Laser Instrument

Group 9

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Project Narrative/Description

Musical instruments have been crafted and played for hundreds of years and designed in numerous ways. One of the most versatile and popular instruments is the piano. The modern-day piano was invented by Bartolomeo Cristofori in the late 1600's and has since then been redesigned in various shapes and sizes. A popular way in reimaging classical instruments is developing their electrical counterparts. Electric pianos have been around for 100 years from electronic keyboards to mobile phone applications that allow anyone to play anywhere. One of the favorite features of keyboards is the ability to change the output tone of the keys so that the user can mimic the sound of any other instrument. This expands the market audience to include a multitude of instrument backgrounds while also creating a standard playing method with piano keys. The most recent innovative adaption of these classical instruments are laser pianos and laser harpsichords. These allow multiple instruments to be played and are standardized to use a set of lasers instead of physical keys.

This project would be an adaptation of the laser piano by creating a generic laser instrument. The primary goals of this project are to produce a laser instrument that will be portable, cost effective, physically adjustable, and allow users to play in a variety of play styles. To accommodate the differences in shape and size of the target audience members, the laser instrument will have a physically adjustable design. This gives users of any size the ability to play the laser instrument in any style they would like, whether the person chooses to play while lying down, sitting at desk, or standing up. The instrument will be cost effective since it is a single device that can perform with multiple instrument sounds. Finally, a lightweight and portable design would make it easier to mimic instruments in places that are typically more difficult for the larger and heavier instruments to perform in. An example would be the classis piano, which is well known for being difficult to transport. The final product of this project would be sought after by users who want to quickly and easily move their piano and perform in a more mobile environment.

In terms of functionality, the laser instrument should have the same capabilities as a typical electronic keyboard and then some. Users will have the ability to adjust features such as volume via turning knob, but also change the instrument audio they would like to play, such as piano or guitar. An important function is that the instrument will have connectivity with an app that improves accessibility, allowing all users to connect via Bluetooth and customize their instrument to their personal likings. The instrument will be more accessible by giving user the option to manually customize the instrument or to use a mobile application.

Finally, the project will utilize a combination of laser diodes and photoresistors to avoid the inaccuracies of implementing a single photonic laser and breaking the beam into multiple individual beams. By eliminating this extra step of breaking a beam of light, the accuracy of reading notes increases, and more time can be focused on implementing more audio functionality to the laser instrument. Laser diodes can be used in a binary way, reading keys as “broken” or “unbroken”, but the addition of an ultrasonic sensors would allow the detection a user's fingers, which can be used to alter the pitch or octave level of any note. This level of adjustability gives user the freedom to choose which notes they want to play and in which octave.

Project Requirement Specifications

Table 1: Project Requirement Specifications

Category	Metric	Requirements
Accidentals Supported	Accidentals	1 (naturals)
Adjustable Design	Scale 1-10	Average user rating > 6
App Connectivity Distance	Feet	3
Audio Frequency	Hz	800 – 10,000
Charge Lifespan	Hours	> 1
Chassis Dimensions	Inches	24 x 12 x 4
Cost	USD	< 600
Diode Light Sensing	Feet	≥ 2
LCD Display	Quantity	1 ≥ 8
Light Resistance Detection	Ohms	10Ω - 100kΩ
Notes	Playable keys	≥ 8
Octaves Supported	8 Notes Per Octave	≥ 2
Output Sound Type	Categories of instruments	≥ 2
Product Weight	Pounds	< 10
Ultrasonic Sensor Frequency	Hz	> 8
Ultrasonic Sensor Range	Centimeters	4 ≥ 15

