that switches the modes of OFF, FOUNTAIN and HARP that the user can use at their discretion. Our team will be utilizing both previously existing elements, as well as our own physical design and technical features to create a project that is versatile and unique.

Our project houses a specially engineered water pump with the ability to generate laminar water flow for our harp strings. These strings will keep a uniform look and have a sense of stability so the precise 'pluck,' interruption, of the water string can be detected. The pump system will be designed such that there is a constant and continuous stream of water flowing as our water harp strings since any break in the water can be interpreted as an interruption. This water management system also operates with low power consumption to conserve its energy pull while also maintaining its reliable performance.

Aqua Strings relies on laser-based sensing for the detection of any interactions done by the user. It has laser sensors positioned downward shooting through the water stream to a photodetector, when the laser is detected then the string is unbroken and when it isn't detected then there is an interaction that needs to be noted. This noted occurrence will then translate the input into a musical, audio tone to be played through the speaker. This setup allows for an elevated level of accuracy and real-time sensing, since the robust calibration of these sensors will reduce the possibility of false triggers that could occur for numerous reasons, including the displacement of water done by the user's hand or changes of the lighting conditions in the room the device is in. This ensures there are little to no undesired outcomes, facilitating a flawless experience for the user.

The project also involves a sophisticated audio generation system that maps sensor inputs to digital notes that are saved on file. Users will be able to modify and adjust the different modes of the audio output, whether that entail different sounding notes or different octaves (not determined yet). In addition to this audio display, the laser sensors will also have a color being refracted through the beam, color dependent on the specific sensor we acquire and the wavelength of the laser, to add to the visual component of the project.

A closed loop, recirculating water management system is also embedded into the design of the machine allowing for sustainable operation by collecting and redistributing the water. Flow monitors, consisting of water level sensors, are used to track water levels in the upper and lower reservoir ensuring consistent operation of the machine free of unnecessary interruptions. The system design is intuitive since it takes constant inputs which turns the water pump on or off in relation to water levels preventing overflows.

Safety and waterproofing of all systems are imperative as electricity and water aren’t a desired mix in our project, especially if users are touching the water strings. All electronic parts are either isolated or encased to prevent users from encountering hazards. It would be a good idea to include sensors to either measure current being passed through the water and/or other overload protection systems to avoid mechanical and/or electrical failures.

Aqua Strings delivers real-time functionality with virtually immediate responses to the inputs detected in the machine. These inputs include water streams breaking causing tones to play, the switching between modes that change the sound of the notes played, and the monitoring of the water levels within the reservoirs. Little to no latency is a major component for this project because without it the project would be inconsistent and not act as expected.

Our project takes our designs of efficiency and user-friendly experience into one product. It operates in a simplistic way to the user and is a bit more complex on the backend but allows for an innovative redesign of a traditional musical instrument. Through concepts of sustainability to progressing technology, our project delivers an in-depth experience unique to this interactive machine.

is a machine that will simply serve as a water harp. Our machine will be able to read user inputs in the form of movement, as the user’s fingers or hand pass through the flowing strings of water, causing a note or sound to play out of a speaker embedded in the machine. Our team will be utilizing both previously existing elements, as well as our own physical design and technical features to create a project that is versatile and unique.

1.4 Existing Products

Thread fountains are a type of water display that is available in today's market and are typically seen through modern and artistic sculptures. Being the focal points in many public spaces such as hotels, offices, or art galleries, the idea for a thread fountain is to have strings of water flow straight down in a linear cascade-like effect. There are a series of strings fixed from the top to the bottom of the fountain, which serve as a guide for each string of water to follow. The strands of thread in the fountains are one of the most important components of achieving the highly smooth illusion of the water flow. Thread fountains also vary in size, shape, and complexity. Some designs have up pre-programed patterns and effects to add another layer of visual entertainment to the viewer. Through the utilization of motors, magnets, and LED lights, thread fountains can achieve many types of visually artistic and entertaining effects and patterns.

An electric harp is a modern extension of the musical instrument, where instead of a musician having to physically pluck harp strings to generate a sound, the strings are replaced with sensor technology to detect finger movements along the empty space. Through various motion sensors along the harp frame, hand movement detected from a set sensor can be translated into a specific note played through a built-in sound system. Numerous adaptations of electric harps have been created and are in current use, primarily for art and entertainment purposes. Electric harps can range from having lasers serve as strings or having invisible string as a whole. Electric harps are not as widely seen or utilized in the professional music world, though they are seen to become more widespread for musicians who may have mobility limitations and are looking for a more accessible instrument to play.

Our team gathered inspiration through both thread fountains and the electric harps. We wanted to design a project that has an element of art and entertainment as well as incorporating music and sound. Motion sensor-based harps can be seen to exist, however adding the element of water adds a unique sensory experience that has rarely been done before. In addition, the thread fountains that are in use today rely on the placement of the string for the water to flow. Aqua strings will have free flowing water drop from the top to the bottom of the structure without the utilization of a thread. This way, the generation of the sound will be solely reliant on the motion sensors rather than the physical pulling of a string. Our project will also utilize elements of both a harp and fountain through having different modes to switch to. Having this versatility adds another layer of uniqueness and creativity to our project, that has not been seen with previously existing products.

1.5 Engineering Specifications Table

Component(s)	**Parameter**	**Specifications**
Photoresistor	Detection Time	< 10 ms
Photoresistor, MCU, Speaker	Response Time	< 100 ms
Water Pump, Level Sensors	Water Level Maintenance	< 2 in of water
Laser	Wavelength	650 nm (Red)
Laser	Power	< 5mW
Pump	Flow Rate	< 1 gallon / minute
Pump	Lift Height	1.5 m
Reservoirs (Upper/Lower)	Capacity	2 gallons each