Block Diagram

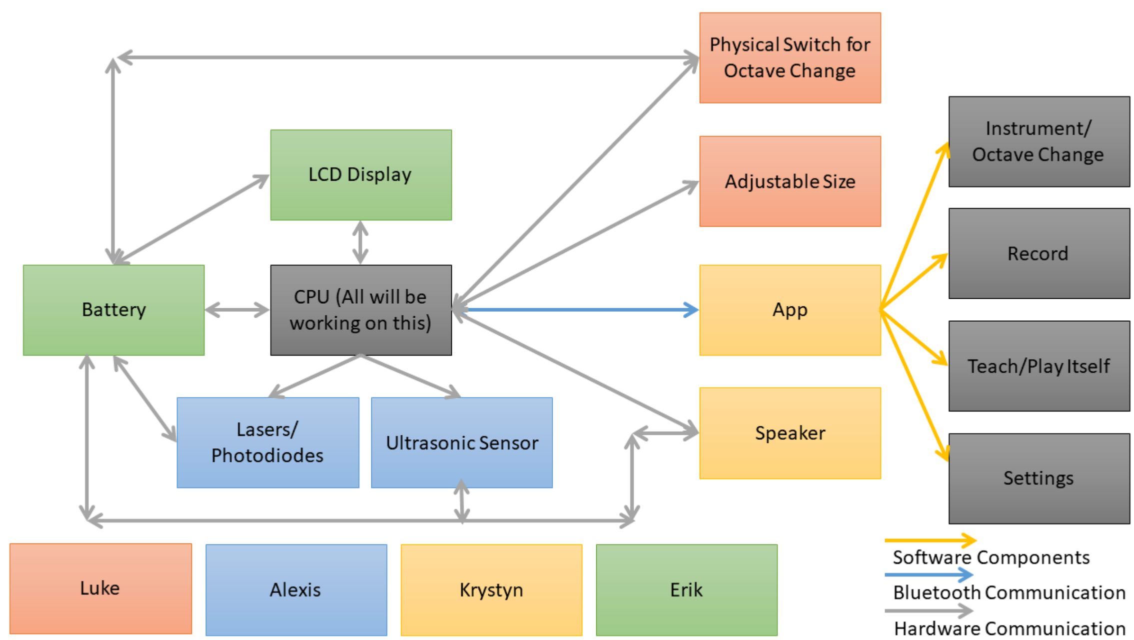

Figure 1: Block Diagram Team Responsibilities

Figure 1 shows the breakdown of the all the work to be done and who oversees each task. The only color not labeled, dark gray, is work that will be divided up among team members. Colored boxes link team members to their chosen portion of the project to manage. The colored arrows dictate how the project pieces are connected.

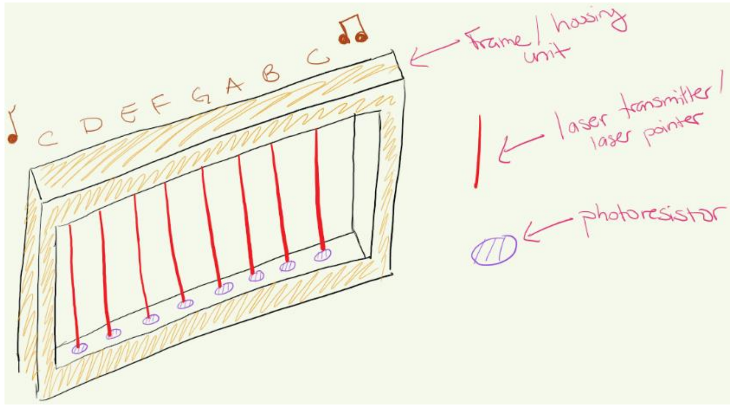

Figure 2: Basic Design Overview

Figure 2 is a prototype illustration of a basic model. A rectangular shape that points laser diodes towards photo resistors. This overall original design was the basis for the project. This design was based after models the group had seen, but this was designed to have more simplicity and a more visible user experience. It was intended to be a smaller profile to make it more portable for a user, able to bring the device anywhere and play it anywhere. In Figure 2, the basics of the project are shown: a compact frame that encompasses a total of 8 different notes that are played by breaking the light between a laser diode and a photo resistor. The design depicted is meant to have no back wall or preventative surface so the user could see through the device's center. The structure was meant to be no more than a rectangular frame for the sake of being lighter and possibly able to be foldable for more portability. Although not labeled as so on the design, the letters above the 'keys' created by the beams of light were intended to be labeled on the frame in some manner, so users know what notes they are playing. It was also an example of the plan to only include the natural accidentals of all notes, and a singular octave as well.