1.6 Hardware Block Diagram

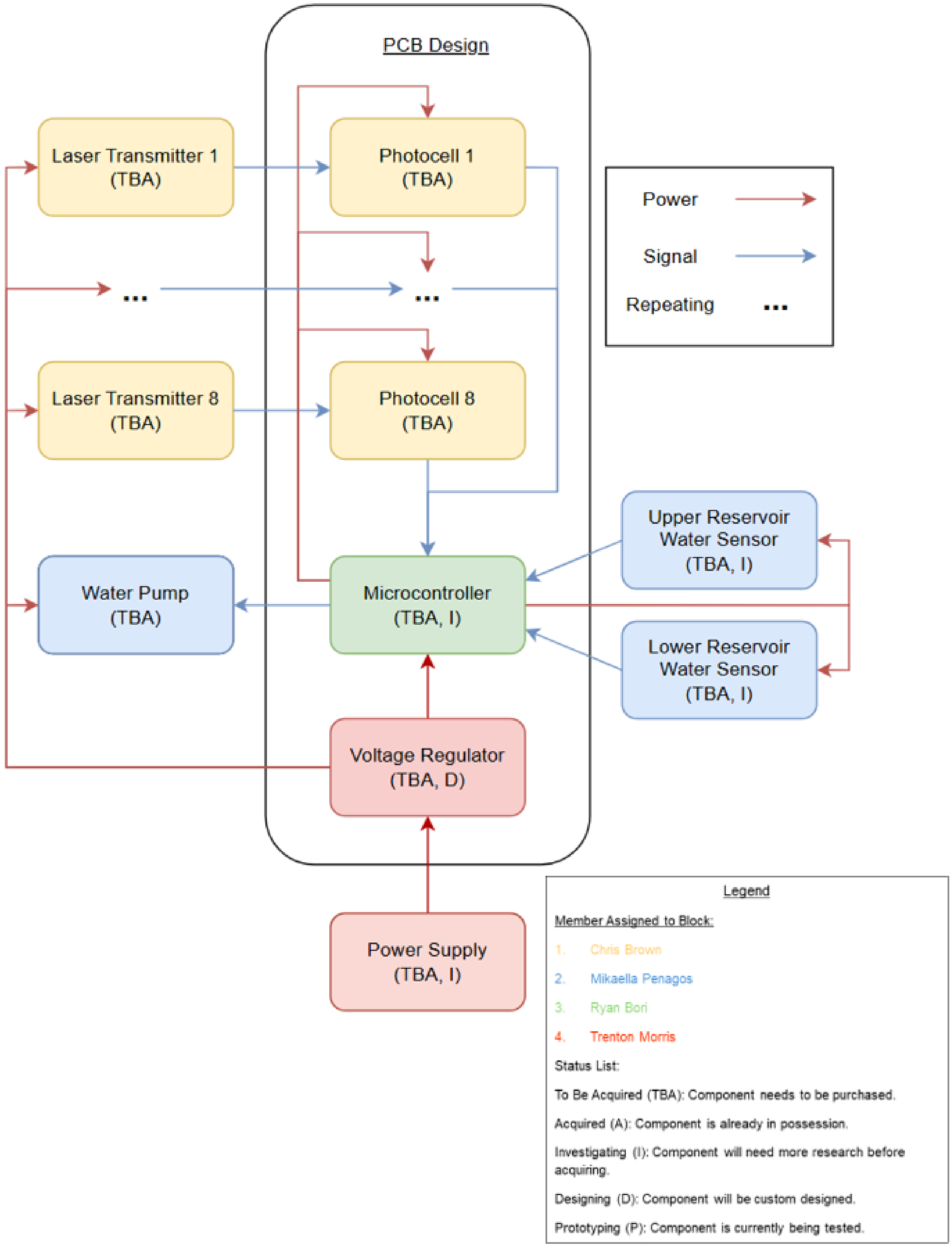

Figure 1: Hardware Diagram

Legend

Member Assigned to Block:

- Chris Brown
- Mikaella Penagos
- Ryan Bori
- Trenton Morris

Status List:

To Be Acquired (TBA): Component needs to be purchased.

Acquired (A): Component is already in possession.

Investigating (I): Component will need more research before acquiring.

Designing (D): Component will be custom designed.

Prototyping (P): Component is currently being tested.

Completed (C): Component is in its final test state.

Components' Inputs and Outputs

- Power Supply:
  - Input: External power (adapter/outlet) or battery.
  - Output: Power to all components through regulator or microprocessor.
- Microprocessor:
  - Input: Signals from photocells, water level readings, and switch knob.
  - Output: Control signals for MIDI sounds, playback, and pump system.
- Photocell(s):
  - Input: Infrared laser beam (unless interrupted by hand).
  - Output: Signal to the microprocessor indicating an interruption.
- Laser:
  - Input: Power from power supply unit/voltage regulator.
  - Output: Continuous infrared beam.
- Pump System:
  - Input: Power from power supply unit/voltage regulator.
  - Output: Water flows to the upper reservoir.
- Reservoirs (Upper and Lower)
  - Input: Water from the pump (upper reservoir) and falling water (lower reservoir).
  - Output: Water columns (upper reservoir) and collected water for recirculation via pump (lower reservoir).
- Water Level Sensors:
  - Input: Power from microcontroller and stimulus of water.
  - Output: Signal for when the water level reaches a certain threshold.

1.7 Software Block Diagram

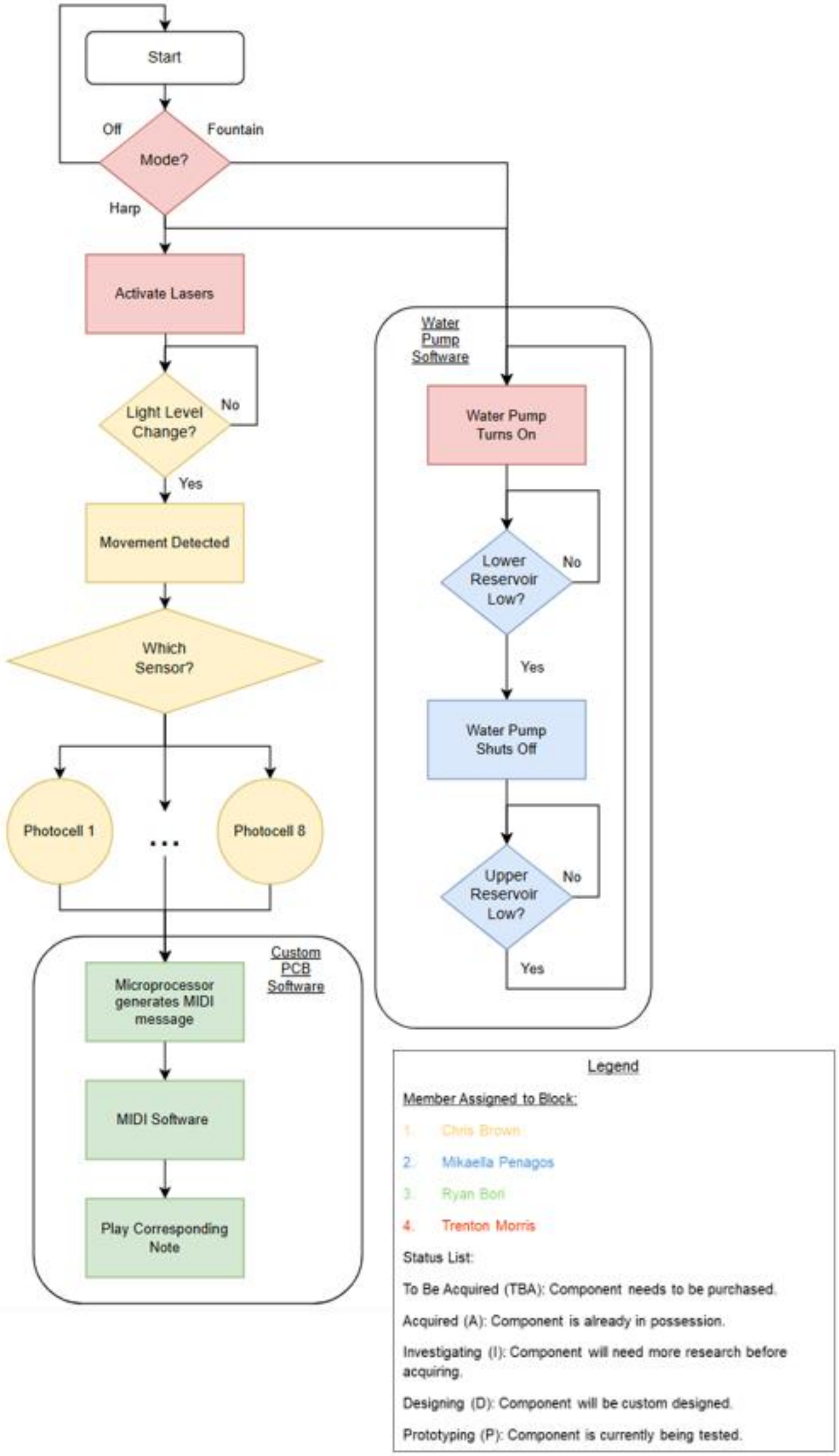

Figure 2: Software Diagram

1.8 Prototype Illustration

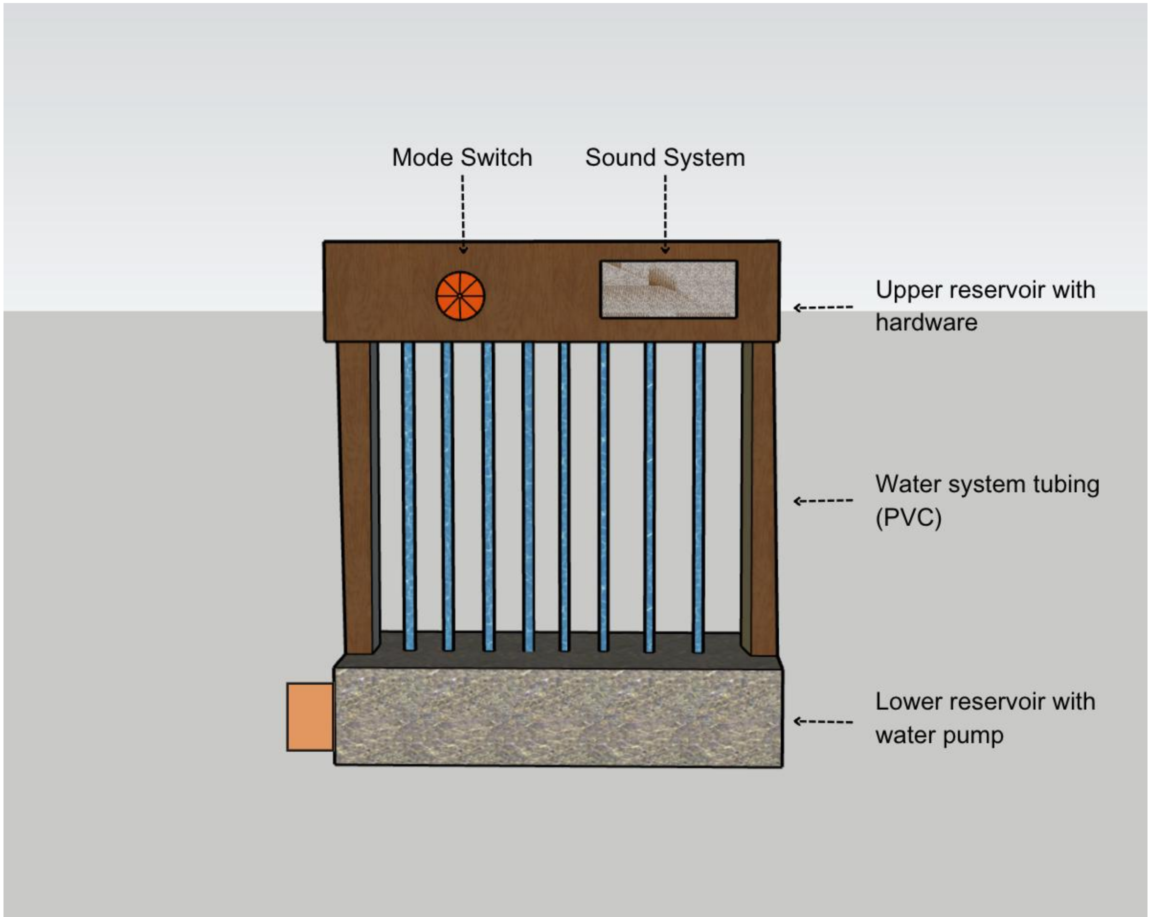

Figure 3: Prototype Illustration

The prototype illustration in the figure above displays our planned design of project Aqua Strings, highlighting some of the key parts of the construction. The frame can be seen to be made from wood giving us a sturdy foundation and an easy material to work with to mount our reservoirs, sensors, and electronics. As can be seen in the illustration, the harp features an upper reservoir which will house essentials, including the mode switch for user control along with the sound system for audio feedback from playing the strings.

Water flows from the upper reservoir, creating eight water strings, the harp's interactive element. The lower reservoir then collects the fallen water and recycles it back up to the top reservoir via the built-in water pump and PVC water system for easy transportation. This enclosed water system works to ensure a consistent flow of water while also preventing overflow in the bottom reservoir. The harp's structure is estimated to be 2 feet tall, allowing it to be portable for demonstration and performance purposes.