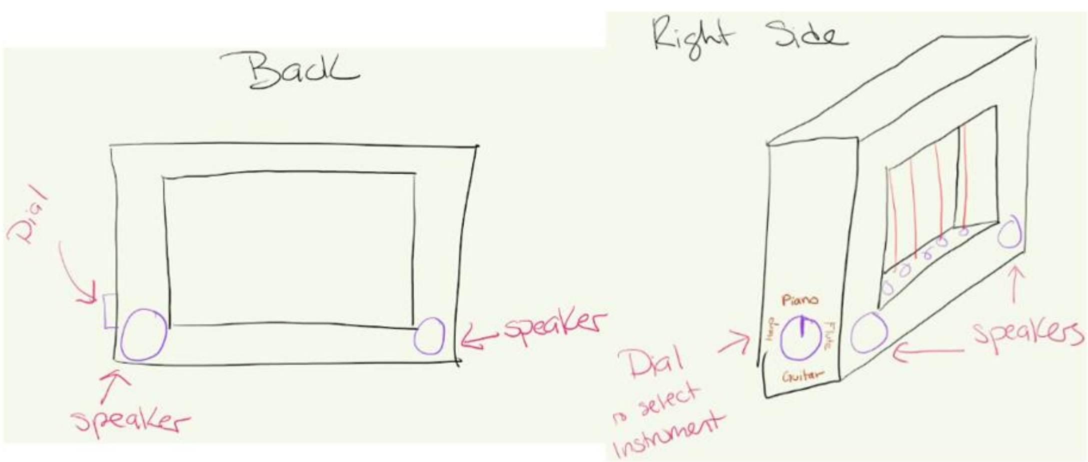

Figure 3: Basic Design Back and Side Views

The back and side of the device illustrated in Figure 3 will feature volume-controlled speakers and a dial that allow changes in the audio output. The original design of the device was meant for more than just a singular portable instrument, but to be an abundance of different instruments that could be played by the same device. These instruments would be chosen by the dial on the side, giving users the ability to customize the current sound of an instrument when they played it. Only four are listed on the draft design, but depending on the memory inside the device, many more instruments could be included in the device and displayed on the dial. This first draft of the body of the design included speakers so that the user could hear what they are playing as they play it. Although depicted on the 'back' of the design, the speakers could be placed in the front, so the user has a better sound environment to hear what they are doing more directly.