1.10 Budget and Financing

Component	Subsystem	Quantity	Unit Estimated Cost	Total Estimated Cost
Water Pumps	Water System	2	$11.00	$22.00
Water Reservoir (Top and Bottom)	Water System	2	$4.00	$8.00
Flow Control Valves	Water System	8	$5.00	$40.00
Tubing (PVC Pipes)	Water System	10 ft	$3.50 for 10 ft	$3.50
Laser Modules	Detection	8	$8.00 for 10	$8.00
Photodiodes	Detection	8	$6.00 for 10	$6.00
Custom PCB	Electronics	1	$50.00	$50.00
Speaker System	Audio	1	$4.00	$4.00
Solenoid Valves	Water system	8	$13.00	$104.00
Power Supply	Electronics	1	$30.00	$30.00
Water Flow Sensors	Water System	2	$9.00	$18.00
Wooden Frame	Structure	1	$60.00	$60.00
Control Panel	User Control	1	$10.00	$10.00
Miscellaneous Cost	All	1	$50.00	$50.00
Total				$413

Figure 4: Budget Plan

Our budget for Aqua Strings will be completely self-funded by the group. The estimated cost is subject to change and will be further adjusted later throughout the actual ordering process due to available suppliers. The total estimated cost for this project is $413, however some components may be able to be sourced from the senior design lab or from cheaper options, reducing our overall expenses.