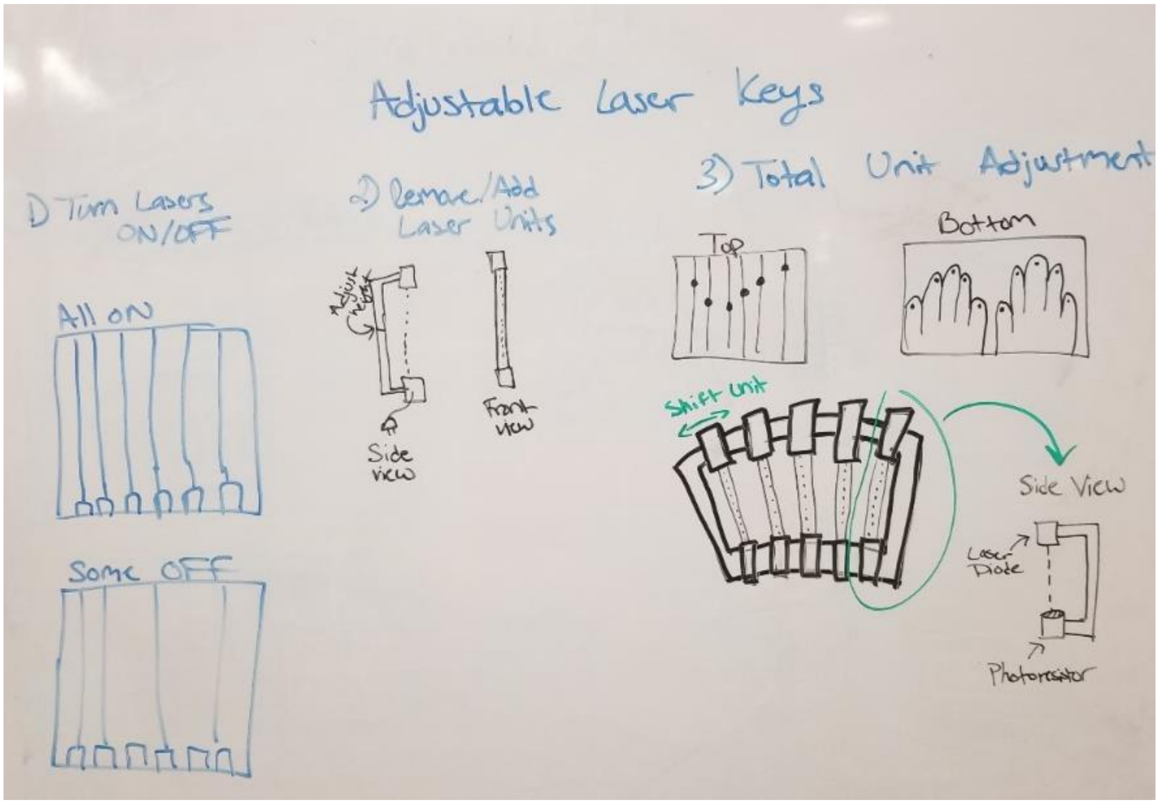

Figure 4: Adjustable Designs I

Three different concepts for how the adjustable units will operate with the laser diode and photo resistor pairings are featured in Figure 4. These initial prototype ideas and possibilities were recorded when deciding on the project itself. The main reason for adjustability was the idea that all hands are different and giving the ability to size it to the player would be a helpful feature. The first of these options to give user customization was the ability to lasers off and on. If a user only wanted to work with specific notes and not accidentally hit notes they didn't want, they could turn them off. Or in the event that it was easier to visualize, being able to space notes by turning them off would also give a user the ability to customize their device for more productive playing of the instrument. The second idea that was given a low priority was the idea of modular laser pieces that would no longer give a free back. But with this difference, users could then add or remove keys to give a wider or shorter range to play notes on. And to give more customization, the key backing could shorten or lengthen for players to make it easy to move the smaller, modular pieces, or for during the experience of playing the device. The final idea to introduce customization for users was the ability to move the keys into a more comfortable position for the user's hands. Due to the difference in finger length and in finger width, the idea to move the lasers in two different directions was introduced. If a user chose to dedicate a finger to a laser, this gave an ease of playing. To incorporate this, the lasers and corresponding photo resistor would be moved perpendicular to the frame to accommodate finger length. To give the user ability to decide how far apart the notes would be to accommodate finger width, the laser and photo resistor would slide parallel to the frame. This idea also included the idea of a curved frame and more modular pieces to move the light and resistor together and keep them aligned.

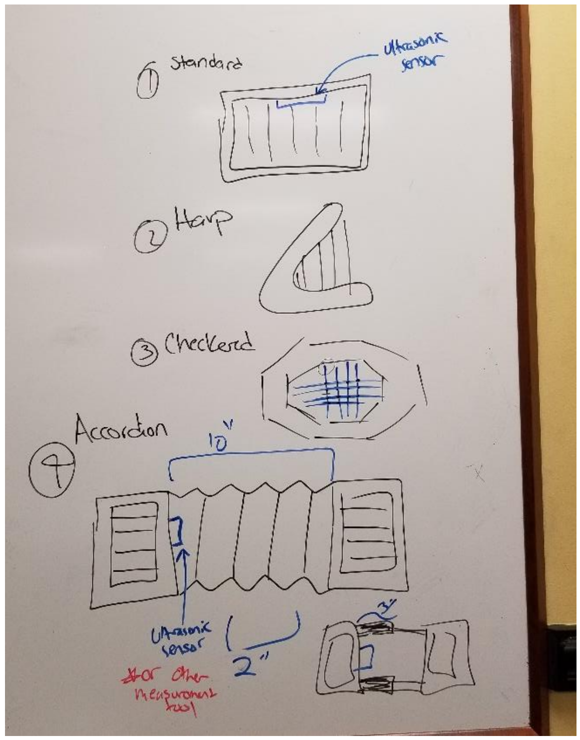

Figure 5: Overall Structure Designs

The following designs are various ides of how the overall laser instrument will be constructed. Key aspects that are significant while drafting these designs are implementing several laser diodes and photoresistors as playable notes, supporting multiple octaves during use of the instrument, and maintaining a portable design. The first four designs in Figure 5 highlight various ways the laser diodes could be mapped to incorporate an ultrasonic sensor or alternative distance measuring sensor to calculate multiple octaves ranges for the instrument. The first design is a simple square with an ultrasonic sensor mounted within the inner portion of the frame. The second design features a harp structure that limits or excludes a distance measuring sensor in the design. The third design's checkered layout increases the difficulty of implementing laser diodes as overlaying beams could disrupt each other. The fourth design features an accordion style in which an ultrasonic sensor or distance sensor will produce various octaves based on the distance between the two hand blocks of the instrument.

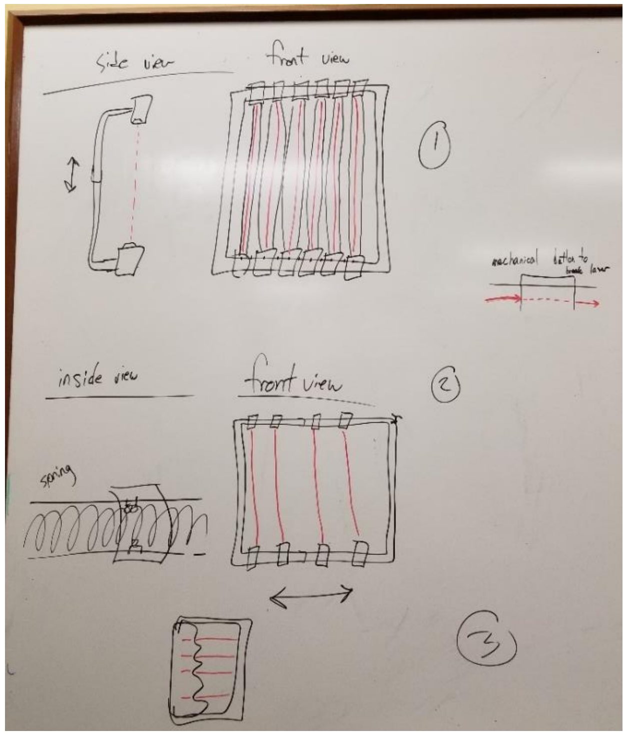

Figure 6: Adjustable Designs II

All of the designs in Figure 6 focus on making sure the structure of the laser instrument can accomidate a larger range of user hand sizes. The first two designs in Figure 6 focus on implementing an adjustable unit that consist of a laser diode and photoresistor. The first design uses a telescopic component to create the diode and resistor unit. The second design utilizes springs to create a constant spacing between the individual units. The third design features the most mobile structure where a user holds the device while playing and uses a mechanical piece that acts as an extension of a finger to break or connect the laser diode to the photoresistor.