A key requirement of our project is the Custom PCB, which will integrate the microcontroller, laser sensor system, power distribution, audio output and water flow control logic. This PCB will handle the signal processing for detecting when the water strings are played, playing the correct note audio output. The estimated cost of designing and the fabrication of the PCB is $50, but this could change based on design, complexity, manufacturer, and component selection.

Our project will require a 12V/5V power supply, capable of powering the electronic sensors, our custom PCB, and the water pumps. To retain the portability of the harp we will be using a LiPo battery system, this will allow for our harp to run on battery power or be directly plugged into the wall. The estimated cost for the power supply and battery system is $30.

The frame of our harp will be constructed out of wood, we chose this material for its affordability, ease of modifying and to fit the theme as wood is what many traditional harps are made of. The wooden frame for the harp along with any fasteners or adhesive to keep the frame together is estimated to be $60. Additional miscellaneous costs such as any wiring, connectors or tools are estimated at $50.

Many of the components were estimated based on current market research, the final prices may vary when we go to purchase our components. Certain components may also be found from alternative sources such as 3D printing or preowned materials, also possibly lowering our costs.

1.11 Project Milestones for SD1 and SD2

Our Aqua Strings project is structured over two semesters Senior design 1 in the Spring and Senior Design 2 in the Summer. Senior Design 1 focuses on research, documentation and planning, while Senior Design 2 spends it semester prototyping, testing, finalizing the design and assembly. Some of the key milestones of Senior Design 1 include the completion of major documentation, initial component selection and dry prototyping to ensure the systems' functionality. Senior Design 2 is dedicated to system integration including reservoir construction, PCB fabrication, and wet testing the laser dedication system. The final stage will include system optimization, repeated testing and a final live demonstration.

SD1:

Milestone	Week #	Due Date	Description
Complete Divide and Conquer Document	Week 4	January 24, 2024	First 10 pages of our Divide and Conquer Report
Order Electronics	Week 6	N/A	Ordering our essential electronic components for testing compatibility and initial prototyping
Complete 60-Page Mid-Report	Week 10	March 24, 2024	First half of our final 120-page report
Build Single Laser, Dry Prototype	Week 11	N/A	Constructing and testing a single laser-based detection system without introducing water
Determine Components for Custom PCB	Week 12	N/A	Finalize needed components and designing the layout of our custom PCB
Complete 120-Page Final Report	Week 16	April 22, 2024	final documentation detailing our research, system design and initial testing

Figure 5: Senior Design 1 Milestones

SD2:

Milestone	Week #	Due Date	Description
Build Test Reservoir Enclosure	Week 1	TBD	Construct the enclosure for the water reservoir and pump system
Complete PCB Design for Print	Week 3	TBD	Finalize and prepare the custom PCB layout for manufacturing
Test Single Laser, Wet Prototype	Week 4	TBD	Evaluate our laser-based detection system with water in the system
Test Multiple Laser, Wet Prototype	Week 6	TBD	Expand our testing to multiple laser water strings simultaneously
Finalize Reservoir and Pump System	Week 8	TBD	Ensure optimal water flow for consistent operation
Perform Final System Tests	Week 10	TBD	Conduct full-scale testing and debugging of the whole water harp system
Final Live Demo Presentation	Week 12	TBD	Showcase our completed project to faculty for final review and grade

Figure 6: Senior Design 2 Milestones

Citations:

[1] LaserFlow Non-contact Velocity Sensor,

https://www.teledyneisco.com/water-and-wastewater/laserflow

[2] Vesiharp Musical Fountain,

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[3] The Waterphone, an inharmonic, otherworldly instrument,

https://thekidshouldseethis.com/post/the-waterphone

[4] The Laser Harp,

https://www.laserspectacles.com/resources/the-laser-harp/

[5] Thread Fountain,

https://www.cascade.it/en/prodotto/thread-fountain/

[6] Arduino Laser Harp,

https://www.instructables.com/Arduino-Laser-Harp-1/

[7] Quick Arduino MIDI Laser Harp

https://www.instructables.com/Quick-Arduino-MIDI-Laser-Harp/

[8] Block Diagram Software

https://app.diagrams.net/

Legend	Engineering Requirements	Cost	Weight	Detection Time	Response Time	Sustained Water Height	
Marketing Requirements							
Cost							
Portability							
Ease of Use							
Reliability							
Upgradeability							
Target							