Estimated Budget and Financing

Table 2: Financing

Item	Cost	Amount	Total
PCB Print			~$30
Photoresistors (x30)	$4.65 (Amazon)	1	$4.65
5V Laser Diodes (x10)	$5.49 (Amazon)	1	$5.49
5V Power Source	$10	1	~$10.00
Power Regulator	$1.81 (Mouser)	5	$9.05
Speaker	$1.95 (Adafruit)	3	$5.85
Buttons (x20)	$2.50 (Adafruit)	1	$2.50
Ultrasonic Sensors (x5)	$8.98 (Amazon)	1	$8.98
Bluetooth Module	$7.99 (Amazon)	1	$7.99
LCD screen	$8.96 (unsure)	3	$26.88
Chassis / Frame			~$50
CPU			~$10
RLC components			~$30
Audio Amplifier	$3.95	1	$3.95
Rotary Encoder	$1.75	2	$3.50
Total			**$205.34**

Project Milestones

Table 3: Milestones

Objective	Start	End	Status
Senior Design I			
Initial meeting	8/30/19	8/30/19	Complete
Brainstorming ideas	9/2/19	9/20/19	Complete
Divide and Conquer I	9/16/19	9/20/19	Complete
Divide and Conquer II	9/20/19	10/4/19	In-progress
30 Page Documentation	10/4/19	10/18/19	In-progress
60 Page Documentation	10/18/19	11/1/19	In-progress
100 Page Documentation	11/1/19	11/15/19	In-progress
SD1 Final Paper	11/15/19	12/1/19	In-progress
Senior Design II			
1st prototype	10/20/19	1/10/19	N/A
2nd version	1/10/19	3/13/19	N/A
Final Design	3/13/19	4/17/19	N/A
Final Paper	1/10/19	4/17/19	N/A

Project Decision Matrix

Table 4: Decision Matrix

Pros	Cons
Portable	Multiple pieces (Extra things to work on)
Increased mobility for components of system	Requires accuracy for lasers
Gestures/motion would give more to project	More research into design
Plentiful resources	Software requires consistent updating
Open-ended design	Includes some mechanical engineering
Combination of both hardware and software	

House of Quality Diagram

Table 5: House of Quality I

		Engineering Requirements																
		Accidentals Supported	Adjustable Design	App Connectivity Distance	Audio Frequency	Charge Lifespan	Chassis Dimensions	Cost	Diode Light Sensing	LCD Display	Light Resistance Detection	Notes	Octaves Supported	Output Sound Type	Product Weight	Ultrasonic Sensor Frequency	Ultrasonic Sensor Range	Time Spent
		+	+	-	+	+	-	-	+	+	+	+	+	+	-	+	-	-
Marketing: Cost	-	↓	↓	↓		↓	↑	↑↑		↓↓		↓	↓	↓	↑			↑
Marketing: Sound Quality	+	↑			↑↑		↓	↓				↑	↑	↑	↓	↑↑		↓
Marketing: Accurate Performance	+				↑↑			↓	↑		↑↑						↑↑	↓
Marketing: Wide Audience	+		↑↑			↑	↑	↑↑		↑↑		↑		↑	↑			
Marketing: Battery Life	+	↓		↓	↓	↑↑		↓↓		↓↓					↑	↓		
Marketing: Portability	+		↑↑	↑		↑↑	↑↑	↓							↑↑			
Targets for Engineering Requirements		1 (naturals)	Average User Rating > 6	>= 3 ft	800-10,000 Hz	> 1 hrs	24 in x 12 in x 4 in	< $600	>= 2 ft	1 <= # displays <= 8	10 – 100k Ω	>= 8 keys	>= 2 octaves	>= 2 instruments	< 10 lbs	> 8 Hz	4 <= # cm <= 15	< 40 hrs/week

Legend

Table 6: House of Quality Legend

↑	Positive Correlation
↑↑	Strong Positive Correlation
↓	Negative Correlation
↓↓	Strong Negative Correlation
+	Positive polarity AKA Increasing the Requirement
-	Negative Polarity AKA Decreasing the Requirement

From the House of Quality Diagram (Table 5), it is apparent that not all of the requirements must be included in the project. Below (Table 7) is a copy of the table where unnecessary engineering requirements and unaddressed marketing requirements are highlighted. The unnecessary engineering requirements yield negative correlations to the marketing requirements or have minimal impacts to the marketing requirements. These engineering requirements are possible detriments to the project design. The unaddressed marketing requirements are those that have little to no positive correlation with any of the existing engineering requirements.

Table 7: House of Quality II

			Engineering Requirements																
			Accidentals Supported	Adjustable Design	App Connectivity Distance	Audio Frequency	Charge Lifespan	Chassis Dimensions	Cost	Diode Light Sensing	LCD Display	Light Resistance Detection	Notes	Octaves Supported	Output Sound Type	Product Weight	Ultrasonic Sensor Frequency	Ultrasonic Sensor Range	Time Spent
			+	+	-	+	+	-	-	+	+	+	+	+	+	-	+	-	-
Marketing	Cost	-	↓	↓	↓		↓	↑	↑↑		↓↓		↓	↓	↓	↑			↑
	Sound Quality	+	↑			↑↑		↓	↓				↑	↑	↑	↓	↑↑		↓
	Accurate Performance	+				↑↑			↓	↑		↑↑						↑↑	↓
	Wide Audience	+	↑	↑↑			↑	↑	↑↑		↑↑		↑	↑	↑	↑			
	Battery Life	+	↓		↓	↓	↑↑		↓↓		↓↓					↑	↓		
	Portability	+		↑↑	↑		↑↑	↑↑	↓							↑↑			
Targets for Engineering Requirements			1 (naturals)	Average User Rating > 6	>= 3 ft	800-10,000 Hz	> 1 hrs	24 in x 12 in x 4 in	< $600	>= 2 ft	1 <= # displays <= 8	10 – 100k Ω	>= 8 keys	>= 2 octaves	>= 2 instruments	< 10 lbs	> 8 Hz	4 <= # cm <= 15	< 40 hrs/week

In the following House of Quality diagram (Table 8), the problem areas have been removed from the original diagram and are a reflection of where the design currently stands. The previous diagrams reflect what will eventually be changed about the project's design.

Table 8: House of Quality III

			Engineering Requirements														
			Accidentals Supported	Adjustable Design	Audio Frequency	Charge Lifespan	Chassis Dimensions	Cost	LCD Display	Light Resistance Detection	Notes	Octaves Supported	Output Sound Type	Product Weight	Ultrasonic Sensor Frequency	Time Spent
			+	+	+	+	-	-	+	+	+	+	+	-	+	-
Marketing	Cost	-	↓	↓		↓	↑	↑↑	↓↓		↓	↓	↓	↑		↑
	Sound Quality	+	↑		↑↑		↓	↓			↑	↑	↑	↓	↑↑	↓
	Accurate Performance	+			↑↑			↓		↑↑						↓
	Wide Audience	+	↑	↑↑		↑	↑	↑↑	↑↑		↑	↑	↑	↑		
	Battery Life	+	↓		↓	↑↑		↓↓	↓↓					↑	↓	
	Portability	+		↑↑		↑↑	↑↑	↓						↑↑		
Targets for Engineering Requirements			1 (naturals)	Average User Rating > 6	800-10,000 Hz	> 1 hrs	24 in x 12 in x 4 in	< $600	1 <= # displays <= 8	10 – 100k Ω	>= 8 keys	>= 2 octaves	>= 2 instruments	< 10 lbs	> 8 Hz	< 40 hrs/week

It is important to note that the majority of the impacts to marketing requirements are negative, so the design will require future additional engineering requirements to keep project costs low. The other option is to approach the target customers and discuss the necessity for keeping the project low cost. This would also help determine how much time and energy needs to be put towards that aspect of the project.